Security of Sustainable Energy Supplies



Göran Andersson

VBIK, 1 oktober 2025

Outline

- A few words about EASAC, European Academies Science Advisory Council
- History of challenges in electric power engineering
- Some highlights from the EASAC report *Security of Sustainable Energy Supplies (SoSES)*
- Concluding remarks

EASAC – European Academies Science Advisory Council

28 National Science Academies
from EU, CH, NO, & UK

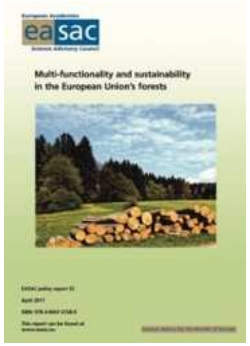
Three scientific panels: **Energy, Environment, Life Sciences**

Mission:

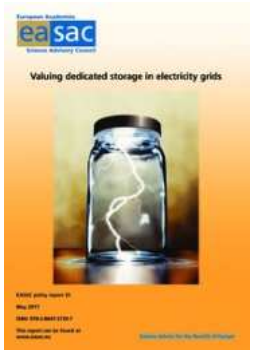
- science-based advice for policy makers
- NOT policy for science (research policy)
- BUT highlight gaps in research and skills

Reports and other documents available at *www.easac.eu*

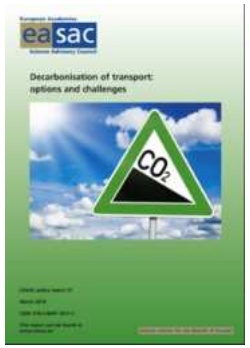
Energy Reports from EASAC



Forests 2017



Storage 2017



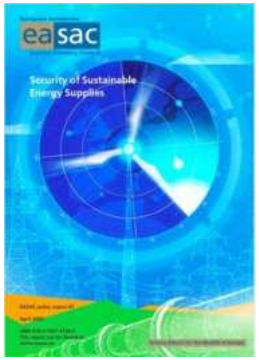
Transport 2019



Buildings 2021



Future of gas 2023



Security of sustainable energy supplies 2025 (Feb '24 - Mar '25)



Changing Wildfires – Policy Options for a Fire-literate and Fire-adapted Europe 2025

Example from Transport Report (2019)

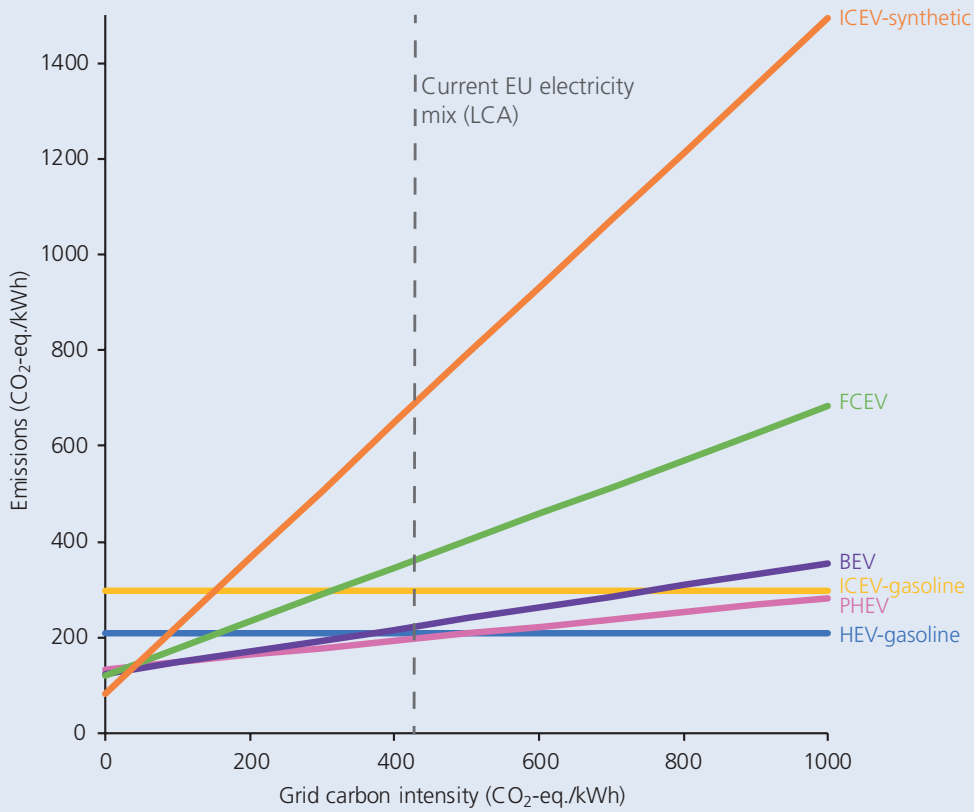
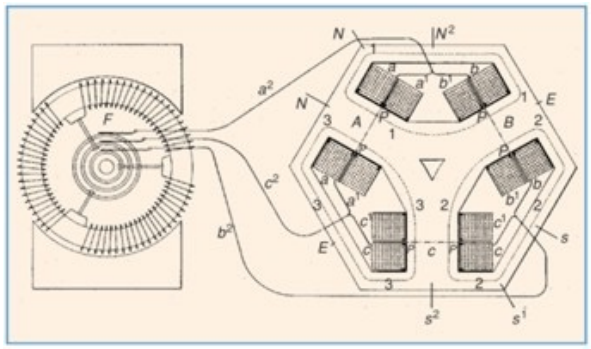


Figure 3.5 Sensitivity of emissions of different passenger car technologies to carbon intensity of electricity mix. (Adapted from Cox 2018.)

History of challenges in electric power engineering

From Goran Štrbac, Imperial College

Challenge 1: To make it work (≈ 1880 – 1920)





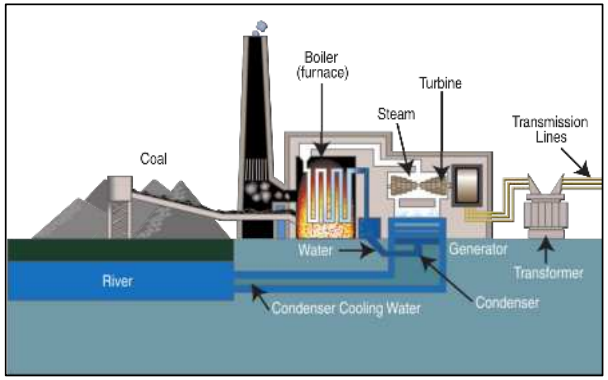


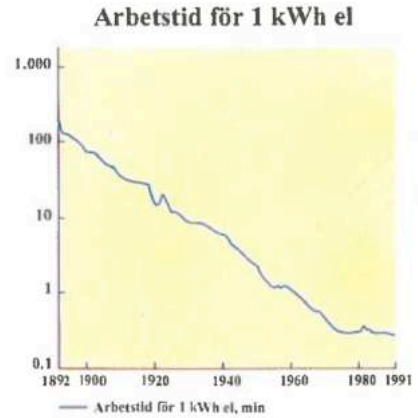




Challenge 2: To make it big and affordable (≈ 1920 – 1990)

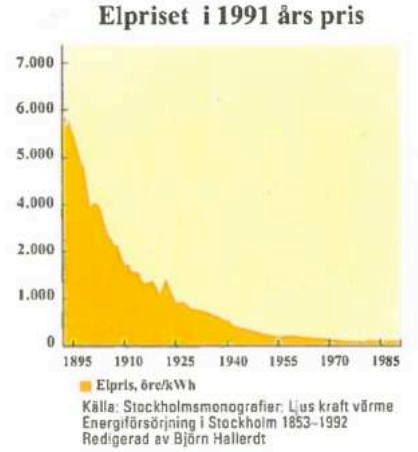












Challenge 3: To make it sustainable, market based and still affordable (≈ 1990 -)

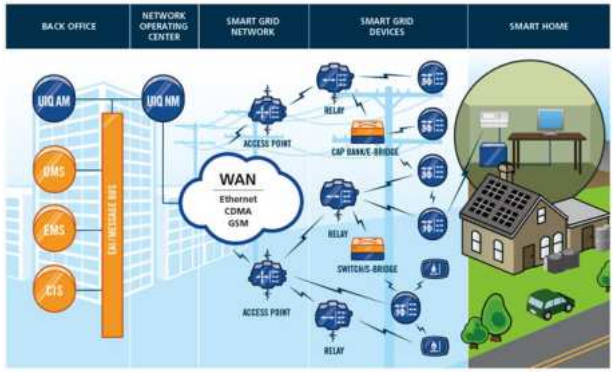


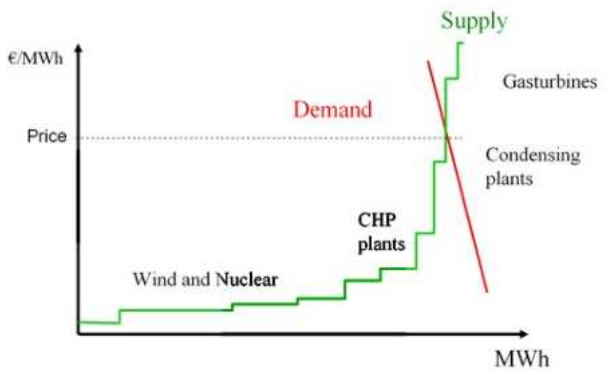




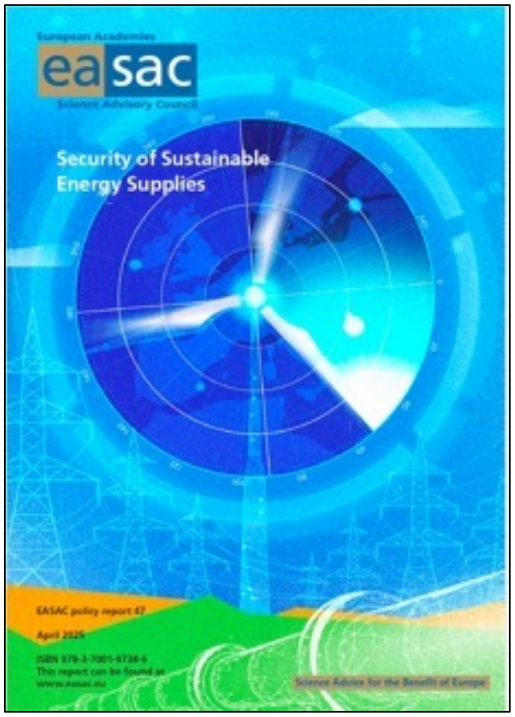








Security of Sustainable Energy Supplies



Report, 87 pages, 300+ references (May 2025)
Available at *www.easac.eu*

Working Group on SoSES

Nominated expert	Country
Prof. Reinhard Haas	Austria
Prof Thijs van de Graaf	Belgium
Prof Claire Dupont (co-chair)	Belgium
Prof Neven Duic	Croatia
Prof Soteris Kalogirou	Cyprus
Dr. Antonín Fejfar	Czech Republic
Dr. Rita Sik-Simon	Czech Republic
Prof Frede Blaabjerg	Denmark
Prof Alar Konist	Estonia
Prof Paula Kivimaa (co-chair)	Finland
Bertrand Charmaison	France
Costis Stambolis	Greece
Dr Bálint Hartmann	Hungary

Nominated expert	Country
Prof Attila Imre	Hungary
Dr Vidas Lekavičius	Lithuania
Prof Koen Kok	Netherlands
Dr Gerd Kjølle	Norway
Prof Magnus Korpås	Norway
Prof. Piotr Lampart	Poland
Prof. Manuel Collares-Pereira	Portugal
Prof. Dr. Ionut Purica	Romania
Prof. Dr. David P Serrano	Spain
Prof Mathias Ekstedt	Sweden
Prof. Bert Allard	Sweden
Prof Russell McKenna	Switzerland
Prof Benjamin Sovacool	UK

26 experts from
21 countries

Source: EASAC

SoSES Report: “a Starting Point” for Discussion

0. **Executive summary :** Highlights, Infographic, Recommendations
1. **Introduction**
2. **The energy transition** (switch from fossil fuels to sustainable energies)
3. **Sustainable energy technologies, energy carriers, and fuels** (strategic roles)
4. **Critical and strategic raw materials** (metals & rare earth elements)
5. **Cyber security** (digitalised EU energy sector must be protected)
6. **The European electricity system** (grid flexibility management)
7. **Energy security risks, benefits, and threats** (what more must be done?)
8. **Conclusions**

Source: EASAC

Energy security – what does it mean ?

"Uninterrupted availability of energy supplies at affordable prices"

Threats

Volatile geopolitics: malicious attacks and cyberattacks on energy infrastructure, supply chains, and trade

Climate change: climate damage, growing cooling demand

Old thinking: Import to Europe

New thinking: Invest in Europe



Source: EASAC

Energy security, how?

Energy security

→ Energy efficiency

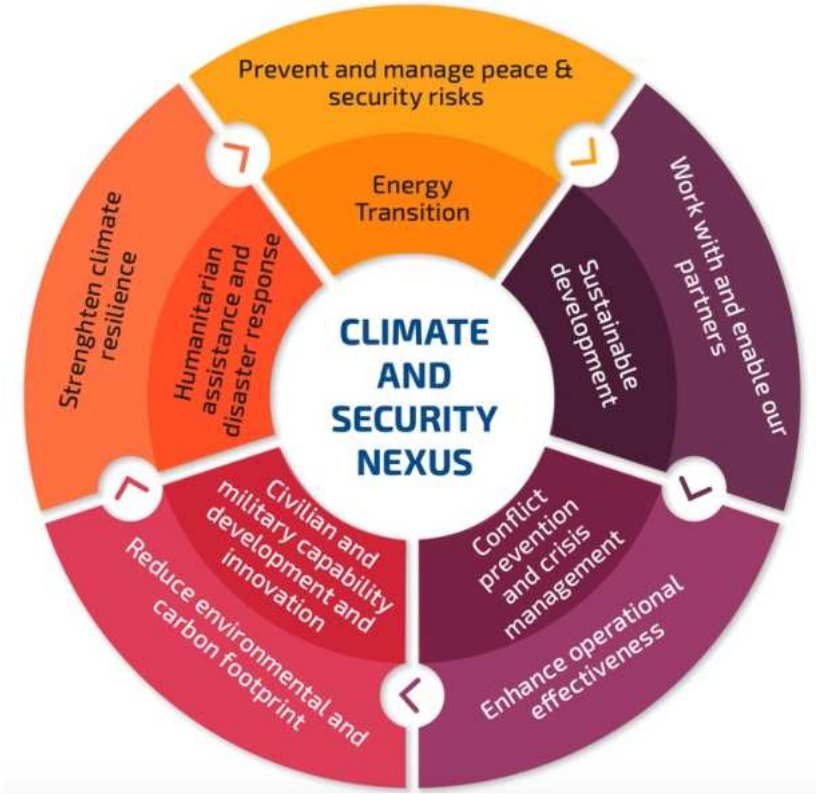
→ Electrification



Владимир Ленин

“Communism is Soviet power plus the electrification of the whole country.”

EU policies on security have a long history



EU Strategic Compass, 2023

More focus needed on implementation

- Foreign affairs and security policy
- Green Deal
- European Economic Security Strategy
- Resilience and critical entities and infrastructure
- Cyber security acts
- Net Zero Industry Act
- Critical Raw Materials Act
- Clean Industrial Deal

➡ **No security without energy security**

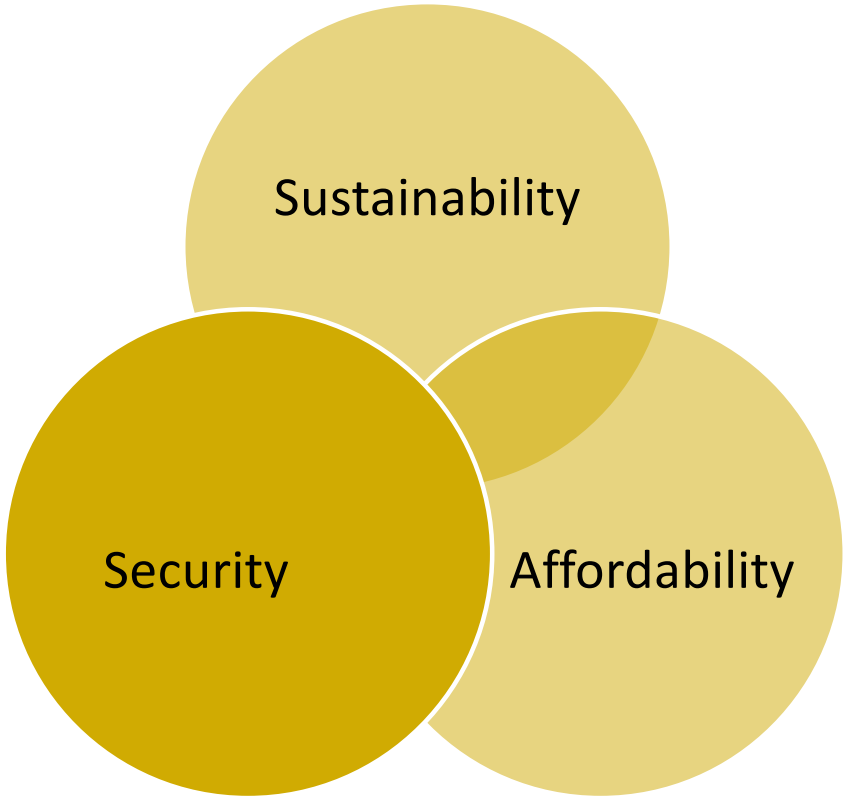
Source: EASAC

European energy policy trilemma

Focus has shifted from sustainability to security

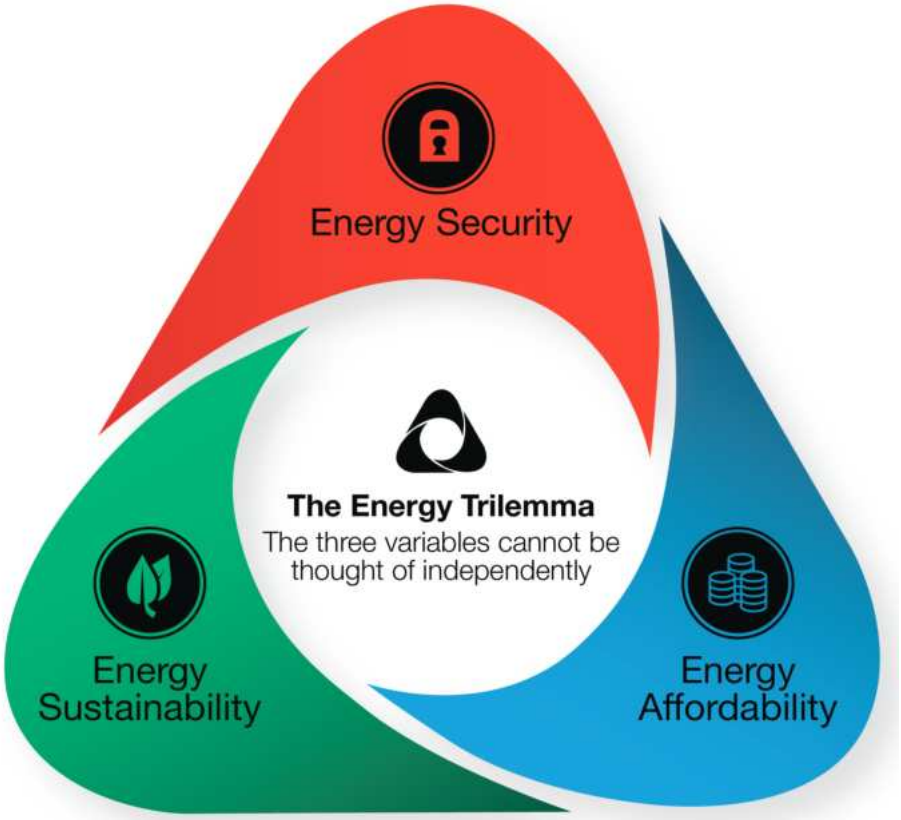
Green Deal
work with global markets to reduce GHG emissions

REPowerEU
Clean Industrial Deal
respond urgently to geopolitical attacks



Source: EASAC

The Energy Trilemma



Source:
Arup's "Five minute guide to Energy Trilemma"

WEC Energy Trilemma Index

2023 Country rankings

Index rank	Country name	Balance grade	Trilemma score	Energy security score	Energy equity score	Enviromental sustainability score
1	Denmark	AAAa	83.2	72.2	95.8	83.5
1	Sweden	AAAa	83.1	73.4	93.4	85

Source: WEC

Invasion of Ukraine highlighted security risks

Europe is too dependent on imported fuels

- *Natural gas* 45% from Russia in 2022
- *LNG* 45% from USA in 2024
- *Nuclear fuels* 79% from Russia in 2023

Europe is too dependent on imported energy technologies & materials

- *Solar cells* > 90% from China
- *Batteries* growing demand for EV & stationary unit imports
- *Rare earth elements* 98% from China in 2022
- *Critical raw materials* supply chains lack diversity and labour protection

Cyberattacks on grids doubled between 2020 and 2022 (Eurelectric)

Source: EASAC

“Security Milestones”

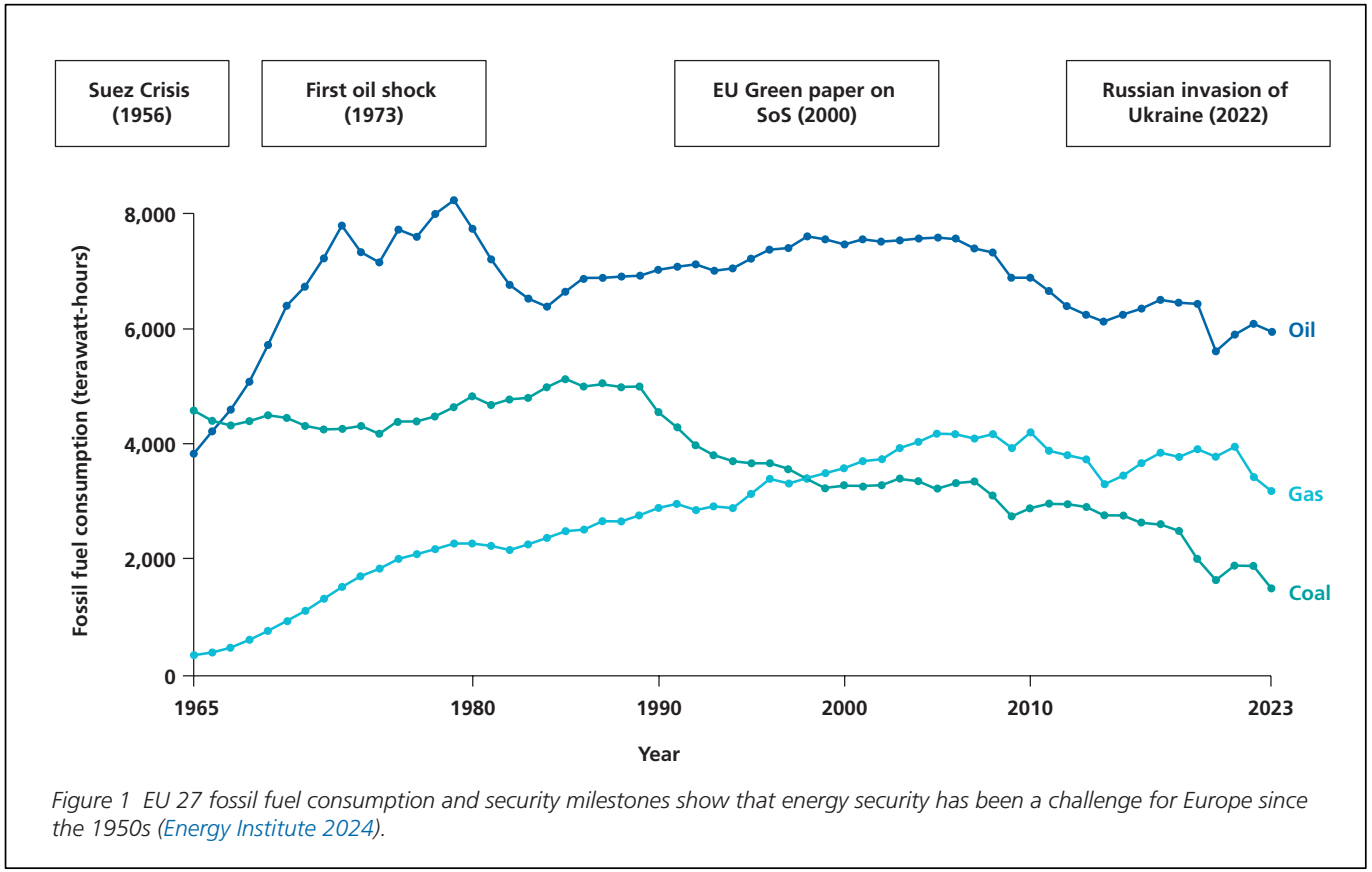


Figure 1 EU 27 fossil fuel consumption and security milestones show that energy security has been a challenge for Europe since the 1950s (Energy Institute 2024).

Source: EASAC

Analogies to the oil crisis of the seventies

- ”***Lithium batteries are the new oil***”, **(Elon Musk 2022)**
- ”***Hydrogen is the new oil***”, **(Lepercq 2019)**
- ”***Semiconductors are the new oil***”, **(Meyer & Murray 2021)**
- ”***Water is the new oil***”, **(TIME 2024)**
- "***Minerals are the new oil***”, **(Washington Post 2025)**
- ”***Data is the new oil***”, **(Humby 2006)**

Source: Olle Olsson, Energimyndigheten

Energy System Models

- Numerous different energy system models have been used to study, analyze, and evaluate various future scenarios

- But, remember

  “Essentially, all models are wrong, but some are useful”

  George E.P. Box



EASAC Energy System Modelling Workshop (Oct. 2024)

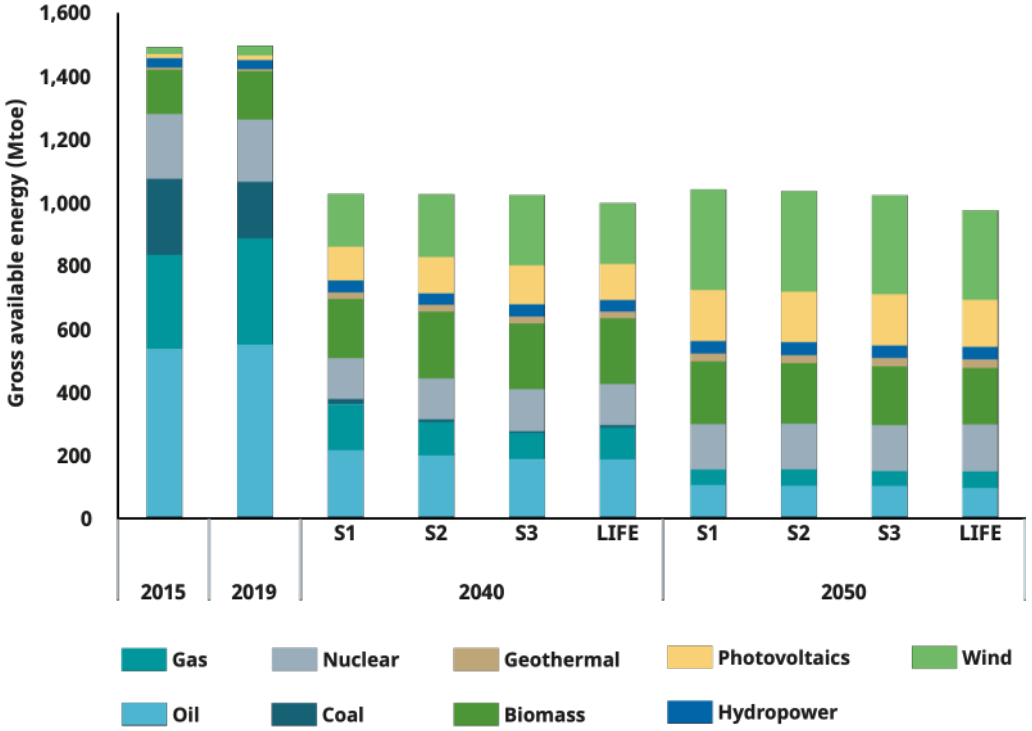
- There is no universally optimal mix of electricity supplies
- There are still uncertanties relating to the security and costs of transitions to sustainable energy supplies
- Holistic energy systems modelling is needed for EU adequacy and flexibility assessment
- Modelling fully integrated energy systems is computationally costly
- A mix of flexiblity measures is needed to manage electricity systems with high percentage VRES
- Backup dispatchable generating capacity will be needed
- Dunkelflauten (periods of low wind and sun) are a challenge for all VRES-dominated systems
- Strong cross-border interconnections provide flexiblity to energy systems, but their use must be manage fairly

Source: EASAC

Many energy systems and scenarios are being modelled

Emerging trends:

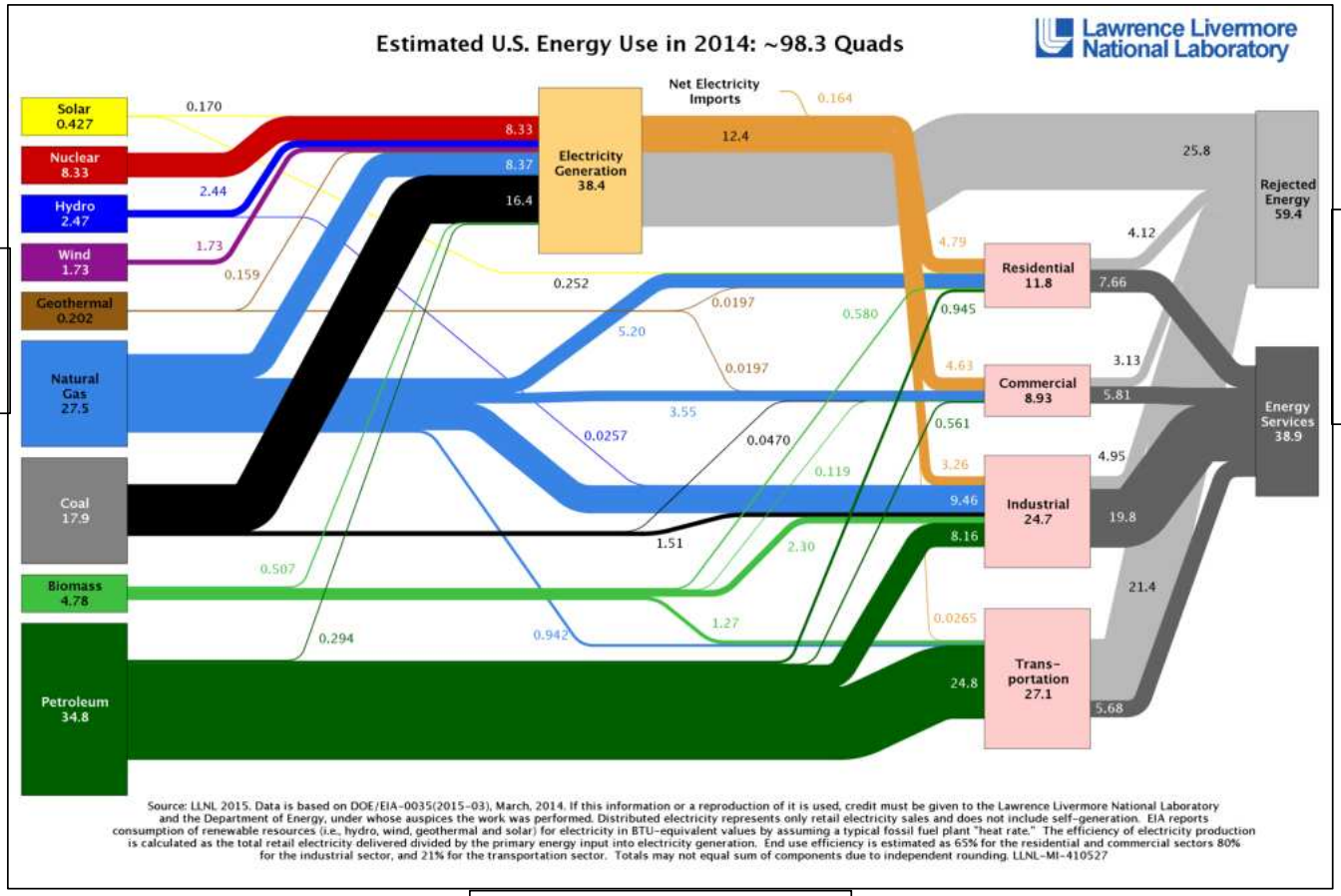
- EU electricity supplies could double by 2050
- Rapid growth in variable renewables
- Hydrogen will be used in industry, transport, & managing grid flexibility
- High % renewables can be feasible



Source: EASAC

Sankey diagram – TPES vs TFEC

TPES:
Total Primary Energy Supply



TFEC:
Total Final Energy Consumption

Energy flows in US

Final energy consumption in EU

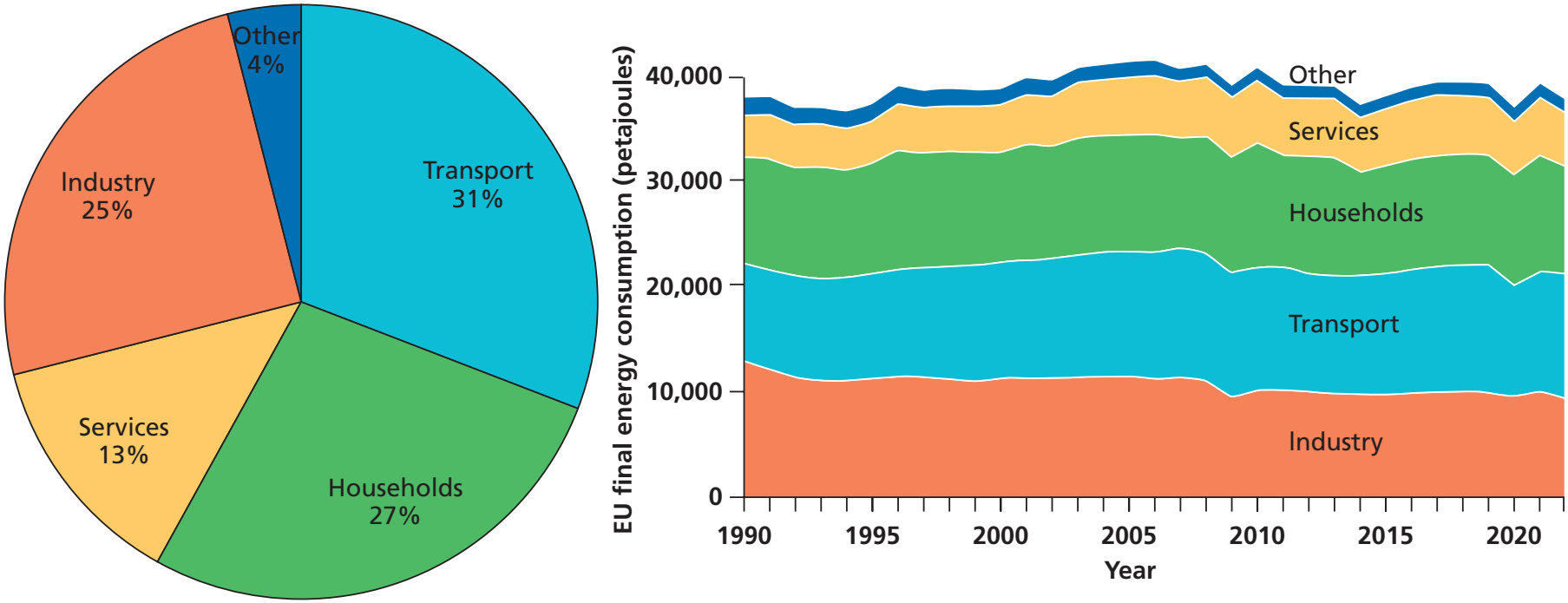


Figure 7 EU final energy consumption was dominated by the transport, household, and industry sectors in 2022, and this sector distribution had hardly changed since 1990 (Eurostat 2024g).

Source: EASAC

Security policies for energy consumption & infrastructure

Energy efficiency first

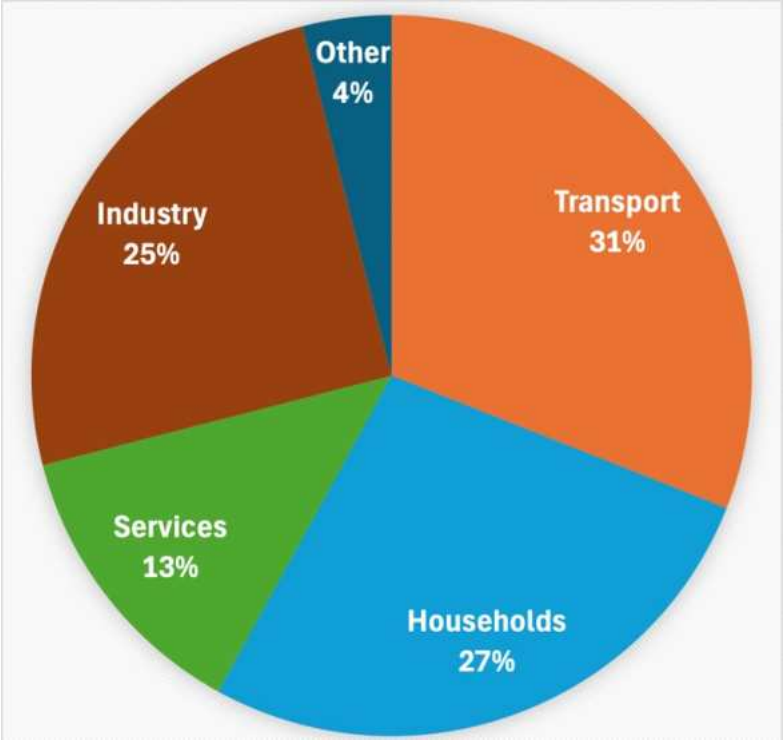
- Reduce energy demand (electrification)
- Circular economy
- Embodied energy in materials & systems

Energy market design

- Demand response (time-of-use tariffs)
- Integration
- Capacity mechanisms (Dunkelflauten)

Military, cyber & extreme weather protection

- Critical infrastructure



EU 27 final energy consumption 2022

Source: EASAC

Security policies for fuel and energy technology supplies

Transition away from fossil fuels

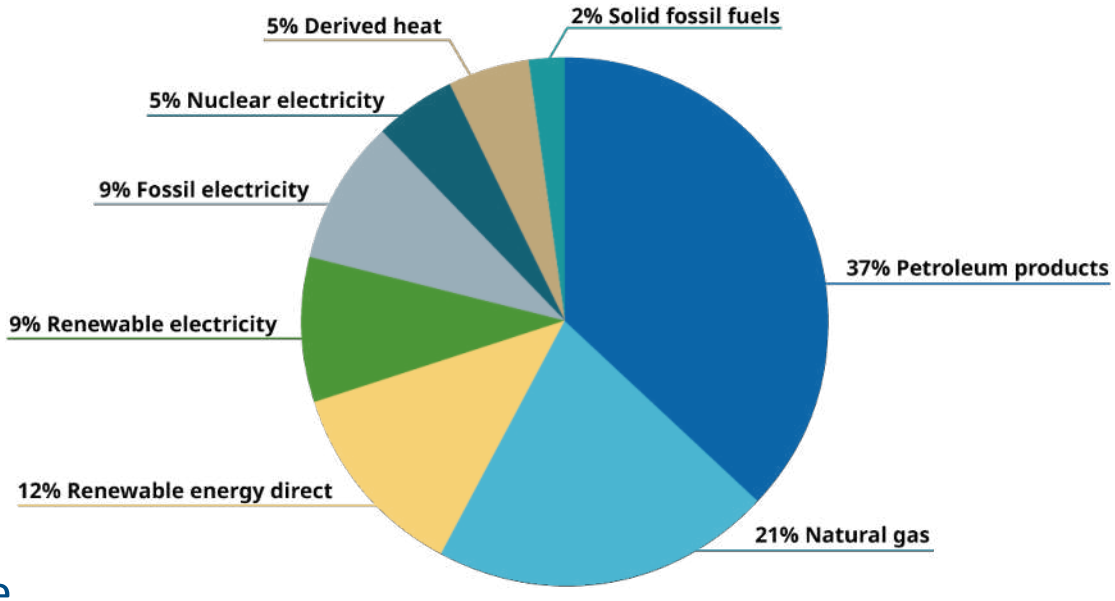
Produce more fuels & technologies in Europe

Coordinate fuel purchasing (EU Platform)

- Fossil (short term) and renewable fuels
- Enriched uranium for nuclear reactors

Diversify supplies of critical raw materials

- Partner with suppliers in 3rd countries
- More extraction & processing in Europe



EU 27 final energy consumption 2022

Source: EASAC

Grid flexibility and integration improve energy security

Electricity mix with grid flexibility

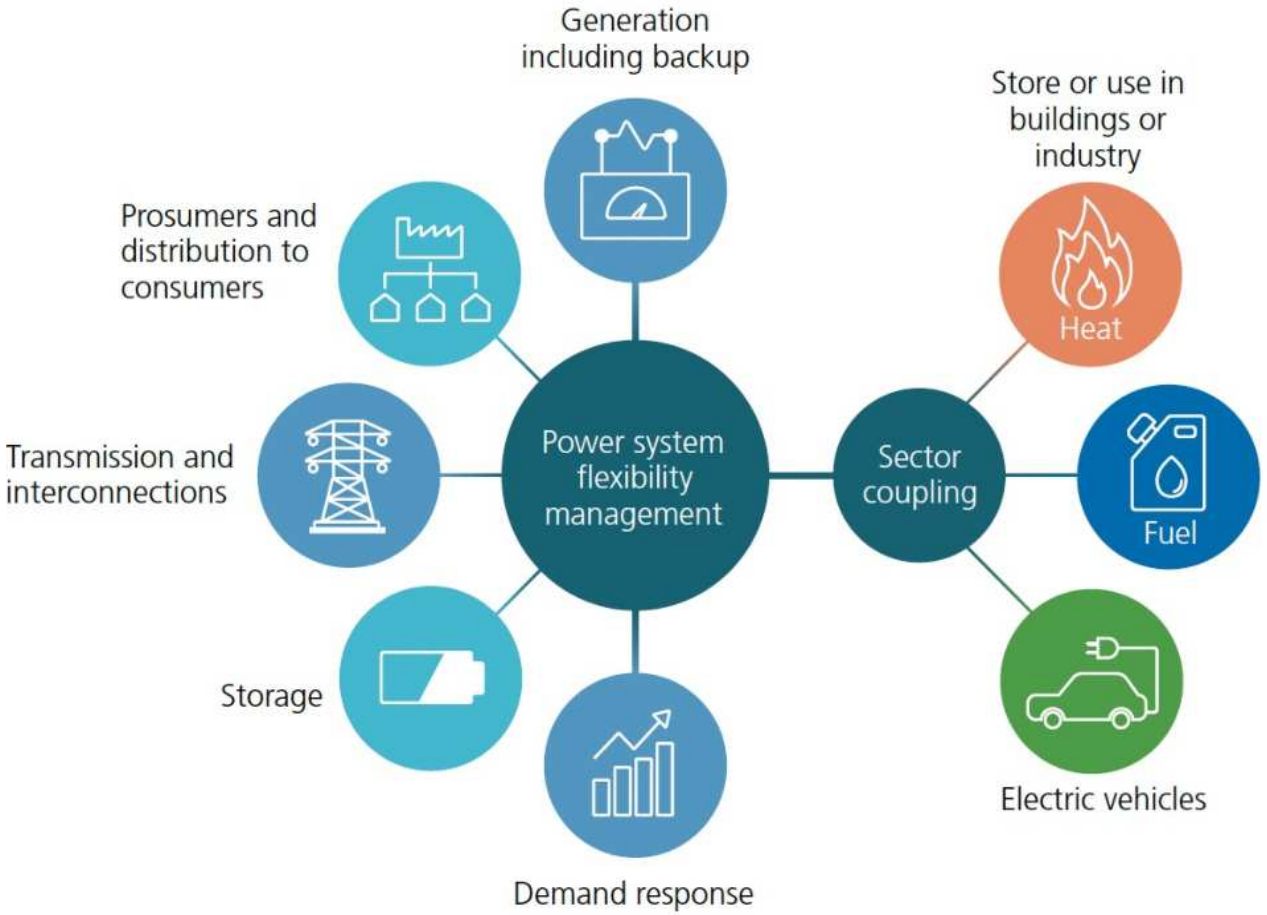
- Variable renewables
- Nuclear (large and SMR)
- Backup generation

Integration lowers costs

Integration options

- District heating / cooling
- Electric vehicles
- Hydrogen and e-fuels
- Carbon capture & storage

Cyber protection (digitalisation)



Source: EASAC

Invest in Energy Security - create value in Europe

Mobilise long term public and private financing:

- Strengthen electricity infrastructure and interconnectors
- Manufacture electricity generators (VRES, Nuclear, SMR, CCS, ..)
- Manufacture end-use technologies (EVs, heat pumps, ..)
- District heating/cooling
- Storage of electricity (Battery Alliance)
- Storage of heat (for buildings and industry)
- Sustainable hydrogen and e-fuels
- Critical raw materials extraction and processing



Source: EASAC

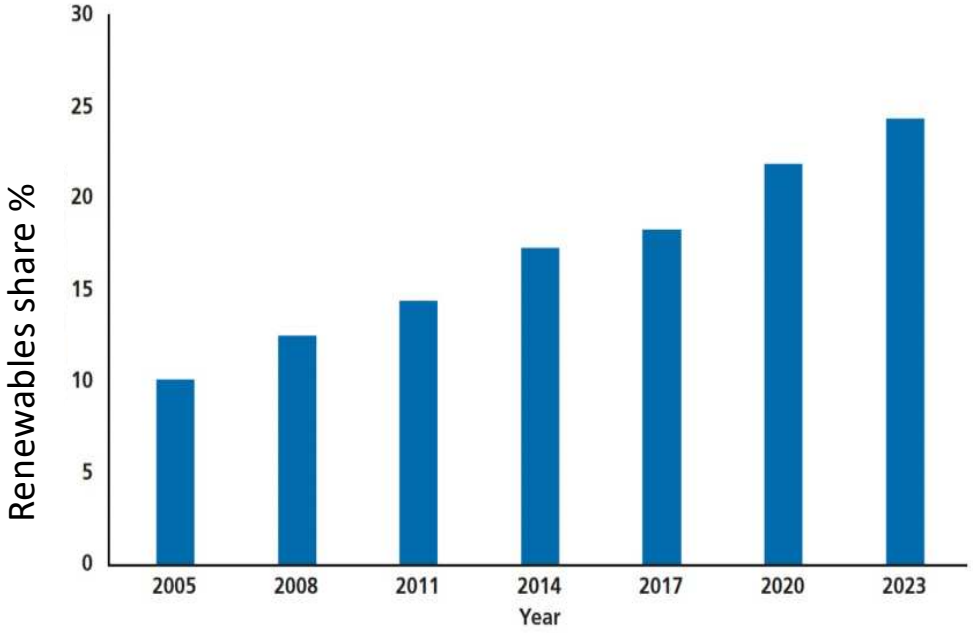
Transition to Sustainable Energy Brings Security Benefits

Energy security benefits

- Less dependence on fossil fuel imports
- Less volatile energy prices
- Less conflicts in energy markets
- Less supply interruptions

Wider benefits

- Lower climate damage and health costs (due to lower GHG emissions)
- Value creation in Europe (local production of fuels and technologies)



Source: EASAC

Critical Raw Materials (CRM)

Critical Raw Materials Act, 2023 (CRMA)

In March 2023 the CRMA was proposed "for a regulation of the EU Parliament and of the EU Council, establishing a framework for ensuring a secure and sustainable supply of critical raw materials".



"At the time, Europe depended on China for 98% of its rare-earth needs, 97% of its lithium supply and 93% of its magnesium supply. Benchmarks have been set for domestic capacities of the EU by 2030:

- **extract at least 10% of the annual consumption,**
- **process at least 40% of the annual consumption and**
- **recycle at least 25% of the annual consumption"**

Source: EASAC

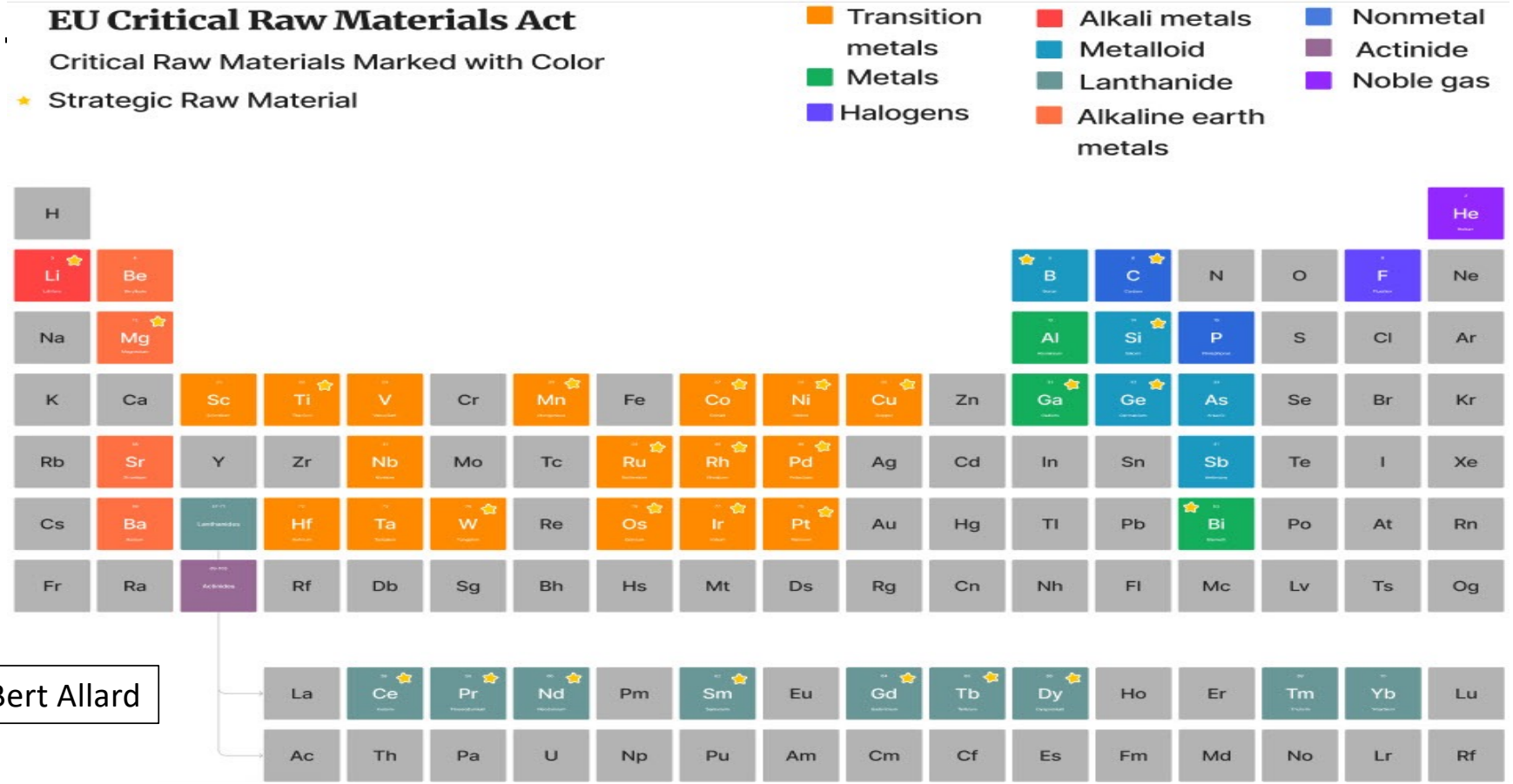
CRM

- **“Critical and strategic raw materials are needed for energy security. Raw materials, metals, and rare-earth elements (including nickel, cobalt, lithium, graphite, and copper) are used in energy supply technologies and systems (e.g. wind and photovoltaic generators) and in end-use energy technologies (e.g. batteries and electric vehicles). Those that carry high supply risks are classified as critical raw materials or strategic raw materials.**
- **Actions required by EU policies for critical and strategic raw materials must be implemented by governments and industries to ensure Europe’s future energy security”**

Source: EASAC

CRM, EU

CRM – EU Critical Raw Materials Act, 2023



Source: Bert Allard

Supply of CRM to EU

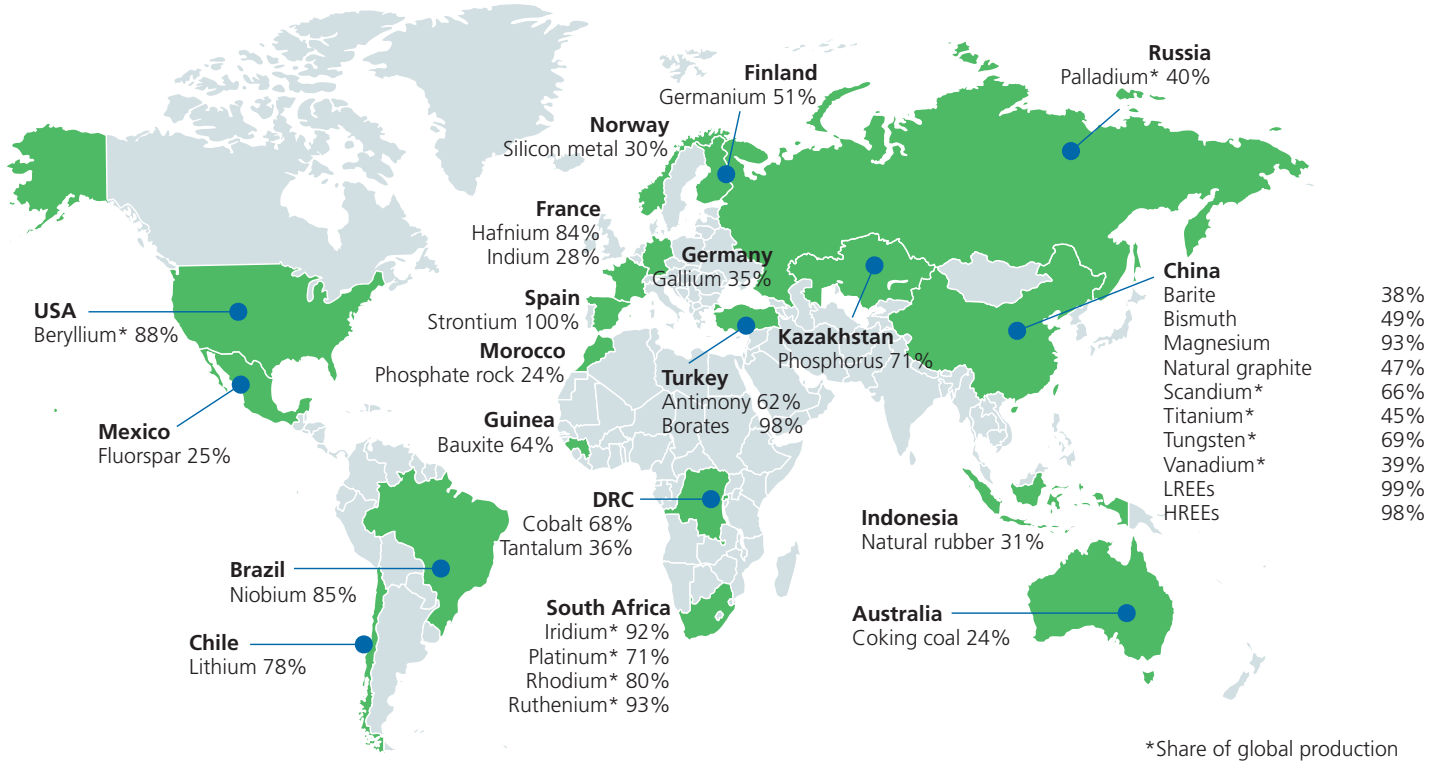
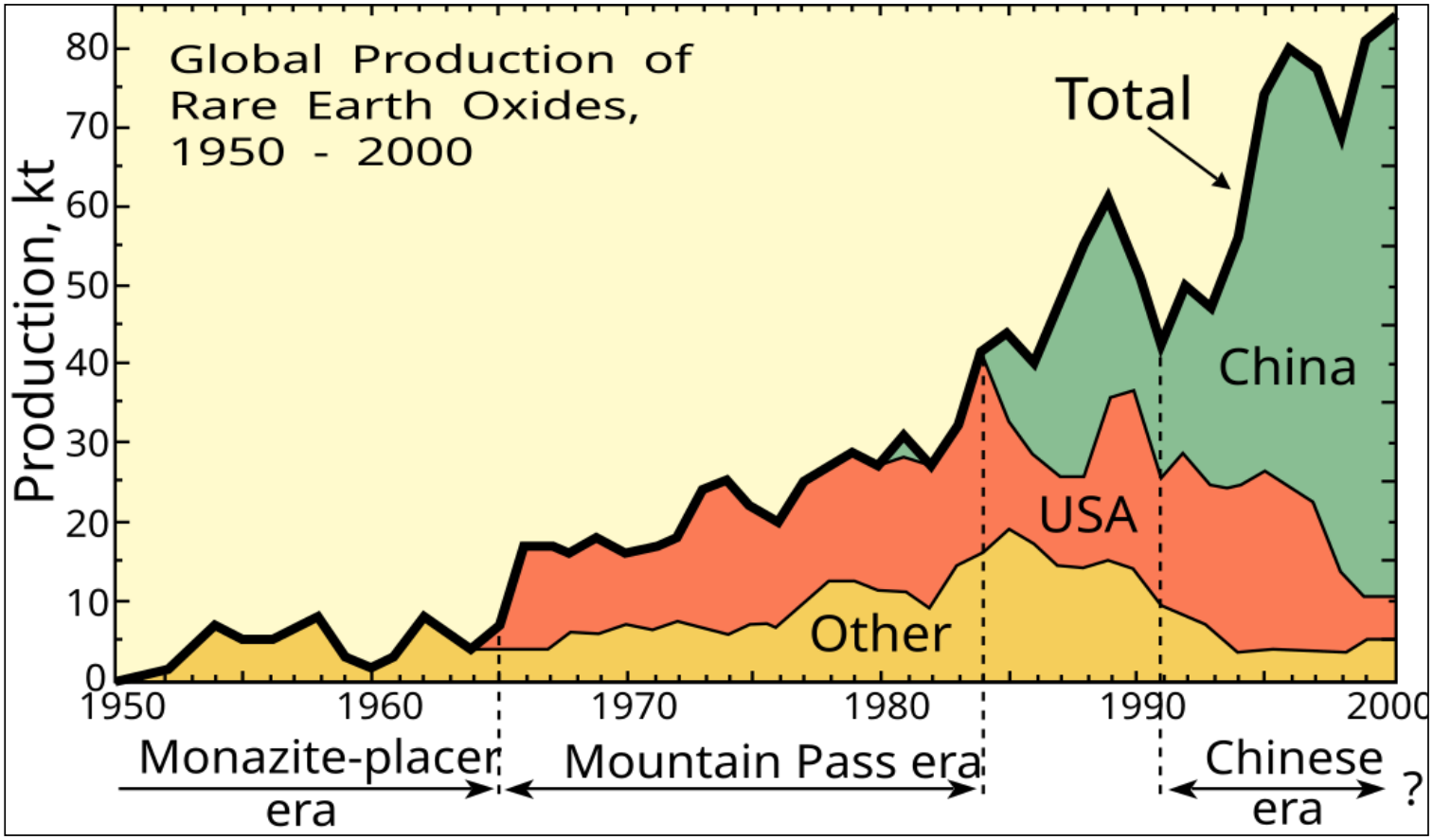


Figure 11 The biggest suppliers of critical raw materials to the EU (percentage of annual EU consumption) in 2020 included Africa, Latin America, China, and the USA (EC 2020c). Abbreviations: HREEs, heavy rare-earth elements; LREEs, light rare-earth elements.

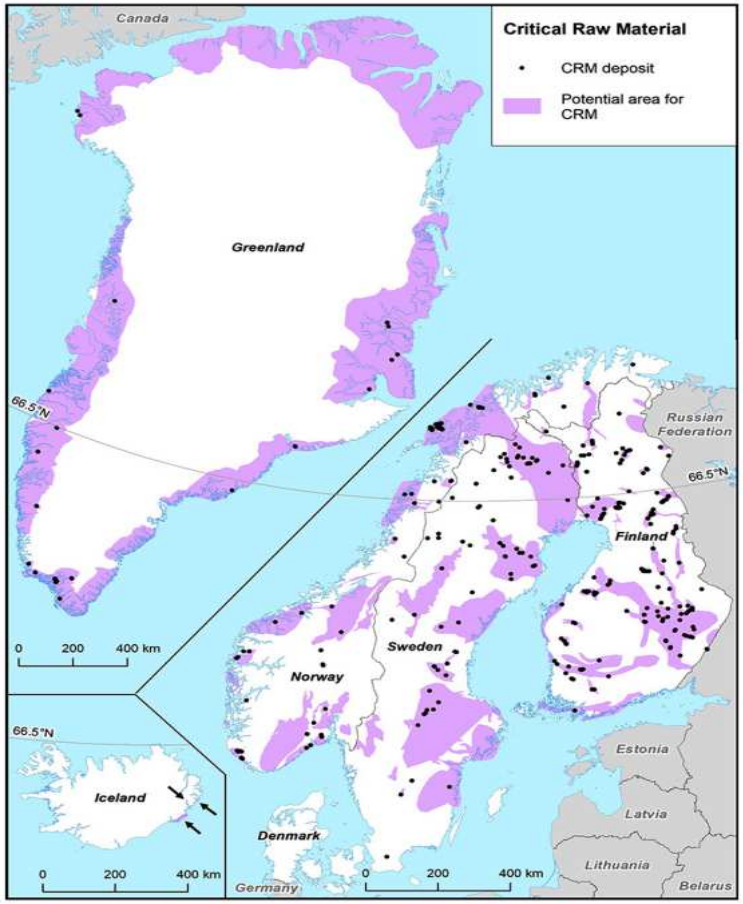
Source: EASAC

China dominates production of Rare Earth Elements (REE)



Source: Bert Allard

CRM – Sweden and Nordic Countries (1)



CRM – Sweden and Nordic Countries (2)

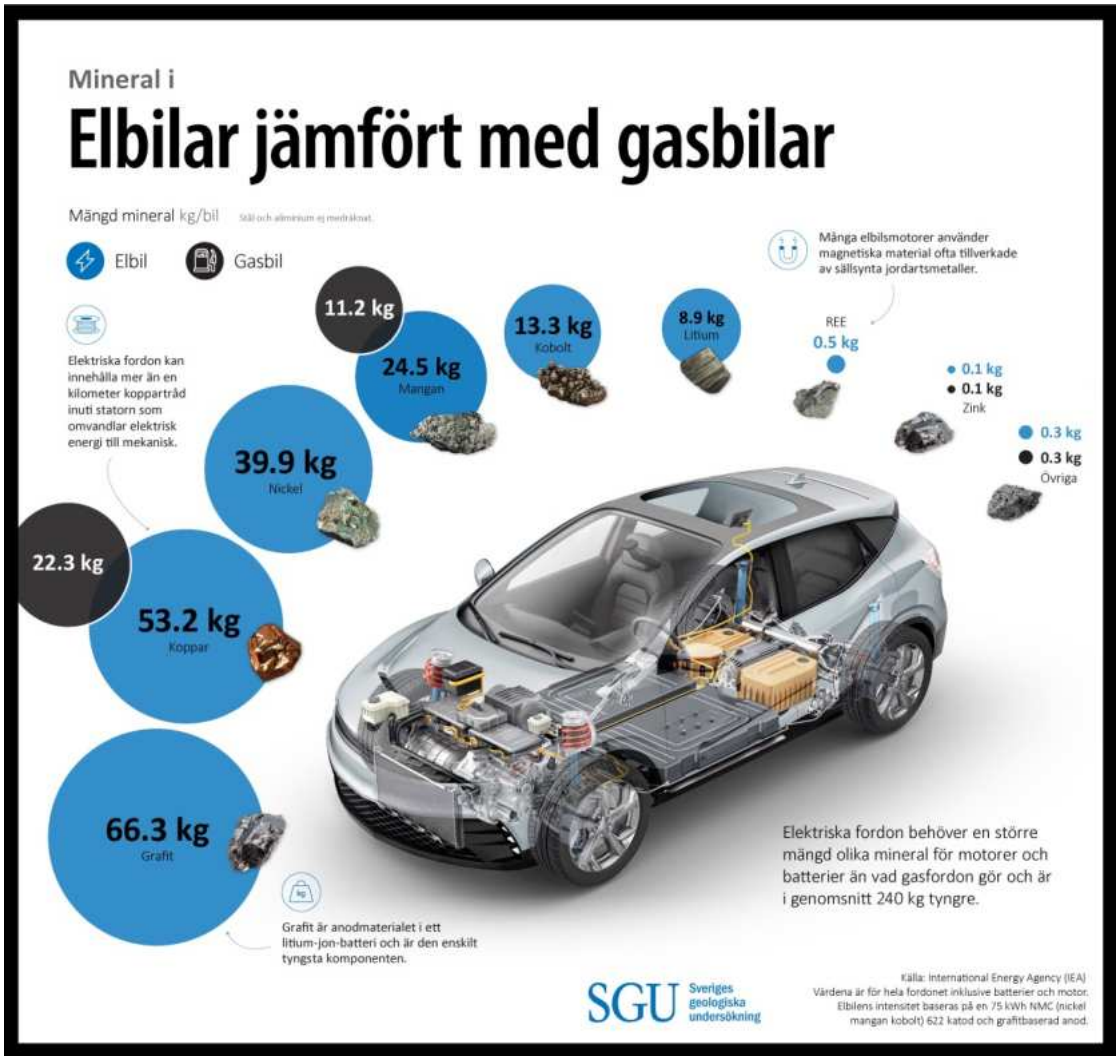
HÄR FINNS DE SÄLLSYNTA JORDARTSMETALLERNA I EUROPA:

FYNDIGHET	LAND	MALM miljoner ton	HALT TREO (%)	MÄNGD TREO (miljoner ton)
Per Geijer	Sverige	1 249	0,174	2,17
Kiirunavaara	Sverige	1 629	0,018	0,29
Malmberget	Sverige	2 265	0,022	0,50
Norra Kärr	Sverige	110	0,5	0,55
Olserum	Sverige	7,8	0,061	0,05
Fen	Norge	559	1,57	8,78
Korsnäs	Finland	13,5	1,02	0,14
Katajakangas	Finland	0,46	2,4	0,01
Kringlerne	Grönland	4 300	0,65	27,95
Kvanefjeld	Grönland	1 010	1,1	11,11
Motzfeldt	Grönland	340	0,26	0,88
Sarfartôq	Grönland	8,34	1,72	0,14
Storkwitz	Tyskland	4,4	0,45	0,02
Totalt	Grönland			40,08
Totalt	Norge			8,78
Totalt	Sverige			3,56
Totalt	Finland			0,15
Totalt	Tyskland			0,02

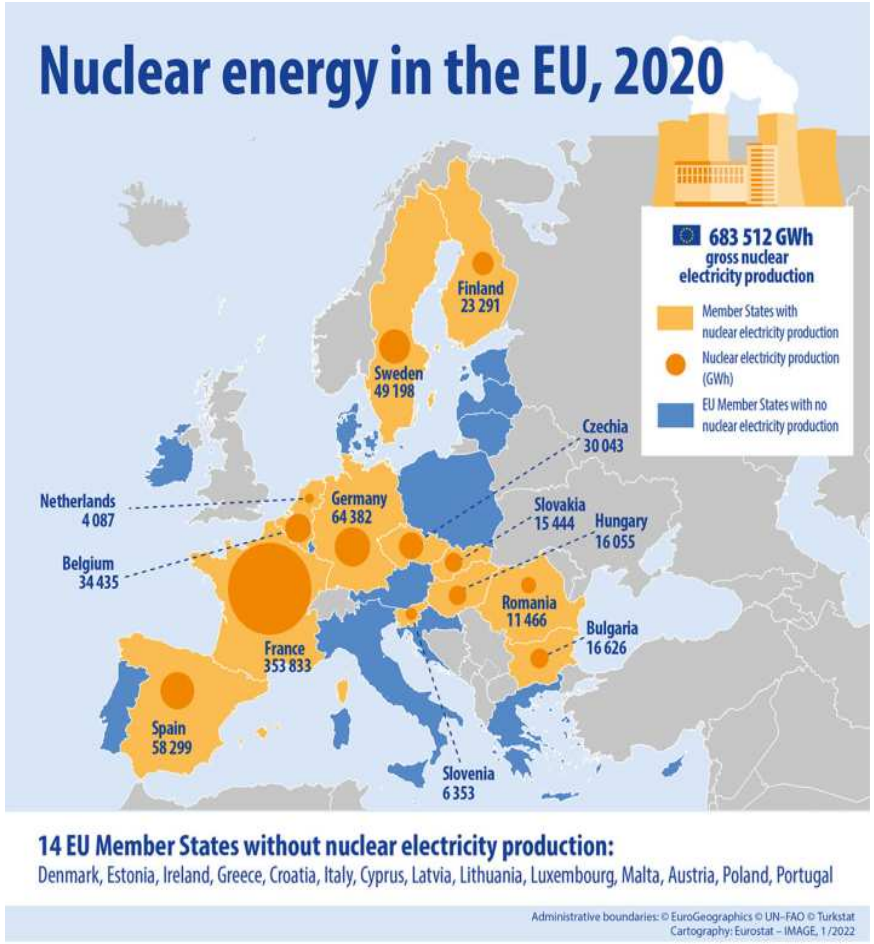
De viktigaste mineralerna för REE-utvinning är bastnäsit och monazit. I flera av fyndigheterna ovan finns flera olika REE-mineral, vilket ger anrikningstekniska och metallurgiska utmaningar för utvinningen. I LKAB:s gruvor utvinns metallerna som en biprodukt av järnmalmsbrytning.

Kemisk Tidskrift 25

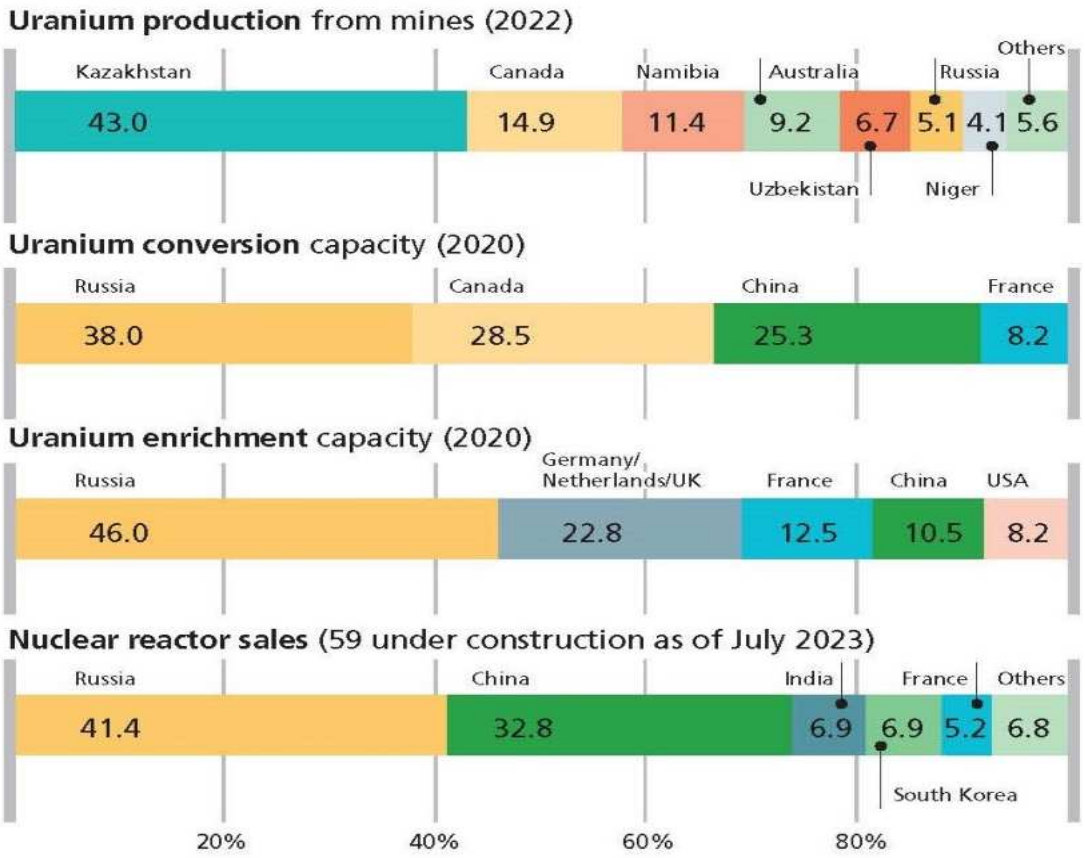
TREO = Total Rare Earth Oxide


Mineral i
Elbilar jämfört med gasbilar
Mängd mineral kg/bil
Stål och aluminium ej medräknat.
Elbil
Gasbil
Elektriska fordon kan innehålla mer än en kilometer koppartråd inuti statorn som omvandlar elektrisk energi till mekanisk.
11.2 kg
24.5 kg
Mangan
13.3 kg
Kobolt
8.9 kg
Litium
39.9 kg
Nickel
22.3 kg
53.2 kg
Koppar
66.3 kg
Grafit
Grafit är anodmaterialet i ett litium-jon-batteri och är den enskilt tyngsta komponenten.
Många elbilsmotorer använder magnetiska material ofta tillverkade av sällsynta jordartsmetaller.
REE
0.5 kg
0.1 kg
0.1 kg
Zink
0.3 kg
0.3 kg
Övriga
Elektriska fordon behöver en större mängd olika mineral för motorer och batterier än vad gasfordon gör och är i genomsnitt 240 kg tyngre.
SGU
Sveriges geologiska undersökning
Källa: International Energy Agency (IEA)
Värdena är för hela fordonet inklusive batterier och motor. Elbilens intensitet baseras på en 75 kWh NMC (nickel mangan kobolt) 622 katod och grafitbaserad anod.

Nuclear Energy in Europe

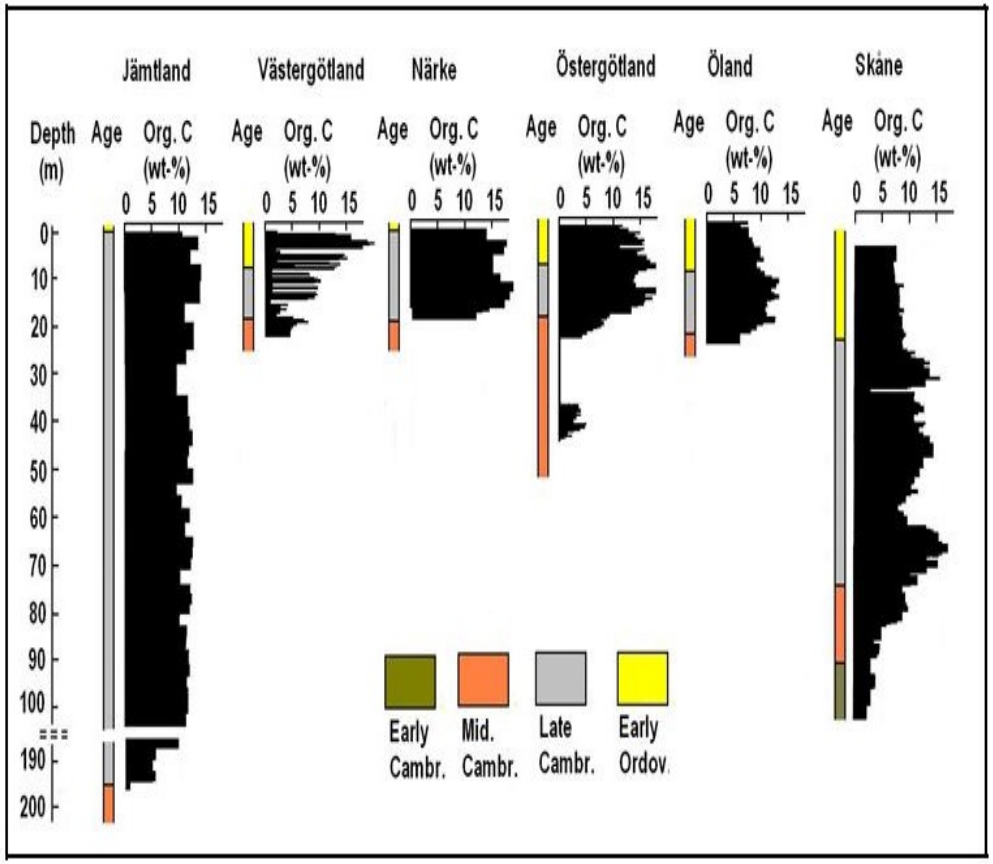


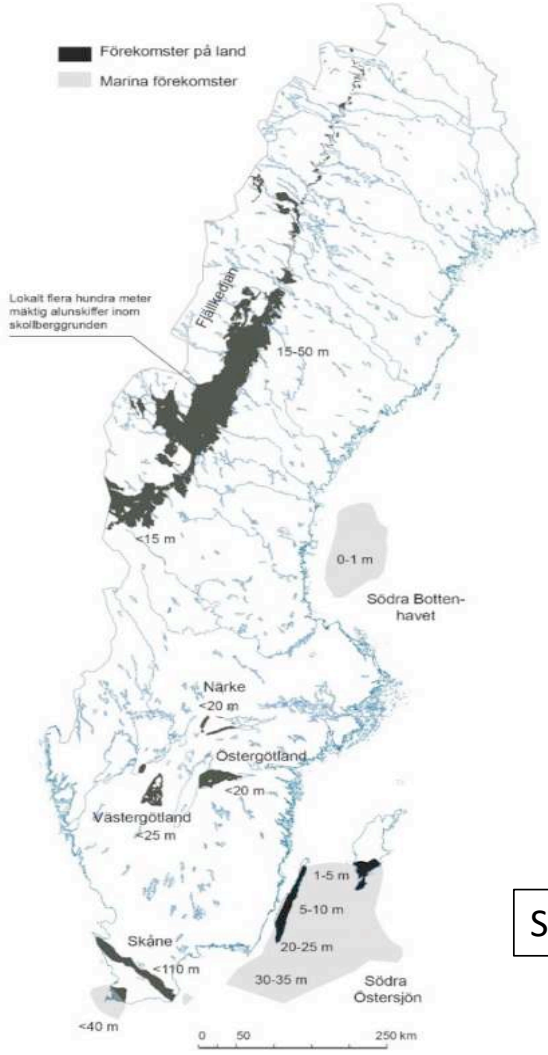
Nuclear Energy in Europe



Source: EASAC

Alunskiffer - Uran





Source: Bert Allard

Uranhalten i alunskiffer i olika delar av Sverige:

Område	Uranhalt g per ton
Närke	150
Östergötland	100
Öland	70
Skåne	50
Billingen	200
Billingen, uranrik del	300
Jämtland, södra Storsjöområdet	245

Source: SGU

Cyber Security Incidents

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Tech

Ukrain

11 January 20

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Main — News - 23 January 2024, 12:58

Lviv neighbourhood l
heating, hot water by

The estimated time of restoratior



Ukraine's energ



A power cut that hit part of the Ukrainian capital, Kiev, in December has been judged a cyber-attack by researchers investigating the incident.

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hadde tilgang til lukkesystemet i en dam ved Risevatnet i Bremanger i flere timer i april. Saken er anmeldt til Kripos.

Satellite cyber attack paralyzes 11GW of German wind turbines

The communication channels affected are also used by photovoltaic systems.

MARCH 1, 2022 MARIAN WILLUHN

GRIDS & INTEGRATION TECHNOLOGY UTILITY SCALE PV GERMANY



Source: Mathias Ekstedt

Cyber SecurityIncidents in numbers

- Since 2022 (until Nov 2024), energy sector cybersecurity center EnergiCERT counted 48 publicly known attacks against European energy companies including supply, 31 ransomware attacks, of which almost half with data theft, and 15 affecting networks' operational technology.

Energy Poverty in EU

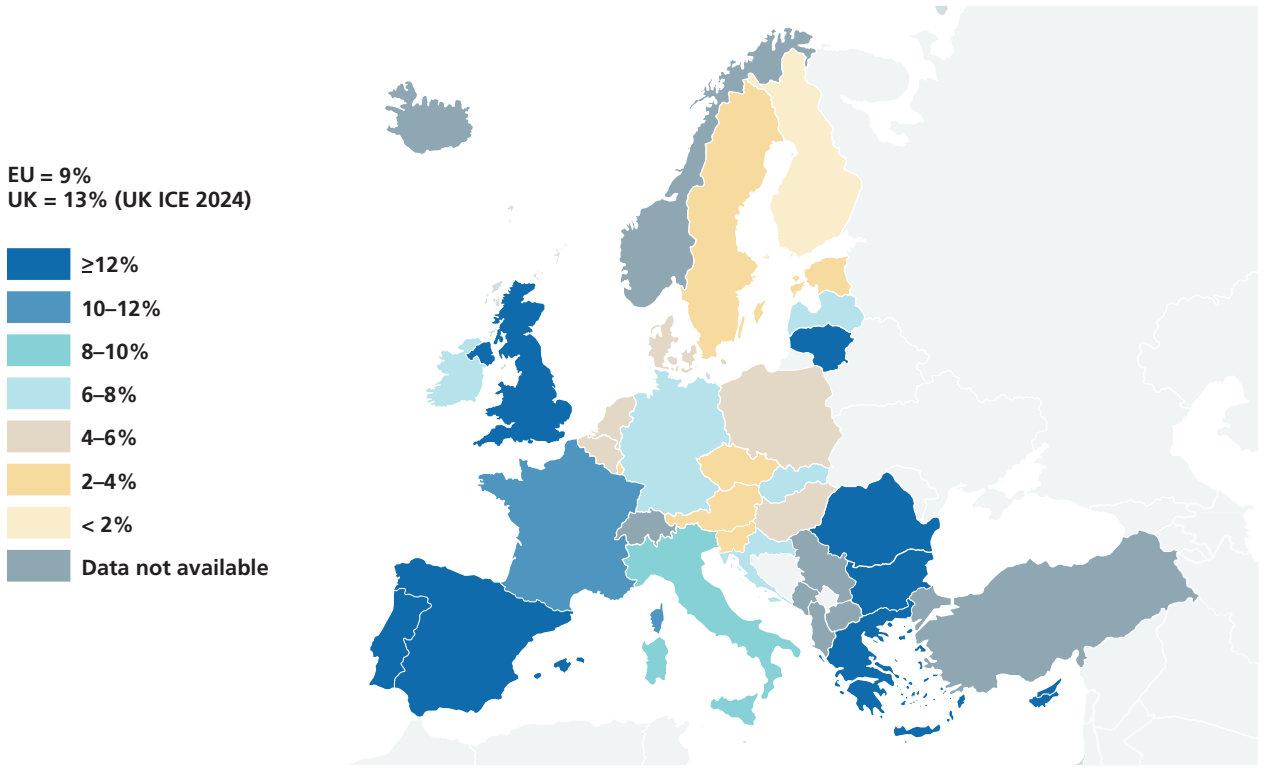


Figure 3 Levels of energy poverty in EU Member States. On average, 9% of the EU population were unable to keep their homes adequately warm in 2020 (Eurostat 2024c); in comparison, the figure for the UK was 13% (UK ICE 2024).

Source: EASAC

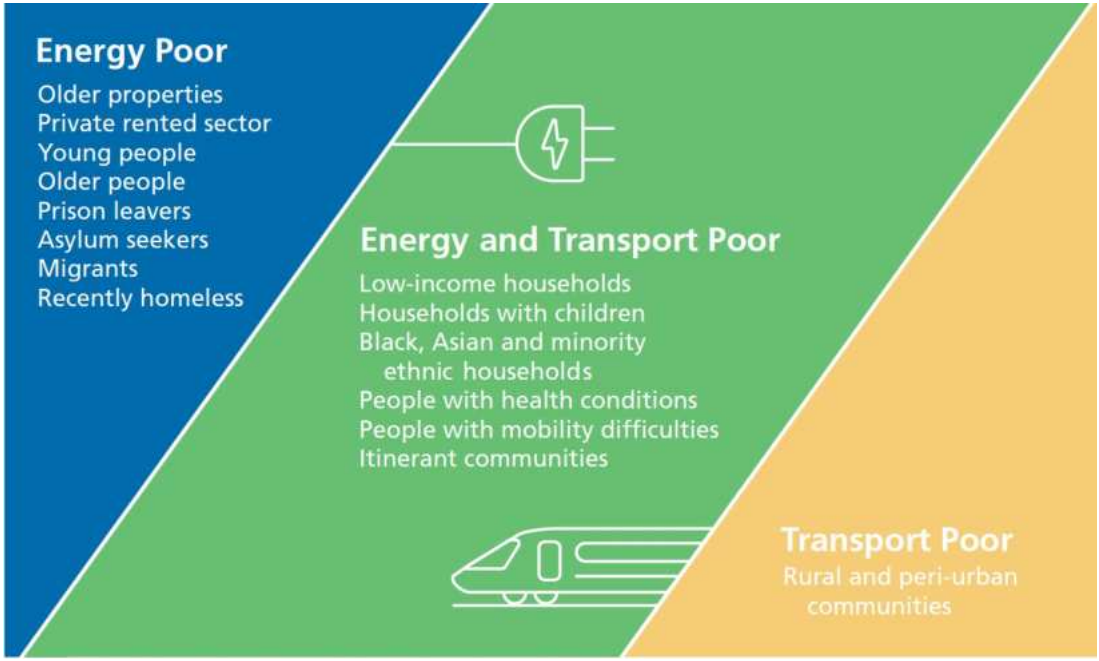
“Fair Transition” to reduce energy poverty

High prices incentivise energy saving but “Polluter pays” is not affordable for all

Vulnerable groups and households need support (eg EU Social Climate Fund):

- for investing in energy efficiency to reduce energy needs
- to pay their energy bills

Engage with citizens to accelerate the transition (empower local communities)



Source: EASAC

Concluding remarks – coordinate & implement policies

- **Energy security – phase out fossil fuel imports**
  Invest in electricity infrastructure, and in fuel and technology production
  Prepare defences for cyber and malicious attacks, & diversify supply chains
- **Sustainability - reduce GHG emissions**
  Invest in sustainable energy to reduce climate damage and improve health
  Demonstrate global leadership, and help others to follow
- **Affordability – mobilise long term investment financing**
  Engage with consumers to reduce energy demand and investment needs
  Help strategic industries and vulnerable groups (reduce energy poverty)
- **Science (evidence)-based EU policies** help to build investor confidence
  Support foresight, research, training, and skills development for energy security

Source: EASAC

No Security without Energy Security

Key Energy Security Threats



- Geopolitical disruption
- Increase of physical and cyberattacks
- Interruption of fuel and technology supply chains
- Volatile prices and growing energy poverty
- Escalating climate costs
- Lack of system flexibility

Old Thinking:
Import to Europe

98% 2022	98% 2022	45% 2022	45% 2024
Rare Earth Elements (REEs)	**Crude oil and petroleum products**	**Gas from Russia**	**LNG from the USA**
Source: European Commission	Source: European Commission	Source: European Commission	Source: European LNG-Tracker

New Thinking: Invest in Europe

- Put energy efficiency first with circular economy
- Transition away from fossil fuels
- Enhance cyber and physical security
- Incentivise flexibility and market integration
- Produce fuels and technologies in Europe
- Prioritise decentralised systems
- Empower communities with a fair transition
- Diversify suppliers

More resilient systems
More value creation in Europe
Better trade balance
Fewer climate and health costs
Less energy poverty

Investments in sustainable energies are investments in Europe's energy security!

Source: EASAC

Final remark about the future

“Plans are useless, but planning is indispensable.”



Dwight D. Eisenhower

Planning used to be predictive

New paradigm: Planning is exploratory, i.e. study of possible scenarios.

Tack till

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Olle Olsson, Energimyndigheten