RSC PP 2025/03
Robert Schuman Centre for Advanced Studies
Florence School of Regulation

# POLICY PAPER

## Thought experiment for a targeted European industrial policy based on electrification by 2050

Ronnie Belmans

European University Institute
**Robert Schuman Centre for Advanced Studies**
Florence School of Regulation

# Thought experiment for a targeted European industrial policy based on electrification by 2050

Ronnie Belmans

RSC Policy Paper 2025/03

ISSN 1830-1541



Published in February 2025 by the European University Institute.
Badia Fiesolana, via dei Roccettini 9
I – 50014 San Domenico di Fiesole (FI)

Italy



With the support of the Erasmus+ Programme of the European Union

The European Commission supports the EUI through the European Union budget. This publication reflects the views only of the author(s), and the Commission cannot be held responsible for any use which may be made of the information contained therein.

**Robert Schuman Centre for Advanced Studies**

The Robert Schuman Centre for Advanced Studies, created in 1992 and currently directed by Professor Erik Jones, aims to develop inter-disciplinary and comparative research on the major issues facing the process of European integration, European societies and Europe's place in 21st century global politics.

The Centre is home to a large post-doctoral programme and hosts major research programmes, projects and data sets, in addition to a range of working groups and ad hoc initiatives. The research agenda is organised around a set of core themes and is continuously evolving, reflecting the changing agenda of European integration, the expanding membership of the European Union, developments in Europe's neighbourhood and the wider world.

For more information: http://eui.eu/rscas.



**Florence School of Regulation**

The Florence School of Regulation - FSR Energy & Climate is a centre of excellence for applied research, policy dialogue and executive training, with the purpose to enhance economically and socially sound energy and climate regulation in Europe and worldwide.

Founded in 2004 by three European regulators in the energy sector, the FSR has been providing a unique forum where regulators, utilities, policy-makers and academics meet, discuss and get trained.

The FSR sits as a programme of the Robert Schuman Centre for Advanced Studies of the European University Institute in Florence, Europe's intergovernmental institution for doctoral and postdoctoral studies and research.
Florence School of Regulation, European University Institute
Via Boccaccio 121, I-50133 Florence, Italy
FSR.Secretariat@eui.eu.
+39 055 4685 878

## Abstract

The rewable energy resources within EU27 are highly dominated by wind and solar energy delivering electricity as output. As electrification is the most efficient way to deliver the energy services demanded by society and industry, its direct use is the most effective way to decarbonisation. The present European industry policy is not compatible with electrification focus, as it tries to address a too wide palet. As electrification is the practical implementation of the “energy efficiency first” principle, the industrial policy must be compatible. As a thought exercise, the paper describes a potential industrial basis for Europe in 2050 usingexamples of the electricity sector, the industry intensive industry and the materials and circularity industry. A prosperous European net-zero industry requires ‘safeguards’ for existing incumbents to be removed, and those resources redirected towards much more ‘future proof’ sectors, spearheads where it wants to be first in class.  Strategic security in its various aspects and time horizons must be part of the discussion.  Industrial value chains within the EU, based on fossil fuel and material flows are substituted by circular material flows and electricity based on locally harvested renewables.  Europe must build an industrial system based on its strengths,. electrification being key.

## Keywords

Electrification, industrial policy, carbon neutrality, energy policy

## Acknowledgements

Thanks to FSR colleagues Jean-Michel Glachant, Leonardo Meeus, Ilaria Conti, James Kneebone, Andris Piebalgs, Lucila De Almeida, Jorge Vasconcelos, Nicolò Rossetto, Alberto Pototschnig, Catharina Sikow-Magny, Ignacio Pérez Arriaga, Pippo Ranci and colleagues from Belgium, Koenraad Debackere (KULeuven), Pieter Vingerhoets (VITO/EnergyVille), Pieter Lodewijks (VITO/EnergyVille) for their feedback on an earlier version of this text.

## Introduction

Industrial strategy and energy resources have been linked for centuries.

Up to the first industrial revolution, energy was harvested and consumed locally. Typical installations were water - and windmills to deliver work, as a substitution or addition to animal and/or human labor. Wood was used for heating and cooking.

Coal extraction and the invention of the steam engine triggered the first industrial revolution. It began in the UK in the mid 18th century and ended in the first half of the 19th century. Steam was the driving force for industry (steel making, machines, railways, textiles, …). Industry developed around coal mines and where a combination of iron ore and coal was found, steel industry flourished[1].

At the end of the 19th and beginning of the 20th century[2], the second industrial revolution, also called "technological revolution" saw many changes: new manufacturing processes, advanced steel making, industrial paper production, chemistry based on petroleum, … Petroleum came in as an energy source for many applications, especially mobility. Electricity found its way generated by hydropower and coal fired power plants. Both electricity (shorter distance) and petroleum were easy to transport and localization of the energy resource and its applications in industry or in cities and villages where no longer firmly linked.

After the second world war, the third industrial revolution started, the digital revolution (digital age, computer age, internet age)[3]. Automation in industry was driven by electrification and the demand for electric energy for the digitalization exploded. Natural gas was introduced linked to local availability and political choices, as a cheap and abundant source for residential heating and cooking, and nuclear energy supplied electricity in specific countries. Renewable energy sources (wind and solar) began to enter the system in small quantities linked to the strive for climate neutrality, effectively starting from the beginning of the 21st century mostly supplying electricity.

Fossil fuels were still dominant at the end of the 20th century. Oil was (and still is) the driving force of the world economy, whilst natural gas demand was (and still is) growing globally and has become a key source of heat and feedstock for industry, as well as the primary energy source of electricity in many places, including the EU. Electricity demand has remained rather flat in the EU over the years.

However, in advanced economies attitudes towards the use of fossil fuels were beginning to change in the light of a growing scientific consensus around the causal effect between the $CO_2$ produced from the combustion of fossil fuels and climate change[4]. Fast forward a couple of decades, and the EU is legally bound to reach net-zero emissions in its economy by 2050[5], China have committed to the same objective 10 years later[6], and many other economies are following suit. This means a transformation from (in the EU's case) imported fossil fuels, to energy supplied overwhelmingly by locally harvested renewable resources delivering electricity.

The carbon neutral electric energy is supplied by a reliable and intelligently controlled grid, delivering the energy services to society as a whole in a far more efficient way than fossil fuels ever could. The basic laws of thermodynamics reign: electrification based on local carbon neutral energy resources is the most effective way to deliver the required energy services: using electricity as energy carrier between renewable resources and final use is equivalent with "energy efficient first" principle that must be implemented by the member states. Energy efficient first is one of the five dimensions of the Energy Union being: energy security; the internal energy market; energy efficiency; decarbonisation;

1 https://www.britannica.com/event/Industrial-Revolution.
2 https://www.britannica.com/topic/history-of-Europe/A-maturing-industrial-society.
3 https://mpra.ub.uni-muenchen.de/110972/1/MPRA_paper_110972.pdf.
4 https://www.ipcc.ch/about/.
5 https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategyen.
6 https://interactive.carbonbrief.org/the-carbon-brief-profile-china/index.html.

and research, innovation and competitiveness¨[7] The "Energy efficiency first principle" is spelled out in the regulation (EU) 2018/1999 of the European Parliament and of the Council[8]. As the resources are harvested locally, strategic policy challenges are far less.

The demand for electricity is going to increase by 60% by 2040 compared with today and more than doubling by 2050 according to the analysis performed by the EU commission[9]. The analysis performed in the study ignores several electrification targets which are already feasible, indicating that these figures potentially are an underestimate.

Today we are discussing how industrial activities will look in a net-zero society, and how will we get there. For example, Mr. Draghi in his competitiveness strategy for Europe[10] writes: "To capitalize on the decarbonization push, Europe should refocus its support for clean tech manufacturing, focusing on technologies where it either has a lead or where there is a strategic case for developing domestic capacity". By trying to address all technologies, we risk spreading our limited resources (material, energy, human, financial) over too many technological choices. If we want global leadership and breakthroughs, more focus is needed. This paper presents a thought experiment by an electrical engineer. What if Europe would be bolder in choosing for electrification and focus on electrification for a targeted industrial policy. Where could it lead us?

The brief is structured in two sections. Section one discusses the limitations of the current industrial policy; section two discusses what the future might look like if we go all in on electrification.

## 1. Limitations of the current industrial policy initiatives in Europe

In what follows, we first present electrification as an alternative for the dependency of imported fossil fuels, and then discuss to what extent the industrial policy initiatives developed under the previous European Commissions already have a focus on electrification.

### *1.1 Electrification as an alternative for the dependency of imported fossil fuels*

The energy transition from imported fossil fuels to locally harvested renewable resources that directly produce electricity is far more than a climate issue. Using fossil fuels in huge volumes as we do today has multiple impacts on the European economy and society.

- A continuous outflow of cash from the European economy
- Exposure to the volatility of international fossil fuel markets[11]
- Security of supply issues. Including those caused by political unrest, geopolitical leverage, or the vulnerability of transport routes.
- A need for strategic reserves within the EU

7 https://energy.ec.europa.eu/strategy/energy-unionen.
8 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32018R1999.
9 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52024SC0063.
10 https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-aheaden.
11 At the time of writing (01. 2025) gas prices are back to very high levels. https://www.statista.com/statistics/673333/monthly-prices-for-natural-gas-in-the-united-states-and-europe/.

According to the International Energy Agency (IEA)[12], the EU's fossil fuel energy import bill increased from 341 G€ in 2019 to 416 G€ in 2023 (approximately 2.7% of GDP). From the Draghi report, in 2023, the total EU payments for imported fossil fuels (coal, gas and oil) amounted to 390 G€. This was substantially higher than the historical 2017-2021 average, primarily driven by higher prices as volumes were on average only up by 7%. 50 G€ both in 2022 and 2023 were paid to Norway, around three times higher than the 2017-2021 average, due to both increases in volumes and prices. This is less than 460 G€, the number found in the Eurostat[13]. A slight drop is seen in the first half of 2024[14]. The numbers diverge due to different definitions used by the various international organisations but clearly indicate the immense outflow of cash.

For comparison, one of the important elements in the energy transition is expansion of the electricity grid to incorporate the massive growth in renewable energy resources. Ember[15] calculated that from now to 2030 63 G€ yearly must be invested in the electricity grids, 5 G€ higher than the 58.3 G€ calculated in 2022 by the EU[16]. Ember assumes this number must be increased to 85 G€ per year after 2030. Eurelectric calculates an annual annual investment need of 63 G€ till 2050 in distribution grids[17] ACER has a comparable figure ranging from 75 to 100 G€[18].

Looking at cash flow, by investing in renewable electricity and grids, thus applying electrification for efficiently supplying all energy services on land, the costs of the import of fossil fuels will diminish, freeing more money to accelerate the energy transition further reducing the demand for fossil fuel import, spiralling down the societal cost for energy services while reducing the $CO_2$-emissions. Directing investments in the energy system towards electrification is the key to a fast reduction of the use of fossil fuel.

### *1.2 Industrial policy initiatives of the previous European Commissions*

Though electrification is mentioned in almost all legislation, regulation and communication of the EU as part of the solution for addressing the climate challenge, there is no consistency in applying this focus. In the various policy initiatives of the previous commissions, many items are listed, and the coherence amongst them is hard to see, neither is the link with the electrification as a key route.

The three lists that matter, are included in the below table. First, there is the list of relevant industrial sectors included in the Net Zero Industry Act (NZIA)[19], which encompasses final products, components, and machinery necessary for manufacturing net-zero. Second, there is a list of energy technologies included in the Strategic Energy Technology Plan (SET-Plan)[20]. Third, we have the status reports of the Clean Energy Technology Observatory, providing an accurate status of the European industry and R&D.

The lists are called strategic, but they are also the result of a political strategy that follows technology neutrality, in which tough choices are avoided. This is also reflected in the Critical Raw Materials Act. Which materials we consider strategic is closely intertwined with our strategic technology choices.

12 https://commission.europa.eu/document/download/ec1409c1-d4b4-4882-8bdd-3519f86bbb92_en?filename=The%20future%20of%20European%20competitiveness_%20In-depth%20analysis%20and%20recommendations_0.pdf.

13 This number is less than the number found in https://ec.europa.eu/eurostat/statistics-explained/images/2/23/EU_imports_of_energy_products%2C_2021_-_2024_Sept_2024.png being 462 G€.

14 https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20240923-1.

15 https://ember-energy.org/latest-insights/putting-the-mission-in-transmission-grids-for-europes-energy-transition/.

16 https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX%3A52022DC0552.

17 https://powersummit2024.eurelectric.org/wp-content/uploads/2024/05/Grids-for-Speed_Report.pdf.

18 https://www.acer.europa.eu/sites/default/files/documents/Publications/ACER2024MonitoringElectri cityInfrastructure.pdf.

19 https://setis.ec.europa.eu/set-plan-progress-report-2022_en.

20 https://setis.ec.europa.eu/set-plan-progress-report-2022_en.

A link with pushing electrification as the most efficient route to deliver the energy services required is not clear at all, there is no consistency amongst the lists and the overall impression is that it is “shooting from the hip”: listing everything that individual countries or industries put forward. The link with the overall strive to energy and resource efficiency and greenhouse gas reduction on a European system level is not made.

As a comparison, Annex 1 provides an insight in the present policies of other economic areas in the world.

| NZIA | Set-Plan | CETO |
|---|---|---|
| 1 Solar photovoltaic and solar thermal technologies | 1 Solar photovoltaics | 1 Wind energy |
| 2 Onshore and offshore renewable technologies | 2 CSP/STE (Concentrated Solar Power/Solar Thermal Electricity | 2 Heat pumps |
| 3 Battery, storage technologies | 3 Offshore wind | 3 Geothermal Energy |
| 4 Heat pumps and geothermal energy technologies | 4 Deep geothermal | 4 Water electrolysis and hydrogen |
| 5 Hydrogen technologies, including electrolysers and fuel cells | 5 Ocean energy | 5 Ocean Energy |
| 6 Sustainable biogas/biomethane technologies | 6 HVDC (High Voltage Direct Current) | 6 Smart Thermal Networks |
| 7 Carbon capture and storage (CCS) technologies | 7 Positive energy districts | 7 Photovoltaics |
| 8 Grid technologies | 8 Energy systems | 8 Carbon Capture, Utilisation and storage |
| 9 Nuclear fission energy technologies, including nuclear fuel cycle technologies | 9 Energy efficiency in buildings | 9 Novel Energy Storage |
| 10 Sustainable alternative fuels technologies | 10 Energy efficiency in industry | 10 Hydropower and Pumped-Hydro |
| 11 Hydro-power technologies | 11 Batteries | 11 Battery technology |
| 12 Other renewable energy technologies | 12 Renewable fuels and bioenergy | 12 Fuel Cell Technology |
| 13 Energy system-related energy efficiency technologies, including heat grid technologies | 13 CCS-CCU (Carbon Capture and Storage/Carbon Capture and Use) | 13 Early-stage Technologies |
| 14 Renewable fuels of non-biological origin technologies | 14 Nuclear safety | 14 Renewable Fuels of Non-Biological Origin |
| 15 Biotech climate and energy solutions | | 15 Advanced Biofuels |
| 16 Other transformative industrial technologies for decarbonisation | | 16 Bioenergy |
| 17 $CO_2$ transport and utilisation technologies | | 17 Smart Grids |
| 18 Wind propulsion and electric propulsion technologies for transport | | 18 Solar Thermal Energy |
| 19 Other nuclear technologies | | |

## 2. What might the future look like if we go all in on electrification?

In what follows, we discuss three industry groups: 1/ Electricity sector; 2/ Energy intensive industry; 3/ Materials and circularity industry. How might the EU look like in 2050, if we go all in on electrification in industrial policy?

### *2.1 How might the EU electricity sector look like in 2050 if we go all in on electrification?*

In 2050, the EU has developed a broad industrial framework in the electricity sector that is competitive in the global market grown from the roots that were already there in 2025. The list is long, but new technologies, that are still in an infant stage today, will also be there and by far most of them will be based on digitalization and electrification. The technologies that take a prominent place in Europe are likely to include:

- Electric boilers/heat pumps/… providing industrial heat (both low and high temperature)
- Power system components (HVDC, cables, ac system components, demand side control, flexibility), including grid stabilising/flexibility systems
- Wind and certainly offshore wind turbines and systems
- Building comfort/energy control (heat pump, tap water, …)
- Nuclear industry

A strategic level of batteries and solar panel production is based in Europe, while mass production is located where cheap labor, access to materials and low energy costs are present. In time, the demand for batteries, solar panels and EVs in the EU has leveled out after a peak.[21] Their lifetime is long compared to mechanical systems requiring almost no maintenance. The materials used can be recycled to remain within the EU. There are exceptions to this general “rule”. For instance, a niche market of PV manufacturing has emerged: building integrated PV, locally tailored to demand with very high added value.

Wind energy remains a top priority in Europe, with a major domestic manufacturing capacity, particularly in offshore wind turbines including lots of floating wind applications. Marine industry and engineering became top knowledge serving projects worldwide. Electricity grids are fully integrated and the experience in interconnections is the basis of Europe’s high value export products and services. European companies design and engineer grids all over the world including the software needed for flexibility and market integration.

Power system components became an integrated industry. Europe delivers the highest quality power system components. The top knowledge of the European countries was streamlined over the last two decades to reach the critical mass for being a global player. Optimized classical components (transformers, switchgear not containing greenhouse gases, cables, …) are combined with new developments and systems (HVDC, DC switchgear, high temperature superconductors, …). Experience integrating large quantities of variable renewables into a complex electricity system has proven valuable, particularly through smart grid technology and best practices[22]. Intelligence and redundancy have shown to be capable to deliver a very high security of supply.

21 Compared to the use of fossil fuels, the future electricity system (and the overall energy supply for land applications) operates with very limited OPEX (say fuel costs). Most of the costs are CAPEX (investments) that have a long lifetime. Therefore, the capital needed after the match between generation-storage-demand has been reached will level out to replacement need.

22 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2023:757:FIN&qid=1701167355682.

The electrification of all industrial heat demand has been achieved. Europe is leader in electrification of industrial processes, including the flexibility of demand[23]. Low temperature heat, the majority of demand, is delivered by heat pumps. High temperatures are produced by a wide spread of technologies, depending on the application. Europe is the knowledge and engineering center worldwide for these technologies. The fast reach for carbon neutrality of the industry led to the deployment and experience of electric heat and processing. Flexible manufacturing is the result and high value production systems are exported.

The smartgrids approach to building comfort including the distributed charging of transport (e-bikes, cars, buses, delivery vans, trucks) has paid off. Consumers no longer worry of their energy supply but choose for the level of comfort suppliers provide. Heating and cooling in cities are based on a combination of low temperature heat networks supplied by geothermal resources and waste heat (e.g. from data centers). Flexibility is reached by control of all system elements. All elements in the grid are aggregated locally and on a system level. The electricity supply is very reliable and resilient as local entities have sufficient resources and intelligence to operate stand alone, when required. The approach is a proven export product of the European industry.

Natural gas use became very expensive due to carbon pricing and the switch to structurally more expensive LNG over Russian pipeline gas. However, local renewable electricity resources, and local biogas have replaced the majority of this natural gas demand. Where necessary, energy intensive clean molecules like ammonia and methanol are imported.

The nuclear energy value chain has been chosen by several European countries as part of the carbon neutral electric energy system. After the lifetime extension of the existing nuclear and a limited deployment of small water-based reactors[24], a thorough but European project led to the choice of a common so-called “generation 4” industrial design. As all the generation 4 reactor designs are breeder reactors, a closed fuel cycle was developed in parallel. Industrial manufacturing started and the first batch of these power plants entered the power system in the fifth decade of this century. In parallel, an industrial manufacturing was developed for producing the required nuclear fuel. The enrichment is much higher than the level needed in the water-cooled reactors (HALEU[25], High-Assay Low-Enriched Uranium). A very though legislative process was needed to address the challenges of non-proliferation in a global context. A vast industry emerged exporting its products worldwide, with world leaders combined with newcomers. System integration and engineering are key.

23 https://www.cre.fr/fileadmin/Documents/Rapports_et_etudes/import/Rapport_GT2_-__Comite_de_prospective_de_la_CRE_01.pdf.

24 Many different reactor types as follow-up of these water based small versions of the present reactors that are in operation all over the world are seen in publications. Both existing, established manufacturing companies (e.g. Westinghouse, EDF) and start-ups propose a wide variety of advanced fission reactors with different nuclear cycles. No real industrial products are available for the time being. They are all known under the general denominator “Generation 4”. There is a vast literature available. https://www.gen-4.org.

25 https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/high-assay-low-enriched-uranium-haleu.

### 2.2 How might the EU energy intensive industry look like in 2050 if we go all in on electrification?

Steel industry has undergone a major change. De-oxidation of the iron ore is performed in countries with a lot of renewable energy potential and thus competitive green hydrogen production and the resulting sponge iron is imported. The amount needed is limited as Europe has developed a very efficient recycling process of scrap steel across the continent. Steelmaking is performed in electric arc furnaces, supplied by carbon neutral electricity. The primary steel is the input for high quality steel products. As such, only a small part of the added value at the start of the value chain, is no longer present on the continent. The electric energy needed in the arc furnace is relatively small compared to the green electricity needed in the de-oxidation process using hydrogen produced by electrolysis. Correct detailed figures are hard to find. In an integrated process the energy consumption of the electric arc furnace is found to be around 10 to 12 percent of the overall energy demand per ton of steel produced[26]. Therefore, the DRI part using green hydrogen of the process is better performed where a surplus of very cheap renewable electricity is available. The various try-outs using importing green hydrogen and producing locally green hydrogen in Europe have proven to be too expensive for competitiveness reasons.

The organic chemical industry is for a large portion bio-based. The biomass that was used in the twenties for heating buildings was re-oriented to bio-based chemistry, using heat pumps to provide residential heat[27]. Annex 2 shows the feasibility given the present used amount of biomass for energy purposes. Shifting the use of biomass towards chemistry feedstock applications that are much harder to make carbon neutral while supplying energy services with electric energy, is very attractive.

Nevertheless, a part of the high-level chemical materials industry requires very clean base molecules (e.g. methanol, ammonia). Kevin M. Van Geem and Bert M. Weckhuysen discussed this route in detail[28]. These are imported from countries with extremely good renewable energy resources and produced from green hydrogen and where appropriate combined with $CO_2$ sourced from Direct Air Capture (DAC). The production of these e-molecules can be piggybacked on the molecules required for shipping (where both ammonia and methanol are used) and aviation (with longer chain, e-kerosine). As with steel, the high added value industry is still present in Europe.

Biochemistry has taken a lot of basic research in the twenties and the thirties and has become a real spearhead for Europe in a carbon neutral industry (and an export product). Using the biochemistry route, all processing steps are within Europe and when equipping the installations with CCS, they contribute to the necessary negative emissions needed to compensate for remaining use of fossil fuels or emissions from agriculture. A limited CCS network is installed, also for handling the emissions of the cement industry.

In short, the “energy intensive industry” will be totally different to its configuration in 2025, but will deliver high quality products in a carbon neutral and efficient way that reflects Europe’s assets and limitations.

---

26 https://www.mdpi.com/1996-1073/13/3/758.

27 Wouter Arts, Ilié Storms, Joost Van Aels; Bert Lagrain, Bruno Verbist, Jos an Orshoven, Pieter Johannes Verkerk, Walter Vermeiren, Jena-Pual Lang, Bart Muys, Bert F.Sels: “Feasibility of wood as a renewable carbon feedstock for the production of chemicals in Europe,” Wiley on line library, DOI: 10.1992/bbb.2575; biofuels, bioprod., bioref (2024).

28 https://link.springer.com/article/10.1557/s43577-021-00247-5.

### *2.3. How might the materials and circularity industry look like in 2050 if we go all in on electrification?*

The material flow is totally different compared to what we are used to:

- Present: fossil fuels coming in at a very high cost, burned (or turned into plastics) and disappearing from the economy
- Future: materials coming in (as raw materials or embedded in products), put into operations in products (often for a decade or more) and recycled to become new products.

The much smaller replacement market can be served locally, combined with circularity.

Europe has few minerals to be mined that are needed for the products of the future[29], and therefore, circularity will be exploited to a maximum in 2050. The industrial credo must be: “no atom that entered Europe will be left unused”. We could call this “material efficiency first”.

For instance, at the end of their lifetime, batteries can be recycled and turned into new batteries, increasing the capacity as during the lifetime of the battery, technology will have improved. The same holds for PV panels, EV’s and other products. Therefore, the strategic manufacturing capacity of these products, needed as replacement (see above) has a second target: using the material coming out of recycling.

The material efficiency will never reach 100%. Therefore, European high-quality mining is going to be critical to substitute the losses and as a strategic resource. Also, the European strategic products in the energy system, discussed above (e.g. steel), benefit from recycling.

It is evident that the same circularity must be envisaged for all products society needs. By doing so, Europe will be far less vulnerable to the uncertainties of material supply. A catalogue and database of the available materials is going be the basis, where materials embedded in products must be carefully assessed. Circularity of materials requires energy input, this can be local renewable electricity. In its final form, industry is a circle of material use and reuse, rotated by clean energy.

## Conclusions

As a thought exercise, we describe a potential industrial basis for Europe in 2050. We do not pretend that this will be the future, we only want to demonstrate that European de-industrialization is not an inevitable result of decarbonization, as it is characterized at times in the literature[30]. We try to show that there are optimistic scenarios where Europe capitalizes on its assets to carve out a meaningful space in future net-zero industries. We caveat that any version of a prosperous European net-zero industry will require ‘safeguards’ for existing incumbents to be removed, and those resources redirected towards much more ‘future proof’ sectors where a clearer case of long-term competitiveness can be made. The EU does not have the resources (material, energy, human, financial) to sustain vested interests from the old world and capture industries of the future.

How much local production of strategic products needs to be available within Europe, including chemistry and steel, as discussed above, but also aluminium, cement, paper, and how the transition of car manufacturing and other transport modi fit into the overall picture, is a key discussion that goes far beyond these basic energy-industry considerations. However, they cannot be avoided and must be tackled as soon as possible.

29 https://www.delorscentre.eu/en/publications/detail/publication/mining-for-tomorrow.
30 https://www.intereconomics.eu/contents/year/2023/number/4/article/deindustrialisation-a-european-assessment.html.

Nevertheless, given the boundary conditions of Europe (geography, weather, international naval connections, …), some things cannot be produced efficiently and effectively locally. Europe should look at spearheads where it wants to be first in class. Strategic security in its various aspects and time horizons must be part of the discussion. Imitating other countries or spreading our limited resources over too many targets is ineffective and inefficient. Without a clear focus, like the focus on electrification, we risk losing on all fronts.

Similarly, by trying to keep all existing value chains alive, like ICE (Internal Combustion Engine) as hybrid, hydrogen supplied or synthetic fuels; or hybrid heat pumps in order not to disturb the consumer and protect the existing assets, we risk slowing down the transition and making it far more expensive.

Industrial value chains within the EU, now based on fossil fuel and material flows will fundamentally change as raw materials and fossil fuel imports are substituted by circular material flows and electricity based on locally harvested renewables. We need to build on our European strengths that must be seamlessly integrated, so we can play a role in the global political scene where uncertain and ad hoc alliances are built.

We must become an independent player supplying top products and services. National standards and intra-EU competition will weaken us, we must integrate our resources. It is very uncertain that carbon pricing (based on ETS) and taxing carbon at the borders to protect all our industry (CBAM) are accepted by the rest of the world. However, our own electrification basis will no longer require such protective action. As a comparison, in Europe, 21% of the final energy use is supplied by electricity, in China it is almost 30% in 2023[31]. In EU27 in 2022, 33.3% of the final energy use in industry is supplied by electricity[32], while the potential is 60 to 90%, this number is stagnating. In China this figure is almost the same 33% but increasing rapidly[33].

As the global markets are becoming more fragile, we must build an industrial system based on our strengths. Electrification is a firm basis as it stabilizes our energy resources needed. A firm and consistent policy that harmonizes the approach is a must as we need to invest in the new world, while still depending (and paying) for the old.

31 https://yearbook.enerdata.net/electricity/share-electricity-final-consumption.html.
32 https://powerbarometer.eurelectric.org/wp-content/uploads/2024/10/Power-Barometer-2024_Presentation.pdf.
33 https://www.iea.org/countries/china/efficiency-demand.

## Annex 1. Comparison with other economic areas

The economic rationale and options of a country/region/continent differ. Therefore, a high-level overview is provided to illustrate different approaches in some key countries. Both renewable (and carbon neutral nuclear) and critical raw materials are discussed. We limit the discussion to open, developed economies.

In both Australia and Canada, renewable resources are abundant, and the countries strategies are clearly based on producing basic products to use in the local industry and export (sponge iron, basic molecules, e-fuels). Both have efficient and fast regulation and legislation in place to advance their critical minerals production, processing and supply chains. While having limited demand for their own strategic technology production, they aim to create resilient and sustainable supply chains and extract more economic value from their own resources through international partnerships. In Australia, a lot of attention is given to building the required workforce[34].

The USA have implemented the Inflation Reduction Act. It is a widely defined program across the economy, to strengthen domestic supply chains, lower household energy costs while reducing greenhouse gas emissions. A second element is to renovate and build the necessary national infrastructure for the energy transition[35]. Almost all technologies reducing carbon emissions are supported: carbon dioxide capture, utilization and storage (CCUS), heat pumps, green hydrogen, electric vehicles (EVs) and energy storage (electricity grids[36], CCS[37], hydrogen[38], electric vehicles[39]): it is shooting from the hip. At the same time, the USA has become the largest exporter of fossil fuels. A federal framework and a set of actions address critical mineral supply chain challenges[40].

Japan resembling a lot Europe being very dependent on other world regions. has put forward the GX (green transformation) strategy[41]. A lot of attention is given to CCS and hydrogen within the whole package. Also advanced nuclear reactors are an important element as well as solar energy. Offshore wind faces difficulties in development due to the specific geographical conditions[42]. Japan has a significant critical raw materials processing and manufacturing industry. It has secured its supply through trade, investing in mining overseas, stockpiling, innovation (limiting the use and substituting present critical raw materials) and recycling. Domestic submarine mining is considered as a valid and economically viable option.

The South-Korean approach is very centralized[43]. CCS (also for biomass) and nuclear are a substantial supplement of wind and solar based electricity production. Deployment of CCS and green hydrogen in the industrial production is crucial. Its strategy for ‘securing reliable supply of critical minerals’ identifies 33 critical minerals to ensure economic security and ten further strategic critical minerals to ensure stable supply chains for South Korean high-tech industries. Critical mineral stockpiles are reinforced to suffice for 100 days. It established the Korea Mine Rehabilitation & Mineral Resources Corp. (KOMIR), a government agency to support the stable supply of core mineral resources, manage supply chain risks and dependencies, and develop overseas mining and processing capacity.

34 https://www.aph.gov.au/About_Parliament/Parliamentary_departments/Parliamentary_Library/Budget /reviews/2024-25/NewIndustry-Policy.

35 https://www.energy.gov/lpo/inflation-reduction-act-2022.

36 https://www.energy.gov/gdo/inflation-reduction-act#:~:text=Through%20the%20Inflation%20Reduction%20Act,transmission%20lines%20across%20the%20country.

37 https://www.landgate.com/news/the-ira-and-ccs-development-explained#:~:text=How%20has%20the%20IRA%20changed,as%20a%20CO2%20sales%20price.

38 https://www.energy.gov/eere/fuelcells/financial-incentives-hydrogen-and-fuel-cell-projects.

39 https://electrificationcoalition.org/work/federal-ev-policy/inflation-reduction-act/.

40 https://www.commerce.gov/data-and-reports/reports/2019/06/federal-strategy-ensure-secure-and-reliable-supplies-critical-minerals.

41 https://spectra.mhi.com/japans-green-transformation-strategy-boosting-industrial-decarbonization.

42 https://www.wfw.com/articles/japanese-offshore-wind-developments/.

43 https://www.sciencedirect.com/science/article/pii/S0959652624031986.

## Annex 2. Energy analysis of biomass potential for bio-chemistry

The largest source of molecules today is petroleum. All petroleum passes through refineries to make transport fuels, performance chemicals and monomers for polymer production.

Also, natural gas is used for non-energy applications, for instance production of fertilizers. Coal is used as carbon feed in blast furnaces in steel mills. We will discuss here the flow of the petroleum molecules and try to find out how this flow may look in future. The overall energy input is 1,053 TWh. Figures from 2019, being the last year before COVID, are used.

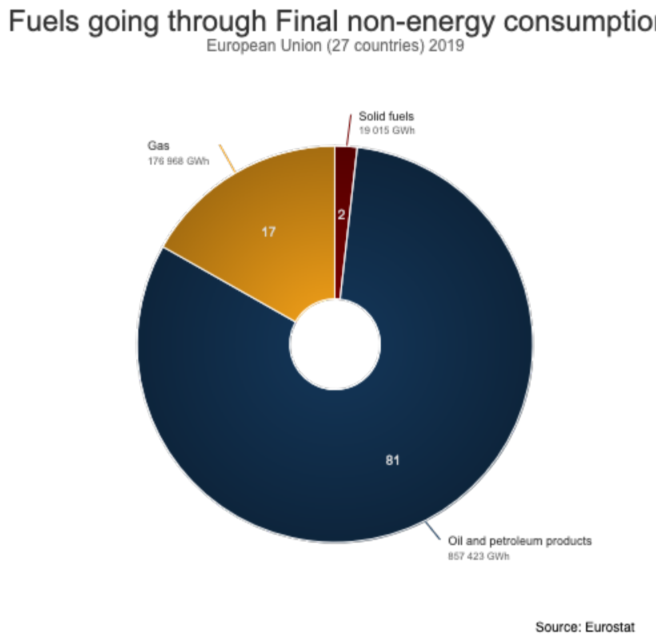


**Figure A2.1 Fuels going through to Final non-energy consumption (say material production)**

Further, we will try to estimate demand for biomass for substituting parts of the input. Therefore, it is appropriate to have a look on how much renewable flows are already available, that may be diverted to other applications. As seen from the pie chart, 1,103 TWh of primary solid biofuels are used today. 798 TWh of these primary solid biofuels go into building heating, 333 TWh are used to produce primarily electricity. Using heat pump and no longer burning wood for producing electricity, these primary solid biofuels can be freed up for biochemistry, i.e. as a carbon source. As the carbon content of solid biofuels per unit of energy is higher than petroleum of natural gas, enough carbon atoms in theory should be available in the primary solid biofuels to substitute the carbon now present fossil resources.

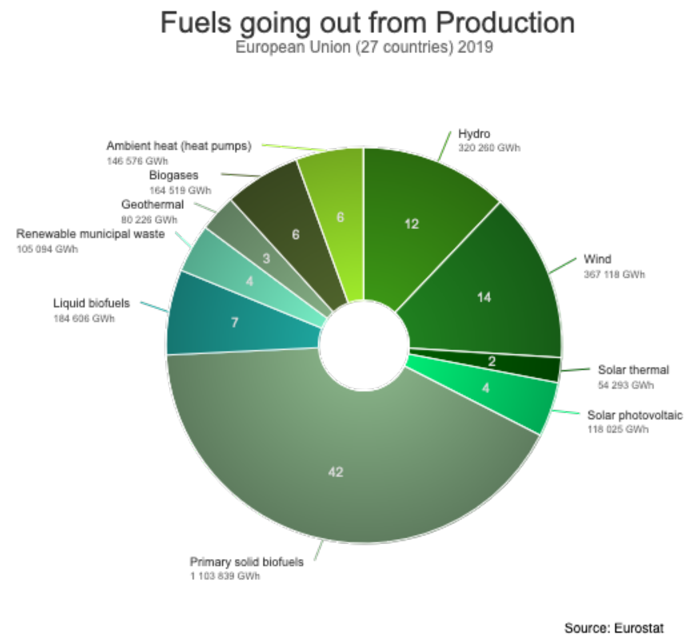


**Figure A2.2 Renewable energy input in EU27 in 2019**

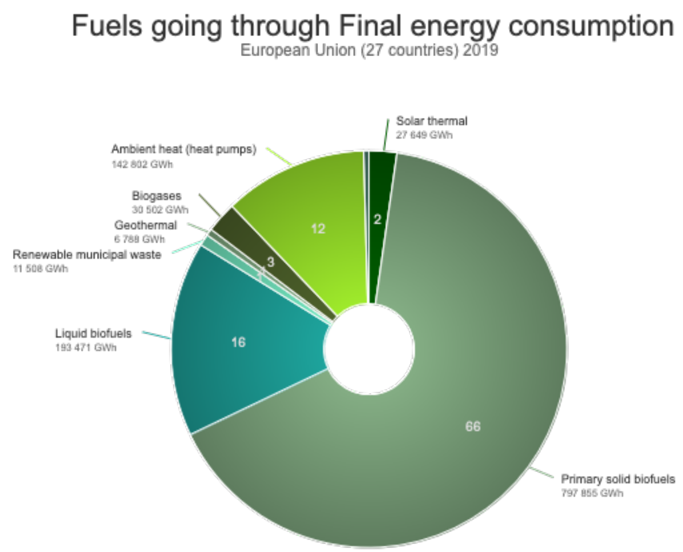


**Figure A2.3 Final renewable energy use**

Although we are dealing with non-energy applications, an important note can be made. The fuel use for international navigation and long-distance shipping is 984 TWh. Liquid biofuels, now already available, can cover 20% of this demand. Using them for land transport, as done now (blending with diesel or gasoline), is a waste of resources. The biogases can also shift to more effective resources like producing plastics.

## Authors

**Ronnie Belmans**

emeritus KULeuven, advisor EnergyVille, advisor FSR

ronnie.belmans@kuleuven.be