ANALYSIS

Nuclear Power and International Trade

Trade policy for a net-zero energy system

Kommerskollegium
National Board of Trade Sweden

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Summary

Nuclear power is under revival with a renewed policy focus on how it can help meet countries' climate ambitions. However, the global market for nuclear goods and services is still relatively small and the industry has arguably failed to maximise the efficiency, cost, scale and innovation gains from international trade. For nuclear power to contribute more to the climate transition, new reactors will need to be competitive on cost. Trade policy can contribute to cost reductions by addressing barriers to trade.

International trade is important for the operation of the EU nuclear power industry. Natural uranium is mostly sourced from outside the EU, along with two-thirds of enriched uranium. There are concerns around security of supply with around 20 per cent of the EUs enriched uranium sourced in Russia. Trade is also vital for the Swedish industry, including through imports of enriched uranium, and for components and services of skilled persons to complete annual maintenance procedures. Sweden is also a large exporter of fuel elements.

Trade is conducted according to a system of export controls that manages proliferation risks and thus contributes to facilitating legitimate trade for civil nuclear purposes. Improvements could potentially be made from a trade perspective, but these would need to be carefully assessed by experts so that proliferation and safety outcomes are not weakened. One potential improvement would be to reduce differences in export control licensing processes. Another would be to assess if a risk-based approach could be introduced without risking non-proliferation objectives. These suggestions are also relevant to trade within the EU's internal market and there are opportunities to streamline and harmonise transportation procedures at EU level.

An easy win for the EU would be to remove the tariffs on the import of various nuclear products, parts and components. In addition, international regulatory cooperation has the potential to promote the development of a global market for small modular reactors (SMRs), thus helping to realise gains from international trade.

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Authors: Neil Swanson and Erik Merkus

Valuable comments and suggestions have been gratefully received from Anna Sabelström, Linda Bodén and Karl Ekenstaf, National Board of Trade Sweden. We would also like to thank the people that kindly gave their time for interviews and to answer our questions.

1 Introduction

At the 28th Conference of the Parties to the UN Framework Convention on Climate Change (COP 28), more than 20 countries committed to the Declaration to Triple Nuclear Energy by 2050.[1] Sweden was one of 11 endorsing countries from the EU. Indeed, the Swedish Government recently proposed reforms to promote the development of nuclear power, including allowing reactors to be built in new locations and introducing risk sharing and credit guarantees.[2] The aim is to have new nuclear production with a capacity of at least 2,500 MW in place by 2035 with much higher ambitions for 2045.[3] This compares to a nuclear capacity of 6,900 MW in 2022.[4]

Several companies are considering investments in new reactors in Sweden and decisions will ultimately be based on commercial considerations[5] given the economic and political[6] risks involved. Decisions are thus affected by policy choices across a range of domains, including trade policy.

This report investigates the nuclear energy sector from a trade policy perspective. It covers nuclear power's role in the transition to a net-zero energy system, reviews how trade policy could support small modular reactor development, analyses trade flows and tariff barriers to trade, and examines trade-related rules concerning export controls and transportation. The report concludes with a discussion and policy recommendations.

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1 At COP28, Countries Launch Declaration to Triple Nuclear Energy Capacity by 2050, Recognizing the Key Role of Nuclear Energy in Reaching Net Zero | Department of Energy ,December 1 2023

2 The credit guarantees are on more favourable terms than for renewable energy and come to a total of SEK 400 billion. Other reforms include increased research funding and speeding up permitting processes. budgetpropositionen-for-2024-hela-dokumentet-prop.2023241.pdf (regeringen.se)

3 Förslag till färdplan för ny kärnkraft (regeringen.se)

4 Sweden's total installed electrical capacity was around 46,000 MW at the end of 2022. However, as several generation sources are intermittent, nuclear makes up a higher proportion of total supply than it does of total generation capacity. Energiåret (energiforetagen.se)

5 The Swedish electricity market is deregulated, so the choice to invest in new nuclear facilities, or indeed any other production technology, ultimately rests with energy market actors.

6 Svenskt Näringsliv (2022) Startprogram för ny kärnkraft. Accessible here (in Swedish): https://www.svensktnaringsliv.se/sakomraden/hallbarhet-miljo-och-energi/startprogram-for-ny-karnkraft_1191089.html

2 Scope and method

The purpose of this paper is to highlight issues that are relevant to the National Board of Trade's mission to facilitate free and sustainable trade. Trade and climate change is a strategic focus area for us, and nuclear power is prioritised by the Swedish Government as one of the technologies that will form a part of Sweden's future net-zero energy system. Other sustainability aspects are covered in the report, with an analysis of nuclear development in relation to Agenda 2030 and trade. The import of certain nuclear materials and products also raises issues related to trade policy's role in energy security, this is covered in the discussion section.

We limited the scope of the study to trade in nuclear materials and products for electricity generation, and the trade analysis is limited to tariff barriers, export controls and transportation. Areas that were left out of scope include services trade and agreements, investment rules relating to the Energy Charter Treaty, and trade analysis of other segments within the nuclear industry such as decommissioning and waste storage.

The analysis is primarily conducted for the EU and Sweden but where relevant a global perspective is taken, for example in relation to industry developments, climate change and Agenda 2030.

This work was mainly conducted as a desk study. However, during the project we have had email contact, interviews or discussions with the following organisations: The Swedish Energy Agency, Swedenergy, The Swedish Radiation Safety Authority, The Swedish Institute for Standards, and Westinghouse Electric Sweden. We extend our thanks to everybody who took the time to speak to us.

3 Nuclear energy, trade and the climate transition

Key points:

- International trade is important for the Swedish nuclear power industry. For example, imports of components and the services of skilled persons are essential for annual maintenance procedures.
- Freer international trade has the potential to improve efficiency, reduce costs, and promote economies of scale and innovation.
- Small modular reactors (SMRs) have the potential to lower the cost of new nuclear developments by standardising designs, producing a series of reactors in factories and benefiting from global value chains.
- International regulatory cooperation on SMRs could shape new regulations (e.g. for SMR wastes and fuels) and approaches to licensing. When the market is mature, cooperation on international standardisation would also help to facilitate trade.

Nuclear power is receiving increased policy focus[7] in relation to countries' climate transition plans.[8] In this section we cover nuclear power in net-zero energy systems and international trade's relevance for the nuclear industry, including the development of SMRs.

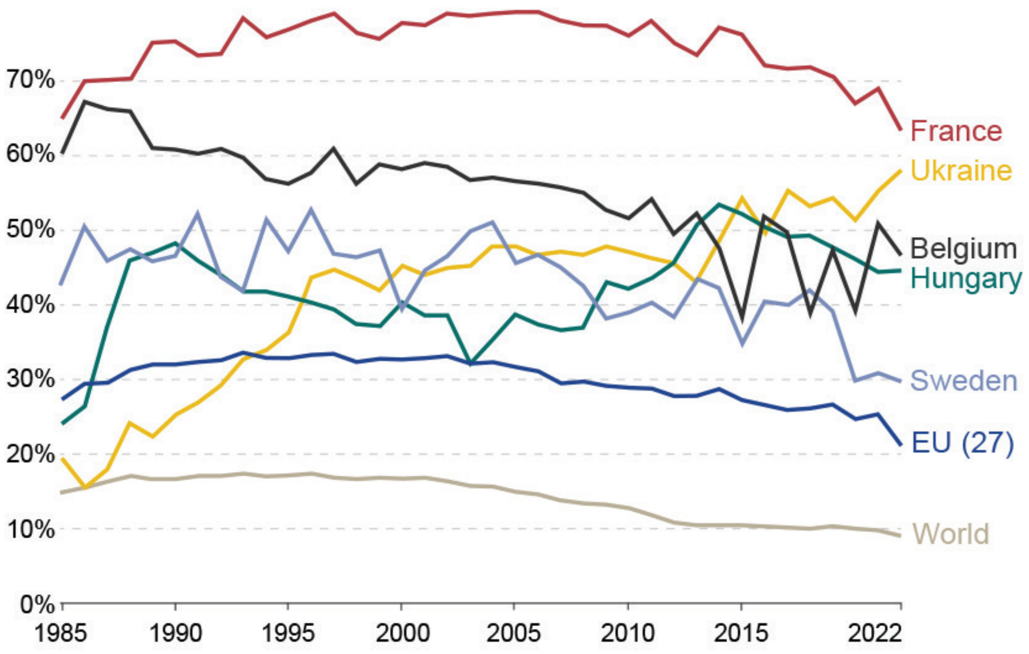
3.1 Nuclear in a net-zero energy system

Nuclear power has the potential to play an important role in the climate transition by complementing renewables with dispatchable low-emission electricity, district heating, and heat for industrial processes. Indeed, several European countries already supply large proportions of their electricity from nuclear (see figure below), albeit with an aging nuclear fleet.

[7] Nuclear power's comeback is down to small modular reactors | World Economic Forum (weforum.org)

[8] Home: Second International Conference on Climate Change and the role of Nuclear Power 2023: Atoms4NetZero | IAEA

Figure 1. Share of electricity production from nuclear



Source: Ember's Yearly Electricity Data; Ember's European Electricity Review; Energy Institute Statistical Review of World Energy OurWorldInData.org/energy. CC BY

Pathways to low-carbon energy systems are provided by several international[9] and national agencies[10]. For example, the International Energy Agency's (IEA) net-zero emissions scenario has a 100 per cent increase in nuclear power capacity between 2022 and 2050.[11] Even with growth in the nuclear industry, global scenarios for future clean energy systems are dominated by renewables. The picture is different at national level with some countries promoting nuclear in their energy mix, as evidenced by the COP28 commitments to triple nuclear energy.

The IEA identify cost as one of the main challenges for new nuclear plants to play a larger role in energy transitions.[12] Extending the life length of existing plants (referred to as long-term operation) is cost competitive with renewable generation[13] but for new reactors in OECD countries this has not been the case. [14]

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[9] The IPCC Special Report on Global Warming of 1.5°C presents mitigation pathways with growth in nuclear power, ranging between 59 per cent and 501 per cent by 2050; Nuclear Power Conference Discusses #Atoms4Climate | News | SDG Knowledge Hub | IISD. Source: Intergovernmental Panel on Climate Change. (2018) Global Warming of 1.5C. Accessible here: https://www.ipcc.ch/sr15/

[10] Energimyndigheten (2023) Scenarier över Sveriges energisystem 2023: Med fokus på elektrifieringen 2050. Accessible here: https://www.energimyndigheten.se/statistik/prognoser-och-scenarier/langsiktiga-scenarier/

[11] International Energy Agency (2022) Nuclear Power and Secure Energy Transitions. Accessible here: https://www.iea.org/reports/nuclear-power-and-secure-energy-transitions

[12] International Energy Agency (2022) Nuclear Power and Secure Energy Transitions. Accessible here: https://www.iea.org/reports/nuclear-power-and-secure-energy-transitions

[13] International Energy Agency (2020) Projected Costs of Generating Electricity 2020 https://www.iea.org/reports/projected-costs-of-generating-electricity-2020

[14] Budget and time overruns have not been as problematic in countries that have been building plants continuously. International Energy Agency (2020) Projected Costs of Generating Electricity 2020 https://www.iea.org/reports/projected-costs-of-generating-electricity-2020

3.2 Trade's contribution

Freer international trade is a helping factor in achieving efficiency and cost improvements. However, the global market for nuclear goods is small and the industry has arguably failed to maximise the gains from cost minimisation and innovation brought by trade.[15] Reactor builds have been traditionally dominated by domestic production or with nationally organised bids involving a high degree of politicisation. Nevertheless, international cooperation and globalised supply chains are becoming more common.[16] Indeed, international trade is important to Sweden's nuclear industry as is shown in Table 1 below.

Table 1. Subsectors of the global civil nuclear industry

Subsector	Swedish Trade Examples
Advisory and support	Participation in international standardisation and cooperation.
Design, construction and operation	Swedish firm involved in building UK power plant.
Components	Import of components and skills to complete annual maintenance procedures (outages)
Fuels	Export of nuclear fuel cartridges by Swedish fuel production plant.
Back-end services (e.g. decommissioning, waste management)	Import of specialist encapsulation equipment for waste disposal.

Source: U.S. Department of Commerce International Trade Administration, and discussion with industry body Swedenergy

Furthermore, trade policy can play an important role in the development of a global industry for SMRs.[17]

3.3 A global industry for small modular reactors

SMRs could be key to achieving cost-competitiveness for new reactors. The shift has been characterised as moving from large projects to traded products.[18] Potential benefits of SMRs include lower absolute financing costs, easier grid connection, design that is standardised allowing factory production of modules for lower cost and

[15] Lévêque François (2015) "The international trade of nuclear power plants: the supply side" Revue d'économie industrielle, 148; DOI: https://doi.org/10.4000/rei.5927

[16] Petti, D., Buongiorno, P. J., Corradini, M., & Parsons, J. (2018). The future of nuclear energy in a carbon-constrained world. Massachusetts Institute of Technology Energy Initiative (MITEI), 272. Accessible here: https://energy.mit.edu/wp-content/uploads/2018/09/The-Future-of-Nuclear-Energy-in-a-Carbon-Constrained-World.pdf

[17] Nuclear power's comeback is down to small modular reactors | World Economic Forum (weforum.org)

[18] IAEA Climate Conference Ends with Call for Major Nuclear Role | IAEA

risk, and flexibility as the lower capacity allows for use in local heat generation (a significant source of GHG emissions).[19]

International trade can help enable the development of SMRs as they "are designed to be deployed in series, using a global supply chain to reduce costs."[20] For example, mass produced, standardised designs would allow for competition and specialisation in the production of parts and components in countries with competitive advantages. Indeed, a report by the OECD and NEA judges that the economic viability of SMRs is dependent upon the development of a global market.[21]

There are more than 80 different SMR models in development or deployment. When the technology matures, cooperation on international standards[22] could help to consolidate design and licensing[23] and facilitate production in global value chains.

Challenges for SMR development include a lack of legislation and regulation (e.g. for new fuels and different types of waste). International regulatory cooperation would be helpful to prevent trade barriers by accounting for relevant international regulatory settings when formulating proposals. Avoiding the duplication of effort and regulatory divergence can be achieved by cooperating, and by recognising existing regulations and international standards. The international standardisation community could play an important part, as could bilateral efforts on regulatory cooperation[24]. Successful cooperation could lower barriers to market access and make trade in reactor technologies and fuels more cost-effective.[25]

The use of international standards and increased regulatory coordination leads to lower administration costs and would facilitate trade in global value chains.

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19 Energiforsk (2020) Small Nuclear Reactors and Where to Use Them. Accessible here: https://energiforsk.se/info/vara-trycksaker-och-annat-informationsmaterial/small-nuclear-reactors-and-where-to-use-them/

20 International Energy Agency (2022) Nuclear Power and Secure Energy Transitions. Page 79. Accessible here: https://www.iea.org/reports/nuclear-power-and-secure-energy-transitions

21 Nuclear Energy Agency (2021) Small Modular Reactors: Challenges and Opportunities Accessible here: https://www.oecd-nea.org/jcms/pl_57979/small-modular-reactors-challenges-and-opportunities

22 The ISO technical committee on reactor technology (ISO/TC 85/SC 6) is monitoring developments and initiatives such as the IAEA Technical Working Group on Small and Medium-sized or Modular Reactors that gathers international experts in development, technology, design, and economics.

23 World Nuclear Association. (2015). Facilitating International Licensing of Small Modular Reactors. Cooperation in Reactor Design Evaluation and Licensing (CORDEL) Working Group of the World Nuclear Association. Accessible here: https://world-nuclear.org/our-association/publications/online-reports/cordel-facilitating-international-licensing-of-sma.aspx

24 For example, the US, EU Trade and Technology council has encouraged cooperated on compatibility standards by the standardisation organisations ASCM and CEN/ CENELEC.

25 The IAEA Initiative on Regulatory and Industrial Harmonization for SMR Development, the IAEA Nuclear Harmonisation and Standardisation Initiative, and the EU SMR pre-partnership are welcome initiatives in this area.

4 Trade flows, tariff barriers, and analysis

Key points:

- Trade in nuclear materials and products happens at various stages along the value chain.
- Natural uranium is mostly sourced from outside the EU, along with two-thirds of enriched uranium.
- Sweden is a large exporter of fuel elements.
- EU import tariffs on nuclear materials and products are generally low.

The purpose of this section is to present an overview of the international trade flows in nuclear materials and products. Nuclear materials include uranium and plutonium including source materials and fissionable materials such as enriched uranium. [26] Nuclear products refers to the specialist equipment used by the nuclear power industry.[27]

We provide an overview of trade at the EU level first, after which we look at Swedish trade flows. The main focus of this section is on imports, as the sourcing of inputs is vital for a well-functioning nuclear energy system, with exports mentioned where relevant.

4.1 The value chain of nuclear materials and products

Trade in nuclear materials and products happens at various stages along the value chain. The first stage covers trade in natural uranium, which is the most upstream product in the nuclear fuel value chain. The second stage is U-235 enriched uranium, for which three countries in the EU possess manufacturing capacity (Germany, France, the Netherlands). The final stage before use in nuclear reactors is the production of nuclear fuel elements, or cartridges, which happens in Germany, Spain, France, Romania, and Sweden. Trade in nuclear products following their use in nuclear reactors ("spent fuel elements") can also be traced back to a number of countries.

For the trade flow analysis, nuclear materials and products can be divided into two groups, using the Harmonized System (HS). Table 2 presents the relevant HS codes in each group.

[26] International Atomic Energy Agency (2022) IAEA Safeguards Glossary, International Nuclear Verification Series No. 3 (Rev. 1) Accessible here: https://www.iaea.org/publications/15176/iaea-safeguards-glossary

[27] Our work to enhance safety - Strålsäkerhetsmyndigheten (stralsakerhetsmyndigheten.se)

Table 2. HS codes for nuclear materials and products

HS code	Explanation
	Uranium materials and products
284410	Natural uranium
284420	Uranium enriched in U 235
284430	Uranium depleted in U 235
284440	Radioactive elements, isotopes, and alloys and dispersions
284450	Spent "irradiated" fuel elements "cartridges" of nuclear reactors
	Nuclear reactor products
840110	Nuclear reactors
840120	Machinery and apparatus for isotopic separation
840130	Fuel elements "cartridges" in casing with handling fixtures
840140	Parts of nuclear reactors

4.2 EU trade in nuclear materials and products

We discuss each stage of the nuclear energy value chain in more detail below.[28] Trade patterns for fuels, components and maintenance services can be affected by initial purchasing decisions because operators of nuclear plants are often reliant on the plant manufactures for these goods and services. For example, several Russian-designed VVER-type reactors are in operation in the EU. These reactors in Bulgaria, Czechia, Finland, Hungary and Slovakia, are reliant on Russian fuel and in 2022 there was around 60 per cent dependence for uranium conversion and enrichment.[29] These figures might be expected to fall as EU efforts to increase capacity are realised.

4.2.1 Trade in natural uranium

The origins of natural uranium (HS 284410) used in Europe are relatively diverse. Data from the Euratom Supply Agency (ESA) shows that in 2022, around a quarter of the natural uranium comes from Kazakhstan and Niger. Canada and Russia supply between 15 and 20 per cent each. Bilateral trade data shows that for natural uranium the three countries with enrichment production capacity (France, Germany, and the Netherlands) are the only importers of natural uranium in the EU27, with France accounting for about half of the EUR 1.2 billion EU27-imports in 2022.

4.2.2 Trade in enriched U-235 uranium

There are five EU member states that have conversion facilities (Germany, Spain, France, Romania, and Sweden). Together, these facilities provide around 35 per cent of the conversion needs in the EU (this figure includes a facility in the United Kingdom). Other large suppliers of uranium enrichment to the EU market are Canada,

[28] Data in this section is sourced from the Euratom Supply Agency (ESA - https://euratom-supply.ec.europa.eu/activities/market-observatory_en), and bilateral trade data from Eurostat Comext (https://ec.europa.eu/eurostat/comext/newxtweb/mainxtnet.do)

[29] Euratom Supply Agency (2023) ESA Annual Report 2022. Accessible here: https://euratom-supply.ec.europa.eu/publications/esa-annual-reports_en

Russia, and the United States (each around 20 per cent). Looking at bilateral trade data, enriched uranium is imported into the EU by Germany, Spain, France, the Netherlands, and Sweden.

The EU is also a large exporter of enriched uranium (HS 284420). Between them, the Netherlands, France, and Germany export around EUR 1.8 billion to third countries, mostly to the US, UK, and the Republic of Korea. Trade between EU member states in enriched uranium is around 4 times smaller at EUR 450 million.

4.2.3 Trade in nuclear fuel elements

The market for nuclear fuel elements (HS 840130) is very competitive, according to the Euratom Supply Agency[30]. Most nuclear reactors in Europe have at least two alternatives for the supply of their fuel elements. Diversification is key, as any delay in the delivery of the fuel elements can have serious consequences. This strategy is also visible in trade statistics. Still, EU member states import almost half of their fuel elements from Sweden, with Germany and Spain together accounting for another 20 per cent of the EU demand. Imports from non-EU sources such as Russia (25 per cent), the US (5 per cent) and the UK (3 per cent) make up the remainder of the demand.

Around 30 percent of the EU27 exports (worth EUR 350 million) are traded with non-EU partners, and only three EU member states report significant non-EU exports: France, Germany, and Sweden. Important partners as export destinations for EU-produced fuel elements are Ukraine, China, Switzerland, the UK, and South Africa (all over 15 per cent of total extra-EU exports).

4.3 Swedish trade in nuclear materials and products

This section briefly looks at trade in nuclear materials and products from a Swedish perspective, focusing on imports of uranium products (HS 2844) and nuclear reactor products (HS 8401). Bilateral trade data on imports in both product groups is a useful starting point but is affected by several methodological issues.[31] The data source for this section is microdata gathered by Statistics Sweden, and values are therefore reported in SEK. It should be noted that the figures in this section display annual averages between 2018 and 2022. The impact on trade flows of the Russian war of aggression in Ukraine is therefore not entirely reflected yet.

If we look at imports of uranium products, the vast majority of Swedish imports are comprised of enriched uranium. Sweden imported around SEK 550 million a year worth of enriched uranium, mostly sourced from Russia, Germany, and the UK. Note that preliminary data shows zero imports from Russia following the invasion. The enriched uranium that was imported into Sweden from Russia was used for fuel

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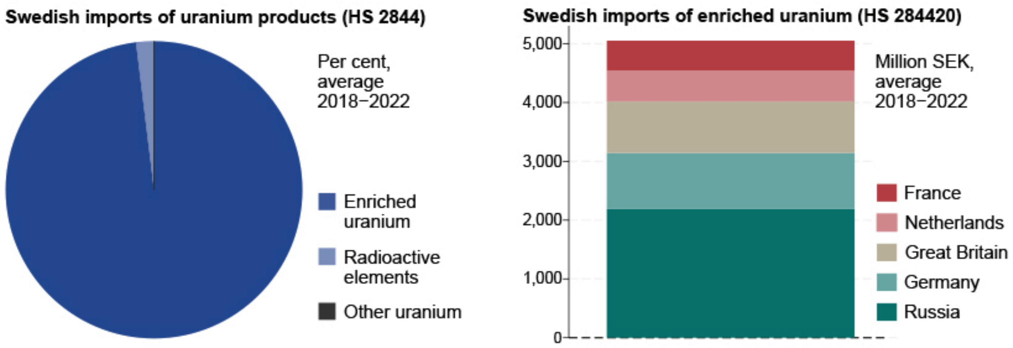
[30] Euratom Supply Agency (2023) ESA Annual Report 2022. Accessible here: https://euratom-supply.ec.europa.eu/publications/esa-annual-reports_en

[31] One issue is related to the “Rotterdam effect”, where imports from, for instance, Kazakhstan are first imported to the Netherlands, after which they are shipped to Sweden. Bilateral trade data are usually recorded by last country of shipment. A second issue is that not all trade may be reported due to security concerns, or specificities of international agreements.

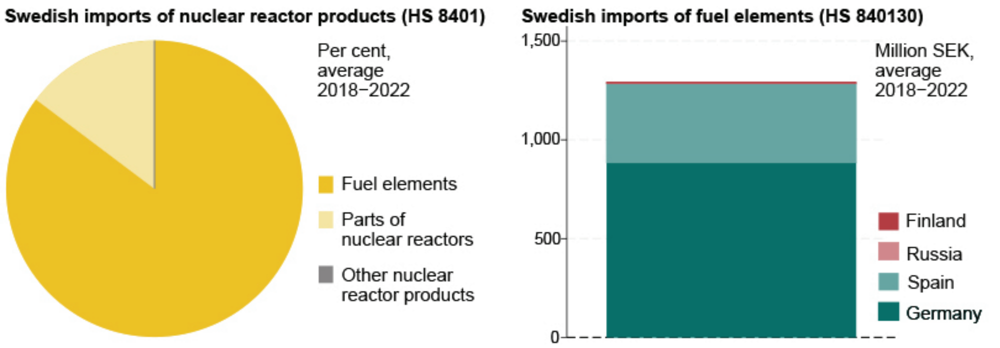
production for plants outside of Sweden. Purchasing decisions are made by the operators of these plants rather than businesses operating in Sweden.

Figure 2. Swedish imports of uranium products



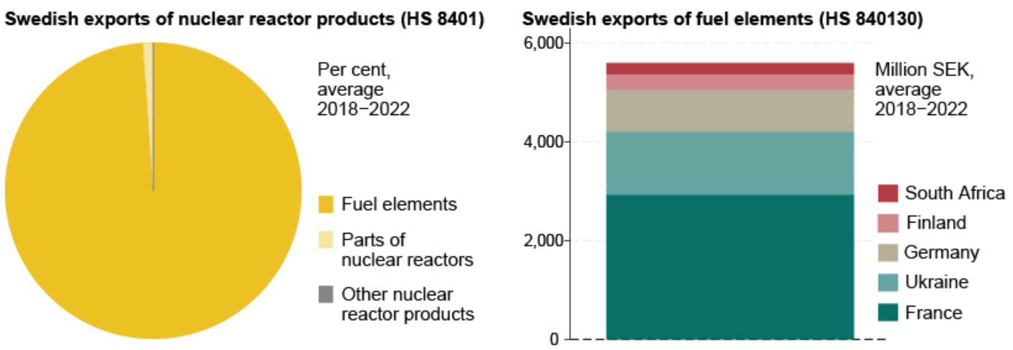
Looking at nuclear reactor products, Sweden largely imports ready-made nuclear fuel elements/ cartridges, sourced predominantly from Germany and Spain. Total annual imports of these fuel elements amount to around 1.3 billion SEK. At the same time, Sweden imports parts of nuclear reactors, which are likely used for maintenance of the active nuclear power plants around the country.

Figure 3. Swedish imports of nuclear reactor products



As we touched upon briefly in the previous section, Sweden exports fuel elements to other countries as well. In fact, the export values are about 4 times larger than import values. Most of Swedish exports go to France, Ukraine, and Germany.

Figure 4. Swedish exports of nuclear reactor products

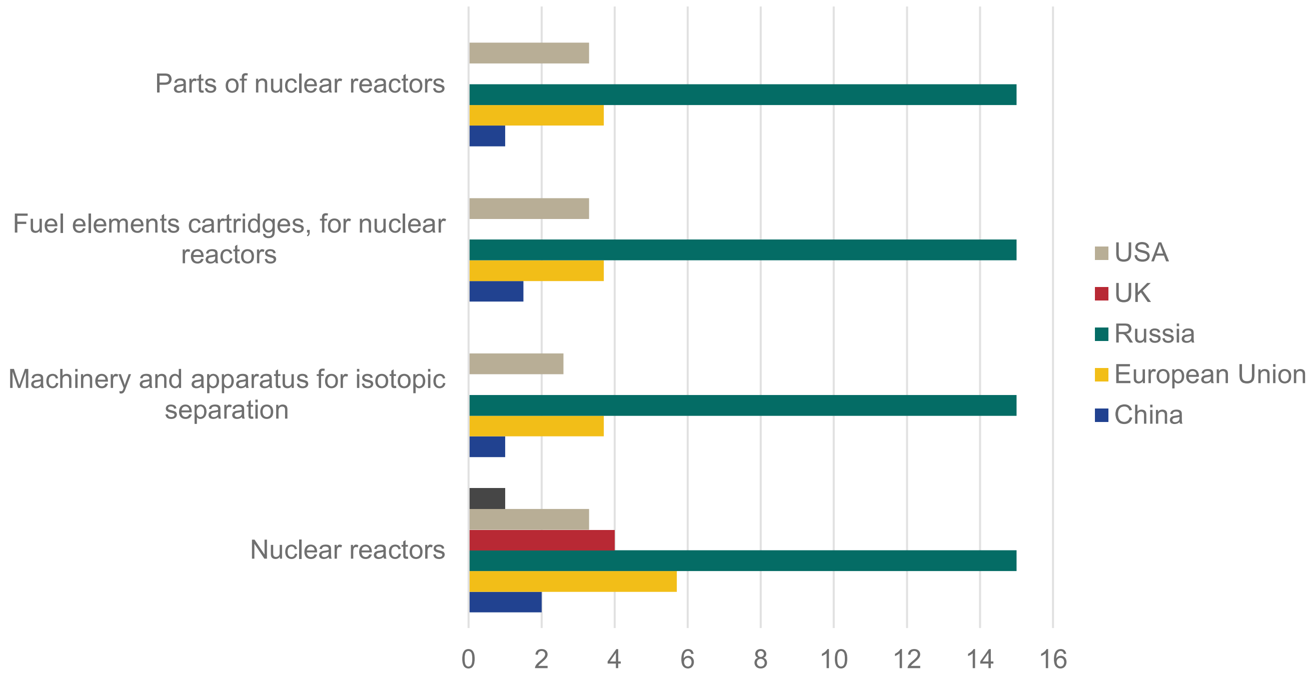


4.4 Tariffs

Tariffs on uranium and nuclear reactors are unlikely to be the largest barriers to trade for the industry. A basic analysis of applied MFN tariffs shows that for most countries, tariffs on uranium are generally low. Moreover, trade in uranium is mostly based on natural endowment and conversion and enrichment facilities, so tariffs are unlikely to drive or divert trade patterns. The EU has a tariff on depleted uranium of 1.7 per cent, and all other uranium traders under MFN-zero tariffs.

MFN tariffs on nuclear reactors are generally higher for some of the major players in the global market. For instance, the EU has MFN tariffs of 3.7 per cent on fuel cartridges and 5.5 per cent on nuclear reactors. While most imports come from countries with which the EU has free trade agreements, this makes imports from other partners more expensive. Russia applies 15 per cent MFN tariffs throughout this list of products, while other major players such as Canada, South Korea, and Japan, have an applied MFN tariff of 0 per cent.

Figure 5. Applied MFN tariffs of nuclear reactors (HS 8401)



5 Trade related rules for nuclear

Key points:

- Trade in materials, products and information exchange are subject to export controls managed at a national level within in a global framework.
- Export controls help manage proliferation risks and thus contribute to facilitating legitimate trade for civil nuclear purposes.
- Reforms could facilitate trade by reducing divergences between national licensing approaches and by considering different licencing procedures for low-risk technologies and countries. Any reforms must not weaken non-proliferation outcomes.
- Transportation of nuclear materials could be streamlined within the EU through a harmonised pan-European arrangement to approve cross-border transportation packages and an EU project for licensing registered carriers.

Having examined trade flows for nuclear materials and products, we now cover rules governing international trade for the industry.

Trade in nuclear materials, facilities and equipment as well as information and software is highly regulated for reasons of non-proliferation of nuclear weapons, safety, and energy security. Controls are implemented at national level and are based on the regulatory framework and monitoring provided by the International Atomic Energy Agency, international agreements and conventions,[32] and bilateral agreements[33] between countries involved in nuclear trade. The Swedish Radiation Safety Authority is the responsible agency in Sweden.

5.1 Export and import controls

Export control rules are to prevent the proliferation of nuclear weapons. The control regime was established with the formation of the International Atomic Energy Agency (IAEA) in 1957, with the Non-Proliferation of Nuclear Weapons Treaty signed in 1968. A committee of signatories (Zangger Committee) listed goods that should be subject to export controls. Importing states are also subject to IAEA safeguards to monitor and detect nuclear materials.[34] The Nuclear Suppliers Group was set up in 1974 and developed more detailed lists and dual-use lists. the UN Security Council Resolution 1540 of 2004 also requires states to prevent the proliferation of nuclear, chemical and biological weapons.

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[32] World Trade Organization (2023) International Export Regulations and Controls Accessible here: https://www.wto.org/english/res_e/publications_e/international_exp_regs_e.htm

[33] The EU has bilateral agreements on the peaceful use of nuclear energy with Australia, Canada, Japan, Kazakhstan, Ukraine, the United States, the United Kingdom and Uzbekistan.

[34] World Nuclear Association (2018). An Effective Export Control Regime for a Global Industry. Accessible here: https://world-nuclear.org/our-association/publications/online-reports/an-effective-export-control-regime-for-a-global-in.aspx

WTO members are permitted to apply these various export controls according to the national security exemptions in GATT article XXI (GATS article XIV) and the general exemptions under GATT article XX.[35]

Export controls cover transfers of items, software and technology, which have been specially designed and prepared for nuclear applications. Export licences are required and in Sweden, the Swedish Radiation Safety Authority reviews exports on a case-by-case basis.[36] The control regime is conducted in accordance with the EU Dual-Use Regulation[37] and complementary domestic legislation[38].

In practice, the export licensing process requires judgment of the item in question against legislative requirements. Information and evidence are required on what is being sent, who the end user is (normally with a company as the legal person), and how the item will be used. Export licencing is a core part of exporting companies' operations, and a lot of resources are devoted to the process given the importance of controls.

Controlled nuclear technologies are listed in the various agreements and their supporting documents. Examples of controlled items include nuclear reactors, various equipment for use in reactors and for processing materials (e.g. control rods, reactor coolant pumps, neutron detectors, gas centrifuges) and materials such as uranium, heavy water and nuclear grade graphite.

In addition to the export control regime there are also specific sanctions in place for Iran, North Korea and Russia.[39]

Sanctions against Russia

The updated EU sanctions against Russia (EU) 2022/328 (amending (EU) 833/201440) prohibit the sale and export of nuclear materials, products, technology, and software. This covers dual-use items listed in Part II of Annex I to Regulation (EU) 2021/821 (Dual Use Regulation).

Imports of nuclear materials and technologies have been exempted from the sanctions regulation (EU) 833/2014 to ensure the continued functioning of civil nuclear operations in certain Member States.

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35 World Trade Organization (2023) International Export Regulations and Controls Accessible here: https://www.wto.org/english/res_e/publications_e/international_exp_regs_e.htm

36 Our work to enhance safety - Strålsäkerhetsmyndigheten (stralsakerhetsmyndigheten.se)

37 EU-förordning 2021/821 (PDA-förordningen). Controlled nuclear items are listed in Annex I under CATEGORY 0 - NUCLEAR MATERIALS, FACILITIES AND EQUIPMENT

38 In Sweden's case Lag (2000:1064) om kontroll av produkter med dubbla användningsområden och av tekniskt bistånd, som också omfattar bestämmelser om straff för brott mot rådets förordning

39 Exportkontroll - Strålsäkerhetsmyndigheten (stralsakerhetsmyndigheten.se)

40 Council Regulation (EU) No 833/2014 of 31 July 2014 concerning restrictive measures in view of Russia's actions destabilising the situation in Ukraine.

The import regime varies for different materials and technologies. Importing countries and companies are checked as part of national export control regimes and in addition some imports are managed at the EU level. For example, in the EU, the purchase of uranium on international markets is coordinated by and must be approved through the Euratom Supply Agency (ESA). The aim of centralised monitoring and control is to ensure a diverse, regular, and fair supply of materials. The ESA can limit how much uranium is purchased from specific countries and recommends that countries have at least a year's worth of fuel in storage.

In addition to the IAEA safeguards and export control regime, import licences for nuclear materials, products and technologies are also required in several countries.[41] Licences for the import of nuclear materials and wastes are required in Sweden and are issued by the Swedish Radiation Safety Authority.[42]

5.2 Export control reforms to facilitate trade

The objectives of export and import controls are to prevent nuclear materials falling into the wrong hands, not to hinder trade. Indeed, the export control rules help to manage proliferation risks and thus contribute to facilitating legitimate civil trade.[43]

The World Nuclear Association argue that export control procedures could be improved without risking proliferation objectives. While we do not have the expertise to assess the arguments from a proliferation perspective, the trade argument is compelling. Helping reduce the time and cost associated with licensing requirements would reduce a barrier to the flow of goods, technologies and services over borders as well as making international cooperation on technical and safety issues easier. Reductions in time and resources needed for administration would also be meaningful for the industry in the EU.

The World Nuclear Association suggest the following improvements.[44]

- Licensing of exports is currently applied differently by countries. Governments that apply IAEA safeguards could decide to cooperate to reduce divergences between licensing approaches and mutually recognise each other's export and domestic control regimes.
- The current system applies the same control regime to all listed technologies regardless of risks posed. A risk-based export control regime could be designed to determine the level of scrutiny required based on destination risks and technology

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41 Examples include Finland, Hungary and the US.

42 Nuclear Energy Agency (2008) Nuclear Legislation in OECD and NEACountries: Sweden (2008 update). Accessible here: https://www.oecd-nea.org/jcms/pl_24241/nuclear-legislation-in-oecd-and-nea-countries-sweden-2008-update

43 Anthony, I., Ahlström, C., & Fedchenko, V. (2007). Reforming nuclear export controls: the future of the Nuclear Suppliers Group (No. 22) Accessible here: https://www.sipri.org/publications/2007/reforming-nuclear-export-controls-future-nuclear-suppliers-group

44 World Nuclear Association (2018). An Effective Export Control Regime for a Global Industry. Accessible here: https://world-nuclear.org/our-association/publications/online-reports/an-effective-export-control-regime-for-a-global-in.aspx

risks. For example, reactors, components, spare parts or repair services traded between Nuclear Suppliers Group members should pose lower risks and could be traded under a general licence.[45] Higher risk technologies (e.g. enrichment or reprocessing technologies) and destinations would be subject to individual licensing requirements or bans as is currently the case.

- Most products require licences for transfers within the EU.[46] Trade within the EU is seen as low risk by the World Nuclear Association and could be notifiable but not restricted for low-risk technologies.

Timing it right for fuel sales

Fuel elements are expensive and are traded on a competitive world market. While export controls are not seen as a barrier, risks arise in relation to timing when developing new customer relationships. For potential customers to judge the value of the product, detailed technical specifications need to be sent and this information requires an export license. The time required to obtain licences varies depending on administrative capacity and average times vary by country. Individual contracts are highly valuable and can span long time periods, meaning there is a lot at play even if the probability of losing a new customer due to administrative delay is low.

5.3 Transportation

International transport of nuclear materials, technology and waste is conducted according to safety and security standards established by the IAEA.[47] These cover all modes of freight (air, land and water) and are adopted in the mandatory global International Maritime Dangerous Goods Code by the International Maritime Organisation for shipment by sea, and by the International Civil Aviation Organization Technical Instructions for shipment by air.[48] The standards cover various aspects such as transport package design, material categorisation, documentation, labelling, and container requirements.[49]

Responsibility for land transport lies with the national governments. In Sweden, domestic transport permits are issued by the Swedish Radiation Safety Authority and comply with the extensive international regulatory framework for transporting dangerous goods.[50] This includes the agreement concerning the International Carriage of Dangerous Goods by Road (ADR) and the convention concerning International

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45 Note, the WNA recommendation was drafted before the Russian invasion of Ukraine.

46 Strategisk exportkontroll 2021 — krigsmateriel och produkter med dubbla användningsområden (regeringen.se)

47 International Atomic Energy Agency (2018), Regulations for the Safe Transport of Radioactive Material, IAEA Safety Standards Series No. SSR-6 (Rev.1) https://doi.org/10.61092/iaea.ur52-my9o.

48 Op. cit.

49 Op. cit.

50 Authorisation to transport radioactive material - Strålsäkerhetsmyndigheten (stralsakerhetsmyndigheten.se)

Carriage by Rail (COTIF), regulating train transport.[51] The land transport rules are enforced by the Swedish Civil Contingencies Agency, while the Swedish Transport Agency regulates maritime and air carriage. [52]

Transportation of nuclear materials is often problematic, with barriers to trade due to regulatory divergence. A lack of harmonisation and multiple regulations for authorisation of transport is particularly troublesome for cross border freight. Divergent approaches lead to scheduling difficulties, interruptions, and delays which increase operational and administrative costs and can even pose a risk to reactor operations.[53] In addition, local decisions in EU countries to close ports to nuclear materials shipments combined with several shipping companies refusing nuclear materials have created additional transportation problems for the industry. These factors lead the Euratom Supply Agency Advisory Committee working group on prices and security of supply to judge transport to be a risk relevant to security of supply.[54]

The same committee recommends a harmonised pan-European arrangement to approve cross-border transportation packages with validity in each European country. This could be supplemented with an EU project for licensing registered carriers. They also suggest the practical measure of using dedicated charter vessels for shipping nuclear materials. These measures would help reduce administrative burdens, save resources and time and contribute to easier trade in materials at the EU level.

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51 These are codified in Swedish law in the The Swedish Transport of Dangerous Goods Act (SFS 2006:263), the Transport of Dangerous Goods Ordinance (SFS 2006:311), the MSB provisions (MSBFS 2022:3) on the transport of dangerous goods by road (ADR-S), and MSB provisions (MSBFS 2022:4) on the transport of dangerous goods by rail (RID-S).

52 Authorisation to transport radioactive material - Strålsäkerhetsmyndigheten (stralsakerhetsmyndigheten.se)

53 DG Energy of the European Commission (2020) Analysis of Nuclear Fuel Availability at EU level from a Security of Supply Perspective. Accessible here: https://op.europa.eu/en/publication-detail/-/publication/5fad2d20-8fa2-11ea-812f-01aa75ed71a1/language-en

54 Op cit.

6 Agenda 2030 and trade

Key Points:

- The global nuclear industry can contribute to the Sustainable Development Goals (SDG) for climate action (SDG 13), clean energy (SDG 7) and reliable infrastructure (SDG 9.1).
- The main trade-offs are for environmental goals due to waste storage and mining for raw materials which affect life on land (SDG 15).

Aside from contributing to the climate transition (SDG 13), nuclear has other positive and negative impacts in relation to the Sustainable Development Goals.[55] International trade can assist in strengthening synergies with goals related to affordable and clean energy (SDG 7), sustained economic growth (SDG 8.1), and reliable infrastructure (SDG 9.1). For example, transfer of technical knowledge and hardware across borders can assist in making for civil nuclear projects more effective and affordable.

Trade-offs are more prevalent[56] in relation to the environment, mainly due to legacy costs of waste. Water use in nuclear operations can lead to water stress and thermal pollution, conflicting with water pollution goals (SDG 6.3). The negative effects of mining nuclear raw materials affect health and life on land (SDG 15). The very rare risk of leakage and plant failure is also relevant for health and the environment. International trade's effect on these trade-offs is ambiguous. On one hand, growth due to trade could marginally increase strains related to waste, water pollution and mining. On the other hand, international cooperation, technology transfers and flows of technical safety information across borders could reduce environmental damage and health risks.

[55] Analysis of nuclear energy in relation to the Sustainable Development Goals (SDGs) was undertaken using the SCAN tool SDG Climate Action Nexus tool (SCAN-tool) (transparency-partnership.net)

[56] There are also synergies with health and environmental goals because when compared to coal and bioenergy, nuclear power reduces air, water and soil pollution. This contributes to goals on reducing premature mortality (SDG 3.4) and hazardous chemicals (SDG 3.9) and reducing degradation of natural habitats (SDG 15.5).

7 Discussion and recommendations

Nuclear power can play an important role in fossil free energy systems and thus contribute to the climate transition. The extent to which this happens will depend on commercial decisions alongside public policy and financial support.

This report has provided an analysis of international trade issues affecting the nuclear industry, examining the rules that govern trade flows, trade patterns along the value chain and barriers to trade. International trade has implications for energy security and trade policy can help lower costs of fuels, components, parts and services for the operation of existing reactors as well as improving the economics of small modular reactor production for future investments. Several points stand out as important for policymakers.

Cost is identified as one of the main barriers for the development of the nuclear industry.[57,58] Trade policy can help lower costs, reduce administrative burdens and time taken to transfer technologies and services over borders. Specific policy recommendations include:

- Removing existing EU tariffs on nuclear materials and technologies. This could be done in coordination with trading partners that apply tariffs or unilaterally to reduce input costs (Japan, Canada, South Korea have 0 applied MFN tariffs).
- Investigate the potential to introduce risk-based approaches to export licensing with the aim of reducing the time and cost associated with licensing. This would require input from non-proliferation experts as well as agencies involved in export control to ensure any recommendations are not at the expense of proliferation.[59]
- Countries that apply IAEA safeguards could seek to cooperate to reduce divergences between export licensing approaches and aim to mutually recognise each other's export and domestic control regimes.
- Most nuclear materials and technologies require licences for transfers within the EU.[60] As trade within the EU is seen as low risk there are potential gains to improved movement of low-risk nuclear goods and services within the single market. European cooperation could be enhanced in this area.
- Lowering transport costs and administrative burdens would save resources and time and contribute to easier trade in materials at the EU level. The Euratom Supply Agency Advisory Committee Working Group on Prices and Security of Supply suggest a pan-European arrangement for approving cross-border transportation of packages alongside a supplementary EU project for licensing registered carriers.

57 IAEA Climate Conference Ends with Call for Major Nuclear Role | IAEA

58 Linares, P., & Conchado, A. (2013). The economics of new nuclear power plants in liberalized electricity markets. Energy Economics, 40, S119-S125. Accessible here: https://www.sciencedirect.com/science/article/abs/pii/S0140988313002028

59 For example, Inter-governmental organisations including the IAEA, NSG, Wassenaar Arrangement and the UN Office for Disarmament Affairs could be involved.

60 Strategisk exportkontroll 2021 — krigsmateriel och produkter med dubbla användningsområden (regeringen.se)

In relation to short term energy security, nuclear is a dispatchable energy source so contributes to a stable base load and reduces price variation. The energy security risks identified in the trade flow data as well as by the Euratom Supply Agency relate to dependency on specific countries, companies and regions. European reliance on Russian fuels (enriched uranium), and components and expertise (for Russian build reactors in several EU countries) pose a supply risk. Trade diversification strategies can be complemented by actions to make it quicker and easier to licence and transport nuclear materials and technologies from other countries. The suggestions in chapter 5 for international cooperation to ease barriers to trade due to divergent export control regimes and to ease licencing would help the EU to adapt should supply risks materialise.

Finally, small modular reactors (SMRs) have potential to play a large part in the future of the nuclear industry. Potential cost advantages of SMRs are predicated on economies of series with factory production and trade in global value chains. Maintaining free trade by removing tariffs and avoiding other non-tariff barriers is important for the success of SMRs. We recommend:

- International cooperation on regulatory processes, particularly where there is a lack of legislation and regulation (e.g. for licencing, for new fuels and different types of waste). Aiming for common or coordinated regulations and rules would make trade in reactor technologies and fuels easier and with lower barriers to market access.
- Cooperation aiming for the development and use of international standards[61] as the SME market matures.

[61] As encouraged in WTO agreements such as the TBT Agreement and the GPA agreement

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9 Sammanfattning på svenska
Summary in Swedish

I denna analys visar Kommerskollegium hur handelspolitiken kan bidra till att minska kostnaderna för kärnkraft. Vi beskriver kärnkraftens roll i klimatomställningen och analyserar handelsflöden och tariffära handelshinder för kärnämnen och kärnteknisk utrustning. Handelsrelaterade regler för exportkontroll och transport undersöks samt hur handelspolitiken kan stödja utvecklingen av småskaliga reaktorer. Vi ger rekommendationer på hur handelspolitiken kan bidra till färre handelshinder och därmed minskade kostnader för kärnkraftsindustrin.

Det finns idag ett förnyat fokus på hur kärnkraft kan bidra till klimatomställningen. På FN:s klimatkonferens COP28 lanserade ett 20-tal länder, inklusive Sverige, en deklaration om stärkt samarbete med målet att tredubbla produktionen av kärnkraft. För att kärnkraften ska bidra mer till klimatomställningen måste nya reaktorer vara kostnadsmässigt konkurrenskraftiga. Handelspolitiken kan reducera handelshinder och bidra till ökad effektivitet, stordriftsfördelar, minskade kostnader och innovationsvinster.

Utrikeshandel gör kärnkraftsindustrin mer effektiv

EU:s kärnkraftsindustri är beroende av internationell handel för drift, underhåll och utveckling. Till exempel importeras naturligt uran till största delen från länder utanför EU och två tredjedelar av det anrikade uranet importeras från länder utanför EU. Men det finns utmaningar eftersom 20 procent av EU:s anrikade uran kom från Ryssland 2022. Flera EU-länderna försöker nu hitta nya leverantörer.

Handeln är viktig också för den svenska industrin, inte minst för de årliga revisionerna när kärnkraftverken byter ut en del av sitt bränsle och genomför service vid anläggningarna. Importen av anrikat uran, komponenter samt tjänster som utförs av experter är viktiga för revisionsprocessen. Sverige är också en stor exportör av kärnbränsleelement.

Exportkontroll ska vara effektiv och förhindra oönskad spridning

Handeln med kärnämnen, kärnteknisk utrustning och teknisk information omfattas av exportkontroll för att förhindra spridning av kärnvapen. Detta underlättar också handeln för fredliga ändamål.

En möjlig handelseffektivisering skulle vara att minska skillnaderna i licensförfaranden för exportkontroll samt att överväga en riskbaserad metod för exportkontroll. Dessa förslag till förenklingar skulle noggrant behöva följas upp av experter för att inte riskera oönskad spridning och sämre säkerhet. Dessa förslag är även relevanta för handeln på EU:s inre marknad.

Vidare finns det möjlighet att effektivisera och harmonisera transportförfarandena på EU:s inre marknad.

Det skulle också vara en fördel för EU att ta bort tullarna på import av olika kärntekniska produkter, delar och komponenter. Dessutom kan det internationella regulativa samarbetet främja utvecklingen av en global marknad för småskaliga reaktorer, så att industrin kan utnyttja de fördelar som internationell handel medför.

The National Board of Trade Sweden is the government agency for international trade, the EU internal market and trade policy. Our mission is to facilitate free and open trade with transparent rules as well as free movement in the EU internal market.

Our goal is a well-functioning internal market, an external EU trade policy based on free trade and an open and strong multilateral trading system.

We provide the Swedish Government with analyses, reports and policy recommendations. We also participate in international meetings and negotiations.

The National Board of Trade, via SOLVIT, helps businesses and citizens encountering obstacles to free movement. We also host several networks with business organisations and authorities which aim to facilitate trade.

As an expert agency in trade policy issues, we also provide assistance to developing countries through trade-related development cooperation. One example is Open Trade Gate Sweden, a one-stop information centre assisting exporters from developing countries in their trade with Sweden and the EU.

Our analyses and reports aim to increase the knowledge on the importance of trade for the international economy and for the global sustainable development. Publications issued by the National Board of Trade only reflect the views of the Board.

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Kommerskollegium
National Board of Trade Sweden

Box 6803, S-113 86 Stockholm, Sweden
Phone +46 8 690 48 00
E-mail registrator@kommerskollegium.se
www.kommerskollegium.se