The new industrial age

Tailored electrification pathways for Europe’s industrial competitiveness

eurelectric accenture

Content

Context and objectives

A secure energy supply is essential for industry to flourish. European reliance on fossil fuel imports exposes our industries to heightened volatility of fuel and affects electricity prices.

The European Union is also driving towards climate-neutrality by 2050. Industry represents over 20% of carbon emissions (2022), as the third largest sector behind energy supply and domestic transportation[1]. Industrial electrification, supplied by net zero generation technologies, creates an opportunity for industry to increase competitiveness, reduce exposure to external volatility and decarbonise. The path to electrification is well-trodden for processes which require low-medium temperatures (below 500 degrees) with mature technologies available e.g. heat pumps or electric boilers, but more challenging for high-temperature process (above 500 degrees) where technologies are less mature, e.g. electrical crackers for chemicals. Therefore, this study explores different industrial archetypes to understand the competitiveness of industrial electrification vis-a-vis fossil fuel processes and highlight potential actions required to support it.

[1] Greenhouse gas emissions by country and sector

Why industrial sector electrification matters

Electrification of industrial sectors is critical to reinforce Europe's sovereignty, realise economic benefits, address climate impact and enhance its role as an innovation leader

Sovereignty benefits

In 2023 and 2024, fossil fuel imports cost the EU over €350bn annually[2], following a record amount in 2022 of over €600bn[2], exposing industry to geopolitical volatilities (i.e. a loss of supply or volatile prices). Industrial electrification improves energy efficiency, lowers carbon cost, lowers exposure to import dependency and increases European and industrial resilience.

Economic benefits

From a total cost of ownership perspective, this study demonstrates that there is a path towards competitiveness (where electrification outcompetes fossil fuel alternatives), with some industries already there.

Climate impact

Europe is heating at twice the global rate and will have to learn to live in a climate that is 3 degrees warmer, even in the best-case scenario where global warming is limited to the Paris Agreement threshold of 1.5 degrees[3] - resulting in exponentially more heatwaves and other extreme weather events. Between 1980 and 2023, weather- and climate-related extreme weather events caused economic losses of €738 billion in the European Union, with over €162 billion (22%) between 2021 and 2023[4]. Three quarters of industrial CO_2 emissions result from burning fossil fuels that provide process heat. By 2035, 60-90% of industrial energy demand could be directly electrified, with technologies readily available today or under development[5]. To achieve climate neutrality by 2050, immediate action is required.

EU role as innovation leader

IEA analysis found that clean energy (manufacturing, deployment and equipment sales) accounted for 10% of global GDP growth in 2023[6]. The European Union is projected to account for over a third of heat pump manufacturing capacity by 2030, almost doubling from 18% currently[7]. As new electrification technologies are rapidly deployed, Europe has the potential to drive innovation and establish itself as a global player. Similarities could be drawn to offshore wind where European manufacturers benefitted from first mover advantage with Denmark installing the first offshore wind farm in 1991 - and continue to hold leadership in manufacturing of key turbine components, as well as in the foundations and cables industry.

[2] EU imports of energy products - latest developments

[3] European Climate Risk Assessment

[4] Climate change impacts, risks and adaptation

[5] Direct electrification of industrial process heat

[6] Clean energy is boosting economic growth

[7] Advancing Clean Technology Manufacturing

Objectives of this report

The report explores how the costs relating to the electrification of process heat, in three scenarios that are used to test the boundary conditions of different futures, compared to the fossil fuel-based manufacturing process currently used and what could be potentially done to address the gap. This is the lens used for competitiveness in this report.

Current challenges and opportunities

The report explores competitiveness levers relating to upfront technology costs (CapEx) for the electrification and the cost of electricity (OpEx).

Technology costs

Today, only 4% of Europe's industrial process heat is generated by electricity[8]. Technologies readily available today, such as heat pumps, electrical boilers and electric arc furnaces, could already deliver more than 60% of the 1,861 TWh of annual process heating energy demand[9]. For some very high temperature applications, electrification technologies currently represent a higher CapEx cost than fossil fuel comparators as they are still at the start of their journey.

Importantly, significant declines have been seen in the cost of several clean technologies over the last few decades. Solar PV modules are the most iconic example, decreasing from 92 €/watt in 1975 to 0.29 €/watt in 2023, an average of a c. 12% reduction annually for multiple decades[10] driving down the cost of solar generation.

Electrolysers achieved a 66% reduction between 2000 and 2005, as they went from prototype to deployment[11]. Unlocking these levels of reduction, for industrial applications, presents an opportunity to increase the competitiveness of electrification.

The outlook is positive for electric technologies. For example, heat pump investment costs could decrease by 20-40% in certain countries, including Germany by 2030 (IEA, 2022). This is primarily driven by increased scale and manufacturing advancements.

Industry and Original Equipment Manufacturers (OEMs) will need to collaborate closely to drive innovative solutions in engineering, process design and manufacturing to drive efficiencies; especially when economies of scale are harder to be achieved due to a limited number of installations with tailor-made designs.

Additional support may be required through favourable policy frameworks to drive innovation and scaling on innovative solutions to commercial application.

[8] Power Barometer 2024

[9] Direct electrification of industrial process heat

[10] Solar photovoltaic module price

[11] Historical Cost Reduction of PEM Electrolyzers

Electricity costs

The cost of electricity is a combination of energy usage, or the volume of electricity consumed and electricity price, which consists of wholesale price or other supply methods such as PPAs, as well as charges, taxes and levies. Despite a significant decrease, electricity prices remain high post-Russian invasion of Ukraine, predominantly driven by the increase in gas prices, and a wider use of LNG.

When countries introduce more low-cost net zero generation[13] into the electricity mix, this facilitates long-term contraction of affordable renewables and lowers the number of hours of fossil-fuels as the marginal price setter, thus lowering the bill.

The International Energy Agency estimates EU electricity consumers saved €100 billion during 2021-2023 thanks to 150 GW of new solar and wind capacity, displacing 230 TWh of fossil fuel generation[14].

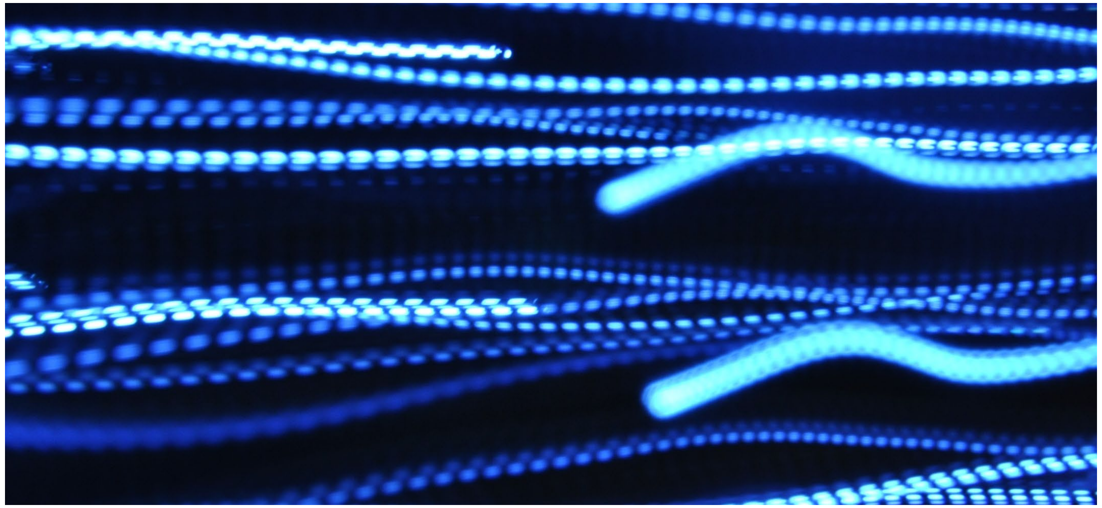
Moreover, this increased penetration of renewable technologies changes the energy system, increasing generation variability. This will create opportunities for certain industries which can take advantage of hours with low pricing caused by abundant renewable generation and gain revenue from marketing this flexibility.

Combined with other flexibility and storage sources, a stable basis of low carbon dispatchable power such as hydropower, nuclear and decarbonised thermal will ensure the physical stability of the electricity system.

Beyond the wholesale price, taxes also contribute to the competitiveness gap, increasing the cost of electricity. Electricity is, o, average, taxed 1.4 times more than gas[14] and burdened with levies, putting it at a disadvantage to its fossil fuel counterparts.

Momentum is building to correct the tax and levy environment for electrification.

When it comes to the total energy bill, electrification unlocks benefits. It significantly improves efficiency and lowers energy usage, for example heat pumps at low to medium heat can be 3-5x more efficient than gas boilers[15]. The planned introduction of a heat pump into the milk powder production process in the Netherlands is expected to reduce energy demand for steam production by 75% [16].



[12] Electricity price statistics

[13] Net-zero generation technologies" refers to those sources of production included in the Net-Zero Industry Act.

[14] Eurelectric's 5 yays and nays for the EU Affordable Energy Action Plan

[15] How a heat pump works

[16] GEA helps Nestlé reduce steam consumption by 75% in its new infant formula plant

Project approach and methodology

Three industrial sector archetypes have been selected to compare different type of energy intensities/temperature requirements, and for each of them two countries have been selected to assess a range of energy mix. Those archetypes are not fully representative of all the European industrial sectors but provide a good range of different opportunities and challenges.

Industrial archetypes

	1. CONCENTRATED ESTABLISHED INDUSTRY	2. DIVERSE ESTABLISHED INDUSTRY	3. FAST GROWING INDUSTRY
CHARACTERISTICS	Concentrated highly energy intensive requiring 24/7 energy, where European players are competing on the global stage	Relatively low concentrated sector, above average energy intensity, competing mainly within the European market	Cleantech industry, where growth is highly linked to competitively priced electricity
ADDITIONAL BENEFIT TO EXPLORE	Guarantee of large-scale demand, reduces investment uncertainty for energy producers and grid operators	Potential to shift demand and explore flexibility options	Virtuous circle between accelerating electrification and industries supporting electrification
MAIN SECTORS	Chemicals (Ethylene); Non-metallic minerals; Metallurgy	Food and beverage (Milk powder); Machinery; Textiles and leather	Batteries (Cell assembly); Offshore wind; Solar
SELECTED PROCESS TEMPERATURE REQUIREMENT	>800	<200	<200
SECTOR SELECTION LOGIC	Highest manufacturing Gross Value Add (GVA)	Second highest manufacturing GVA and food security is the cornerstone of prosperity	Relatively large energy intensity in the manufacturing process and a strategic sector for Europe
COUNTRIES SELECTED	Germany; Spain	France; Denmark	Sweden; Hungary

Total cost of ownership

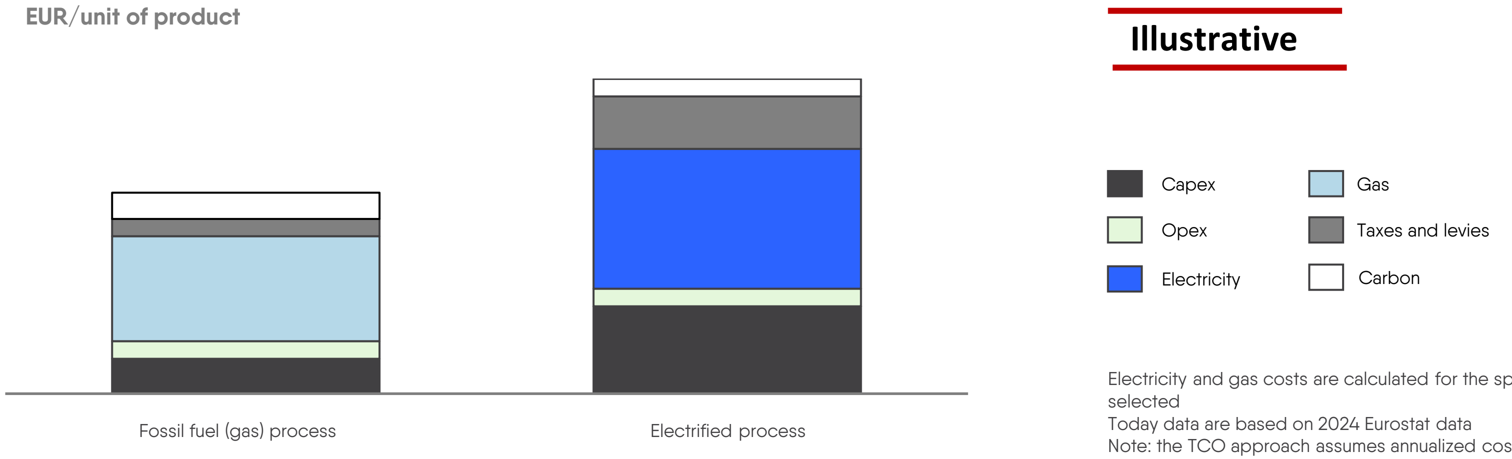
Total Cost of Ownership (TCO) is used to compare the cost of electrification with the cost of the fossil fuel option, comparing today and 2030.

The Total Cost of Ownership covers the CapEx (technology, on annualised basis), the non-fuel OpEx (O&M), the fuel (respectively gas and electricity, including the efficiency of the different technologies) OpEx and the taxes and levies for the two options (electrified and non-electrified).

While the TCO approach considers the annualised costs, it does not calculate the Net Present Value of future cash flows. A detailed description of components and sources can be found in the appendix. The TCO doesn't factor in grid connection fees (shallow or deep). The analysis assumes that the grid can connect and carry an increased load (no expansion needs to happen, and no costs are being incurred). It is also assumed that grid tariffs stay stable as the infrastructure investment costs are distributed across a broader electrified base. This assumes that electrification picks up in other sectors, such as heating and transport and all consumers pay cost-reflective tariffs (no reductions are granted if they are not based in underlying investment cost savings).

Energy component comparison

EUR/unit of product



Electricity and gas costs are calculated for the specific countries selected
Today data are based on 2024 Eurostat data
Note: the TCO approach assumes annualized cost but does not calculate the NPV of future cash flows

Cost outlook scenarios

To project a 2030 view of the competitiveness, the methodology adopts a scenario approach defining three different potential scenarios (BAU, Base and Best) for the different cost components.

These simplified scenarios are established to test the boundary conditions of different futures, to explore the potential competitive level in each scenario and what would need to be true to achieve each scenario. In most cases they are based on expert-assumptions of such boundary conditions and do not represent an accurate forecast of the future.

Major drive of cost reduction

Levers	BAU CURRENT TRAJECTORY	BASE ACHIEVE STATED AMBITIONS	BEST GO FURTHER
1 TECHNOLOGY COST	Accelerate the technology and commercial readiness		
2a ELECTRICITY: GRID COST	Held constant		
2b ELECTRICITY: GENERATION COST 2c ELECTRICITY: CARBON COST (GRID CARBON INTENSITY)	Increasing penetration of net zero technologies into the energy mix, reducing the overall cost of generation and carbon cost		
3 TAXES AND LEVIES	Increasingly favourable tax regime for electricity in comparison to gas		

The average reduction between 2024 and 2030 across all countries reviewed, for technology and electricity, have been defined as follows for the three scenarios:

LEVER	BAU	BASE	BEST
Technology	10%	25%	40%
Average reduction in electricity price, taxes and levies	8%	14%	22%

Technology cost scenarios

Technology cost reduction scenarios are based upon analogues (e.g. heat pump forecasts[17] and electrolysers[18]), Accenture's technology S-curve model[19] and refined with interviews with industry experts. The main change between scenarios is driven by increased maturity (technology and commercial) and deployment level.

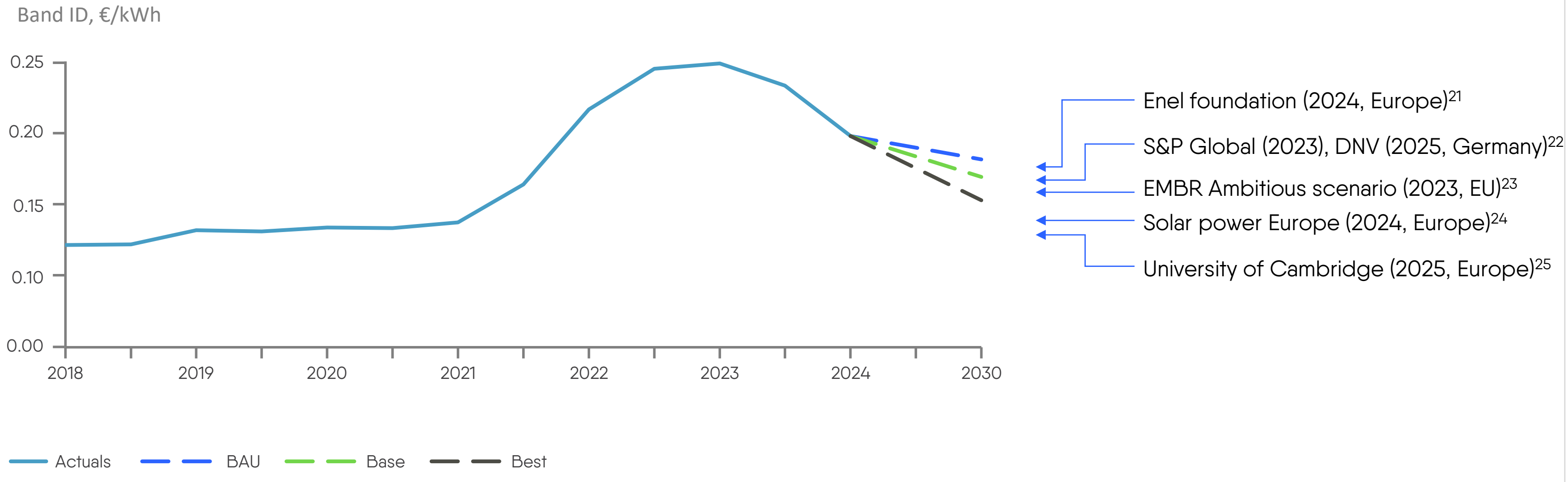
- BAU scenario assumes a conservative learning rate.
- Base scenario assumes technology begins to scale in size and deployment. Unlocking efficiencies in production and design.
- Best scenario assumes effective collaboration across the entire ecosystem to drive larger scaling of assets, process innovation and manufacturing efficiencies driving costs down further.

Electricity price scenarios[20]

The average percentage reduction, from the six countries included, applied to the average EU prices, from the first six months of 2024, would see electricity prices moving back towards pre-crisis levels in a best-case scenario. Our simplified scenarios have been indicatively compared to external studies to pressure test whether the boundary conditions are realistic. The electricity scenarios flex generation and carbon costs (based on country specific evolving generation mix), and taxes and levies for individual countries (based on country specific energy tax and levies).

Electricity prices for non-household consumers (bi-annual)

Indicative comparator points



[17] Reducing heat pump installed costs: Reviewing historic trends and assessing future prospects

[18] Historical Cost Reduction of PEM Electrolyzers

[19] Accenture-Powered-for-Change-Report-2024

[20] Graph uses Band ID to illustrate industrial prices, however each archetype TCO has been modelled based on the appropriate band

[21] Reviving Europe's Industrial Power: How to boost competitiveness through energy

[22] S&P (wholesale energy forecast, converted to an indicative reduction in electricity prices)

[23] Ember (wholesale energy forecast, converted to an indicative reduction in electricity prices)

[24] Solar power Europe (25 reduction applied to prices)

[25] University of Cambridge (30% reduction applied to prices)

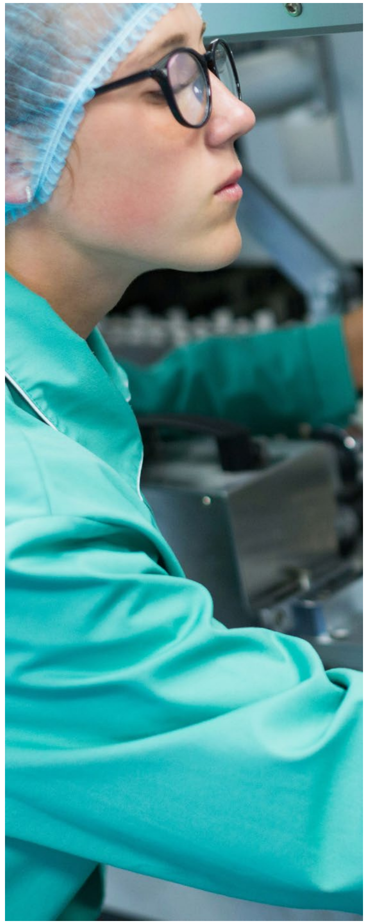
Findings

Electrification can be competitive by 2030

The TCO analysis shows a competitiveness gap between electrification and fossil fuel alternatives, for two of the three archetypes.

On one side, this is because the electrified process heat technologies are more expensive than the equivalent fossil fuel ones, making the transformation more CapEx intensive. On the other side, there is a competitiveness gap between electricity and fossil fuels, leading to power being more expensive on a per MWh basis than alternatives.

The analysis in this report estimates that the two factors contributing to the competitiveness gap can be mitigated and shows a path to competitiveness by 2030 for electrification, more specifically the findings show three situations.

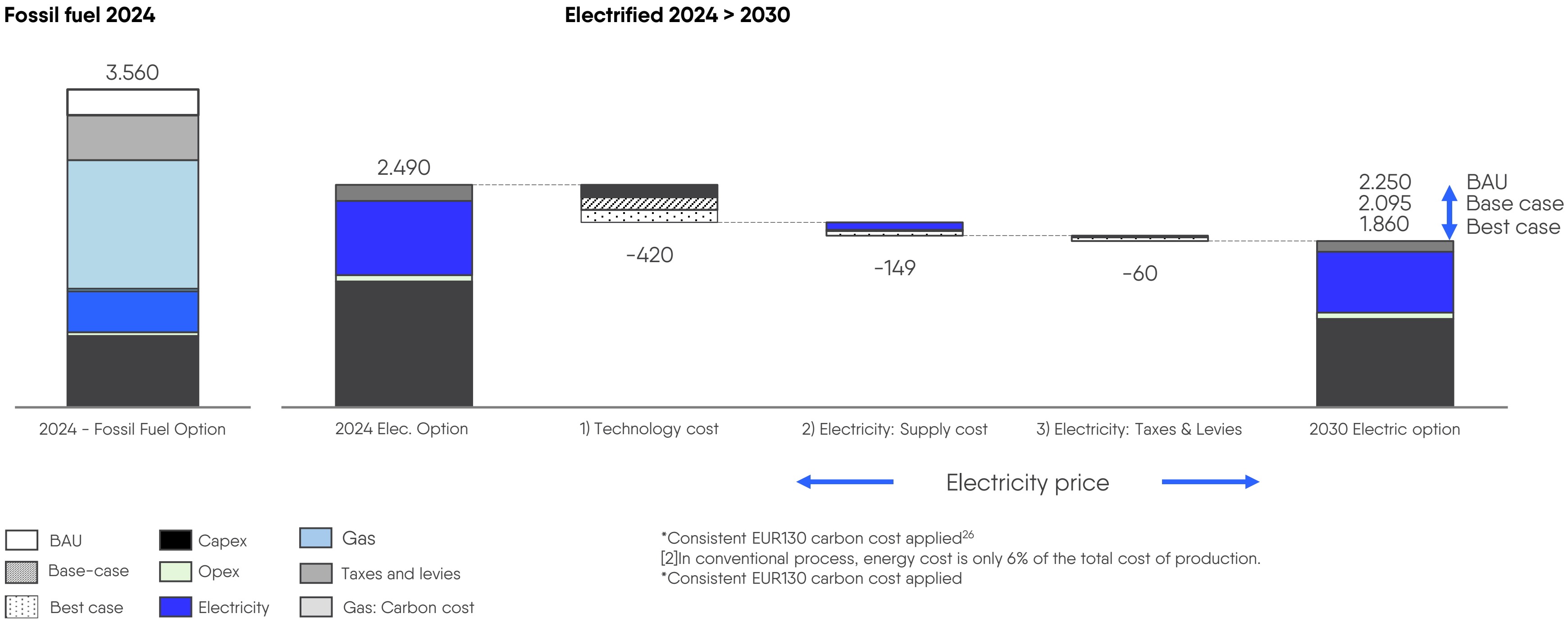


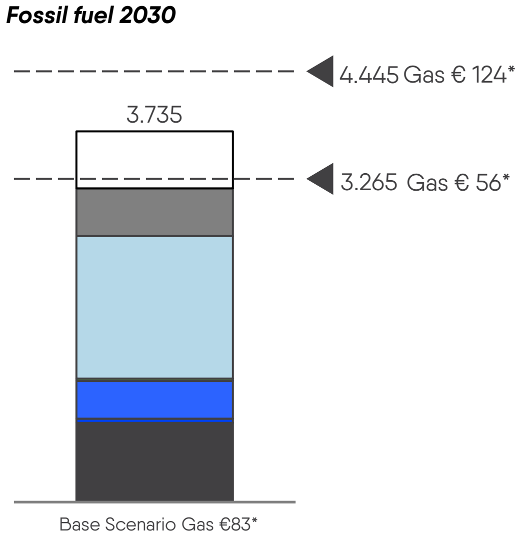
For industrial sectors where the electrification technology is particularly efficient (example: battery assembly where the technology is predominantly heat pumps and a 4x efficiency could be achieved) electrification is already competitive– and is becoming more competitive over time.

The in-scope processes are coating & drying and dry rooms; these fossil fuel driven processes account for almost one fourth of the total energy cost which is 7% of the overall cost of production. For coating and drying, dry coating electrode technology eliminates the need of conventional drying machines reducing the energy demand per kWh of battery cell production as well as equipment footprint. For dry rooms, higher efficiency is driven through heat pumps, which makes these processes already competitive.

Impact of competitiveness levers on the cost of production (energy component) of battery cell manufacturing process

Competitiveness levers | 2030, Hungary, EUR/MWh





*Consistent EUR130 carbon cost applied[26]
[2]In conventional process, energy cost is only 6% of the total cost of production.
*Consistent EUR130 carbon cost applied

[26] ERCST and BloombergNEF

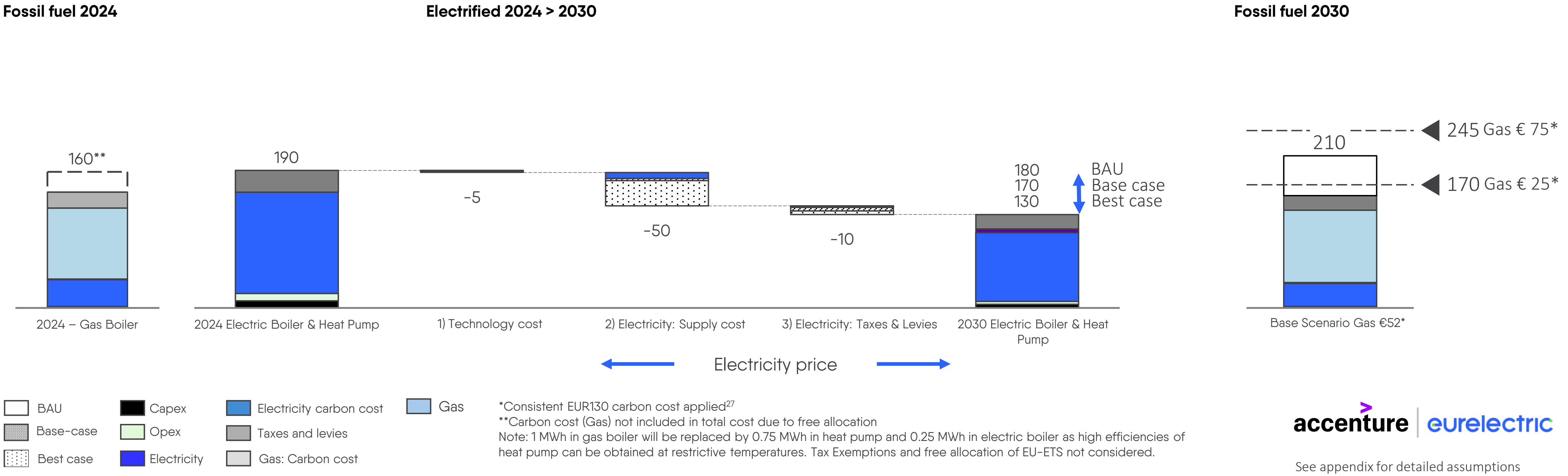
See appendix for detailed assumptions

This archetype focuses on industrial sectors where the process temperature requirement is lower but very OpEx intensive (e.g. milk powder production:, over 90% for both electric and fossil fuel processes. Therefore, reducing energy consumption through electrification and lowering the electricity price has the biggest impact on competitiveness. While not competitive today, our analysis shows a path to competitiveness across all scenarios by 2030.

The in-scope processes are evaporation, drying and CIP (cleaning in place) which require low to medium temp steam for process heat. These fossil fuel driven processes account for c. 5-6% of the total cost of production. Evaporation uses steam at 100 deg C and accounts for one fifth of total process heat consumption while drying requires high pressure superheated steam at 175-250 deg C in a pressurized steam fluidised bed dryer accounting for almost three fourth of overall process heat requirements

Impact of competitiveness levers on the cost of production (energy component) for milk powder

Competitiveness levers | 2030, France, EUR/tonne of milk powder



*Consistent EUR130 carbon cost applied[27]
**Carbon cost (Gas) not included in total cost due to free allocation
Note: 1 MWh in gas boiler will be replaced by 0.75 MWh in heat pump and 0.25 MWh in electric boiler as high efficiencies of heat pump can be obtained at restrictive temperatures. Tax Exemptions and free allocation of EU-ETS not considered.

See appendix for detailed assumptions

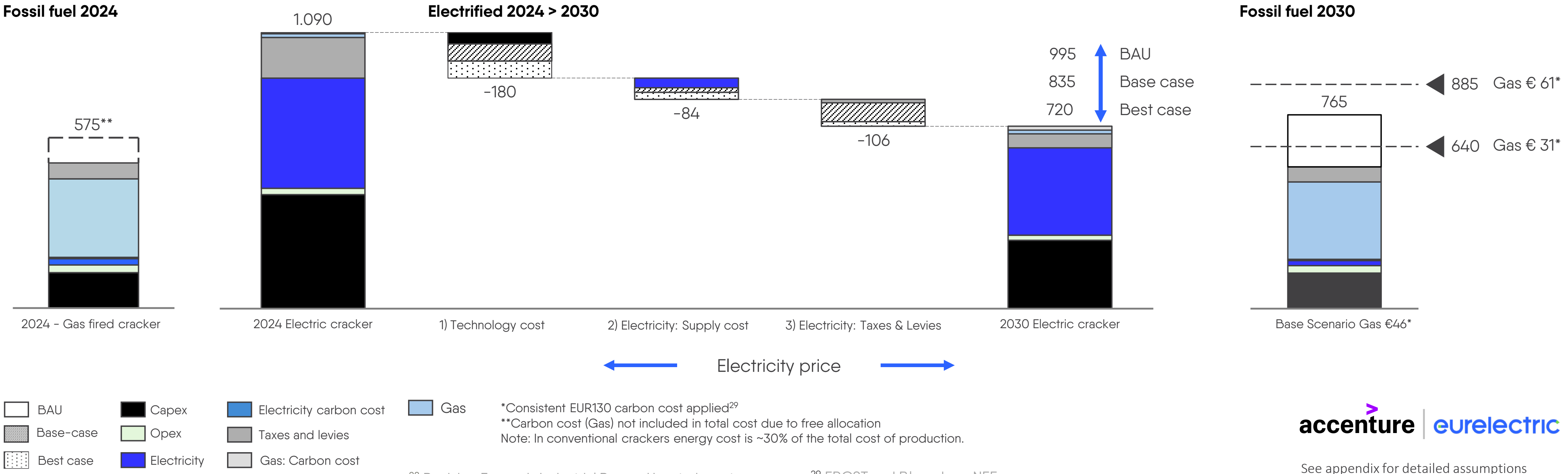
[27] ERCST and BloombergNEF

Industrial sectors that require high temperature process and are energy intensive (like chemical, but also cement, glass, iron & steel as demonstrated in other studies, e.g. Enel Foundation, Compass Lexecon & ERCST[28]) will require a significant reduction of both CapEx and OpEx for electrification to become competitive. For example, in ethylene production, the competitiveness gap between electrification and gas-based alternatives is situated around 10-33% (country dependent) at OpEx level and c. 30% in technology costs.

The in-scope process is steam cracking which accounts for 38% of the overall fossil fuel demand in the chemicals sector. Steam cracking majorly produces ethylene along with other HVC (high value chemicals). Since energy costs represent 30% of the overall cost of production in case of ethylene it is a major candidate for electrification, but the bottleneck is high process temperature requirements and consequently low maturity of electrification technologies.

Impact of competitiveness levers on the cost of production (energy component) for electric crackers

Competitiveness levers | 2030, Germany, EUR/tonne of ethylene



*Consistent EUR130 carbon cost applied[29]
**Carbon cost (Gas) not included in total cost due to free allocation
Note: In conventional crackers energy cost is ~30% of the total cost of production.

[28] Reviving Europe's Industrial Power: How to boost competitiveness through energy

[29] ERCST and BloombergNEF

accenture | eurelectric

See appendix for detailed assumptions

The scenarios highlight how there is a path for competitiveness for all sectors.

The below table shows the competitiveness of electrification within the three archetypes in 2024 and in 2030 across all scenarios, assuming a carbon price of EUR 130[30]. The scenarios highlight how there is a path for competitiveness for all sectors, based on the assumptions laid out in the scenarios described. It is also worth noting that the competitiveness is highly dependent on industry and the country – mainly due to the different cost of energy (both electricity and gas). For example, electrification can be c. 70% more competitive in low- medium temperature applications in Sweden (2030 electrification best case vs 2030 gas base case), where electricity is already cheaper than gas.

		CHEMICALS		FOOD & BEVERAGE		BATTERIES	
	PRODUCT (UNIT)	Ethylene (EUR/tonne)		Milk powder (EUR/tonne)		Batteries (EUR/MWh)	
	ENERGY INTENSITY	c. 30%		5-10%		c. 3-7% (in scope)	
	COUNTRY	Germany	Spain	France	Denmark	Hungary	Sweden
2024	FOSSIL FUEL	575	470	160	280	3.560	4.130
	ELECTRIFIED	1.090	830	190	285	2.490	1.925
2030 Fossil Fuel	BASE	765	665	210	310	3.735	4.405
2030 Electrified	BAU	995	750	180	260	2.250	1.770
	BASE	835	680	170	225	2.095	1.640
	BEST	720	580	130	190	1.860	1.475

30 ERCST and BloombergNEF

Conclusion

The path forward

Technology advancements have made electrification of most industries technically possible. The business case varies greatly across industry, country and scenario. Importantly, this study has demonstrated that there is a competitive path forward for electrification, but it will require action in two specific areas:

Reducing the technology costs especially for high temperature applications

Closing the competitiveness gap between electricity and fossil fuels costs

Reduce technology costs

As mentioned in the previous chapter, while electrification technologies are more efficient - by driving down energy requirements - their CapEx is in general higher than the equivalent, but less efficient than fossil fuelled technology. For example, CapEx for the electrified technology required for battery assembly drying rooms is 50% more expensive than the mature fossil fuel alternative.
The gap is wider for the high temperature process technologies like the e-crackers (3-4x higher), which are currently at an early stage of innovation.

Therefore, the reduction of the electric technologies CapEx is of paramount importance to drive the uptake of industrial electrification and benefit from economies of scale. While lowering the technology cost of low-medium temperature applications would have a relatively limited impact on the previous TCO analysis, **it would lower adoption costs and increase uptake. C.50% (c. 900TWh) of industrial process heat demand is below 500 degrees**[31]. Rapid adoption in this space could electrify almost half of consumption. Another key pillar for rapid uptake is to raise awareness of the technologies among industry and the profession and developing the expertise (e.g. training courses and communication).

CapEx for energy-intensive sectors requiring very high temperatures is significant because the technology is in the early stages of innovation and scaling, and customised solutions are needed. If we look at the cost trajectory of other technologies (e.g. electrolysers), a significant drop in costs (a further 80% reduction forecast in 2021[32]) can potentially be achieved through four primary levers:

- **Increasing scale** (30-50% reduction in CapEx): larger plants can explore different system designs increasing efficiency
- **Improving the manufacturing process and scale (40-50%)**
- **Advancing in technology to extend asset lifetime and efficiency**
- **Improving industrial processes** to lower the temperature needs and therefore being able to use solutions with a high technological readiness at a lower cost

While the boundary condition for our best-case scenario is capped at 40% (significantly lower than 80% forecast in electrolysers) unlocking this potential still requires a supportive research and development environment and collaboration across the entire ecosystem.

With industrials and OEMs working together to drive innovative solutions through the industrial process and technology design, manufacturing and supply chain, Nordic countries have the highest heat pump market shares and the lowest heat pump purchase prices – high adoption enabled economies of scale and accelerated learning rates. Sweden has used a combination of carbon and energy taxes, subsidies and building regulations to increase adoption of heat pumps and district heating[33].

[31] Direct electrification of industrial process heat

[32] Electrolyser costs

[33] Heat-Pumps-Case-Study

Ecosystem collaboration is key.
It is worth noting that the levers might differ by technologies: for the more "mature" technologies e.g. heat pumps needed to electrify the milk powder production, scale and manufacturing will be of essence; for the industrial sectors where the electrification technology is more early stage and / or the scale is limited (e.g. e-crackers for chemical) the reduction may come more from innovation e.g. process re-invention. Europe has a strong track record in developing early-stage clean technologies (from electrolysers to wind turbines and green steel), but difficulties remain in its ability to scale, deploy and maintain their competitiveness. Expanding Europe's clean technology base will be crucial to achieve climate and industrial leadership, while also speeding up the push for energy independence.

Success Story: Electrifying Chemical[34]

Overview
A pioneering collaboration has reimagined production processes in the chemical industry by replacing traditional steam technologies with new solutions, boosting efficiency, cutting CO_2 emissions, enabling electrification in a subsequent step, and strengthening European competitiveness, even in a demanding sector like the chemical industry.

The Challenge
Steam cracking relies on high-pressure steam quenching, which instantly stops reactions and preserve yields. The primary challenge was to develop a solution that replicates steam quench dynamics with the required reliability, technical and economic viability.

The Approach
The success of this initiative can be attributed to a well-structured collaboration framework that emphasised transparency and flexibility. Defining clear targets and responsibilities of several partners along the value chain with different business incentives from the outset empowered the team to focus on joint solution-finding and synchronise efforts – essential for navigating complex projects.

The Solution
At the core of finding the optimal technology to improve the whole process there was a genetic-algorithm–driven optimisation: partners provided individual knowledge to define a shared objective function (weighting technical performance, CapEx and OpEx) fed with multi-party data and ran millions of parameter combinations to evolve the ideal new quench design. By optimising the entire process, this data-driven iterative approach rapidly pinpointed the best trade-offs, unlocking a steam-free process that boosts energy efficiency and emission reduction. Additionally, the new process is ready for a deeper process electrification, an opportunity for further emission and cost reduction. The protected IP of the technical solution is owned by all partners and are free to deploy this IP in their respective business model.

[34] Powering the Transition to Net Zero with Electric Cracking Technology

Closing the competitiveness gap between electricity and fossil fuels

Closing the gap will require creating a true level playing field among energy vectors by removing subsidies to fossil fuel use among other factors and ultimately making electricity more competitive for industrial consumers. Energy efficiency is a key driver of industrial electrification competitiveness, reducing the total energy consumption needs of the off-taker. In our analysis, the level of efficiency for each technology has been aligned to third party sources (see sources in appendix) and held consistent across scenarios. Therefore, this section, focuses on improving the competitiveness of electricity supply. This can be achieved through four sets of actions – consistent with the recommendations from the Clean Industrial Deal and the Affordable Energy Action Plan:

Remove bottlenecks that limit the uptake (and increase the costs) of production from Net Zero Generation Technologies (NZGT)

The scale of the transition should not be underestimated: to deliver on the Fit for 55 targets, Eurelectric's Decarbonisation Speedways require a nearly threefold increase in installed renewable capacity to 1,403 GW by 2030 (from a baseline of 527 in 2020)[35].

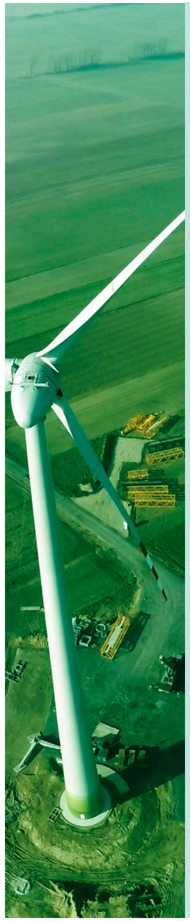
This creates a set of challenges which will need to be overcome to achieve the country targets and EU targets and potentially go further as per our best-case scenario. Removing bottlenecks is extremely critical to reassure industry that their needs can be satisfied in an electrification scenario. For example, the chemical industry is the largest industrial electricity consumer in the EU (165 TWh/year, 2021). That consumption is set to increase by up to 4 times in the transition to climate neutrality[36].

In 2024 CEFIC[37] modelled the electrical capacity needed if all ethylene and HVC crackers were electrified on top of their current electrical consumption. Across the 40 crackers in operation in Europe, electrical capacity needed per cracker reaches up to around 1080 MW, with an average in the range of 430-475 MW, totalling over 18GW.

[35] Decarbonisation Speedways.

[36] Transition pathway for the chemical industry

[37] SMRs-potential-in-the-chemical-industry



Planning and permitting

Bottleneck example

2.2 terawatts of wind, solar and battery storage capacity are waiting to be connected in 4 European markets alone (UK, Italy, Spain and France)[38]. Targets to reduce connection queue from 8/9 years down to 2 years.

Potential solutions

- Ensuring grid permitting authorities are applying criteria on connection requests, a move away from "first come, first serve"[39] preventing speculative capacity reservation. For example, NESO pushing "ready" projects to the front of the queue[40].
- Embracing digital and AI, to automate and orchestrate permitting applications. WindEurope with Accenture and AWS piloted EasyPermits to streamline the process[41].

Supply chain resilience

Bottleneck example

1.8x increase in lead time for large power transformers from 2021 to 2024. Now c. 200 weeks[42].

Potential solutions

- Support and increase EU manufacturing – supporting the Green Deal Industrial plan.
- Increase data capabilities to ensure visibility into supply chains to identify risks, stress test and build resilience where appropriate[43].
- Explore industry wide solutions and co-ordination to manage supply chain and asset deployment timelines.

Skills

Bottleneck example

The UK Nuclear workforce needs to double in the next 20 years to achieve UK targets[44].

European Wind Industry needs more than 200k additional workers between now and 2030[45].

Potential solutions

- Launch of net zero industry academies under the Net Zero Industry Act.
- Potential to learn from the US, who have piloted the Goodwill Clean Tech Accelerator in four cities and currently scaling with an ambition to train 7,000 job seekers[46].

38 Unlocking-Investment-to-Triple-Renewables-by-2030

39 Immediate actions needed to unblock grid capacity for more wind energy

40 NESO

41 Amazon web services Accenture and windeurope launch digital tool to accelerate permitting

42 IEA Building the Future Transmission Grid – pg. 27

43 MIT – Supply chain risks

44 The skills challenges facing the UK's nuclear energy industry

45 Wind Europe

46 Goodwill® Launches Major Green Jobs Program in Partnership with Accenture

De-risk long-term contracts

De-risking investment in net zero green technologies (NZGT) is another critical action to be taken. PPAs and other long-term contracting tools provide predictability to energy producers and consumers, encourage clean investments and support decarbonisation.

Generally, a PPA extends to various timeframes, up to ten or fifteen years: e.g. Covestro and Orsted's 100MW offshore wind energy agreement at a fixed price for 10 years starting in 2025 - is set to be Germany's first zero subsidy project[47].

This helps reduce the risk of fluctuations in the electricity markets, which is desirable for large, debt-financed projects such as wind, solar and nuclear; in addition, a long-term supply contract can capture the value of future cost reductions in these technologies.

While it is unlikely that all the supply would be purchased using these instruments (as industrial players would prefer to keep some exposure to the merchant markets), the increase of their percentage in the mix would benefit the overall cost of supply.

The European Investment Bank (EIB) estimates the commercial PPA market to account for between 140 TWh and 290 TWh by 2030, equivalent to 10% and 23% of expected solar and wind generation respectively[48].

Their lower bound assumes limited additional off-taker demand above large, listed organisations publicly committed to procuring renewables (predominantly Technology companies). The upper bound of EIB modelling assumes a wider participation from energy intensive industries, where demand is still nascent[49].

Nuclear PPAs are also developing in some Member States such as Finland, Sweden or France. Nuclear electricity sourcing has the advantage of providing low carbon and stable electricity supply to industries that require baseload consumption or have limited flexibility capabilities.

[47] Covestro Case Study | Ørsted

[48] Commercial Power Purchase Agreements

[49] The future of European competitiveness

Minimise system costs

Significant renewable penetration is anticipated across all competitive scenarios (BAU, Base, and Best) in this report, creating a requirement to reinforce and boost flexibility.

Meanwhile, nuclear will play a key role in Europe's 2030 energy mix, c. 750TWh in all Decarbonisation Speedway scenarios[50].

A recent study by Eurelectric anticipates that the power system across the EU will require between 531 and 782 TWh of flexibility to support variable renewable generation by 2050, roughly the annual power production of Germany[50].

This flexibility will need to come from both supply and demand. This scenario also includes between 160-180GW of hydropower and 110-120GW of nuclear, in 2050, to ensure system stability and decarbonisation in a cost-effective way.

Progressing to the best-case scenario will require active participation across all flexibility options:

Boost flexibility supply: A combination of flexible dispatchable power and storage.
The dispatchable power will need to be rapidly scaled up or down to balance a more variable system. For example, a recent ENTSO-E study found that sudden notable swings can occur when renewables are curtailed (price, meteorological, or wildlife protection), with reports of 1.5 GW drops in under 30 minutes[51].

Short and long-term storage options, such as batteries, hydropower and decarbonised thermal are required, alongside the continuous contribution of the European nuclear power fleet. In France, modulation of nuclear power plants' output largely contribute to maintaining the stability of the system and to accommodate solar production flowing into the grid at daytime, while ramping up again in the evening.

Hydropower represented 152 GW in 2023 in Europe and the potential for future investments in both capacity extensions at dams/run of river, and for hydro pumped storage is 46GW at EU level according to a study by the Joint Research Centre (EU).

Batteries are also playing a key role in the daily management of California's energy system, smoothing the variability of solar and meeting up to a third of the net load peak (on 30 April 2024, IEA)[52], while long-term storage can assist management of increased seasonal variance or Dunkelflaute periods. Batteries are a key strategic industry for the energy transition, with a potential 10x growth in cell manufacturing capacity in Europe by 2030[53].

The TCO analysis of the battery archetype demonstrates that electrification improves competitiveness. However, the upstream component manufacturing activities are highly concentrated in China, with 90% and 97% of cathode and anode capacity respectively[53].

Battery recycling is a strategic priority for Europe and may provide an avenue for expanding manufacturing capabilities.

[50] Decarbonisation Speedways

[51] ENTSO (2024) TOP 8_Frequency impact of sudden and large swings of vRES infeed

[52] Integrating Solar and Wind

[53] Advancing Clean Technology Manufacturing

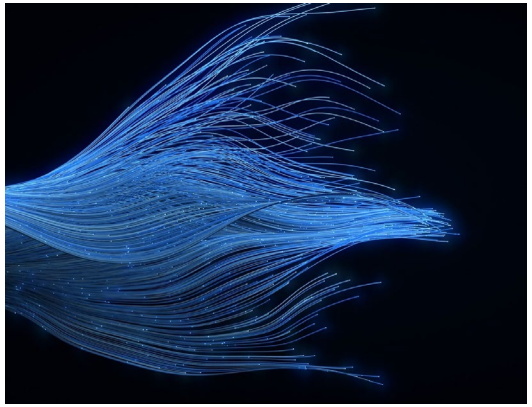
Demand: unlock potential from industrial flexibility

Demand side flexibility will help reduce the costs of balancing the increased variability of supply with the demand. Demand side flexibility provides between 37-68 GW by 2030, under the varying scenarios in Decarbonisation Speedways, with the vast majority coming from consumers. CapEx and OpEx support can play a key role in transforming industrial processes, and making production more flexible, thus unlocking the potential demand-side flexibility.

At the operational level, this can be unlocked through a regulatory framework that enables access to markets, where price signals incentivise consumption adjustments, and contractual arrangements that allow consumers to capitalise on the shift or limitation of their consumption.

In terms of ability to participate, great examples already exist across industries. For example, European data centres, a rapidly growing sector where demand is expected to grow from under 100 TWh in 2022 to 150TWh by 2026[54], can provide flexibility through demand-shifting and on-site storage can provide frequency services to the grid[55].

As much as 40% of energy usage can be demand-shifted, two thirds through temporal (shift timing of non-critical loads) and one third geographical (route process load to other data centres which have available power). Industrial users will require data and forecasting insight to optimise demand-shifting. However, for those industry sectors with 24/7 baseload requirements, like chemicals, innovation may be required to unlock flexibility. Inspiration can be taken from applications of flexibility seen in other concentrated established industries including steel, where a European commission study found estimated electricity cost savings of up to 35% through flexibility[56] and Nystar, a zinc producer, which has an extremely flexible electrified production process and is able to absorb peaks in electricity demand and troughs in supply– acting as a virtual battery for the grid[57].



Nyrstar Showcase: Zinc Production Meets Grid Flexibility[57]

Nyrstar, a European zinc producer, stands out as a leading example of industrial energy flexibility. Its fully electrified production can rapidly scale up or down in response to grid needs. This allows for an increase in electricity consumption when there is a surplus of renewable energy and reducing usage during peak demand periods– acting as a "virtual battery".

By dynamically aligning its energy consumption, Nyrstar supports grid balance without the need for physical energy storage and the integration of intermittent renewable sources such as wind and solar, while helping to reduce system-wide emissions.

This model shows that even energy-intensive industries can unlock flexibility through innovation in process design and energy management.

[54] Electricity 2024 – Analysis and forecast to 2026

[55] Schneider Electric & Aeven to deliver excess power to Danish grid

[56] JRC Publications Repository - Flexibility options in a decarbonising iron and steel industry

[57] Virtual Battery

Reduce taxes and levies

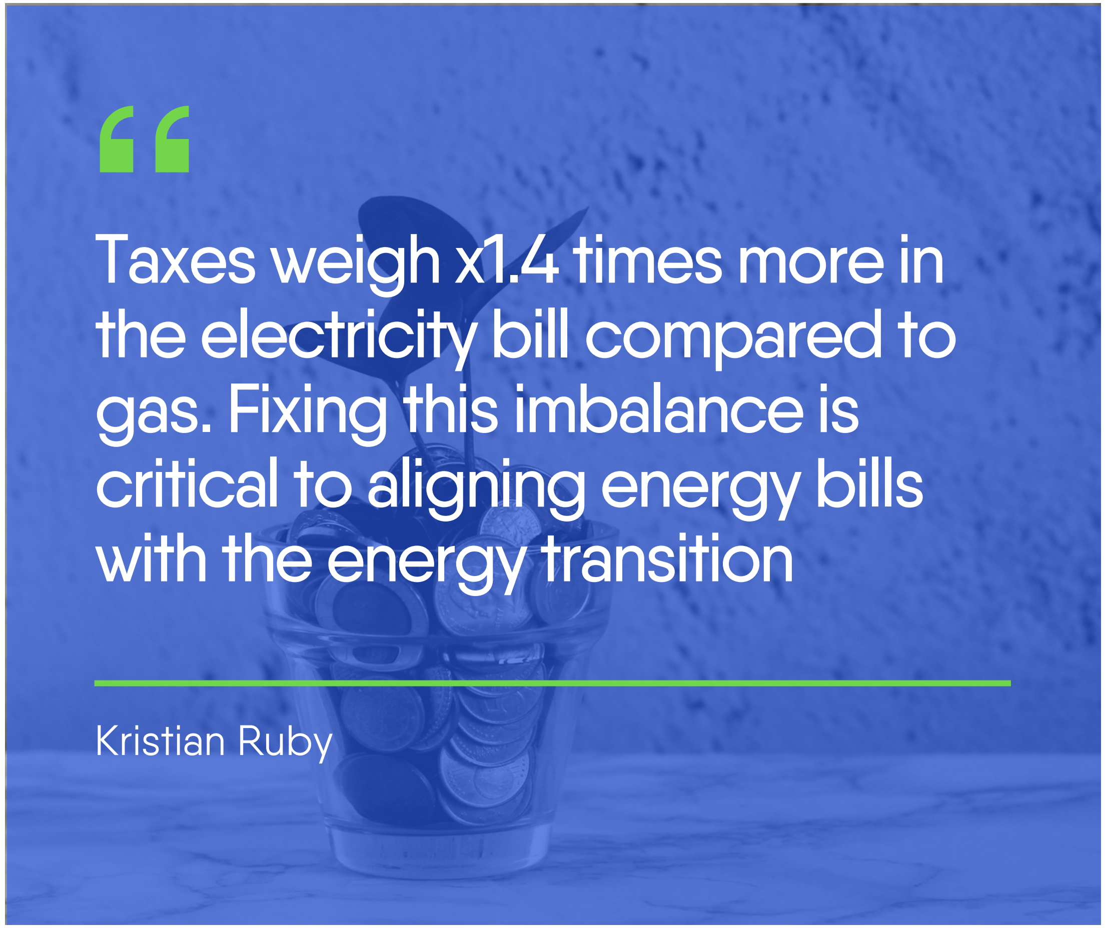
Taxes on electricity in the EU as a share of the final bill are three times higher for household consumers and three and a half times higher for industrial consumers, compared to natural gas (with differences between countries).

The tax burden on electricity must decrease to make it a competitive energy carrier[58]. Our analysis found data surrounding taxes and levies to be opaque, with difficulty decomposing the tax components, and appropriate transparency into the recoverability of taxes and levies per industry relying upon implied rates (and not deducting what was deemed recoverable to apply a fair comparison) through Eurostat.

However, if recoverability was considered, many countries (per Eurostat data) provided a tax credit for using gas. For example, c. 20% credit for non-household Band I4 in Germany (2024 – H1)[59].

A practical next step would be mapping the level and composition electricity taxes across European countries to understand which ones are related to the functioning of the electrical system.

Finally, carbon pricing contributes to ensuring that sufficiently robust and efficient decarbonisation incentives are given to all sectors for achieving the GHG emissions reduction targets at the lowest cost.



[58] Power sector and energy intensives find consensus on how to restore competitiveness

[59] Energy prices - Eurostat

Transition Support

Investment is required to deploy electrification technologies; support is required to enable the transition.

Taken at a sector level, the chemical industry for example may require a €1 trillion to be climate neutral by 2050, split across capital expenditures (800bn) and standstill costs (200bn). With an estimate funding gap of €400bn compared to historical investment levels[60].

On an individual level, SMEs may require a few thousand Euros to electrify smaller processes as they still struggle to prioritise and fund the investment in the current macro environment.

A coordinated approach of supporting individual companies, and sectors, financially through the transition (as required) could accelerate electrification.

With 52% of heavy industries believing that revenue growth is the primary path for improving the economic business case of decarbonisation[61] another potential support mechanism to accelerate industrial electrification may be 'clean quotas' (for example, in public procurement tenders) and 'clean premiums'—higher charges for sustainable products.

These premiums will fund the first phase of efficiency gains in low-carbon power and green industrial infrastructure. Early adopters of any technology typically shoulder high costs – ultimately providing scale and enabling learnings that bring costs down for others.

Light industry can help fund the transition by identifying segments and developing propositions where there is willingness to pay clean premiums.

Accenture research identified a subset of light industry's customers who are willing to do this[61]. 50% of consumers, for example, are willing to pay a premium for more sustainable delivery options.

Clean premiums, can be one transition support approach to encourage early adopters, providing the investment necessary to fuel innovation and drive prices down.

50%

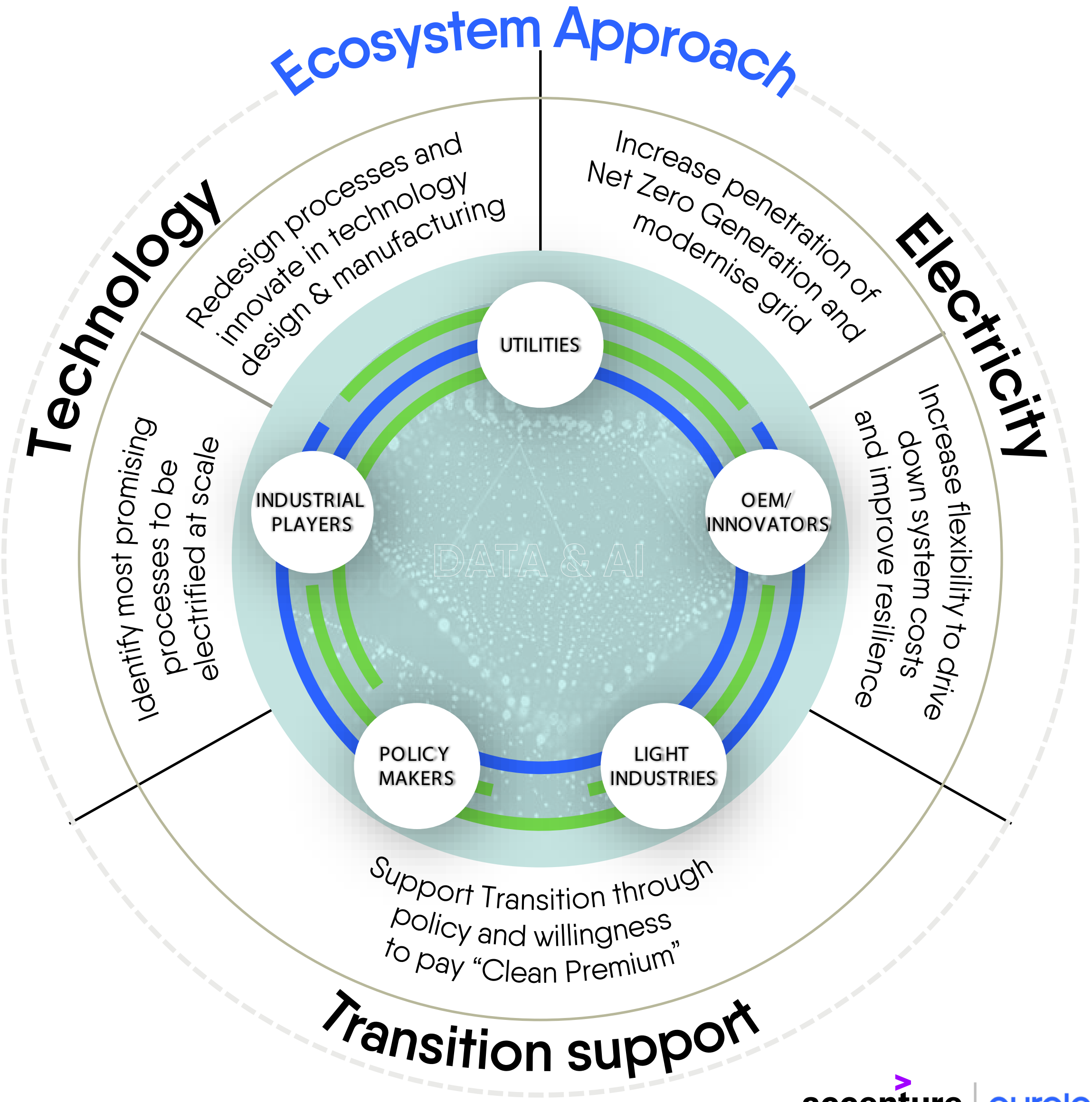
of consumers are willing to pay a premium for more sustainable delivery options[61]

[60] The chemical industry's road to net zero

[61] Accenture Powered for Change Report - 2024

An ecosystem approach

The current pace will not be enough to achieve climate neutrality by 2050. The whole ecosystem will need to work together to achieve the required scale of Net Zero Generation, grid upgrades and flexibility. Utilities will have to work in-lock step with industry and policymakers to ensure aligned roadmaps, investment certainty and co-ordination. From a technology perspective, collaboration across the ecosystem will help to drive innovation, scale and manufacturing efficiencies- driving down the initial investment required. Moreover, sharing data across ecosystem partners will be essential for driving system-wide optimisation, strengthen coordination, and enable collective, AI-powered decision-making, accelerating the transition to a resilient, net-zero energy future.



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Special thanks to Eurelectric’s Chairpersons, Committee and Working Group members

About Accenture

Accenture is a leading global professional services company that helps the world's leading businesses, governments and other organisations build their digital core, optimize their operations, accelerate revenue growth and enhance citizen services—creating tangible value at speed and scale. We are a talent- and innovation-led company with approximately 801,000 people serving clients in more than 120 countries. Technology is at the core of change today, and we are one of the world's leaders in helping drive that change, with strong ecosystem relationships. We combine our strength in technology and leadership in cloud, data and AI with unmatched industry experience, functional expertise and global delivery capability.

About Eurelectric

Eurelectric represents the interests of the electricity industry in Europe. Our work covers all major issues affecting our sector. Our members represent the electricity industry in over 30 European countries. We cover the entire industry from electricity generation and markets to distribution networks and customer issues. We also have affiliates active on several other continents and business associates from a wide variety of sectors with a direct interest in the electricity industry.

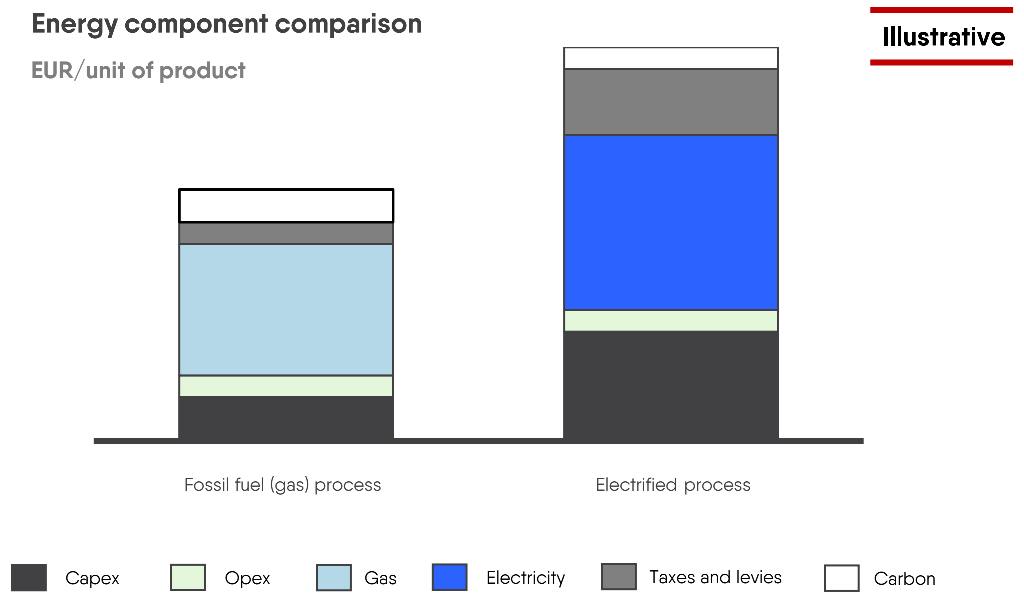
Appendix

Content

1

Methodology, approach and scenarios

Methodology: Total Cost of Ownership is used to compare the cost of electrification with the cost of the fossil fuel option: today and 2030



Electricity and gas costs are calculated for the specific countries selected
Today data are based on 2024 Eurostat data
Note: the TCO approach assumes annualized cost but does not calculate the NPV of future cash flows

COST COMPONENT	DESCRIPTION
TECHNOLOGY CAPEX	• Annualized capital expenditure for the equipment/machinery • Total cost of technology / expected lifetime / production volume
OPEX	• Non-energy operating expenditure including labor and maintenance of the equipment
ELECTRICITY COST	• Includes three core components: - Generation costs - Grid costs - Carbon costs - Excludes tax
GAS FOR PROCESS HEAT	• Gas cost excluding carbon cost and taxes
TAX AND LEVIES	• Taxes and levies associated with gas or electricity[1]
GAS CARBON COSTS	• Cost associated with the carbon released using gas for process heat at the EU ETS price

[1] Recoverable taxes have not been excluded from either gas or electricity therefore energy prices will be inflated, however both gas and electricity prices will be inflated so deemed appropriate for TCO comparison. Recoverable taxes and levies were at a country level whereas the analysis focuses upon specific industries and data providers recognise the difficulty in collecting accurate information.

We look at four key levers across three different scenarios to project the trajectory of the TCO

Differing scenarios are used to test the boundary conditions of different futures, these are not accurate forecasts, they are to identify key areas for action and to indicatively demonstrate the scale of action required.

Major drive of cost reduction

	Levers	BAU – CURRENT TRAJECTORY	BASE – ACHIEVE STATED AMBITIONS	BEST – GO FURTHER
1	TECHNOLOGY COST	Accelerate the technology and commercial readiness		
2a	ELECTRICITY: GRID COST		Held constant	
2b	ELECTRICITY: GENERATION COST	Increasing penetration of net zero technologies into the energy mix, reducing the overall cost of generation and carbon cost		
2c	ELECTRICITY: CARBON COST (GRID CARBON INTENSITY)			
3	TAXES AND LEVIES	Increasingly favourable tax regime for electricity in comparison to gas		
4	CARBON COST (EU ETS)	Increasing carbon cost		

Detailed lever rationale

	LEVERS	RATIONALE
1	**TECHNOLOGY COST**	Reduction in capex based on maturity of the electrification technology • **BAU**: Limited ecosystem collaboration and low learning rates (10% reduction) • **Base Case:** Technology matures and natural scales in size and volume (25% reduction) • **Best Case:** Increased collaboration across the ecosystem unlocks innovation (40%)
2a	**ELECTRICITY: GRID COST**	Held consistent across all scenarios, assuming that, no radical change in cost occurs in a five-year period
2b	**ELECTRICITY: GENERATION COST**	Reduction in electricity generation costs and associated carbon costs, based on an increased penetration of Net Zero Generation technologies (Nuclear, RES) in the supply mix and falling costs of generation over time • **BAU:** Increasing share of Net Zero technologies in line with current rate • **Base Case**: Increasing share of Net Zero generation technologies in line with national commitments for 2030 • **Best case:** increasing share of Net Zero generation technologies beyond national targets
2c	**ELECTRICITY: CARBON COST (GRID CARBON INTENSITY)**	Follows the grid intensity per each generation scenario and the ETS evolution
3	**TAXES AND LEVIES**	• **BAU:** No change in tax rates for gas or electricity • **Base Case:** Same tax rate for electricity and gas • **Best Case:** Electricity tax rate lower than gas
4	**CARBON COST (EU ETS)**	• **BAU:** 80 €/tCO2 (same as 2023) • **Base Case:** 130 €/tCO2 (2030 projection by Bloomberg NEF) • **Best Case:** 160 €/tCO2 (2030 projection by Refinitiv)

Note(s): Combined impact of levers 2, 3, 4 and 5 will move the electricity prices.
1) A future carbon price based on EU-ETS price of Euro 130 is considered based on Bloomberg NEF projection per 2024 State of the EU ETS Report – ERCST

BAU : Business as usual/Current trajectory
Base Case: Achieving stated ambitions
Best Case: Assumes bold actions

1.1

Methodology, approach and scenarios

Technology scenarios

Technology cost: reductions scenarios

SECTOR	TECHNOLOGY	CURRENT TECHNICAL READINESS LEVEL	CURRENT COMMERCIAL READINESS LEVEL
Chemicals	Electricity crackers	6 – technology demonstration	1 – hypothetical commercial proposition
Food & beverage	Electric boilers & Heat pumps	9 – system test, launch & operations	6 – bankable asset class
Battery assembly	Heat pumps & Laser drying	9 – system test, launch & operations 7 – system development	6 – bankable asset class 3- commercial scale up

Note(s): Based on the technical readiness scale initial developed by NASA

BAU 10%, Base 25% and Best 40%.

Technology costs reduction scenarios modelled looking at:

- Analogues (e.g. electrolysers)
- Accenture technology S-curve model
- Interviews with industry experts

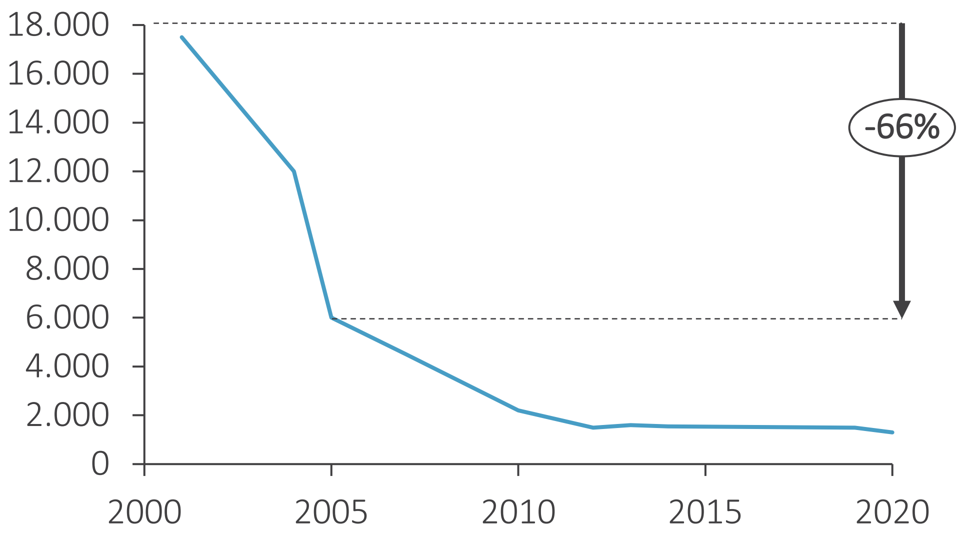
Differing levers are used to unlock technology cost reductions dependent upon the current technical and commercial readiness. For example, design innovation is expected to unlock more savings in immature technologies whereas intelligent manufacturing is a more predominant lever in more mature technologies.

Note: Technical readiness levels ranges from 1-9 and commercial readiness ranges from 1-6

Technology cost scenarios are based on analogues based on different technology at varying levels of maturity

Low maturity example (electrolyser)

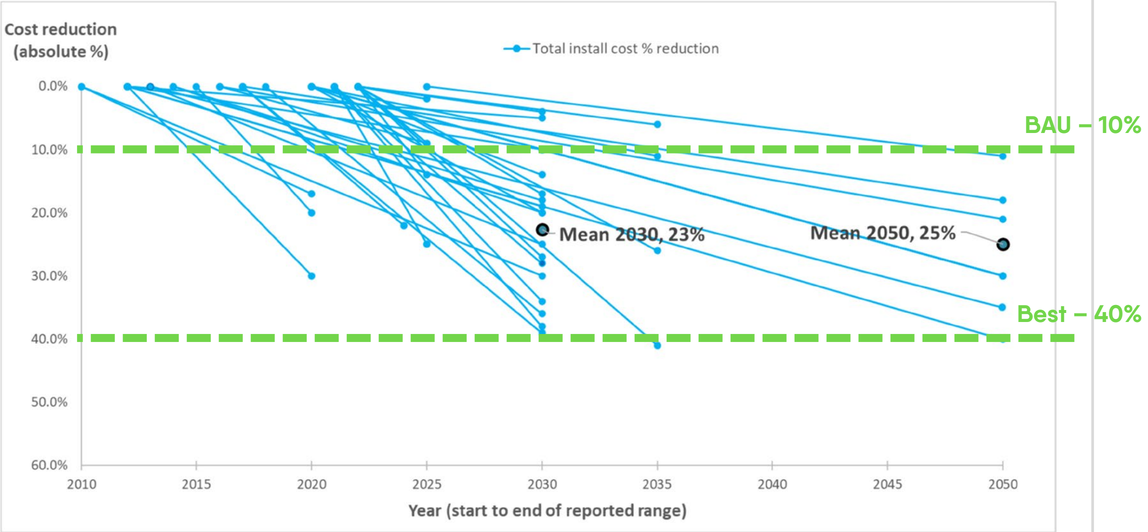
Capital cost($) of PEM(Proton exchange membrane)



Capital costs associated to PEM electrolysers, used as an initial proxy for low maturity technologies. 40% used, aligning low and high maturity best cases, to be conservative.

High maturity example (heat pump)

Cost reduction (%) heat pumps



Academic study, reviewing historic and forecasted price drops (removing outliers) of heat pumps in Europe, the most competitive 5-year estimate between 2025 and 2030 taken in the best scenario (40%)

Sources: Department of Energy, Elsevier Report

1.2

Methodology, approach and scenarios

Electricity scenarios

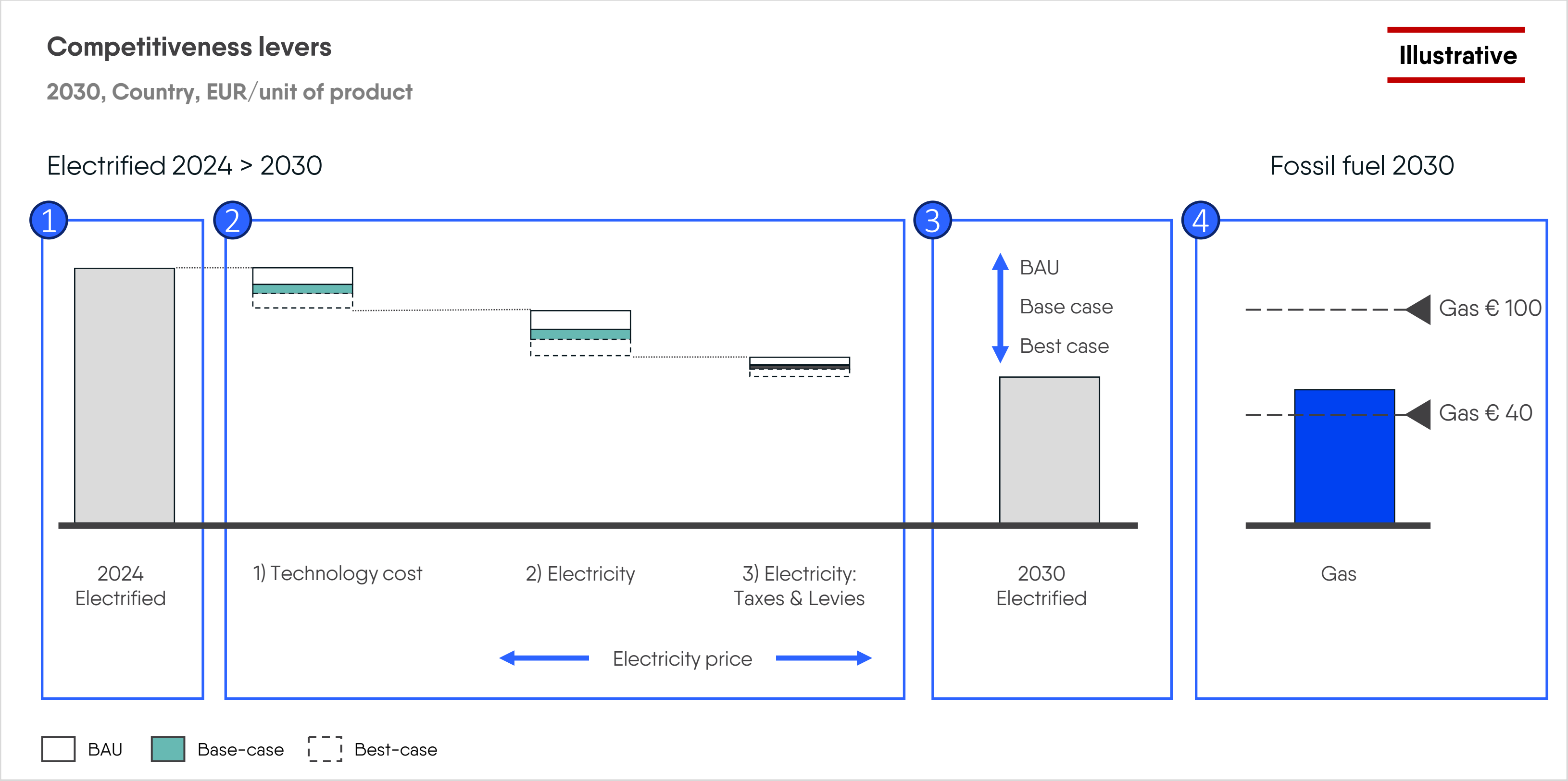
Methodology: potential impact of different levers to increase competitiveness of electrification

METHOD

1. TCO calculated for 2024 electrified process, split into previous cost categories
2. Competitiveness levers applied for each scenario
3. Indicative 2030 TCO across the best, base and BAU scenario
4. Sensitivity analysis against gas price alternative, flexed across asymmetric gas prices to show volatility risk

OUTCOME

1. Identification of the key levers to reduce the cost of electrified and non-electrified processes
2. Indicative comparison of the TCO of electrified process in 2030 and how it compares to fossil fuel alternatives



2

Findings and implications by industrial sector

2.1

Findings and implications by industrial sector

Chemicals Sector Analysis - TCO analysis for Ethylene

Ethylene selected as the product for analysis within the Chemicals sector

SELECTION LOGIC

Largest GVA chemicals subsector : Petrochemicals (32%)

Application with largest fuel demand: Steam cracking (38%)

Product share of steam cracking: Ethylene (34%)

PRODUCT SELECTED

Ethylene

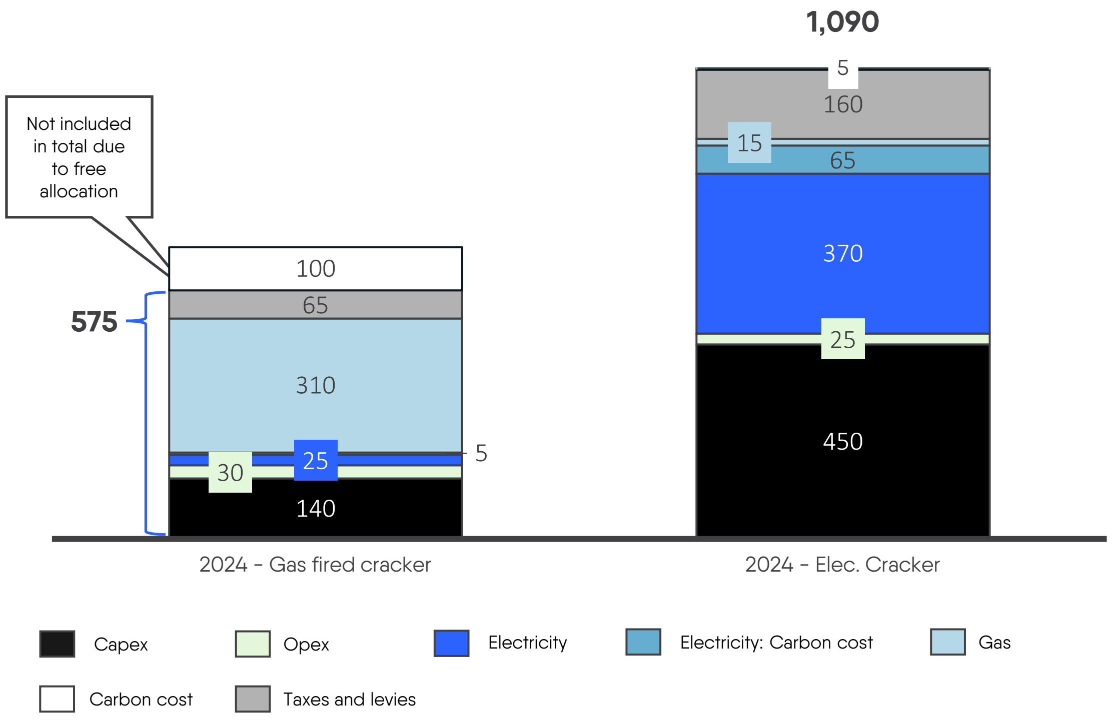
COMMENTS

- Ethylene is the chemical which is produced in the highest quantity in Europe
- Energy costs represent 30% of total costs (excluding by-products)
- Downstream applications:
  - Food packaging
  - Pipes
  - Housewares
- Requires 800+ degrees, therefore the technology is yet to hit maturity
- Top ethylene producers considered for TCO analysis
  - Germany
  - Spain

Current TCO comparison of energy component related to process heat of Ethylene

Energy component comparison | Germany | 2024

EUR/tonne of ethylene



Input data reference | 2024

COMPONENTS (UNITS)	AVG. VALUE (INC. TAXES)	SOURCE
Industrial Electricity Price (Eur/MWh) recoverable taxes and levies, not deducted	164	Eurostat 2024[A]
Gas Price (Eur/MWh) recoverable taxes and levies, not deducted	46	Eurostat 2024[B]
Carbon Cost - EU ETS (Eur/tCO2e)	65	BNEF[C]
Elec. cracker capex[1] (Eur/tC2H4/year)	450	Figure based on SME interview.
Efficiency – Gas cracker (%)	45%	Fraunhofer[3]
Efficiency – Elec. Cracker (%)	90%	Fraunhofer[3]

[1] Electrification capex assumption – with the technology live in demonstration plant(2% of the size of gas fired crackers) capex estimates vary greatly from 2 to 6x that of gas crackers. SME interviews highlighted c.3x as a conservative estimate. DESNZ1, I&EC2

Note: Tax Exemptions of EU-ETS not considered, Free allocation represented by dashed box.
Plant life considered to be 20 years. Electricity cost split between supply, carbon (pre-allocated in cost) and tax
Sources: [1] DESNZ 2023,[2] Industrial and Eng Chemical Research 2023 [3] Fraunhofer –Agora 2024 [C] ERCST 2024

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Competitiveness levers for 2030 | Germany | Ethylene

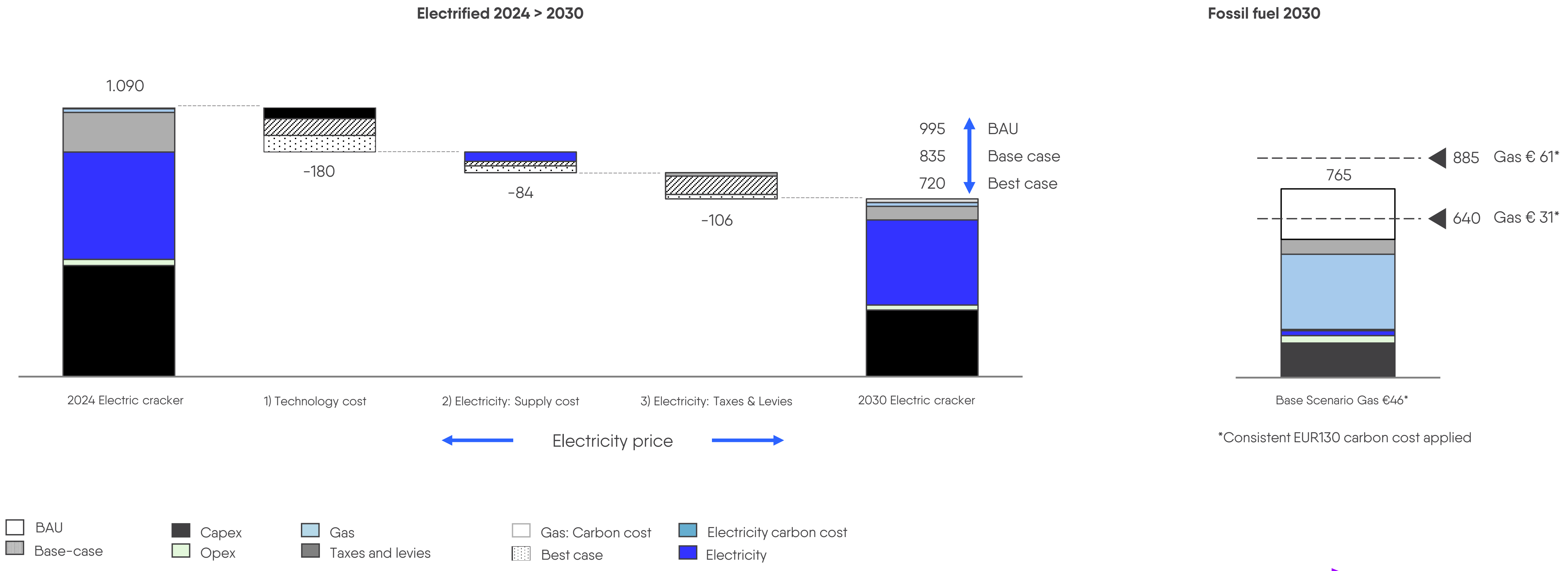
	LEVERS	RATIONALE	BAU	BASE-CASE	BEST-CASE
1	TECHNOLOGY COST	• **BAU**: Limited ecosystem collaboration and low adoption • **Base Case:** Initial collaboration unlocks benefits in design and manufacturing • **Best:** Innovative Solutions Requiring Ecosystem Collaboration	10% reduction	25% reduction	40% reduction
2a	ELECTRICITY: GENERATION	• **BAU:** Achieve 64% net zero generation in the electricity mix as per growth trends since 2019 • **Base:** Achieve national target of 82% net zero generation in electricity mix by 2030[6] • **Best:** Go past the national target, achieving 87% net zero generation in electricity mix by 2030	5-10% reduction	10-15% reduction	20-25% reduction
2b	ELECTRICITY: CARBON COST (GRID CARBON INTENSITY)		15-20% reduction	50-55% reduction	60-65% reduction
3	ELECTRICITY: CARBON COST (EU ETS)	• 2030 EU-ETS price from report published by ERCST – 2024 State of the EU ETS Report (Bloomberg NEF projection)[C]	65	130	160
4	ELECTRICITY: TAXES AND LEVIES	• Current tax rate on gas in Germany is 30% compared to electricity 45% • **BAU:** No change in tax rate • **Base:** Parity in taxes between gas and electricity • **Best:** Rate moved below gas rate to 14%	36% rate	18% rate	14% rate

Note(s): To inform the waterfall chart on the following page, the combined impact of levers 2, 3, 4 and 5 move the electricity price from €164/MWh to €150/MWh in BAU, €123/MWh in the base-case and €109 in the best-case.

Sources: [4] SceinceDirect 2017 [5] DoE, 2022 , [6] IEA Germany 2024

Impact of competitiveness levers on the cost of production (energy component) for electric crackers

Competitiveness levers | 2030, Germany, EUR/tonne of ethylene



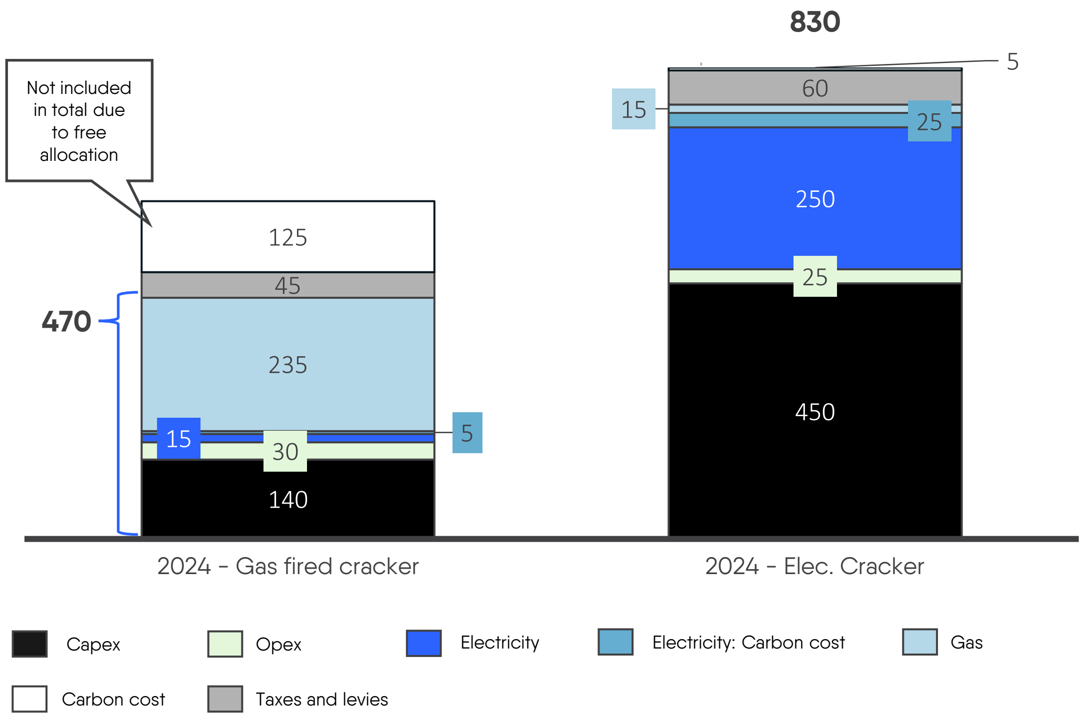
*Consistent EUR130 carbon cost applied

*Asymmetric range taken to demonstrate volatility
Note: In conventional crackers energy cost is ~30% of the total cost of production.

Current TCO comparison of energy component related to process heat of Ethylene

Energy component comparison | Spain | 2024

EUR/tonne of ethylene



[1] Electrification capex assumption – with the technology live in demonstration plant(2% of the size of gas fired crackers) capex estimates vary greatly from 2 to 6x that of gas crackers. SME interviews highlighted c.3x as a conservative estimate. DESNZ1, I&EC2

Input data reference | 2024

COMPONENTS (UNITS)	AVG. VALUE (INC. TAXES)	SOURCE
Industrial Electricity Price (Eur/MWh) recoverable taxes and levies, not deducted	92	Eurostat 2024[A]
Gas Price (Eur/MWh) recoverable taxes and levies, not deducted	35	Eurostat 2024[B]
Carbon Cost - EU ETS (Eur/tCO2e)	65	BNEF[C]
Elec. cracker capex[1] (Eur/tC2H4/year)	450	Figure based on SME interview.
Efficiency – Gas cracker (%)	45%	Fraunhofer[3]
Efficiency – Elec. Cracker (%)	90%	Fraunhofer[3]

Note: Tax Exemptions of EU-ETS not considered, Free allocation represented by dashed box.
Plant life considered to be 20 years. Electricity cost split between supply, carbon (pre-allocated in cost) and tax
Sources: [1] DESNZ 2023,[2] Industrial and Eng Chemical Research 2023 [3] Fraunhofer –Agora 2024 [C] ERCST 2024

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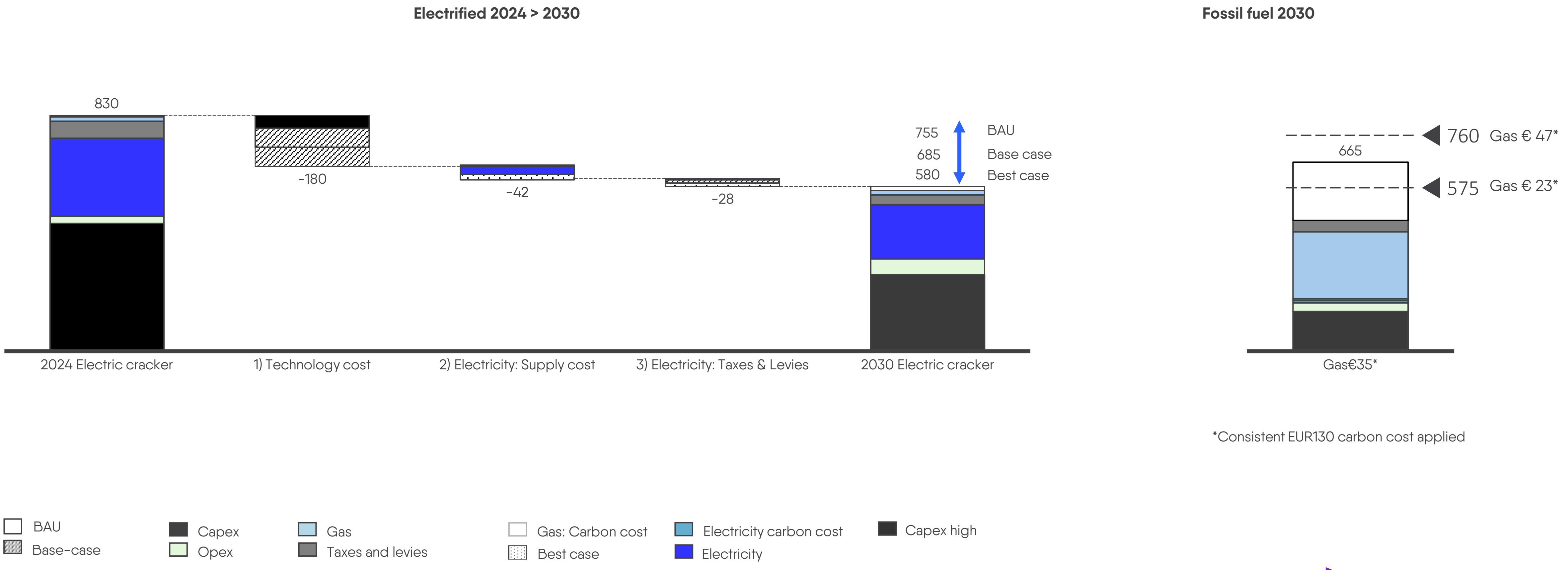
Competitiveness levers for 2030 | Spain | Ethylene

	LEVERS	RATIONALE	BAU	BASE-CASE	BEST-CASE
1	TECHNOLOGY COST	• **BAU:** Poor ecosystem collaboration and low adoption • **Base Case:** Initial collaboration unlocks benefits in design and manufacturing • **Best:** Solutions Requiring Ecosystem Collaboration	10% reduction	25% reduction	40% reduction
2a	ELECTRICITY: GENERATION COST	• **BAU:** Continuing the trend, achieving the 81% net zero generation (national target); 87% net zero technologies • **Base:** Achieving energy mix as per national targets with 81% renewables 87% net zero technologies (coal and oil completely phased out)[7] • **Best:** Go past the national target, achieving 92% net zero generation in electricity mix by 2030	5-10% reduction	10-15% reduction	20-25% reduction
2b	ELECTRICITY: CARBON COST (GRID CARBON INTENSITY)		10-15% reduction	15-20% reduction	30-35% reduction
3	ELECTRICITY: CARBON COST (EU ETS)	• 2030 EU-ETS price from report published by ERCST - 2024 State of the EU ETS Report (Bloomberg NEF projection)[C]	65	130	160
4	ELECTRICITY: TAXES AND LEVIES	• Current implied tax rate on gas in Spain is 17% compared to electricity 21% • **BAU:** No change in electricity tax • **Base**: Parity in taxes between gas and electricity • **Best**: Rate moved below gas rate to 14%	21% rate	17% rate	14% rate

Note(s): To inform the waterfall chart on the follow page, the combined impact of levers 2, 3, 4 and 5 move the electricity price from €92/MWh to €84/MWh in BAU, €82/MWh in the base-case and €73/MWh in the best-case. These are to be further refined
Sources: [4] SceinceDirect 2017 [5] Electrolyzers , [7] Spanish Government 2024

Impact of competitiveness levers on the cost of production (energy component) for electric crackers

Competitiveness levers | 2030, Spain, EUR/tonne of ethylene



*Asymmetric range taken to demonstrate volatility
Note: In conventional crackers energy cost is ~30% of the total cost of production.

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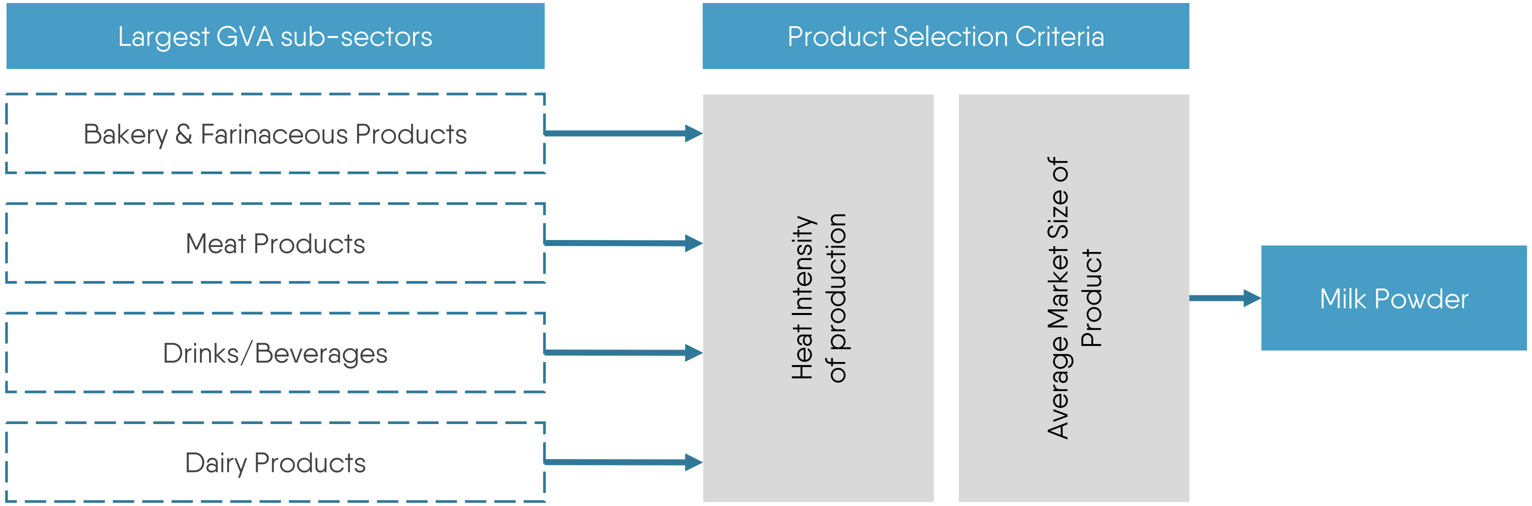
2.2

Findings and implications by industrial sector

F&B Sector Analysis- TCO analysis for Milk Powder

Milk Powder selected as the product for analysis within the F&B sector

SELECTION LOGIC



Note: Limited recent public data for bakery products was available.
Source: [1] PBL Netherlands Environmental Assessment Agency 2020, [2] CLAL.it 2024

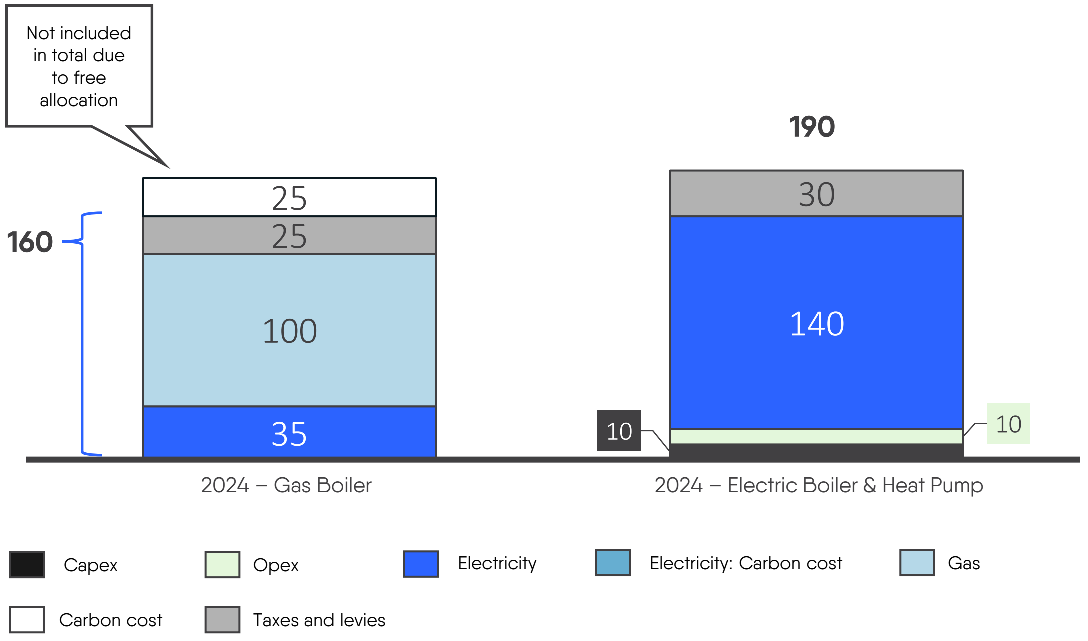
COMMENTS

- Milk Powder is a product which is highly energy & heat intensive, while having a high market value.
- Energy costs represent 6-7% of total costs (excluding by-products)
- Requires pasteurization, evaporation & drying process with operating temperatures till 250°C[1]
- Steam is used across processes, which is generated using gas boilers and can be electrified using heat pumps & electric boilers.
- Top milk powder producers considered for TCO analysis[2]
  - France
  - Denmark

Current TCO comparison of energy component related to process heat of milk powder

Energy component comparison | France | 2024

EUR/tonne of ethylene



Note: 1 MWh gas boiler capacity will be replaced by 0.75 MWh heat pump and 0.25 MWh electric boiler capacity as high efficiencies of heat pumps are limited to temperatures of 160 deg C. Tax Exemptions not considered. Non-fuel OPEX costs for heat pumps are higher due to installation complexity, increased maintenance, and safety costs associated with refrigerants.

Source: [1] PBL Netherlands Environmental Assessment Agency 2020, [3] DESNZ 2023

Input data reference | 2024

COMPONENTS (UNITS)	AVG. VALUE (INC. TAXES)	SOURCE
Industrial Electricity Price (Eur/MWh) recoverable taxes and levies, not deducted	168	Eurostat 2024[A]
Gas Price (Eur/MWh) recoverable taxes and levies, not deducted	52	Eurostat 2024[B]
Carbon Cost - EU ETS (Eur/tCO2e)	65	BNEF[C]
Capex (Eur/kW)	Electric Boiler – 170 Heat Pump – 840	DESNZ[3], PBL[1]
Efficiency – Gas Boiler (%)	75%	DESNZ[3]
Efficiency – Elec. Options (%)	Electric Boiler – 99% Heat Pump – 4X	DESNZ[3]

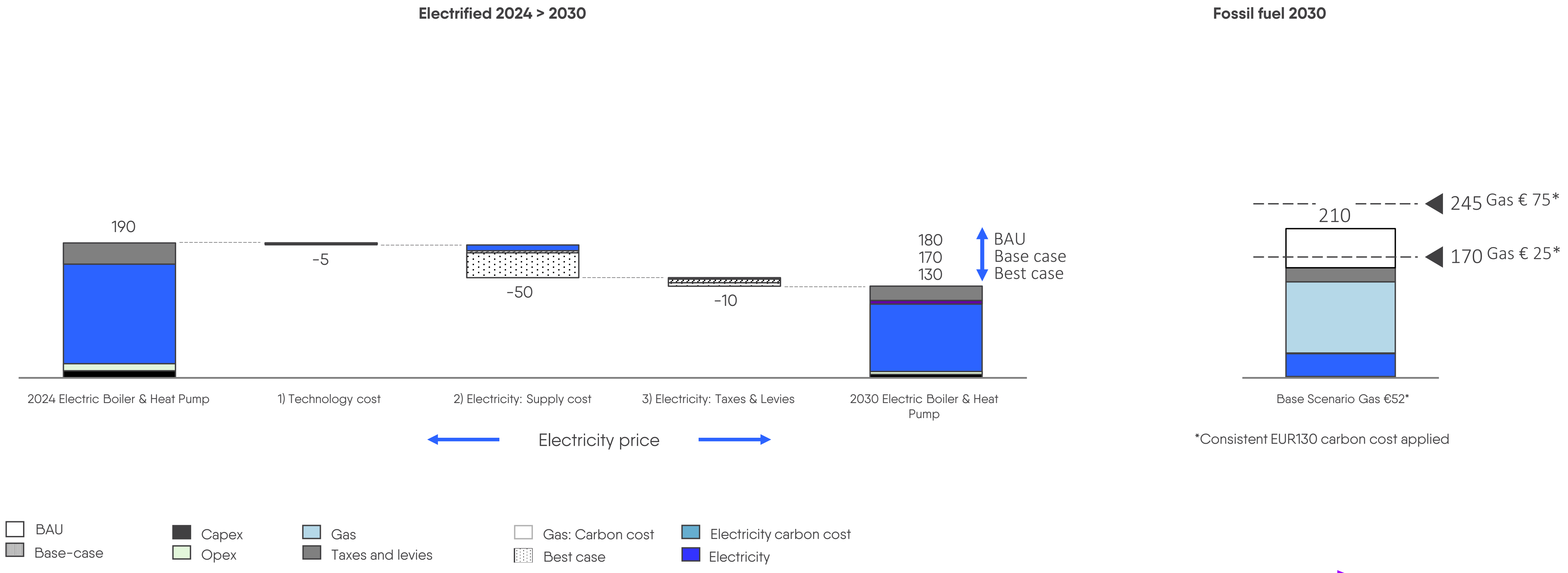
Competitiveness levers for 2030 | France | Milk Powder

	LEVERS	RATIONALE	BAU	BASE-CASE	BEST-CASE
1	**TECHNOLOGY COST**	• Heat Pump and electric boiler technology is mature and is being deployed in F&B industries. With achieving scale, capex (installation and equipment cost) for heat pumps is expected to decrease[4] • **BAU:** Poor ecosystem collaboration and low adoption • **Base Case:** Increased scale • **Best:** Solutions Requiring Ecosystem Collaboration	10% reduction	25% reduction	40% reduction
2a	**ELECTRICITY: GENERATION COST**	• **BAU:** Achieve 94% net zero generation in the electricity mix as per growth trends since 2019 (gas not phased out completely) • **Base:** Increasing share of net zero generation (nuclear & renewables) in the electricity supply mix in line with national goals to 100% net zero generation • Best: Aligned to base	5-10% reduction	5-10% reduction	10-15% reduction
2b	**ELECTRICITY: CARBON COST (GRID CARBON INTENSITY)**		50-60% increase	20% reduction	20% reduction
4	**ELECTRICITY: CARBON COST (EU ETS)**	• Carbon price increase impacts the fossil fuel-based alternative adversely. • **BAU:** No Change • Best & Base case referred from report published by ERCST - 2024 State of the EU ETS Report[C]	65	130	160
5	**ELECTRICITY: TAXES AND LEVIES**	• Tax rate on gas is slightly lower than that of electricity • **BAU:** No change • **Base:** Reduced to achieve parity with gas • **Best:** Rate moved below gas rate to 13% (20% reduction from Base tax rate)	19%	16%	13%

Note(s): Combined impact of levers 2, 3, 4 and 5 move the electricity price from €168 to €142 in the best-case and €152 in the base-case and €159 in the BAU-case
Source: [4] Elsevier 2024, [5] Ministry of Ecological and Inclusive Transition (France) 2017

Impact of competitiveness levers on the cost of production (energy component) for milk powder

Competitiveness levers | 2030, France, EUR/tonne of milk powder



Note: 1 MWh in gas boiler will be replaced by 0.75 MWh in heat pump and 0.25 MWh in electric boiler as high efficiencies of heat pump can be obtained at restrictive temperatures. Tax Exemptions and free allocation of EU-ETS not considered.

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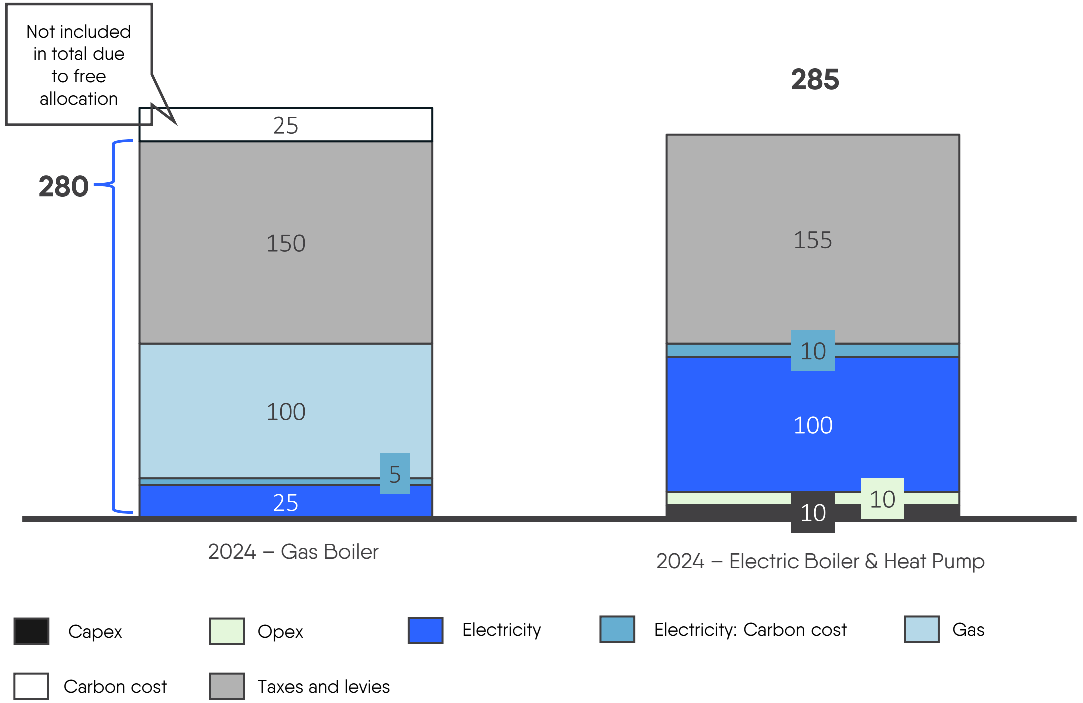
Current TCO comparison of energy component related to process heat of milk powder

Energy component comparison | Denmark | 2024

EUR/tonne of milk powder



Input data reference | 2024

COMPONENTS (UNITS)	AVG. VALUE (INC. TAXES)	SOURCE
Industrial Electricity Price (Eur/MWh) recoverable taxes and levies, not deducted	262	Eurostat 2024[A]
Gas Price (Eur/MWh) recoverable taxes and levies, not deducted	95	Eurostat 2024[B]
Carbon Cost - EU ETS (Eur/tCO2e)	65	BNEF[C]
Capex (Eur/kW)	Electric Boiler – 170 Heat Pump – 840	DESNZ[3], PBL[1]
Efficiency – Gas Boiler (%)	75%	DESNZ[3]
Efficiency – Elec. Options (%)	Electric Boiler – 99% Heat Pump – 4X	DESNZ[3]

Note: 1 MWh gas boiler capacity will be replaced by 0.75 MWh heat pump and 0.25 MWh of electric boiler capacity as high efficiencies of heat pumps are limited to 160 deg C. Non-fuel OPEX costs for heat pumps are higher due to installation complexity, increased maintenance, and safety costs associated with refrigerants. Tax and levies - Per Eurostat Denmark has the highest rate of tax and levies but also the highest recoverable rate of tax and levies, Eurostat data nets the two elements to an effective rate of near zero. It is worth noting that Eurostat nets Danish gas tax and levies rates to c. -20%. Statistics Denmark "In particular the non-recoverable taxes are difficult to compile"1. Therefore, Danish energy prices (gas and electric) are more than likely overpriced for the Milk powder industry, but consistent treatment has been applied across gas and electric.

Source: [1] PBL Netherlands Environmental Assessment Agency 2020, [3] DESNZ 2023.

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Competitiveness levers for 2030 | Denmark | Milk Powder

	LEVERS	RATIONALE	BAU	BASE-CASE	BEST-CASE
1	TECHNOLOGY COST	• Heat Pump and electric boiler technology is mature and is being deployed in F&B industries. With achieving scale, capex (installation and equipment cost) for heat pumps is expected to decrease[4] • **BAU:** Poor ecosystem collaboration and low adoption • **Base Case:** Increased scale • **Best:** Solutions Requiring Ecosystem Collaboration	10% reduction	25% reduction	40% reduction
2a	ELECTRICITY: GENERATION COSTS	• **BAU:** Achieve 94% net zero generation in the electricity mix as per growth trends since 2019 • **Base:** Increasing share of net zero generation in the electricity supply mix in line with national goals to 100% net zero generation by 2030[6] • **Best:** Aligned to base case	10-15% reduction	15-20% reduction	20-25% reduction
2b	ELECTRICITY: CARBON COST (GRID CARBON INTENSITY)		40-50% reduction	60% reduction	60% reduction
3	ELECTRICITY: CARBON COST (EU ETS)	• Carbon price increase impacts the fossil fuel-based alternative adversely. • **BAU**: No Change • Best & Base case referred from report published by ERCST - 2024 State of the EU ETS Report[C]	65	130	160
4	ELECTRICITY: TAXES AND LEVIES	• Tax rate on electricity is substantially lower than that on gas • **BAU:** No change • **Base:** Parity with gas tax rate • **Best:** Rate moved below gas rate to 90% (20% decrease from Base tax rate)	143%	111%	90%

Note(s): Combined impact of levers 2, 3, 4 and 5 move the electricity price from €262 to €173 in the best-case and €200 in the base-case and €231 in the BAU-case. Tax and levies - Per Eurostat Denmark has the highest rate of tax and levies but also the highest recoverable rate of tax and levies, Eurostat data nets the two elements to an effective rate of near zero. It is worth noting that Eurostat nets Danish gas tax and levies rates to c. -20%. Statistics Denmark "In particular the non-recoverable taxes are difficult to compile"1. Therefore, Danish energy prices (gas and electric) are more than likely overpriced for the Milk powder industry, but consistent treatment has been applied across gas and electric.
Source: [4] Elsevier 2024, [6]. Danish Ministry of Energy, Utilities and Climate 2019

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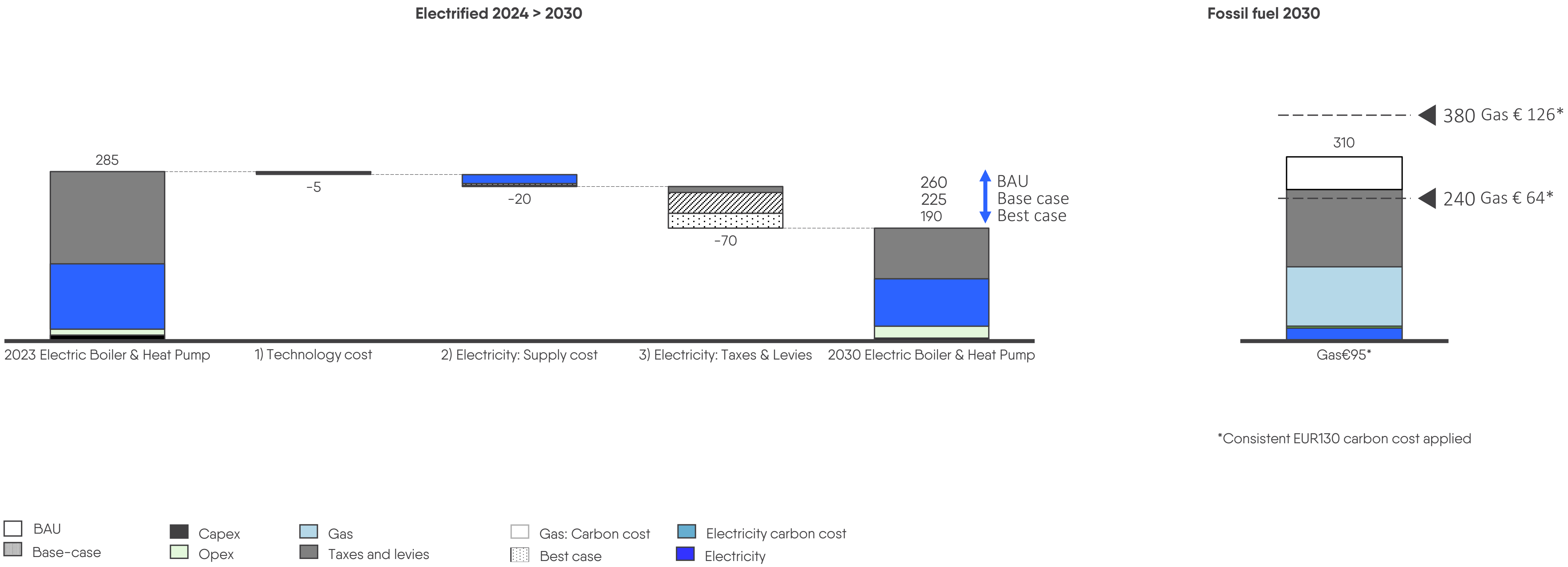
Impact of competitiveness levers on the cost of production (energy component) for milk powder

Competitiveness levers | 2030, Denmark, EUR/tonne of milk powder



Tax and levies - Per Eurostat Denmark has the highest rate of tax and levies but also the highest recoverable rate of tax and levies, Eurostat data nets the two elements to an effective rate of near zero. It is worth noting that Eurostat nets Danish gas tax and levies rates to c. -20%. Statistics Denmark "In particular the non-recoverable taxes are difficult to compile"1. Therefore, Danish energy prices (gas and electric), and the associated reduction are more than likely overpriced for the Milk powder industry, due to tax and levies, but consistent treatment has been applied across gas and electric.

2.3

Findings and implications by industrial sector

Batteries Sector Analysis - TCO analysis for Dry Coating Process + Integrated Heat Pumps in Dry Rooms in Cell Manufacturing

Europe's battery manufacturing footprint is largely focused on battery cell production, which accounts for just 6% of the energy cost of total cost

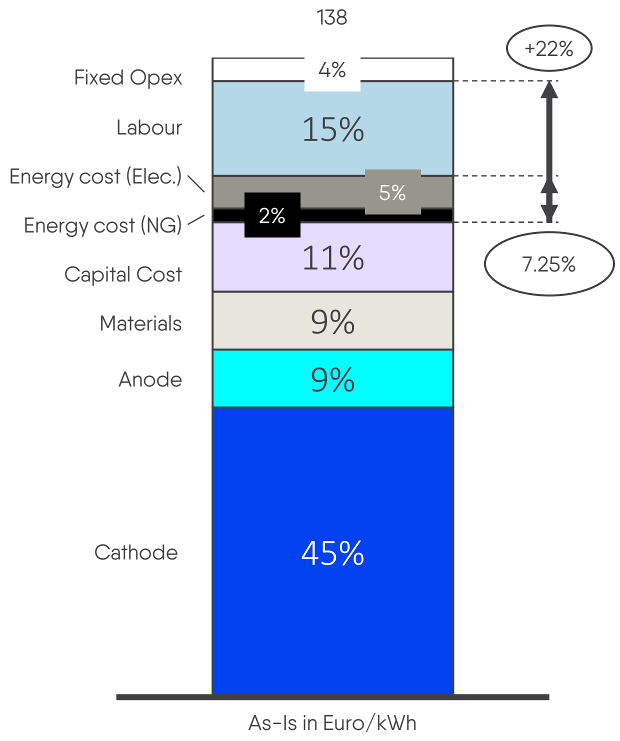
EV BATTERY VALUE CHAIN (EXCLUDING DOWNSTREAM)	ENERGY COST OF TOTAL	COMMENTS
Raw Material Mining → Raw Material Refining → Cell Components → Battery Cell Production	20%	• EV battery manufacturing is a highly energy intensive process
Raw Material Mining → Raw Material Refining → Cell Components → Battery Cell Production	14%	• However, most of the energy consumed is surrounding parts of the value chain which are predominantly located outside of Europe
Raw Material Mining → Raw Material Refining → Cell Components → Battery Cell Production3 Analysis scope	6%	• Battery Cell production is the main part of the EV battery value chain located in Europe and hence the focus of the analysis • While the remaining energy cost is less significant, it is important to note that batteries are a key piece to Europe's climate neutral goal. Reviewing the electrification potential ensures that Europe can reduce the carbon associated with battery production, at a competitive price. I.e. electrification is not a blocker to scaling battery roll out

Sources: [1] IEA 2024 [2]_IPCEI 2024,

Drying and Dry rooms consumes most of the natural gas usage during Battery cell manufacturing process: Hungary

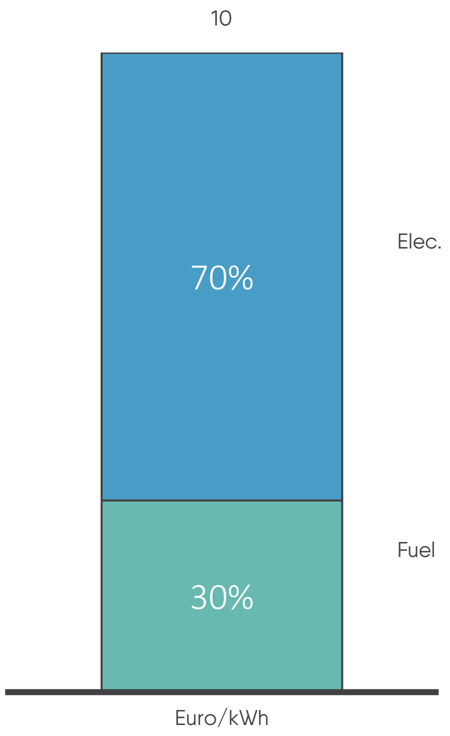
Full Cost of Production (in EUR/kWh)

% breakdown for Hungary



Energy Cost Component (in EUR/kWh)

Fuel vs electricity in %



Battery cell manufacturing process

Total Energy Cost

ELECTRODE MANUFACTURING	Mixing
	Coating & drying (14%)
	Calendaring
	Sitting
	Vacuum drying (2%)
CELL ASSEMBLY	Winding
	Assembly
	Washing
	Dry Rooms (13%)
CELL FINISHING	Formation
	Ageing
	Testing & Handling

Primarily or fully electrified

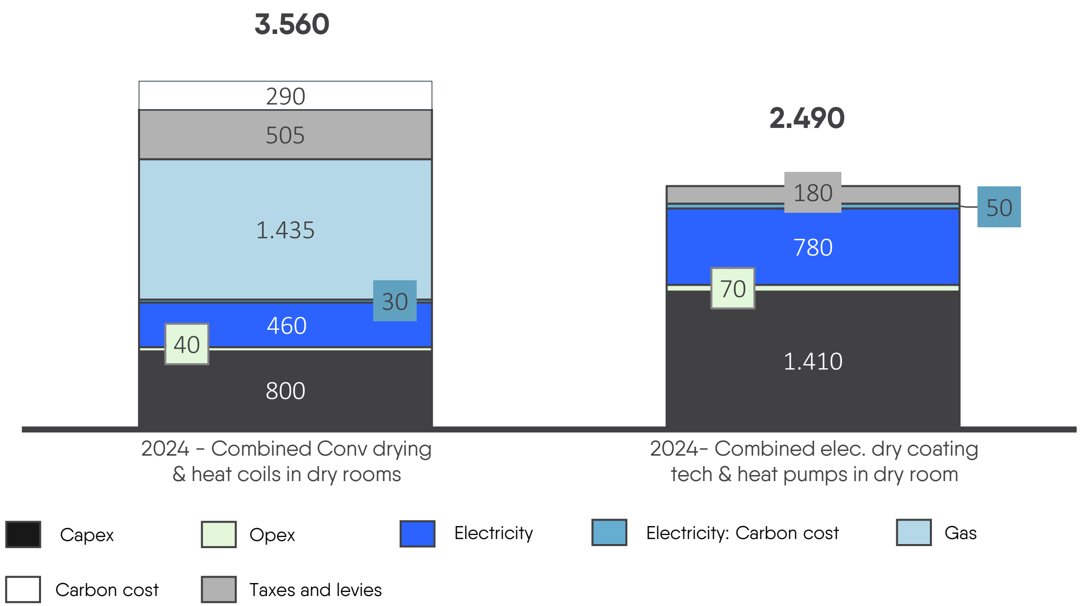
Primarily fuel driven process (% of total)

Sources: [3] Elsevier 2021 [4] European Battery Alliance 2023

Current TCO comparison of energy component related to industrial heat pumps for dry rooms & dry electrode coating

Energy component comparison | Hungary | 2024

EUR/MWh of Output



Note -*Calculated; For electrification, dry coating electrode technology is opted which eliminates the need of conventional drying machine, and extra elec. energy forces are required for extrusion process of dry powdered electrode material
Sources: [5] IEEE 2023,[6] DESNZ 2023 [7] IGP Photonics [8] ScienceDirect 2025 [9] Batteries 2024

Input data reference | 2024

COMPONENTS (UNITS)	VALUE (AVERAGE)	SOURCE
Industrial Electricity Price (Eur/MWh) recoverable taxes and levies, not deducted	213	Eurostat 2024[A]
Gas Price (Eur/MWh) recoverable taxes and levies, not deducted	83	Eurostat 2024[B]
Carbon Cost - EU ETS (Eur/tCO2e)	80	ERCST[C]
Elec. Dry Coating Capex Elec. Dry Rooms with Heat Pumps (in Eur/MWh/year)*	660 750	IEEE and Fraunhofer Research Institute (FFB)[5], DESNZ[6] (for HP – 840Eur/kW)
Efficiency - Coating & Drying Conv. Dry Rooms w/ Gas Boilers	~25% ~80%	IGP Photonics[7] DESNZ[6], ScienceDirect[8],
Efficiency Elec Dry electrode* Efficiency/COP of Heat Pumps	~70% ~COP 4X	Batteries MDPI [9] ScienceDirect[8]

Competitiveness levers for 2030 | Hungary | Dry coating & Heat pumps

	LEVERS	RATIONALE	BAU	BASE-CASE	BEST-CASE
1	TECHNOLOGY COST	• Electric dry coating is innovative and in emerging stage, though widespread commercial deployment is being tested. Capex is reduced due to low footprint[10]. Heat pumps with dehumidifier in dry rooms is new concept, but technology is mature.[11] With scaling of battery manufacturing capacity, the adoption is expected to increase • **BAU:** Poor ecosystem collaboration and low adoption • **Base Case:** Increased scale • **Best:** Solutions Requiring Ecosystem Collaboration	10% reduction	25% reduction	40% reduction
2a	ELECTRICITY: GENERATION	• **BAU:** Continuing the trend achieve 88% net zero generation target NZGT (new nuclear and renewables) in the electricity mix as per growth trends since 2019, coal and oil not phased out completely • **Base:** Achieve target of 90% net zero generation NZGT in electricity mix by 2030 (new nuclear and renewables) and coal and oil completely phased out [12] • **Best:** Go past the target to achieve 95% net zero generation in electricity mix by 2030	10-15% reduction	15-20% Reduction	25-30% Reduction
2b	ELECTRICITY: CARBON COST (GRID CARBON INTENSITY)		55-60%	60-65%	65-70%
3	ELECTRICITY: CARBON COST (EU ETS)	• Carbon price increase impacts the fossil fuel-based alternative adversely. • **BAU:** 80 €/tCO2 (same as 2023) [C] • **Base Case**: 130 €/tCO2 (2030 projection by Bloomberg NEF) [C] • **Best Case:** 160 €/tCO2 (2030 projection by Refinitiv) [C]	80	130	160
4	ELECTRICITY: TAXES AND LEVIES	• Current electricity tax rate in Hungary is 28% which is lesser than gas, 32% • **BAU:** No change in tax rate • **Base:** No change in tax rate • **Best:** Rate moved below gas rate to 18%	23%	23%	18%

Note(s): To inform the waterfall chart on the following page, the combined impact of levers 2, 3, 4 and 5 move the electricity price from €213MWh to €187MWh in BAU, €185MWh in the base-case and €165MWh in the best-case.
Source : [10] RWTH Aachen University 2023 [11] NemiTek 2021 [12] Hungary- Equillibrium Institute 2022 [C] ERCST 2024

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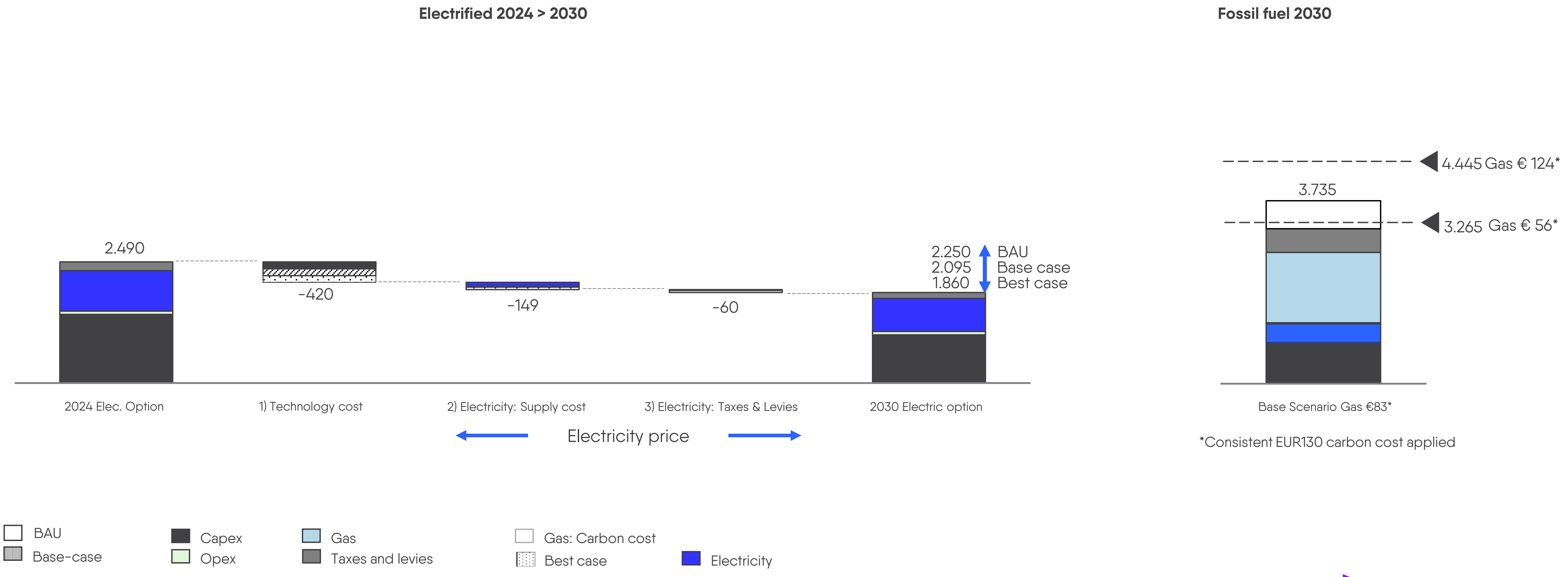
Impact of competitiveness levers on the cost of production (energy component) of battery cell manufacturing process

Competitiveness levers | 2030, Hungary, EUR/MWh



Note [1] *The country aims to cut natural gas consumption by 40% by 2030, posing significant risks to gas availability.
[2] In conventional process, energy cost is only 6% of the total cost of production.

*Consistent EUR130 carbon cost applied

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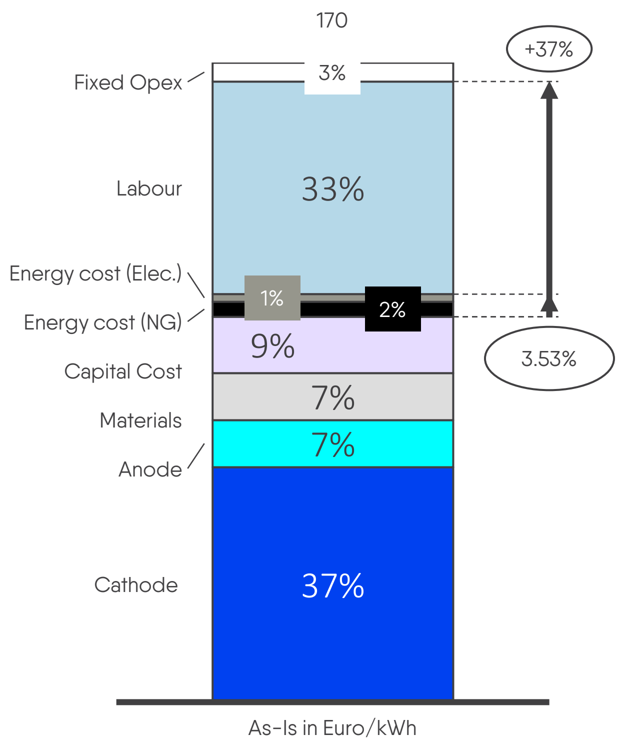
Drying and Dry rooms consumes most of the natural gas usage during Battery cell manufacturing process: Sweden

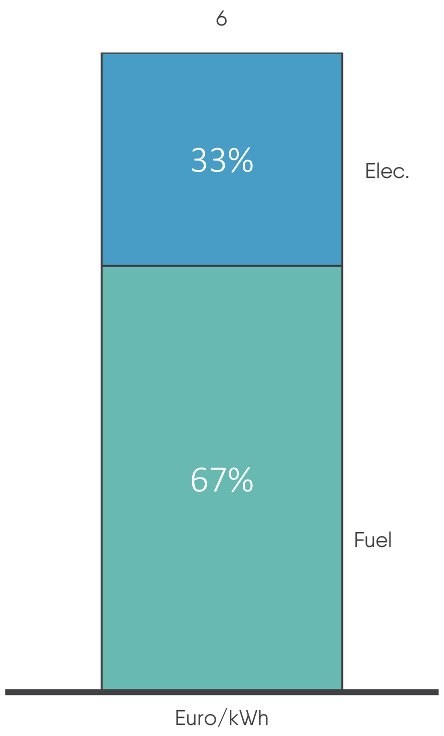
Full Cost of Production (in EUR/kWh)

% breakdown for Sweden



Energy Cost Component (in EUR/kWh)

Fuel vs electricity in %



Battery cell manufacturing process

Total Energy Cost in %

ELECTRODE MANUFACTURING	Mixing Coating & drying (29%) Calendaring Sitting Vacuum drying (5%)
CELL ASSEMBLY	Winding Assembly Washing Dry Rooms (26%)
CELL FINISHING	Formation Ageing Testing & Handling

Primarily or fully electrified

Primarily fuel driven process (% of total)

Sources: [3] Elsevier 2021 [4] European Battery Alliance 2023

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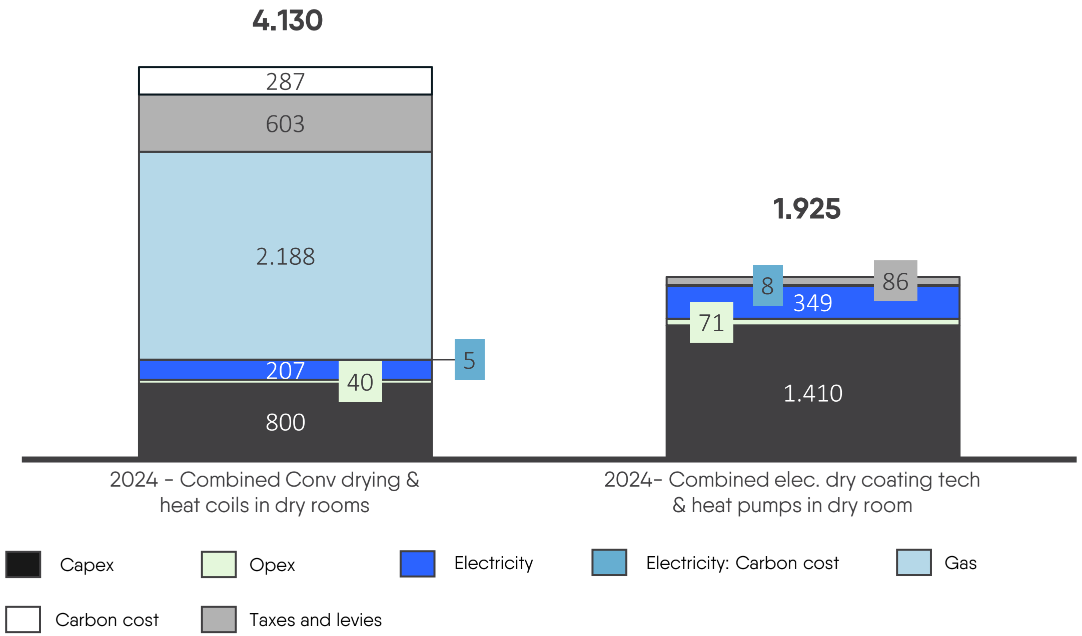
Current TCO comparison of energy component related to industrial heat pumps for dry rooms & dry electrode coating

Energy component comparison | Sweden | 2024

EUR/MWh of Output



Input data reference | 2024

COMPONENTS (UNITS)	VALUE (AVERAGE)	SOURCE
Industrial Electricity Price (Eur/MWh) recoverable taxes and levies, not deducted	91	Eurostat 2024[A]
Gas Price (Eur/MWh) recoverable taxes and levies, not deducted	124	Eurostat 2024[B]
Carbon Cost – EU ETS (Eur/tCO2e)	80	ERCST[C]
Elec. Dry Coating Capex Elec. Dry Rooms with Heat Pumps (in Eur/MWh/year)*	660 750	IEEE and Fraunhofer Research Institute (FFB)[5], DESNZ[6] (for HP – 840Eur/kW)
Efficiency – Coating & Drying Conv. Dry Rooms w/ Gas Boilers	~25% ~80%	IGP Photonics[7] DESNZ[6], ScienceDirect[8],
Efficiency Elec Dry electrode* Efficiency/COP of Heat Pumps	~70% ~COP 4X	Batteries MDPI [9] ScienceDirect[8]

Note -*Calculated; For electrification, dry coating electrode technology is opted which eliminates the need of conventional drying machine, and extra elec. energy forces are required for extrusion process of dry powdered electrode material

Sources: [5] IEEE 2023,[6] DESNZ 2023 [7] IGP Photonics [8] ScienceDirect 2025 [9] Batteries 2024

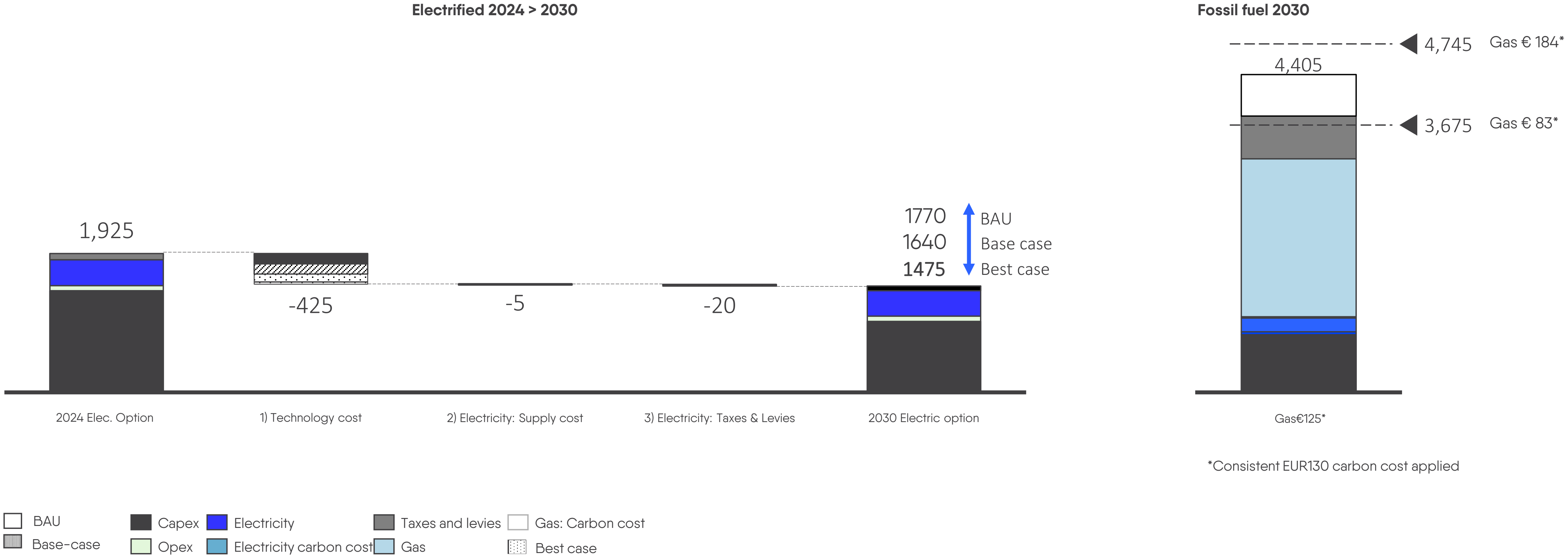
Competitiveness levers for 2030 | Sweden | Dry coating & Heat Pumps

	LEVERS	RATIONALE	BAU	BASE-CASE	BEST-CASE
1	**TECHNOLOGY COST**	• Electric dry coating is innovative and in emerging stage, though widespread commercial deployment is being tested. Capex is reduced due to low footprint[10]. Heat pumps with dehumidifier in dry rooms is new concept, but technology is mature.[11] With scaling of battery manufacturing capacity, the adoption is expected to increase • **BAU:** Poor ecosystem collaboration and low adoption • **Base Case:** Increased scale • **Best:** Solutions Requiring Ecosystem Collaboration	10% reduction	25% reduction	40% reduction
2a	**ELECTRICITY: GENERATION**	• **BAU:** Achieve 97% net zero generation target NZGT in the electricity mix as per growth trends since 2019 • **Base:** Achieve target of 98% net zero generation target NZGT in electricity mix by 2030 • **Best:** Go past the target to achieve 99% net zero generation in electricity mix by 2030	0-5% Reduction	5-10% Reduction	5-10% Reduction
2b	**ELECTRICITY: CARBON COST (GRID CARBON INTENSITY)**		0-10% Reduction	0-10% Reduction	0-10% Reduction
4	**ELECTRICITY: CARBON COST (EU ETS)**	• Carbon price increase impacts the fossil fuel-based alternative adversely. • **BAU:** 80 €/tCO2 (same as 2023)[C] • **Base Case:** 130 €/tCO2 (2030 projection by Bloomberg NEF) [C] • **Best Case:** 160 €/tCO2 (2030 projection by Refinitiv) [C]	80	130	160
5	**ELECTRICITY: TAXES AND LEVIES**	• Current tax rate on gas in Sweden is already much higher (62%) compared to electricity 26% • **BAU:** No change in tax rate • **Base:** No change in tax rate • **Best:** Rate moved below gas rate to 20%	25%	25%	20%

Note(s): To inform the waterfall chart on the following page, the combined impact of levers 2, 3, 4 and 5 move the electricity price from €91MWh to €90MWh in BAU, €90MWh in the base-case and €85MWh in the best-case.
Source : [10] RWTH Aachen University 2023 [11] NemiTek 2021 [13] Sweden IEA 2024 [C] ERCST 2024

Impact of competitiveness levers on the cost of production (energy component) of battery cell manufacturing process

Competitiveness levers | 2030, Sweden, EUR/MWh



Note [1]*The country already have higher gas prices. Volatility is demonstrated with fluctuations of ±20% on Gas€150.
[2] In conventional process, energy cost is only 6% of the total cost of production.

*Consistent EUR130 carbon cost applied

3

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    a. Germany and Spain – Band IG : Consumption > 150 000 MWh
    b. Hungary and Sweden - Band IE : 20 000 MWh < Consumption < 70 000 MWh
    c. France and Denmark - Band ID : 2000 MWh < Consumption < 20 000 MWh

B. Eurostat, "Gas prices components for non-household consumers", 2023, Energy prices - Eurostat
    a. Germany and Spain – Band I6 : Consumption > 400 000 GJ
    b. Hungary and Sweden - Band I3: 10,000 GJ < Consumption 100 000 GJ
    c. France and Denmark - Band I4: 100,000 GJ < Consumption < 1,000, 000 GJ

C. BNEF, "2H 2024 EU ETS Market Outlook", Oct 2024, 2H 2024 EU ETS Market Outlook: On Tenterhooks Over Supply | BloombergNEF

Power Generation mix:
Power mix data 2024 from ENTSO-E for all countries https://energy-charts.info/charts/energy_pie/chart.htm?l=en&c=DK&year=2024&interval=year

4

Scenarios: Country comparison

4.1

Scenarios: Country comparison

Electricity scenarios

Electricity price scenarios per country

	REDUCTION		
COUNTRY	BAU	BASE	BEST
Germany	9%	25%	33%
Spain	9%	11%	21%
France	5%	10%	15%
Denmark	12%	24%	34%
Hungary	10%	11%	20%
Sweden	3%	3%	10%
Average	8%	12%	20%

If Germany reaches their Net Zero Generation targets (base) it will be the country from our sample which transforms the energy mix the most. Germany also has the second largest delta between Electricity and Gas Tax and levies percentages in the sample.

For Denmark, in the best-case scenario, 28% of the reduction comes from taxes and levies. Excluding this would move the average price reductions to 6%, 8% and 14%

Note: 1) Analysis does not exclude Eurostat "recoverable" taxes because this is at a country level and analysis is at an industry level and the recognised difficultly of accurately capturing the level of recoverable taxes - this will artificially inflate the energy prices (both gas and electric). Per Eurostat, in 2024 Denmark has the highest rate of tax and levies but also the highest recoverable rate of tax and levies, Eurostat data nets the two elements to an effective rate of near zero. It is worth noting that Eurostat nets Danish gas tax and levies rates to c. -20%. Statistics Denmark "In particular the non-recoverable taxes are difficult to compile"1. Therefore, Danish energy prices (gas and electric) are more than likely overpriced, as industries pay less tax and levies than included, for the Milk powder industry, but consistent treatment has been applied across gas and electric.

Net zero generation (Renewables and Nuclear) per scenario

		2030 SCENARIOS		
COUNTRY	NET ZERO GENERATION % (2024)	BAU	BASE	BEST
Germany	62%	64%	82%	87%
Spain	80%	87%	87%	92%
France	91%	93%	100%	100%
Denmark	84%	94%	100%	100%
Hungary	72%	89%	91%	91%
Sweden	99%	99%	100%	100%

Reductions in generation cost, and associated carbon costs, are based on the assumptions of increased production of net zero cost-effective technologies (Nuclear, Renewables) will drive down the underlying cost of generation while reducing carbon intensity of the grid.

2030 Net zero generation scenarios have been based on the progress towards, or past, national targets (aligned to Fit for 55 scenarios from Decarbonisation speedways):

BAU scenario is assuming current rate of growth (based on average growth in last 5 years)

Base scenario is assuming that each country achieves the 2030 Net Zero Commitments (Fit for 55 inspired decarbonisation speedways)

Best case scenario assumes that the penetration of Net Zero generation technologies exceeds the 2030 target (where relevant)

The reduction in carbon related to generation is calculated based on the new energy mix.

Source(s): IEA, Varying national targets, Accenture analysis

Electricity cost: generation costs assumptions for each technology

	LCOE European average (EUR/ MWh)		
TECHNOLOGY	2024	2030	DELTA
Coal	0,28	0,30	+0.02
Gas	0,19	0,18	-0.01
Nuclear	0,16	0,13	-0.03
Wind	0,06	0,05	-0.01
Hydro	0,06	0,06	-
Solar	0,05	0,03	-0.02

The component of electricity prices which is related to generation, is reduced based upon lower cost NZTs making up a larger proportion of the generation mix.

The percentage reduction in the cost of generation between the 2024 and 2030 energy mix was modelled for each country, based upon the levelized cost of generation for each technology.

For the simplified scenarios, a scaling amount of the reduction in generation cost was applied to the component of electricity price relating to generation. A quarter in BAU, a third in Base and a half in Best.

For example, if a countries generation cost reduced by 30% on a LCOE basis between 2024 and 2030, in the base scenario the component of electricity price relating to generation was reduced by 10%.

Source(s): IRENA, S&P Global, BNEF, Accenture analysis

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Scenarios: Country comparison

Tax scenarios

Tax rates and levies reduction scenarios

		2030 SCENARIOS	
COUNTRY	BAU: ELECTRICITY TAX & LEVY IMPLIED RATE (%)	BASE	BEST
Germany	36%	18%	14%
Spain	21%	17%	14%
France	19%	16%	13%
Denmark[1]	143%	111%	90%
Hungary	28%	23%	18%
Sweden	26%	25%	20%

Gas tax rate

Source(s): Eurostat, [1] WebReport

The clean industrial energy act recognised the discrimination between gas and electricity tax rates. Momentum appears to be building surrounding the reduction of tax rates. Our scenarios apply the following rates:

- BAU: country rate remains the same
- Base: Electricity tax rate is aligned to the gas tax rate
- Best: Electricity tax rate is brough down further than the gas rate

This tax covers duties, levies, and other taxes recognised in Eurostat data.

Recoverable taxes have not been excluded from either gas or electricity; value at a country level whereas the analysis focuses upon specific industries and difficulties stated in accurate collection of recoverable rates by data providers. This inflates both the electricity and gas price included in the model, compared to actual rates paid by industrial users, however it was deemed that this would not materially impact TCO comparison.

Carbon cost for electricity is included in generation, not tax and levies.

Note: 1) Denmark has the highest rate of tax and levies but also the highest recoverable rate of tax and levies, Eurostat data nets the two elements to an effective rate of near zero. It is worth noting that Eurostat nets Danish gas tax and levies rates to c. -20%. Statistics Denmark "In particular the non-recoverable taxes are difficult to compile" 1. Therefore, Danish energy prices (gas and electric) are more than likely overpriced but consistent treatment has been applied across gas and electric.

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