Special Issue

Blueprint for competitive decarbonization of European industry

In practice and in policy

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Europe's Clean Industrial Deal

The European Union's current industrial policy is not fit to address the mounting challenges of competitiveness, security, and decarbonization. To revitalize European industry, decarbonization must be positioned as a key lever for reducing energy bills, enhancing energy resilience, and driving technological innovation, thereby strengthening the EU's strategic autonomy and boosting competitiveness and growth.

The Clean Industrial Deal and the Affordable Energy Action Plan presented by the European Commission rightly recognize the role of energy efficiency, electrification, and sector integration to bring down energy bills. Similarly, they highlight the need to double-down on the European clean-tech sector to boost competitiveness and decarbonization.

For these levers to be turned into real-life decarbonization and create a predictable market for European clean-tech manufacturers, companies need a manual for what to do and policymakers need to know how to best enable them. This paper outlines "competitive decarbonization" as a game-changing industrial strategy. By leveraging a combination of powerful economic incentives and high-return technological investments with short payback times, Europe's industrial sector can lead the way in sustainability, innovation, and competitiveness on the global stage.

This paper serves as a call to policymakers and business leaders alike. Industry doesn't need to wait for policy; it can begin its transformation today with proven solutions. However, with a consistent, predictable vision for European industry, policymakers can accelerate the adoption of these solutions, placing Europe at the forefront of both global markets and industrial decarbonization.

Key takeaways

European industry is facing challenges on multiple fronts. **While decarbonization remains a central EU objective, competitiveness in global markets is waning and dependency on energy imports continues to burden the economy.** Solving these challenges requires a new industrial strategy referred to in this paper as "competitive decarbonization" with focus on both utilizing and supporting Europe's leading edge in select clean technologies. This approach aims to enhance energy resilience, drive technological innovation, and bolster competitiveness.

By increasing efficiency, electrifying, and integrating industrial processes with existing technologies, the EU can decarbonize industry while increasing economic growth, innovation, and energy independence.

Analysis shows that collective investments of just EUR 100 billion in existing technology within **energy efficiency, electrification, renewables, and energy system optimization could reduce the EU's gas consumption by 27 billion cubic meters**[1] – roughly 80% of the EU's total gas imports from Russia in 2024.[2] With the right investments, Europe can significantly increase its energy resilience (see p. 15).

Even single energy efficiency technologies can provide major savings for industry. For example, in European industry, **variable speed drives (VSD) could bring electricity savings of 121 TWh,**[3] **and EUR 22.6 billion in electricity cost savings.**[4] **This is as much as 10% of the EU's 2030 energy efficiency goal.**[5] Similarly, retrofitting industrial hydraulic systems has the potential to achieve up to 50% energy savings at application level (see p. 14).[6]

A Danfoss factory in Grodzisk, Poland, has already demonstrated the economic potential of competitive decarbonization. **The facility saved EUR 420,000 and 1,800,000 KWh per year simply by implementing existing energy efficiency solutions.** The project had a payback time of less than 2.5 years (see Danfoss Poland case on p. 11).

Sparking competitive decarbonization requires targeted policy action. European policymakers must focus on improving long-term predictability, simplifying regulatory processes, and incentivizing implementation of existing policies and technologies for energy efficiency and electrification. This includes funding, price incentives, and procurement rules that support European clean-tech manufacturing (see full policy recommendations on p. 18).

Competitive decarbonization, in brief

Industrial decarbonization is critical for Europe's economic future

In September 2024, Mario Draghi, former Italian Prime Minister and former President of the European Central Bank, released a landmark report entitled *The future of European competitiveness*.[7] That report carried one simple message: European industry[8] is falling behind.[9]

Faced with increasing competition from other major global economies, Europe's high and highly volatile energy prices put a significant strain on industries. According to the report, companies in the EU pay electricity prices 2-3 times those in the US,[10] and natural gas prices 4-5 times higher.[11] Additionally, Europe's slowing population growth is sparking concerns around future workforce capacity, while a shrinking productivity rate seems unlikely to close the gap.[12] In this context, profitability and innovation – let alone competitiveness in global markets – face major challenges.

Fortunately, while the EU's ambitious climate targets are a testament to its commitment to the global decarbonization agenda, its historical leading position in many clean technologies, such as renewables and energy efficiency, is also evidence of its ability to mobilize skills and resources to shape global markets.

With competitiveness, security, and decarbonization high on the agenda of both lawmakers and industry leaders, more and more companies around the world are already turning the challenge of decarbonization into a powerful driver of value creation and competitive advantage. Yet existing policies both at the EU and Member State level don't sufficiently address the competitiveness gap with other major global markets, put too little emphasis on Member State implementation, and fail to address the importance of lowering energy prices. This weakens the position of the European economy and puts the EU at geopolitical risk.

This paper highlights several key technologies and policies which can ensure that competitiveness and decarbonization operate in harmony towards a stronger, more sustainable Europe. It outlines the building blocks of a new industrial strategy of "competitive decarbonization."

What is competitive decarbonization?

Competitive decarbonization transforms an industry's decarbonization efforts into a vehicle for industrial development, competitiveness, geopolitical independence, energy resilience, and economic growth.

It all starts with increasing the uptake of energy efficiency measures. The first priority must always be to reduce energy consumption by scaling energy-efficient technologies. This opportunity exists across all sectors. Energy efficiency is a critical lever to drive the world towards an ambitious, cost-effective, and sustainable energy transition.

Next, industries must electrify wherever the technologies are mature enough to do it in a cost-efficient way. Not only is this a precondition for the transition to renewables, but it also increases efficiency, as electric technologies in many cases use far less energy than their fossil-driven counterparts.

Finally, sectors and processes must be more closely integrated to make the best use of the incredible amounts of wasted by-products generated every day by industries, such as excess heat.

All in all, competitive decarbonization represents a new industrial strategy and a key lever in boosting Europe's strategic autonomy. It offers a pathway for companies to redefine their relationship to energy and thereby open new market opportunities – all while reducing costs and emissions.

The technologies already exist

The most overlooked element in industrial decarbonization is the availability of proven technologies. While extensive political capital is spent advocating for the moonshot technologies of the future, highly impactful technologies with short payback times are ready to be implemented today. Indeed, the vast majority of the technologies that we need to decarbonize industry while simultaneously revitalizing European competitiveness already exist – things like variable speed drives, highly efficient industrial hydraulic systems, industrial heat pumps, and heat recovery technologies. For example, estimates show that existing technology can electrify 78% of industrial energy use, with the possibility of 99% electrification with technology already in development.[13] However, most of these readily available technologies are not being deployed at the scale they could be, and therefore not having the impact they're capable of.

There are clear steps we can take to accelerate decarbonization without sacrificing competitiveness today or in the future. It all starts with the low-hanging fruits of energy efficiency. On page 9, several of those key technologies, as well as their benefits, are explained in greater detail.

If the solutions already exist with favorable payback times, why aren't they being implemented at the scale Europe needs? The rest of this paper showcases some of the most impactful solutions to this challenge.

Key technologies in focus

Variable speed drives

Explainer: By default, a motor can run at full speed or be turned off, much in the same way a standard light bulb can be switched either on or off. Oftentimes, it is necessary to lower the speed of the motor – for example, to slow the speed of a conveyor belt or a fan. A common way to lower the speed is to put brakes on the system. However, this means it's still consuming the same amount of energy as it does when it's running at full speed. Instead of lowering the speed of a motor with brakes, a VSD can control the speed of the motor, making sure that it runs at the required speed without wasting energy.

Key data: In the EU alone, VSDs can bring electricity cost savings of EUR 22.6 billion,[14] while avoiding 25.4 million tons of CO_2 emissions – comparable to the annual footprint of up to 3.6 million European citizens.

Industrial hydraulic systems

Explainer: Hydraulic systems serve as the backbone of many industrial processes. They use pressurized fluids in a system of, for example, pumps and motors to generate, control, and transmit power for light and heavy-duty machinery. Hydraulic systems are often used in heavy industry for very energy intensive processes. Because of the energy intensity, even small improvements in energy efficiency can lead to great energy savings. However, due to their performance characteristics, these systems are nearly impossible to replace. Modern hydraulic systems are highly efficient, and retrofitting legacy systems can lead to up to 50% energy savings.[15]

Key data: Hydraulic systems accounted for 11% of the German industrial electricity demand in 2017[16] – a picture which is likely similar across the EU.

Industrial heat pumps

Explainer: Heat pumps use electricity to source pre-existing heat from air, water, or ground sources. Industrial heat pumps can deliver 2-5 heat units with only one input unit of electricity, depending on what output temperature is needed.[17] This means that they use much less energy than fossil-fuel powered heat units and at the same time enable a transition to renewable energy. Additionally, they bring other key co-benefits such as reduced air pollutants and lower sound levels compared to standard industry boilers. Heat pumps to electrify industrial process heat up to 200°C are already ready for implementation today, while temperatures over 200°C can be partly electrified.

Key data: With existing technologies, 60% of process heat that is not yet electrified can already be directly electrified today. In 2035, this will be nearly 90%.[18]

Heat recovery technologies

Explainer: All across industry, heat is lost every day as a byproduct of production processes. This byproduct is known as "excess heat" or "waste heat". Excess heat is generated by everything from machines on an assembly line to the motors of a refrigeration system. However, this heat can be captured and reused to supplement heat generation for other uses, whether on-site, through industrial microgrids, or in wider district heating networks. The primary way to reuse excess heat is through the installation of a heat recovery unit (HRU). An HRU is worth considering in many cases where unused heat energy is produced as a waste product. This a proven technology with a payback time of 1-3 years.[19]

Key data: 90% of district heat is produced through fossil fuels.[20] Excess heat can play a major role in replacing these fossil fuels. In fact, 23% of the industrial excess heat is below 100°C[21] and is therefore suitable for district heating.

Competitive decarbonization, in practice

What does competitive decarbonization look like in practice? And what can European industries do to release themselves from a long-lived dependency on fossil fuel imports?

To answer these questions, this section of the paper examines two cases: one examining the real-world implications of competitive decarbonization at a factory in Poland, and another focusing on the collective energy, emissions, and economic savings the EU would realize if only a few of the most impactful efficiency technologies are implemented at an EU scale.

Case story #1

Danfoss factory in Grodzisk, Poland

It's critical for companies and policymakers alike to see that competitive decarbonization is not only possible but has already been executed successfully at real industrial production sites in Europe.

Competitive decarbonization is particularly impactful in countries where manufacturing industry is a major part of the economy, as these are simultaneously major drivers of economic activity and consumers of energy. In that context, Poland is a textbook case to focus on. It is one of the most industrialized economies within the EU, with over 20% of its GDP from industry, supporting over three million jobs. Additionally, Poland's energy mix is heavily reliant on fossil fuels, with natural gas accounting for 27% and coal and its derivatives comprising 23%.[22]

Global engineering company Danfoss has a production site in Grodzisk, Poland, just outside of Warsaw, producing components for indoor heating and cooling systems. The campus consists of three halls with a total of 82 production lines, spread over a total of 37,400 m^2, responsible for a yearly turnover of EUR 335 million. The production halls demonstrate how industry can decarbonize in a competitive way, whether through the construction of new facilities or the retrofitting and modernization of existing ones.

In 2021, the Grodzisk campus was expanded with the construction of a new, 13,077 m^2 factory, known as Hall #3. Through careful design, with electrification and energy efficiency measures kept in mind, this facility keeps its CO2 emissions at a bare minimum. Hall #3 has been visited by over 1,000 stakeholders – ranging from facilities managers to policymakers – to learn about the solutions for competitive decarbonization and their applicability elsewhere.

The other two halls that make up the campus were opened in 1997 (Hall #1) and 2008 (Hall #2). While these facilities were not constructed with CO_2 neutrality in mind, they are continuously being retrofitted with energy-efficient solutions with short payback times and minimal disruption of operations.

80%	30%	EUR 3-5m
of the machines could be switched off when not in use	reduction in energy consumption	annual savings on energy bills

Increase efficiency

The first step towards competitive decarbonization is to increase efficiency. As part of a push to reduce energy consumption, Hall #3 in Grodzisk was part of pilot testing Danfoss' so-called "Shutting Off Initiative". A standard practice in many industries with factory production is to leave large machines on standby when not in use. The thinking is that this increases productivity when production is to resume again. However, the Danfoss pilot showed that 80% of the machines could be switched off when not in use – without any effect on productivity. As a result of the Shutting Off Initiative, Hall #3 at the Grodzisk campus was able to save 4,607 kilowatt hours (kWh) of energy per day. This is enough electricity to drive a modern EV more than halfway around the globe – every day.[23] An initiative such as this requires little to no investment in new technologies yet brings substantial energy and economic savings. Once this initiative is fully rolled out to all of Danfoss' 101 factories**, the company expects savings in the range of 80 million kWh annually – between 8% and 10% of its total energy usage, corresponding to EUR 3-5 million saved, simply by shutting off machines when not in use.**

Beyond the simple yet effective savings of the Shutting Off Initiative, another major energy-saving measure at the Grodzisk campus is variable speed drives (VSDs). In Hall #3, 16 VSDs control the motor speed of the fans in the air handling units to optimize airflow and energy consumption. The VSDs also enable condition-based monitoring – a proactive maintenance strategy that involves continuous data reporting about the condition of each of the fans' motors, which allows the system to predict potential failures before they happen and schedule maintenance only when necessary. This reduces unplanned production downtime and associated costs, as well as enables facilities managers to plan maintenance and expenses in advance. **The VSD-equipped air handling units in Hall #3 save up to 40% of energy when compared to conventional air handling units, also bringing considerable economic savings in the form of reduced energy bills.**

Electrify

The main heat source in Hall #3 – the campus' CO_2-neutral factory – is the excess heat recovered from compressors, chillers, and production stations in operation at the factory. While the next section will expand more on excess heat as an important second step towards achieving competitive decarbonization, it is worth noting here that this excess heat is only able to be captured and reused through electric heating devices – namely, heat pumps. The heat pumps installed at the factory have a seasonal coefficient of performance (SCOP) of 3.8. This means that the pump can generate 380 kW of heat power output from only 100 kW of electric power input – a highly efficient rate of energy conversion.

Heat pumps can both heat and cool air, depending on what is needed. During periods between seasons where outside air temperature has a wider range of fluctuation, the ventilation system is supported by two air-to-water heat pumps. An additional benefit of these heat pumps is that they are reversible devices, meaning they can also support chillers in the summer to provide cooling. Depending on the outside temperature and heat demand, the system automatically switches between the different sources so that it can work as efficiently as possible.

Finally, in addition to the normal heating capacity of the electric air handling units, four electric boilers also operate in the winter months, when heat demand is greatest. This has enabled the factory to decrease its costs from heating with natural gas, as well as its dependence on volatile fossil fuel markets.

Integrate

Retrofitting and continuously monitoring the energy use in existing facilities is a key part of reducing energy in operations. A good example of this is in Danfoss' oldest production hall on the Grodzisk campus, Hall #1, where in 2023 two new air handing units (AHU) were installed in only 10 days – evidence that such solutions can be implemented quickly and with limited impact on production. Additionally, an existing AHU without energy recovery was rebuilt and from now on both cools and heats the production environment to ensure a good indoor climate. All these AHUs allow the factory to recover energy in the exhaust air from production equipment, which is produced as part of normal operations. Instead of this heat escaping into the atmosphere, it can be captured

2,860 TWh/year of waste heat accessible in the EU, almost the same as EU's total energy demand for heat and hot water.

and reused to heat air and water in other parts of the building, ultimately saving money on factory heating bills.

For example, the air exhausted from the entire volume of the production hall and the waste heat from production stations, such as welding or soldering stations, are collected in one large ventilation duct and discharged straight into the central ventilation located on the roof. The warm air discharged from the production hall pre-heats the fresh air, which is taken from outside the building.

In addition to recovering excess heat for reuse, both the new and retrofitted AHUs also supply cool air to the factory. Prior to their implementation, additional money was spent to rent a separate air-conditioning unit to help cool the facility for the production staff during the hot summer months. The new solution not only saves the factory on equipment rental costs, but also simplifies the heating and cooling processes, creating a comfortable workplace.

The AHUs were part of a larger project to modernize the HVAC system of the factory.

As a result of this, in 2023, the 6,700 square meter building saved 1,800,000 kWh in electricity and gas per year – equal to a savings of EUR 420,000. This gives the project a payback time of less than 2.5 years.

Case story #2

EU's potential for competitive decarbonization

What benefits can competitive decarbonization bring if existing efficiency technologies are scaled across the EU? Following the three steps of competitive decarbonization – increase efficiency, electrify, and integrate – this section explores the potential energy, emissions, and economic savings potential for European industry.

Increase efficiency

Motors in the EU industrial sector consume 729 TWh of electricity annually.[24] 35% of these motors have significant potential to reduce energy consumption through variable speed drives (VSDs).[25] This excludes those already equipped with VSDs. The potential is approximately 121 TWh per year,[26] equal to 4.5% of the EU's electricity generation.[27] This is as much as 26% of the EU's wind production, or nearly 48% of its solar production in 2023.[28]

Rather than powering inefficient motor use, renewable electricity saved through the implementation of VSDs in industry could be redirected to abate fossil fuel-generated electricity elsewhere in the energy system. In total, **VSDs can bring electricity cost savings of EUR 22.6 billion,[29] while avoiding 25.4 million tons of CO_2 emissions – comparable to 12% of EU emissions from industrial processes.[30]**

The EU's Energy Efficiency Directive aims to reduce annual energy consumption by 1,174 TWh by 2030. While many VSDs are already installed across the EU, **expanding the reach of this one technology can lead to savings that amount to 10% of the EU's 2030 energy efficiency goal.[31]** With payback periods as short as six months, VSDs offer one of the most cost-effective and impactful methods for industry to reduce energy consumption.

Another often-overlooked technology with great potential to reduce industrial energy consumption is industrial hydraulic machinery, which uses vast amounts of energy. In fact, hydraulic systems accounted for 11% of the German industrial electricity demand in 2017[32] – a picture which is likely similar across the EU. Many of these hydraulics systems are legacy installations which have a major untapped potential to save energy through retrofits. Hydraulic systems are often used in heavy industry for processes that require enormous amounts of energy. Because of the energy intensity, even small improvements in energy efficiency can lead to big energy savings. Moreover, up to 50% energy savings have been achieved by retrofitting legacy machinery, demonstrating that there is great untapped potential to reduce energy costs and GHG emissions in heavy industry.[33]

EUR 22.6b
can be saved annually by applying VSDs in EU industry

37%
of the EU's industrial process heat can be met by heat pumps

13%
of the EU's industrial heat demand can be met by excess heat

What would it take to increase energy security in the EU?

Energy independence is a cornerstone of the EU's competitiveness. As part of the EU's efforts to increase its energy security, the Union has pledged to quit Russian gas by 2027.[34] However, in 2024, the EU imported 33 billion cubic meters (bcm) of Russian gas – 21% more than in 2023.[35] Without a rapid shift in policy, this is a trend that is expected to continue in 2025.[36]

To reduce dependence on gas imports, companies, households, and governments across the EU must make strategic investments in the energy transition. An IEA analysis shows that collective investments of only EUR 100 billion[37] can reduce the EU's gas consumption by 27 bcm (which equals to 80% of the EU's total gas imports from Russia in 2024).[38] The investments can pay themselves back within 2-3 years thanks to reduced gas import bills and can prove to be important measures in the EU's ongoing efforts to increase energy security.

The investments must be spent on three priority areas:

- **Increase efficiency:** A EUR 50 billion investment in energy efficiency in buildings and industry can reduce gas use by 8 bcm. This means that energy efficiency alone can reduce the EU's gas import with what is equivalent to almost a quarter of its imports from Russia.
- **Rapidly deploy renewables:** A EUR 40 billion investment in renewables can reduce gas use by 7.5 bcm.
- **Electrify and optimize:** The final EUR 10 billion investment must be spread across three key areas: electrification of heat (2 bcm), optimization of gas and hydrogen production (4.5 bcm), and enablers of behavioral changes such as smart meters (5 bcm).

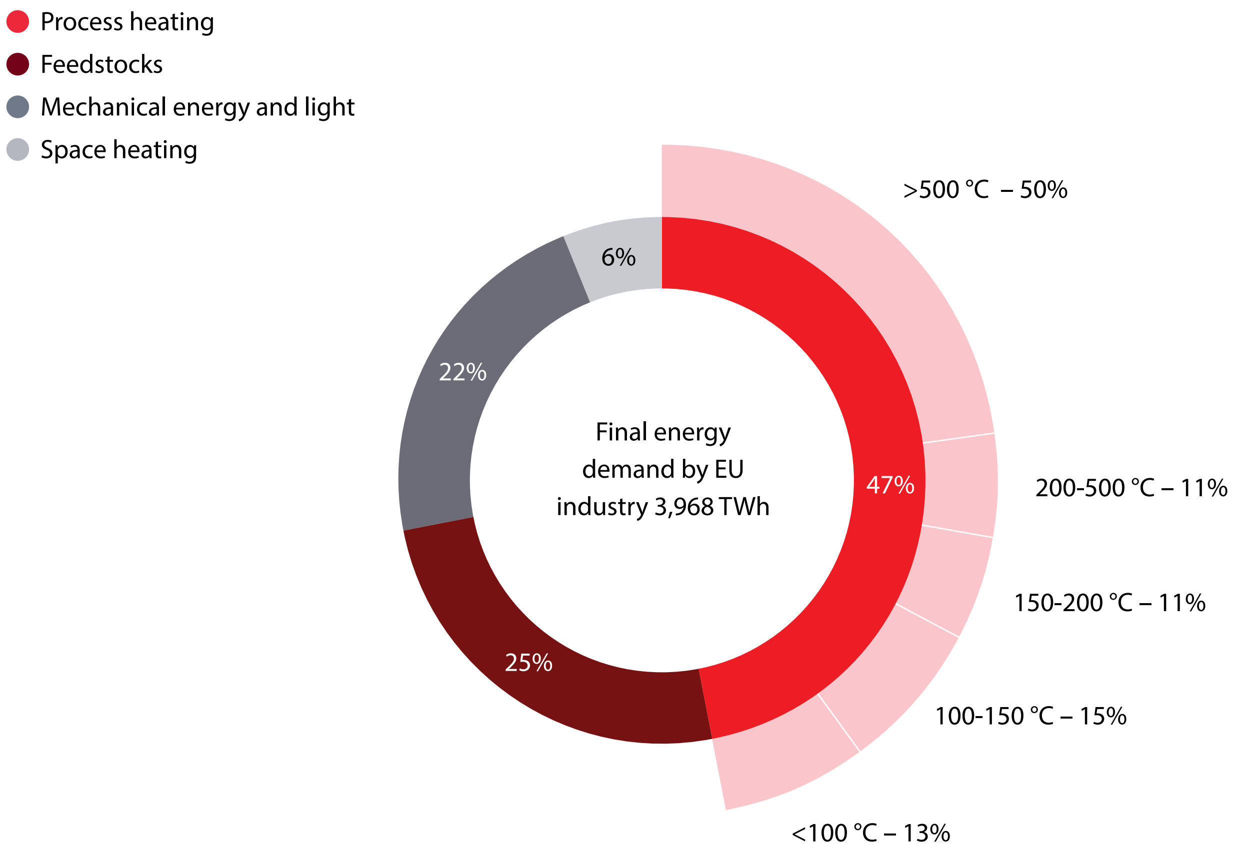
Electrify

There is major potential to electrify heat in industries. This way, the EU can enable renewable energy use and reduce reliance on fossil fuels. **Today, 47% of industrial energy is used for process heat,[39] three quarters of which stems directly from fossil sources. However, with existing technologies, 60% of process heat that is not yet electrified can already be directly electrified today.** In 2035, this will be nearly 90%.[40] By powering this heat production with renewable electricity, industry can significantly reduce energy consumption and minimize the effect of high energy prices, while replacing fossil fuels and reducing CO_2 emissions.

Heat pumps are highly effective for generating steam in industrial applications, particularly for temperatures up to 200°C.[41] They can deliver 37% of the EU's process heat requirements, with a particularly high potential in the pulp and paper, food and beverages, and chemical sectors.[42] Along with other electrification technologies like electric boilers and arc furnaces, heat pumps can meet a substantial portion of industrial heat demand, contributing significantly to the decarbonization of the industrial sector.

Europe already has a highly mature heat pump industry, with over 250 heat pump and component production sites spread across the continent.[43] However, despite requiring an annual average growth rate of 17% to meet the EU's goal of 60 million installed heat pumps by 2030, sales actually decreased by 6.5% in 2023.[44] This is a clean technology where Europe can take the lead in innovation, skills, and growth, but doing so requires a policy framework that supports heat pump production, installation, and research and development.

Energy demand by end use and temperature in the EU industry



Based on Frauenhofer ISE (2024)

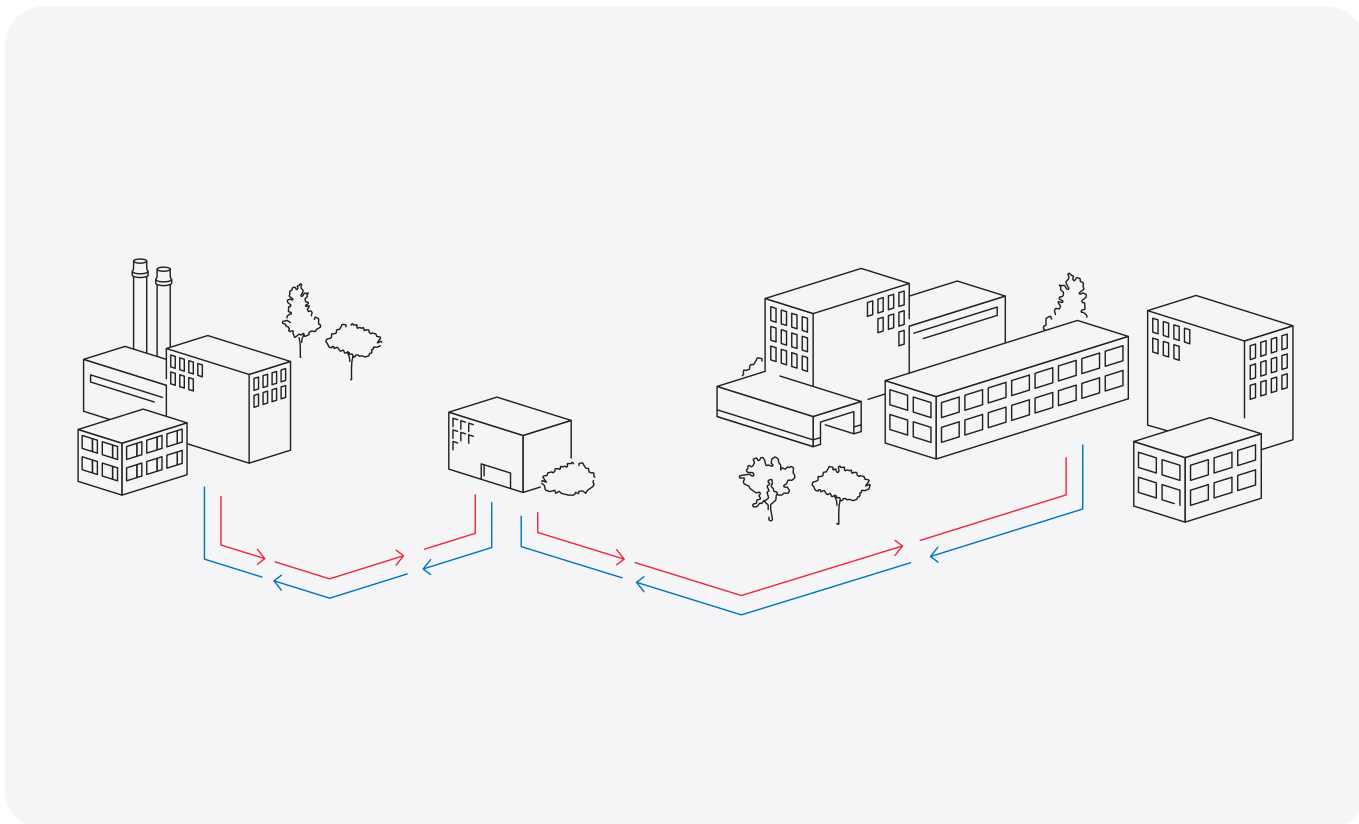
Integrate

In 2019, EU industry wasted 29% of its total energy consumption into the atmosphere as excess heat.[45] 279 TWh of this excess heat can be technically recovered and repurposed. More than half of this heat is above 300°C, making it useful for many industrial processes, while the lower temperatures can be used for space heating, either in industries or households.[46]

There are several pathways through which to utilize excess heat. One way is to reuse it directly in the facilities or processes where it was generated, or in nearby facilities through industrial cluster planning. The EU's industry uses 224 TWh for space heating, and 1,861 TWh for process heating. Together, these account for 56% of industrial emissions.[47] 39% of the process heat demand in the EU is below 200°C.[48] In an industrial context, this is considered a low temperature, and makes it all the easier to utilize excess heat for space and process heat. Actually, **industrial excess heat has the potential to cover 13% the industrial heat demand and abate 66 million tons of CO_2e.[49]** Another way to utilize excess heat is through district heating networks. Today, 90% of district heat is produced with fossil fuels, leaving an untapped potential to decarbonize heating.[50] Excess heat can play a major role in achieving this. In fact, 23% of the industrial excess heat is below 100°C[51] and is therefore suitable for district heating. This is equivalent to the heat demand for over 5 million German households[52] and is enough to cover almost three quarters of the fossil energy that goes into producing district heating in Germany.[53]

From practice to policy

These cases are a testament to the power of existing technologies to transform European industry. They demonstrate that competitive decarbonization in Europe is not a pipe dream but rather a matter of systematically implementing solutions that we already know work. If industry is willing, and if policymakers set up a simplified framework for incentivizing investments in energy-efficient solutions, Europe can turn decarbonization into its greatest growth opportunity while becoming less dependent on foreign energy imports. The next section explores the greatest challenges to competitive decarbonization in Europe and proposes actionable policy solutions.



Competitive decarbonization, in policy

Challenge #1

Lack of predictability hinders long-term planning

European industry operates within a complex regulatory landscape, responding to legislation implemented at the EU, national, and local levels. Sudden changes in policies create uncertainty and unpredictability for companies – as witnessed by the uncertainty in heating schemes in Germany, which meant sales and renovation activities went down by 50% as private investors stopped all activities to wait for new a framework and funding. When the regulatory environment for energy or performance requirements, EVs, or heat pumps is uncertain, companies withhold investments in upgrading their technologies, particularly those with higher CAPEX costs. Stop-and-go policies are a killer for investor confidence.

Policy solution #1

Ensure continuity of ambition, predictability, and long-term thinking

To stimulate industrial appetite for investment and innovation, Europe needs a solid policy framework for industry which provides a clear outlook of at least 10 years. Policy helps set the direction and level of ambition. Setting a general target for electrification of 35% by 2030, as well as specific targets for sectors, will help build trust in policy development and put pressure on implementation. Politicians must also prioritize existing legislation, which has still yet to be sufficiently implemented. For example, there must be a rapid and harmonized implementation of legislation adopted in the last mandate, including of the Energy Efficiency Directive, the Energy Performance of Buildings Directive, and the Electricity Market Design reform.

Challenge #2

Weak or non-existent incentives mean less electrification

While technologies to electrify exist and renewable energy is a cheaper alternative to fossil fuels, the incentives are not sufficiently available to consumers, including industry. Taxes and levies are currently contributing to Europe's comparatively high electricity prices for end-users and make it unattractive to switch from gas to electricity. Policy should not hinder the most cost-effective – and cleanest – solutions. Additionally, when industry is pressured by high and volatile energy prices and fierce international competition, the upfront CAPEX cost might hinder the implementation of otherwise cost-effective solutions, especially for smaller businesses.

Policy solution #2

Incentivize electrification

Beyond setting the 35% electrification target and targets for subsectors, incentives can be put in place through a mix of taxation and financing. Harmonizing electricity taxes across Europe and removing non-energy-related taxes and levies from electricity bills will incentivize the adoption of electrification of end-use. Further, a European Electrification Bank should be established. This would offer financial incentives for industries to electrify, helping industries adopt electrification technologies more effectively and overcome CAPEX hurdles. It could also centralize funding by coordinating resources from various sources, leveraging the European Investment Bank to attract private investments, and serving as a "one-stop shop" for technical guidance and progress monitoring. The use of tax incentives such as tax credits, reduced VAT, and accelerated depreciation should also be used to incentivize faster deployment of readily available solutions, in turn spurring greater investments in their development and manufacturing from European manufacturers.

Challenge #3

Europe has insufficient energy infrastructure

Making Europe's energy system more independent, resilient, efficient, and electric requires not only a shift in the supply and demand of energy but also the energy infrastructure to enable it, including power grids and modern district energy networks. Europe's grids are too often insufficient, outdated, and disconnected to allow Europe to reap the benefits of investments in renewable energy, such as flexibility and demand-response measures that are necessary to run a system based on fluctuating renewable energy sources. At the same time, with increasing geopolitical tensions, care must be taken to make the grid and our energy infrastructure resilient and secure.

Policy solution #3

Invest in robust, digitalized energy infrastructure

To fast-track electrification and increase European resilience, Europe must prioritize the necessary investments in renewing, expanding, and digitalizing the European grid infrastructure. The EU and its member states must further enhance incentives for network operators to deliver necessary infrastructure investments, such as anticipatory investments. To safeguard this infrastructure, preference and incentives should be given to European supply chains. For flexibility, efficient signals that reflect system needs and access to data for consumers and producers alike is crucial and any regulatory barriers that hinder deployment of flexibility and demand-response solutions must be reassessed and removed. Support schemes for industrial electrification and decarbonization, as well as green hydrogen production, could be made conditional on offering flexibility in a market-based way, with appropriate remuneration.

Challenge #4

Lack of support for European clean-tech manufacturers

The main driver for industrial investment is confidence in market demand, and a European commitment to a decarbonized energy system is the best possible outset for the European clean-tech sector. Yet, to ensure a level playing field in a fiercely competitive global market and to protect critical European energy infrastructure, European technologies must be prioritized.

Policy solution #4

Prioritize European energy technologies

To support a competitive, resilient, and secure Europe, critical European energy infrastructure – particularly energy efficiency and electrification technologies – must receive priority when it comes to funding measures, public procurement, and regulatory support in the form of faster permitting. For example, non-price criteria should be applied in public tenders and security screening for suppliers of strategic Net-Zero Industry Act technologies. This would include solutions that would otherwise leave European energy infrastructure vulnerable, including power cables, demand side flexibility solutions using AI & IoT, digital energy technologies, and energy efficiency and electrification technologies. This concerns specifically those in which Europe is still leading and which need a stable market demand and export opportunities - including heat pumps, variable speed drives, and power semiconductors.

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3. Frauenhofer ICT (2023). Study on the energy-saving potential of electric motors with variable-speed drives in The European Union.
4. The weighted average electricity price was €0.1867/kWh (or €186.7 million/TWh) including non-recoverable taxes for non-household medium-sized consumers between 500 and 2000 MWh in the first half of 2024. (Eurostat 2024, Electricity price statistics, Accessed 21 January 2025) 121.1 TWh/year electricity can be saved with VSDs. With this price, the potential cost savings from electricity is €22.6 billion.
5. The EU has a binding target of decreasing its energy consumption by 11.7% by 2030 from the 2020 EU Reference Scenario, which projects a final energy consumption of 864 Mtoe (10,048 TWh) in 2030. An 11.7% reduction results in a final energy consumption of 763 Mtoe (8,874 TWh) in 2030, or a reduction of 1,174 TWh. (The European Parliament and The Council of The European Union (2023). Directive 2023/1791. Document 32023L1791. Accessed on 27 June 2024.) Frauenhofer ICT estimates that 121.1 TWh can be saved from an expanded implementation of VSDs, on top of what is already being saved from existing VSD installations (Frauenhofer ICT, 2023). This is equivalent to 10.3% of the EU reduction goal. It is worth noting that the Ecodesign Directive Regulation 2019/1781 targets motors in the size range 0.12-1,000 kW, whereas Frauenhofer ICT considers motors in the size range 0.37 kW-1,300 kW. To our knowledge, there are no studies of the consumption of motors above 1,000 kW in the EU. Since the Ecodesign Directive is expected to have an effect on the energy consumption from motor systems (e.g., through more efficient motors), the isolated effect of VSDs may be smaller. However, the Ecodesign Directive "no longer explicitly encourages the use of VSDs" (European Commission (2024), Ecodesign Impact Accounting: Overview report 2024, p. 104), meaning the remaining potential by 2030 is still expected to be very significant. Beyond this, Frauenhofer ICT only studies the potential for variably loaded motor systems. There is also a potential to save energy for constantly loaded motor systems, particularly in cases where these are over-dimensioned. Hence, the potential may very well be even larger than 121.1 TWh.
6. Danfoss calculations and customer measurements.
7. Draghi, M. (2024). The future of European competitiveness – Part A: A competitiveness strategy for Europe. Published September 2024. Accessed 21 January 2025.
8. In this paper, the term "industry" is used broadly to describe sectors in which the primary function is the production and manufacturing of goods. This includes light industry (e.g., textiles, consumer goods, electronics) with relatively low energy demands, as well as heavy industry, which represents some of the most energy-demanding sectors in the global energy system (e.g., cement, steel, and chemical production).
9. In this paper, "Europe" is in many cases used interchangeably with "European Union."
10. Draghi, M. (2024). The future of European competitiveness – Part A: A competitiveness strategy for Europe. Published September 2024. Accessed 21 January 2025.
11. Draghi, M. (2024). The future of European competitiveness – Part A: A competitiveness strategy for Europe. Published September 2024. Accessed 21 January 2025.
12. Draghi, M. (2024). The future of European competitiveness – Part A: A competitiveness strategy for Europe. Published September 2024. Accessed 21 January 2025.
13. Madeddu et al. (2020). The CO_2 reduction potential for the European industry via direct electrification of heat supply (power-to-heat). Environmental Research Letters. 15, 2.
14. The weighted average electricity price was €0.1867/kWh (or €186.7 million/TWh) including non-recoverable taxes for non-household medium-sized consumers between 500 and 2000 MWh in the first half of 2024. (Eurostat 2024, Electricity price statistics, Accessed 21 January 2025) 121.1 TWh/year electricity can be saved with VSDs. With this price, the potential cost savings from electricity is €22.6 billion.
15. Danfoss calculations and customer measurements.
16. Ioshchikhes, B. et al. (2022). Assessing Energy Efficiency Measures for Hydraulic Systems using a Digital Twin. Procedia CIRP Volume 107, 2022, p. 1232-1237.
17. de Boer, R. et al. (2020). Strengthening Industrial Heat Pump Innovation: Decarbonizing Industrial Heat. Accessed 7 February 2025.
18. Frauenhofer ISI (2024). Direct electrification of industrial process heat. An assessment of technologies, potentials and future prospects for the EU. Study on behalf of Agora Industry.
19. Danfoss (n.d.). HRU – Heat Recovery Unit. Accessed 31 January 2025.
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21. Bianchi, G., Panayiotou, G.P., Aresti, L. et al. Estimating the waste heat recovery in the European Union Industry. Energ. Ecol. Environ. 4, 211–221 (2019). https://doi.org/10.1007/s40974-019-00132-7
22. Forum Energii (2024). The 2024+ industrial deal. Strategic pathways to modernise the Polish industry. Published November 2024. Accessed 23 January 2025.
23. A modern EV consumes 21 kWh per 100 km (Weiss, M. et al (2024) Energy Consumption of Electric Vehicles in Europe. Sustainability. 16(17). 7529. https://doi.org/10.3390/su16177529). This means that 4,607 kWh (the energy saved per day through the shutting-off initiative at Grodzisk) is enough to drive an EV 21,938 km every day, more than halfway around the globe (40,075 km).
24. European Commission (2023). 2023 EC EIA Status Report Tables. p. 589. Accessed 29 April 2024.
25. de Almeida, A.T. et al. (2023). Perspectives on Electric Motor Market Transformation for a Net Zero Carbon Economy. Energies, 16, p. 1248.
26. Frauenhofer ICT (2023). Study on the energy-saving potential of electric motors with variable-speed drives in The European Union.
27. In 2022, the net electricity generation was 2,701 TWh in the EU (Eurostat (2024). Electricity production, consumption and market overview. Accessed 21 January 2025). VSDs can lead to savings in the order of 121.1 TWh (Frauenhofer ICT, 2023). 100 / 2,701 TWh * 121.1 TWh = 4.5%.
28. In 2023, the EU produced 466 TWh electricity from wind turbines (WindEurope (2024). Wind energy in Europe: 2023 Statistics and the outlook for 2024-2028) and 252.1 TWh from solar panels (Eurostat (2024). Renewable energy statistics, Accessed 21 January 2025). VSDs can lead to savings of 121.1 TWh in the EU industries. 121.1 TWh is 26.0% and 48.0% of the electricity generated by wind and solar respectively.
29. The weighted average electricity price was €0.1867/kWh (or €186.7 million/TWh) including non-recoverable taxes for non-household medium-sized consumers between 500 and 2000 MWh in the first half of 2024. (Eurostat 2024, Electricity price statistics, Accessed 21 January 2025) 121.1 TWh/year electricity can be saved with VSDs. With this price, the potential cost savings from electricity is €22.6 billion.
30. In 2023, the GHG intensity of the average EU electricity was 210g CO_2e/kWh (EPA 2024, Greenhouse gas emission intensity of electricity generation, country level, Accessed 21 January 2025). If VSDs were installed across all suitable motors in the EU industry, this could lead to 25.4 million tons of CO_2e-reductions. In 2022, 217,183,910 tons CO_2 was emitted from industrial processes in EU (Eurostat (2024). Greenhouse gas emissions by source sector. Accessed 6 March 2025). VSDs can save 25,4 million tons CO_2, or 11,7% of emissions from industrial processes.
31. The EU has a binding target of decreasing its energy consumption by 11.7% by 2030 from the 2020 EU Reference Scenario, which projects a final energy consumption of 864 Mtoe (10,048 TWh) in 2030. An 11.7% reduction results in a final energy consumption of 763 Mtoe (8,874 TWh) in 2030, or a reduction of 1,174 TWh. (The European Parliament and The Council of The European Union (2023). Directive 2023/1791. Document 32023L1791. Accessed on 27 June 2024.) Frauenhofer ICT estimates that 121.1 TWh can be saved from an expanded implementation of VSDs, on top of what is already being saved from existing VSD installations (Frauenhofer ICT, 2023). This is equivalent to 10.3% of the EU reduction goal. It is worth noting that the Ecodesign Directive Regulation 2019/1781 targets motors in the size range 0.12-1,000 kW, whereas Frauenhofer ICT considers motors in the size range 0.37 kW-1,300 kW. To our knowledge, there are no studies of the consumption of motors above 1,000 kW in the EU. Since the Ecodesign Directive is expected to have an effect on the energy consumption from motor systems (e.g., through more efficient motors), the isolated effect of VSDs may be smaller. However, the Ecodesign Directive "no longer explicitly encourages the use of VSDs" (European Commission (2024), Ecodesign Impact Accounting: Overview report 2024, p. 104), meaning the remaining potential by 2030 is still expected to be very significant. Beyond this, Frauenhofer ICT only studies the potential for variably loaded motor systems. There is also a potential to save energy for constantly loaded motor systems, particularly in cases where these are over-dimensioned. Hence, the potential may very well be even larger than 121.1 TWh.
32. Ioshchikhes, B. et al. (2022). Assessing Energy Efficiency Measures for Hydraulic Systems using a Digital Twin. Procedia CIRP Volume 107, 2022, p. 1232-1237.
33. Danfoss calculations and customer measurements.
34. Reuters (2025). EU seeks more US gas, renewable energy to replace Russian supplies. Accessed 4 March 2025.

35. McWilliams, B., G. Sgaravatti, G. Zachmann (2021). European natural gas imports. Bruegel Datasets. Published 29 October 2021. Last updated 22 January 2025. Accessed 28 January 2025.

36. Politico (2025). EU devours Russian gas at record speed despite cutoff. Published 16 January 2025. Accessed 31 January 2025.

37. IEA (2022). How to Avoid Gas Shortages in the European Union in 2023: A practical set of actions to close a potential supply-demand gap.

38. European Council – Council of The European Union (2025). Where does the EU's gas come from?. Acceseed 4 March 2025.

39. Derived from Frauenhofer ISI (2024). In 2019, the total energy demand from industry accounted for about 4,000 TWh, of which about 1868 TWh, or 47% was used for process heating.

40. Frauenhofer ISI (2024). Direct electrification of industrial process heat. An assessment of technologies, potentials and future prospects for the EU. Study on behalf of Agora Industry.

41. Frauenhofer ISI (2024). Direct electrification of industrial process heat. An assessment of technologies, potentials and future prospects for the EU. Study on behalf of Agora Industry. Published 5 June 2024. Accessed 7 February 2025.

42. de Boer, R. et al. (2020). Strengthening Industrial Heat Pump Innovation: Decarbonizing Industrial Heat. Accessed 7 February 2025.

43. European Heat Pump Association (2024). Heat to compete: boosting competitiveness in the heat pump sector. Published 22 August 2024. Accessed 7 February 2025.

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48. Frauenhofer ISI(2024). Direct electrification of industrial process heat. An assessment of technologies, potentials and future prospects for the EU. Study on behalf of Agora Industry. Published 5 June 2024. Accessed 7 February 2025.

49. 279 TWh of excess heat can technically be recovered from EU's industry (Bianchi et al, 2019), which is 13% of the energy the EU's industry uses for space heating (224 TWh) and process heating (1,861) (Frauenhofer ISI, 2024). 75% of process heat in EU's industry is from fossil fuels, and almost half of this is from natural gas, (Frauenhofer ISI, 2024). Other fossil sources have higher emissions than natural gas. Therefore, assuming that all the potentially abated fossil energy is from natural gas, is a conservative assumption. According to DEFRA GHG conversion factors 2024, the use of natural gas emits 0.20264 kg/kWh (net CV) in scope 1 (combustion) and 0.03347 kg/kWh (net CV) in scope 3 (Well-to-tank). Applying these emission factors, 279 TWh emits 66 million tons CO_2e.

50. IEA (n.d.). District Heating. Accessed 31 January 2025.

51. Bianchi, G., Panayiotou, G.P., Aresti, L. et al. (2019). Estimating the waste heat recovery in the European Union Industry. Energ. Ecol. Environ. 4, 211–221.

52. 279 TWh of excess heat can technically be recovered from EUs industry, of which 23% (64.17 TWh) is below 100°C (Bianchi et al, 2019) A German household consumes 12.216 kWh heat on average (Destatis (2023). Energy consumption for room heating (temperature adjusted) by household size. Accessed 12 February 2025.). 64.17 TWh/12,216 kWh per household = 5,252,947 households.

53. 279 TWh of excess heat can technically be recovered from EUs industry, of which 23% (64.17 TWh) is below 100°C (Bianchi et al, 2019). In 2020, Germany produced 126 TWh district heat, of which 70% (88 TWh) was produced through fossil fuels (Bundesministerium für Wirtschaft und Klimaschutz (2021). What exactly is 'district heating'?. Accessed 12 February 2025). 64.17 TWh is 72.8% of 88 TWh.

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