The Market Potential of eFuels

Climate contribution and success factors for ramp-up

efuel-alliance.eu

Authors:
Study coordinators:
Ralf Diemer, eFuel Alliance e. V., Chief Executive Officer
Dr. Tobias Block, eFuel Alliance e. V., Chief Strategy Officer

Co-authors:
Dr. Lukas Mauler, Porsche Consulting GmbH, Associate Partner
Corentin Prié, Porsche Consulting GmbH, Manager

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Executive summary

INTRODUCTION

In the global effort to combat climate change, more than 180 countries have committed to the Paris Climate Agreement, aiming to limit global warming to well below 2°C above pre-industrial levels. This commitment places significant pressure on carbon-intensive sectors such as mobility. The European Union has set forth an ambitious plan for powertrain transition, particularly in on-road mobility, where battery electric vehicles (BEVs) are expected to dominate EU fleets by mid-century. In contrast, internal combustion engines (ICEs) are projected to remain the primary technology in maritime shipping and aviation. Considering the pace of fleet stock renewal and potential industrial bottlenecks in critical powertrain and energy supply chains, ICEs will continue to play a role, and demand for liquid fuels will remain substantial through 2050. eFuels offer the potential for significant carbon savings in mobility fleets if their adoption accelerates. Despite numerous projects preparing for eFuel market entry, financing challenges persist and must be addressed. This analysis provides a quantitative assessment of the eFuel market potential in the EU and outlines the actions required to unlock project financing and enable stakeholders to scale up production.

→ ICEs remain relevant in all mobility segments, particularly in shipping and aviation.

Despite the introduction of new powertrain technologies such as batteries and fuel cells, internal combustion engines are expected to remain significant across all mobility segments in the long term. The European Commission's Impact Assessment[1], published in early 2024, provides a comprehensive analysis of various mobility transformation scenarios. Scenario 3 was designed to meet European climate targets—achieving a 90 percent reduction in CO_2 emissions by 2040 compared to 1990 levels and reaching climate neutrality by 2050. For this reason, Scenario 3 is used as the basis for understanding the European

Commission's mobility transformation plan and will be referred to as the "EU Ambition" scenario throughout this study.

The share of internal combustion engine vehicles (ICEVs) and plug-in hybrid electric vehicles (PHEVs) will remain substantial across all mobility fleets, even by 2040. In maritime and aviation, ICE powertrains are projected to account for more than 80 percent of the fleet stock in 2040, as alternative powertrains are technically limited to a few use cases. Despite the ambitious electrification assumed in this scenario, ICE powertrains in on-road mobility fleets are expected to represent approximately 37 percent of passenger cars and up to 62 percent of trucks and buses.

ICE share for EU 2040
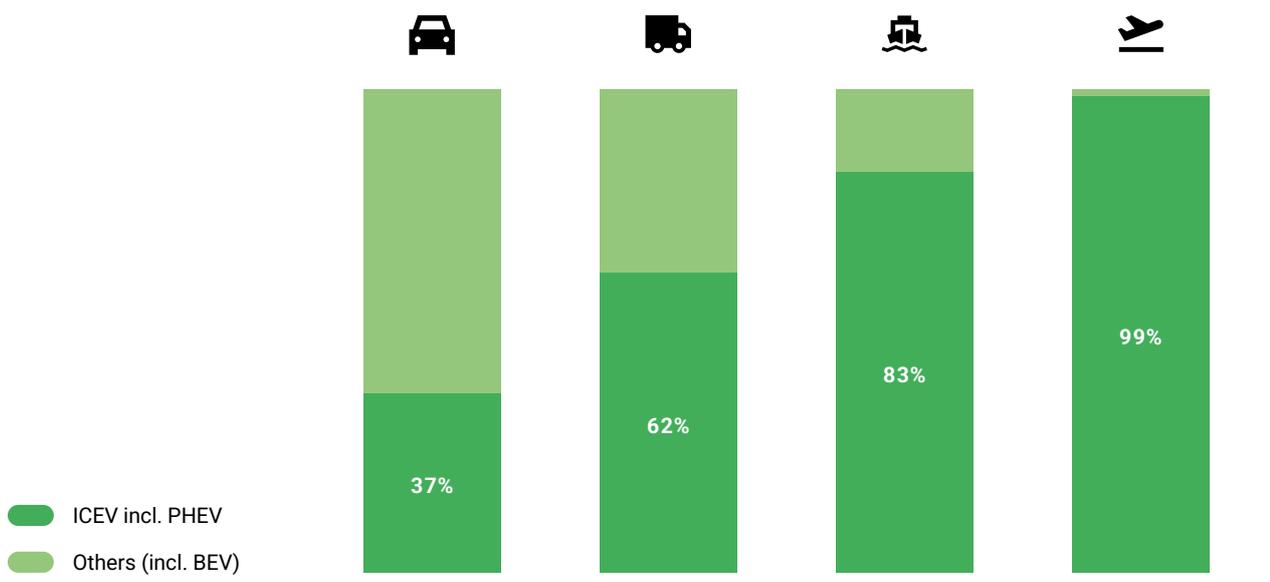Derived from European Commission's Impact Assessment 2024

Figure 1: ICE share forecast in fleet stock of EU mobility segments 2040: "EU Ambition" scenario.
Scope: passenger cars, trucks & buses, maritime shipping, aviation

On-road BEV transition plans in the EU could be delayed.

The European Commission has set ambitious targets for the adoption of battery electric vehicles (BEVs) in on-road mobility segments. Under the "EU Ambition" scenario, there is a clear road map to increase BEV penetration across various fleet categories. The goal is to achieve an 80 percent BEV share in the passenger car fleet stock and a 48 percent share in the truck and bus fleet stock by 2050.

To meet the 2050 targets for passenger cars, the BEV share in new registrations must reach 80 percent by 2034 at the latest, unless ICEVs are retired prematurely. Consequently, BEV registrations for passenger cars need to rise to 7.4 million units by 2030—representing a fivefold increase within seven years. For trucks and buses, a sevenfold growth is required within five years. Achieving the European Commission's ambitious BEV adoption targets for on-road mobility will place significant pressure on battery and related energy supply chains. Concurrent ramp-up initiatives in other regions could lead to potential shortages, underscoring the need for strategic planning and long-term investments.

To assess the feasibility of the transition speed proposed in the "EU Ambition" scenario, a comprehensive industrial bottleneck analysis was conducted. This analysis examined 27 critical factors influencing the pace of mobility transformation, comparing demand and supply to identify potential shortages or excess capacities. Additional dimensions that could impact the transition—such as regulatory changes, geopolitical dynamics, customer trends, social acceptance, and unforeseen economic events—were not included in this assessment.

The analysis was structured into four main supply chain areas:

1. **Battery:**
Supply of lithium, nickel, cobalt, and graphite; anode and cathode production; cell manufacturing

2. **Green electricity:**
Wind and solar power equipment; installation of wind and solar capacity; power grid infrastructure; public charging points

3. **Green hydrogen:**
Wind and solar power equipment; electrolysis systems; hydrogen plant installation

4. **eFuels:**
Wind and solar power equipment; electrolysis systems; eFuel plant installation

The goal is to achieve an 80 percent BEV share in the passenger car fleet stock and a 48 percent share in the truck and bus fleet stock by 2050.

"EU Ambition" scenario
Based on European Commission's Impact Assessment

FLEET STOCK POWERTRAIN SHARE

Passenger cars:

	2023	2040	2050
BEV	4%	58%	80%
PHEV	3%	11%	—
ICEV	93%	26%	4%
HICEV/FCEV	—	5%	14%
			2%

Trucks & buses:

	2023	2040	2050
BEV	2%	24%	48%
HICEV/FCEV	—	14%	31%
PHEV	—	5%	2%
ICEV	98%	57%	19%

Legend: HICEV/FCEV, BEV, ICEV, PHEV

NEW BEV REGISTRATIONS

Million units (passenger cars):

2023	2030	2035
1.6	7.4	9.0

× 5

1,000 units (trucks & buses):

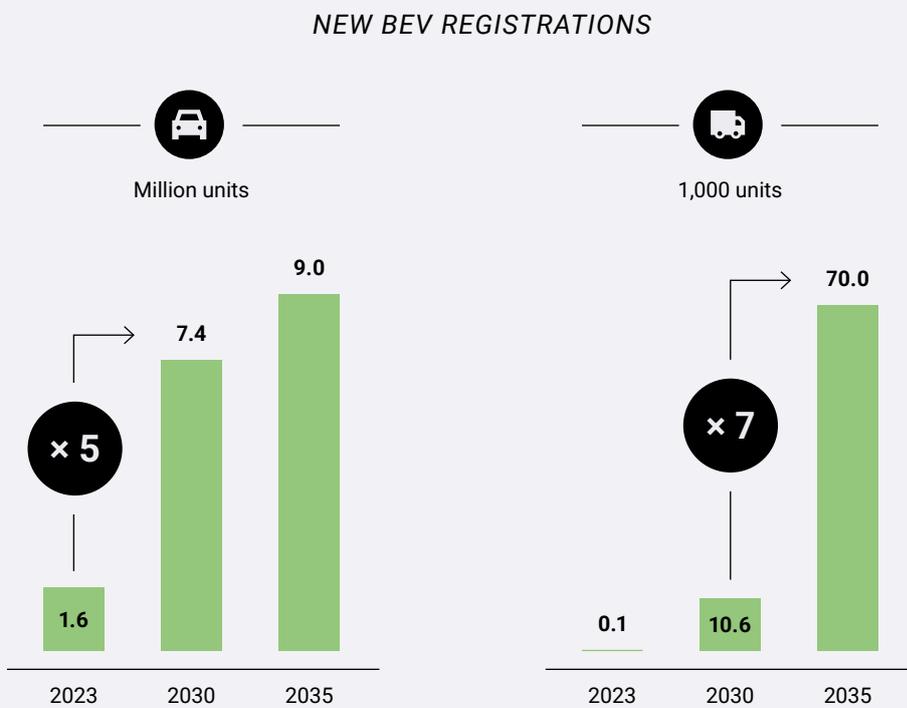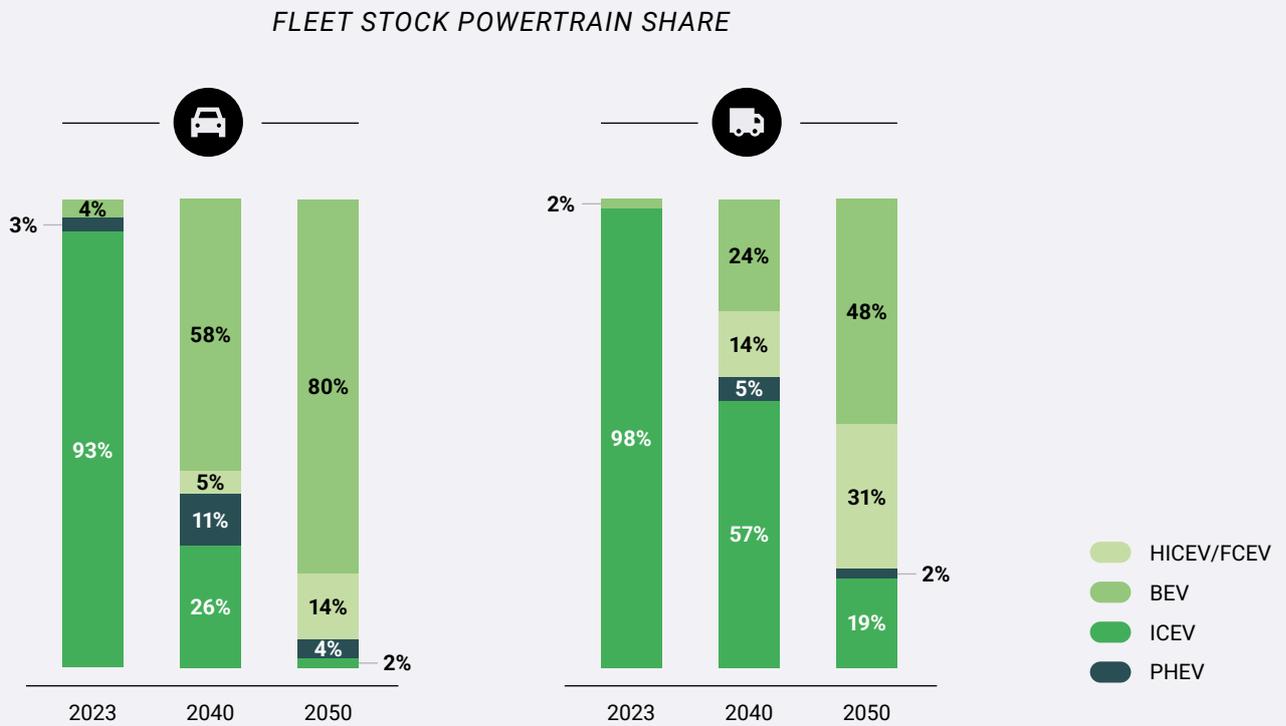| 2023	2030	2035
0.1	10.6	70.0

× 7

Figure 2: BEV share in fleet stock of EU mobility segments and new registrations: "EU Ambition" scenario.
Scope: passenger cars, trucks & buses

In the battery supply chain, bottlenecks are expected under the "EU Ambition" scenario until 2044, primarily due to limited lithium and nickel mining capacities, with deficits of approximately 30 percent and 20 percent over the period, respectively.

For each year through 2050, EU demand for all 27 bottleneck factors was derived from the "EU Ambition" scenario. In the battery supply chain, a technology road map and the EU's material recycling regulations were incorporated. For example, the transition from nickel-based to iron-phosphate chemistries in passenger car batteries is intended to reduce nickel demand. Energy demand projections for 2030, 2040, and 2050 were sourced from the European Commission's Impact Assessment, with interpolations made to align with fleet stock evolution across mobility segments. On the supply side, industrial capacity limitations were forecasted based on industry announcements and

extrapolated trends. Since many supply chains operate globally, it was assumed that the EU would receive a proportional share of global supply corresponding to its share of global demand, where global demand was estimated based on the achievement of announced climate targets.

In the battery supply chain, bottlenecks are expected under the "EU Ambition" scenario until 2044, primarily due to limited lithium and nickel mining capacities, with deficits of approximately 30 percent and 20 percent over the period, respectively. Strong demand growth for battery raw materials at both EU and global levels—driven by climate targets—is a key factor. Due to long lead times and limited project announcements in the mining sector, capacity ramp-up is expected to remain constrained until 2035. After 2035, additional capacities are anticipated, supported by advances in battery technology and material recycling, which should ease supply chain pressures by 2045.

The renewable electricity and hydrogen supply chains are expected to face pressure until 2035, primarily due to the limited pace of project installations within the EU. Additionally, constraints in power grid capacity and hydrogen transport infrastructure may further restrict progress. While these bottlenecks are unlikely to prevent the adoption of new powertrain technologies, they could delay the realization of carbon savings in mobility.

Meeting EU demand for eFuels is expected to be challenging until 2030, primarily due to limited availability of renewable energy equipment and insufficient eFuel production capacity. However, from 2030 onward, project lead times and improved access to renewable power equipment will enable additional capacity expansion. According to the industrial bottleneck assessment, the "EU Ambition" scenario allows for an accelerated eFuel ramp-up starting in 2030.

A scenario was developed to assess the EU transition speed if these bottlenecks cannot be mitigated, referred to as the "Bottleneck-adjusted" scenario. In this scenario, the pace of transition is adapted to reduce pressure on supply chains while maximizing their utilization. Supply chains identified as having additional potential are ramped up to their maximum feasible capacity.

Figure 3: BEV share in EU passenger car fleet stock and new registrations: "EU Ambition" vs. "Bottleneck-adjusted" scenario.

As a result, the ramp-up of BEVs in the passenger car segment is likely to be delayed by approximately five years. In the "Bottleneck-adjusted" scenario, the BEV share in the passenger car fleet stock is halved by 2040 compared to the "EU Ambition" scenario, and the supply chain relief after 2045 does not offset the accumulated delay. By 2050, the BEV share reaches 64 percent, compared to the planned 80 percent. Consequently, the share of ICEs and PHEVs remains higher than anticipated: around 60 percent in 2040 and 25 percent in 2050 for passenger cars. Similar trends are observed in the truck and bus segment.

A delayed phase-out of ICEVs inevitably results in a slower reduction of liquid fuel consumption than originally planned by the European Commission.

A delayed transition scenario leads to increased demand for liquid fuels.

The "EU Ambition" scenario targets a substantial reduction in liquid fuel use in on-road mobility by 2050, driven by a progressive BEV ramp-up. Under this plan, liquid fuel demand is expected to slightly increase in maritime and aviation segments, as internal combustion engines (ICEs) remain the dominant powertrain and mobility demand in these sectors continues to grow.

In the "Bottleneck-adjusted" scenario, cumulative liquid fuel demand is projected to be 14 percent higher than in the "EU Ambition" scenario by 2050. Specifically, for on-road mobility, cumulative liquid fuel demand is expected to remain 23 percent above the EU plan.
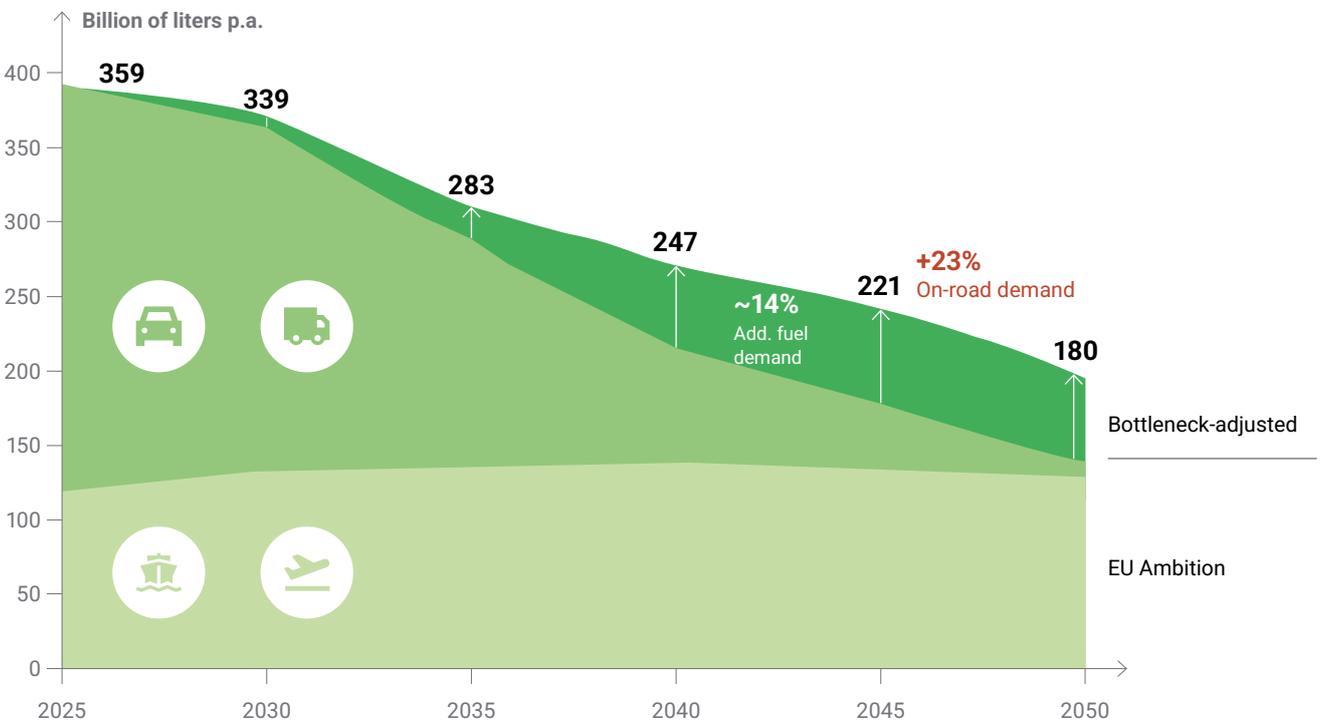
Figure 4: Annual liquid fuel demand in EU mobility: "EU Ambition" vs "Bottleneck-adjusted" scenario.
Scope: gasoline, diesel, fuel oil, methanol, ammonia, and jet fuel | Fuel volume in billion liters gasoline equivalent

If the powertrain transformation in mobility progresses more slowly than planned by the EU, liquid fuel demand will remain higher than anticipated, potentially delaying carbon savings. eFuels can help mitigate CO_2 emissions associated with continued liquid fuel use.

Climate targets could be achieved by accelerating the eFuel ramp-up.

To quantify the potential industrial ramp-up of eFuel capacities, several factors were evaluated on a global scale. Based on projections for eFuel capacity installations and equipment supply for renewable energy and production processes such as electrolysis, the ramp-up of eFuels was modeled and is referred to as the "Industrial eFuel Potential" scenario. The ramp-up shown in Figure 5 represents the

share of global eFuel supply allocated to EU mobility, proportional to its share of global eFuel demand. Capacities allocated to other sectors and markets—including renewable energy and electrolysis equipment—were excluded from this calculation. Results are based solely on the industrial feasibility of the eFuel ramp-up and do not account for additional limiting factors such as regulation, geopolitical dynamics, customer trends, social acceptance, or unforeseen economic events.
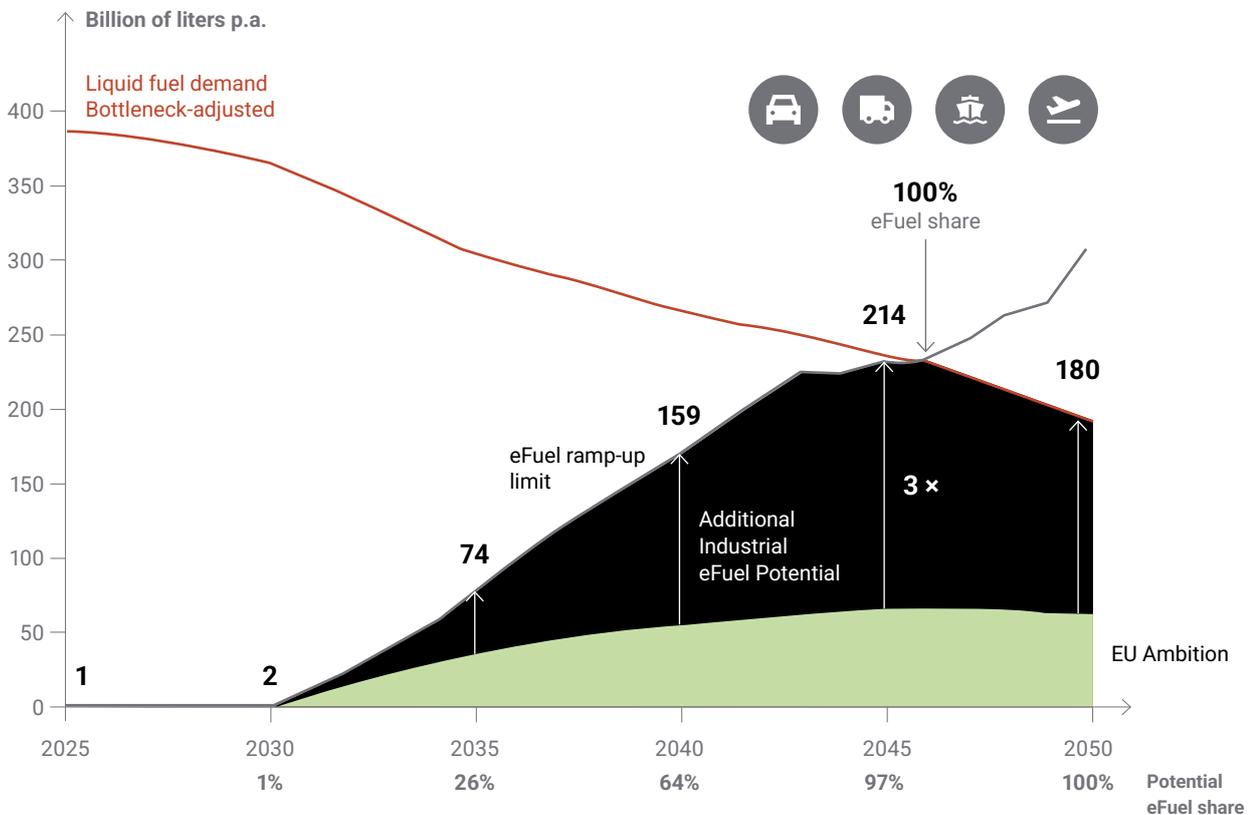

Figure 5: Annual liquid fuel demand in EU mobility in the "Bottleneck-adjusted" scenario and eFuel ramp-up: "EU Ambition" vs. "Industrial eFuel Potential" scenario.
Scope: gasoline, diesel, fuel oil, methanol, ammonia, and jet fuel | Fuel volume in billion liters gasoline equivalent

Under the "EU Ambition" scenario, a significant ramp-up of eFuels in mobility is expected between 2030 and 2040, with demand rising to more than 50 billion liters of gasoline equivalent across the four mobility segments. After 2045, eFuel demand is projected to stagnate, based on the assumption that the powertrain transition will accelerate, resulting in minimal liquid fuel demand for on-road mobility beyond 2045. Additionally, sustainable biofuels—though not illustrated here—are anticipated to play a substantial role in reducing CO_2 emissions within the "EU Ambition" scenario.

By 2045, the eFuel market could reach 200 billion liters of gasoline equivalent, achieving a 100 percent eFuel quota the following year—assuming a delayed phase-out of liquid fuels in on-road mobility as outlined in the "Bottleneck-adjusted" scenario.

In contrast, the "Industrial eFuel Potential" scenario indicates that the eFuel ramp-up could accelerate significantly after 2030, with cumulative volumes potentially reaching three times those projected in the "EU Ambition" scenario. By 2045, the eFuel market could reach 200 billion liters of gasoline equivalent, achieving a 100 percent eFuel quota the following year—assuming a delayed phase-out of liquid fuels in on-road mobility as outlined in the "Bottleneck-adjusted" scenario.

These findings have implications for CO_2 emissions in mobility, which were calculated using a life cycle approach. This methodology includes vehicle production, energy supply chains (well-to-tank), and vehicle use (tank-to-wheel) within the modeling scope. For each powertrain technology, production-related emissions decline over time, driven by improvements in manufacturing and the decreasing carbon intensity of the energy mix. Similarly, energy supply and vehicle use emissions (well-to-wheel) decrease as the energy mix evolves. At the fleet level, the phase-out of fossil energy sources, combined with efficiency gains from on-road electrification, leads to a steady reduction in annual carbon emissions over time.

The Paris Climate Conference in 2015 set a global climate target to limit warming to 1.75°C (or well below 2°C) above pre-industrial levels. To achieve this, the IPCC estimated a remaining CO_2 budget[2] of approximately 1,400 Gt CO_2 as of January 1, 2018, to avoid exceeding the 1.75°C threshold with a 50 percent likelihood. After accounting for global CO_2 emissions through 2024[3], the residual budget is estimated at 700 Gt CO_2 as of early 2025. Allocating a share of this budget to the

EU based on its population proportion, and then to EU mobility according to its emission share among EU sectors[4], results in approximately 19 Gt CO_2 available for EU mobility starting in 2025. This allocation includes life cycle emissions, covering vehicle production, energy supply (well-to-tank), and vehicle use (tank-to-wheel).

To evaluate progress toward climate targets in EU mobility, cumulative CO_2 emissions were calculated and compared with the allocated residual CO_2 budget starting in 2025. Three scenarios were assessed and are illustrated in Figure 6: the "EU Ambition" scenario, the "Bottleneck-adjusted" scenario, and the "Industrial eFuel Potential" scenario.*

* Derived from the "Bottleneck-adjusted" scenario and considering the additional industrial potential of eFuels.
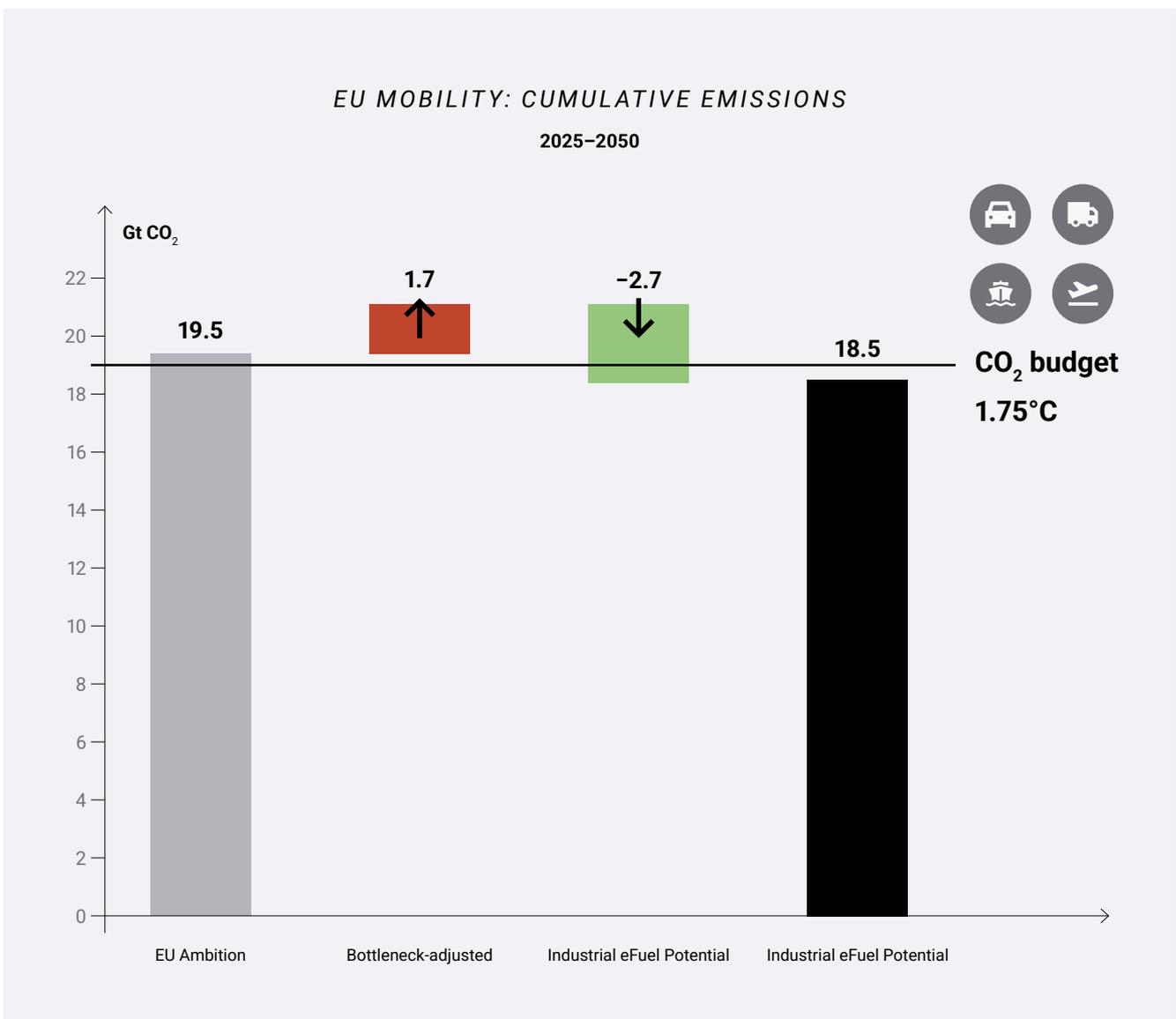
EU MOBILITY: CUMULATIVE EMISSIONS
2025−2050

Figure 6: Cumulative life cycle CO_2 emissions in EU mobility in billion tons CO_2 (Gt): "EU Ambition" vs. "Bottleneck-adjusted" vs. "Industrial eFuel Potential" scenario.

From an industrial feasibility perspective, eFuels can serve as a key lever to achieve climate targets, even if the powertrain transformation in EU mobility is delayed.

The "EU Ambition" scenario roughly meets the CO_2 budget for 1.75°C, provided carbon neutrality is achieved by 2050 in line with European climate targets. In the "Bottleneck-adjusted" scenario, additional liquid fuel demand caused by the delayed powertrain transition could increase cumulative emissions by up to 1.7 Gt CO_2, exceeding the allocated budget for EU mobility. However, by accelerating the eFuel ramp-up to its full industrial potential, these additional emissions can be offset, enabling compliance with the CO_2 budget.

In conclusion, from an industrial feasibility perspective, eFuels can serve as a key lever to achieve climate targets, even if the powertrain transformation in EU mobility is delayed.

Numerous projects plan market entry, currently facing financing challenges.

Significant activity has emerged in the eFuel industry over the past few years, with more than 500 global eFuel projects recently announced. This analysis focuses on fuel types expected to be highly relevant for mobility by 2030: eMethanol, eSAF, eGasoline/eNaphtha, eMethane, and eDiesel. Current announcements indicate strong growth in eFuel supply through 2030, with all regions contributing to the ramp-up—particularly China and Europe.

By 2030, many new players are expected to enter the eFuel market. According to industry announcements, HIF Global is projected to lead production, accounting for 12 percent of global capacity by 2030, with several large-scale projects planned in regions such as South America, the USA, and Australia. Key players from China are planning—and in some cases already constructing—large-scale eMethanol plants in Inner Mongolia, leveraging low-cost renewable energy and representing 18 percent of global announced production by 2030. Other emerging players include Denmark-based European Energy, which has large-scale projects planned in Europe. In total, more than 120 companies have been identified with eFuel scaling plans through 2030, resulting in a highly fragmented supply landscape.

The database reveals a strong focus on eMethanol, which accounts for 82 percent of announced capacity by 2030—particularly in China, where methanol is viewed as a means to reduce oil dependency and decarbonize on-road mobility and shipping. In addition, eMethanol serves as a versatile platform fuel for all mobility segments. Other fuels, such as eSAF, eGasoline/eNaphtha, and eMethane, are also slated for scaling, each representing roughly 5 percent of projected eFuel production by 2030, while eDiesel is not prioritized and mainly appears as a byproduct in

BY COMPANY

2030
eFuel project capacities

~20B l

12%	HIF
5%	MINGYANG
5%	内蒙古源源能源集团有限责任公司 Inner Mongolia Yuanyuan Energy Group Co., Ltd.
4%	CGN
3%	CARBON RECYCLING INTERNATIONAL
2%	
2%	
2%	
2%	
2%	

INERATEC Aalborg Forsyning

INFINIUM ABEL ENERGY

Liquid Wind Arcadia eFuels

MADOQUA TOKYO GAS

CRRC Nordic Electrofuel

Ørsted SPIC

SunGas RENEWABLES BIO GASCLEAN

CEEC
EUROPEAN ENERGY
GOLDWIND
ReNew POWER
Elyse

25% Others

BY FUEL TYPE

- eMethanol
- eGasoline/eNaphtha
- eMethane
- eSAF
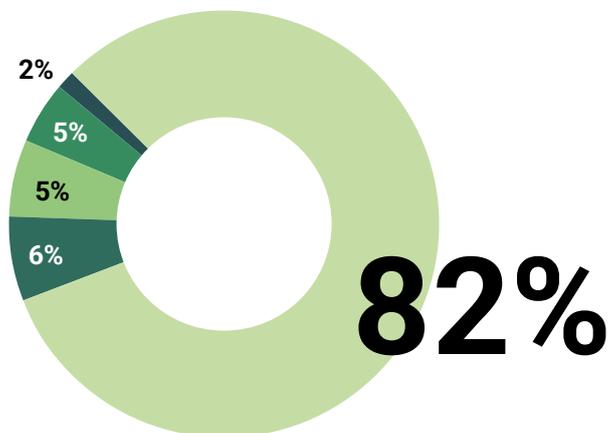- eDiesel

2%
5%
5%
6%
82%
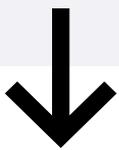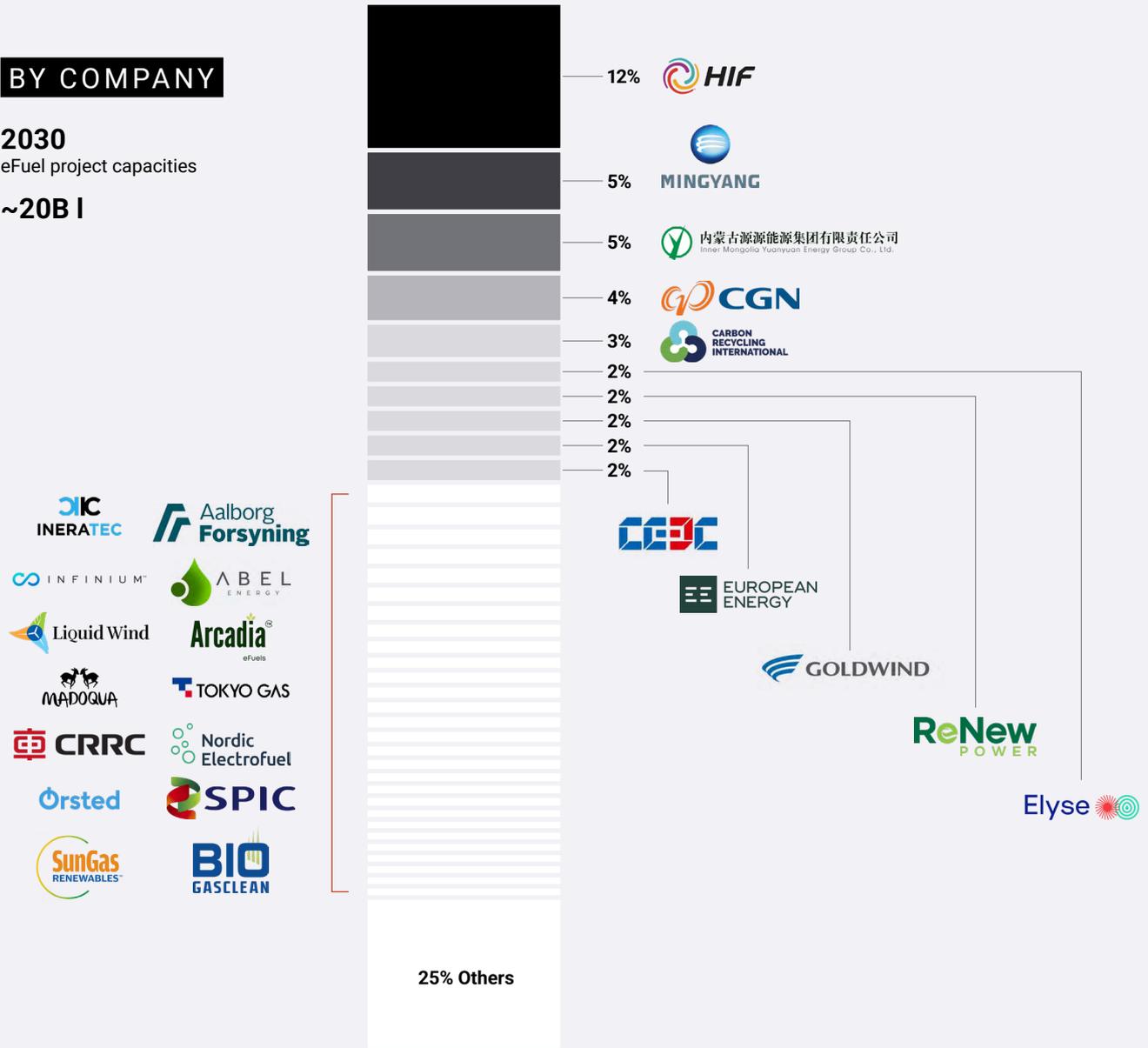
Figure 7: Market share of eFuel production by company and by fuel type based on global announced production in 2030.
Source: Porsche Consulting eFuel Project Tracker, eFuel Alliance[5], IEA[6], Methanol Institute[7] | Scope: eMethanol, eSAF, eGasoline/eNaphtha, eMethane, eDiesel | Fuel volume in billion liters gasoline equivalent | SAF: Sustainable Aviation Fuel

announced projects. High growth is anticipated for eSAF through 2030, and the market balance could shift in its favor over the long term. Furthermore, eMethanol can be converted into eGasoline or eSAF—a detail not always specified in current announcements—which could influence the market share among fuel types by 2030.

While numerous stakeholders have announced plans to scale up eFuel production by 2030, several challenges could delay project execution. Project progress has been tracked across stages: concept or feasibility study, Front-end engineering design (FEED), Final investment decision (FID), construction, and operation. Currently, financing has been secured for only

A supportive regulatory framework and robust ramp-up strategies are essential to unlock eFuel investments.

6 percent of the eFuel capacity planned for 2030, most of which is under construction, with a small portion already operational. Conversely, 94 percent of the announced capacity has not yet reached FID. A significant share—76 percent of total capacity—is still in the concept or feasibility phase, while 14 percent is in engineering and design or awaiting offtaker and investor commitments to secure financing. The FID remains a critical barrier for the eFuel industry. The coming months will be decisive for initiating operations before 2030, given that construction and commissioning can take up to four years. Regulatory uncertainty is a major factor deterring long-term commitments from offtakers and investors. A supportive regulatory framework and robust ramp-up strategies are essential to unlock eFuel investments.

A supportive regulatory framework can unlock eFuel investments.

The mobility transformation outlined in Scenario 3 of the European Commission's 2024 Impact Assessment report—referred to as the "EU Ambition" scenario—is likely to face delays due to bottlenecks in the battery supply chain. In contrast, the industrial feasibility assessment for eFuels indicates the potential to accelerate their ramp-up from 2030 onward to meet climate targets. However, the current state of the eFuel industry still reveals significant weaknesses, which result in limited financing for European projects.

The European Union has established a comprehensive regulatory framework for eFuels, incorporating multiple instruments to stimulate both demand and supply in the mobility sector, particularly in maritime and aviation transport. Remaining challenges to unlock project financing can be addressed by leveraging these established instruments. On the

supply side, long-term project risk remains high due to restrictions on eFuel production. Evolving requirements over time create uncertainty regarding the long-term compliance of initial projects. On the demand side, long-term offtake commitments are lacking, as current demand projections remain low due to insufficient quotas. Furthermore, the regulation primarily targets aviation and maritime segments, for example by setting mandates for aircraft operators, who have limited ability to commit to long-term volume contracts. Consequently, risk levels for production and offtake do not align with investors' expectations, hindering project financing. Several measures could help mitigate project risk on both the supply and demand sides.

On the supply side, aligning long-term eFuel production criteria is essential. In particular, the requirements for temporal correlation with renewable electricity supply should be made more flexible to strengthen market development. Introducing grandfathering provisions for initial projects—should production standards change—could reduce long-term supply risks for offtakers and revenue risks for investors. Additionally, integrating unavoidable industrial CO_2 sources into eFuel production standards could accelerate the ramp-up, especially in regions with limited access to biogenic sources. The adoption of internationally recognized sustainability certificates for CO_2 sources would ensure the sustainability of imported eFuels and support imports from regions with low-cost renewable energy.

On the demand side, long-term offtake commitments can be secured by increasing eFuel quotas with clear long-term projections and defined conditions for non-compliance. Rewarding over-fulfillment of quotas through additional multipliers and credit banking could further incentivize commitments.

Leveraging existing funding schemes—such as SAF Allowances, the EU Innovation Fund, and the European Hydrogen Bank—is essential. Specifically, competition with other eligible technologies can be reduced by introducing dedicated maritime and aviation budgets in European Hydrogen Bank auctions. Within the EU Emissions Trading System (ETS), increasing the number of Allowances specifically for eSAF projects would help airlines offset eSAF costs, reducing competition with bioSAF and enhancing the attractiveness of eSAF offtake. Additionally, allocating eSAF Allowances for the full duration of the offtake agreement, rather than annually, would provide long-term revenue certainty under the ETS. Furthermore, recognizing eFuel use in other

mobility sectors can stimulate demand. For example, introducing eFuel crediting in CO_2 standards for on-road mobility—already implemented in Switzerland—would be effective. Overall, this measure would promote economies of scale, lower investment costs, and mitigate investment and offtake risks through cross-industry risk-sharing.

In conclusion, increasing the attractiveness of eFuel projects and stimulating offtake and financing commitments requires leveraging existing regulatory instruments. Pragmatic production standards, strengthened demand through ambitious quotas in the RED, ReFuelEU Aviation, and FuelEU Maritime, as well as a technology-neutral CO_2 fleet regulation for new vehicles are essential. Investment appeal can be strengthened through collaboration between eFuel producers and cross-industry offtakers, combining cost reductions with scaling strategies and implementing risk-sharing structures. Together with a robust and reliable regulatory framework, these measures are key to unlocking the eFuel ramp-up in Europe and maximizing their contribution to achieving climate targets.

Pragmatic production standards, strengthened demand through ambitious quotas in the RED, ReFuelEU Aviation, and FuelEU Maritime, as well as a technology-neutral CO_2 fleet regulation for new vehicles are essential.

IN BRIEF

▸ Internal combustion engines (ICEs) are expected to remain relevant across all mobility fleets until 2040, particularly in shipping and aviation.

▸ The EU Commission's ambitious plans for widespread adoption of battery electric vehicles (BEVs) in on-road mobility exert significant pressure on battery and energy supply chains. Simultaneous ramp-up initiatives in other regions may lead to shortages, underscoring the need for strategic planning and long-term investments.

▸ If the powertrain transformation in mobility does not progress as swiftly as planned by the EU, liquid fuel demand will remain higher than anticipated, potentially delaying carbon savings.

▸ From an industrial feasibility perspective, the ramp-up of eFuels can be accelerated to achieve climate targets, even if the mobility powertrain transition is delayed.

▸ Numerous projects are preparing to enter the eFuel market; however, they currently face financing challenges. Reaching final investment decision (FID) in the coming months will be crucial to enable operations by 2030. Unlocking eFuel project financing will require regulatory support and robust ramp-up strategies.

▸ To increase the attractiveness of eFuel projects and stimulate offtake and financing commitments, existing regulatory instruments can be leveraged. Aligning eFuel production standards can mitigate long-term compliance risk, while increasing eFuel quotas and introducing eFuel crediting across industries can secure demand.

▸ Moreover, eFuel offtake and financing commitments can be further stimulated through collaboration between eFuel producers and cross-industry offtakers, leveraging unit cost reductions synchronized with scaling strategies, while providing risk-sharing structures.

Background, scope and objective of the study

The Paris Climate Conference in 2015 set a global target to limit warming to 1.75°C (or well below 2°C) above pre-industrial levels. To achieve this, the IPCC highlighted in its 2018 report[2] that a global CO_2 budget must be respected. While the European Union has not directly committed to a CO_2 budget, it has pledged—through the Green Deal—to achieve net-zero greenhouse gas (GHG) emissions across all sectors by 2050.

While sectors such as power generation have achieved significant emission reductions in recent years, mobility remains one of the most challenging areas to decarbonize due to its reliance on fossil fuels and the complexity of transitioning large, diverse fleets. Achieving carbon neutrality will require coordinated action across policy, industry, and society, supported by innovative technologies and infrastructure. Recent EU initiatives, such as the "Fit for 55" package, have introduced ambitious targets—e.g., a 100 percent reduction in tailpipe emissions for new passenger cars and vans by 2035—sparking debates on the role of technologies like eFuels and electrification. However, current regulatory frameworks often focus narrowly on tank-to-wheel emissions, overlooking life cycle impacts such as emissions from vehicle production and energy supply chains (well-to-tank). Life cycle analyses show that a sector-specific approach risks falling short of climate objectives, underscoring the need for an integrated strategy that leverages a mix of technologies across all mobility segments.

→ Mobility plays a critical role in this transition: in 2023, transport-related activities accounted for 794 Mt CO_2eq[8], representing over 25 percent of the EU's total GHG emissions of more than 2,900 Mt CO_2eq[4]. Despite technological improvements, rising mobility demand has largely offset efficiency gains, keeping emissions at persistently high levels.

Decarbonizing mobility is therefore a cornerstone of the EU's climate strategy. This challenge spans four major segments:

· Passenger cars, which dominate road transport emissions;
· Trucks and buses, essential for freight and public transport;
· Maritime shipping, a backbone of global trade and European logistics;
· Aviation, a sector with growing demand and limited alternatives to liquid fuels.

Among other technologies, eFuels offer a viable solution to reduce life cycle CO_2 emissions in mobility. However, their potential contribution to meeting climate targets within European mobility fleets remains unclear, creating uncertainty for ramp-up planning. This study was designed to evaluate the eFuel market potential for on-road, aviation, and maritime segments based on an assessment of different scenarios. The main objective is to provide transparency on the impact of EU fleet transformation scenarios on climate target compliance and to identify the potential role of eFuels in this context. After outlining current challenges, the study defines measures to facilitate the eFuel ramp-up and increase their contribution to meeting the remaining CO_2 budget for European mobility.

Among other technologies, eFuels offer a viable solution to reduce life cycle CO_2 emissions in mobility. However, their potential contribution to meeting climate targets within European mobility fleets remains unclear, creating uncertainty for ramp-up planning.

In maritime shipping and aviation, fleet renewal has limited impact on the powertrain transition due to significantly longer lifetimes compared to on-road mobility. Additionally, international journeys add complexity to European fleet modeling. The technical feasibility of alternative powertrains is also limited in aviation, while ship operators can increase flexibility by using dual-fuel engines in new vessels and retrofitting existing vessels with alternative technologies. Therefore, for these segments, the assessment focused on the energy fueled at European ports and airports, rather than modeling powertrain evolution. This approach considered intercontinental and intracontinental shipping for all vessels over 400 GT, including container ships, bulk carriers, oil tankers, LNG carriers, passenger ships, chemical tankers, and gas carriers. In aviation, the analysis covers all major fixed-wing civil aircraft types in service across Europe—short-, medium-, and long-haul—and includes flights within the European Economic Area (EEA) as well as extra-European routes.

Across the four mobility segments, several powertrain and energy transformation scenarios were assessed.

The first scenario was derived from the European Commission's 2024 Impact Assessment and designed to meet EU climate targets—achieving a 55 percent reduction in CO_2 emissions by 2030 compared to 1990 levels, a 90 percent reduction by 2040, and climate neutrality by 2050. While this scenario does not reflect current EU regulations, it provides insight into the Commission's intentions for mobility transformation and will be referred to as the "EU Ambition" scenario.

The second scenario was based on an industrial feasibility analysis of the "EU Ambition" scenario. Critical bottlenecks in powertrain and energy supply chains were identified and

Within the EU27, four mobility segments were selected for this analysis due to their highest share of greenhouse gas emissions among all mobility sectors: passenger cars, trucks and buses, maritime shipping, and aviation. The transformation was assessed across two key dimensions that directly influence life cycle CO_2 emissions in EU mobility: powertrain and energy.

In on-road mobility segments, the powertrain and energy transformations were evaluated by modeling both fleets and their respective energy demands across several scenarios with varying powertrain and energy quotas. On-road fleet stock was defined based on registered vehicles in the EU27: the passenger car segment includes individual mobility and light commercial vehicles,* while the truck and bus segment covers medium and heavy commercial vehicles as well as buses.

* Fulfill a maximum gross vehicle weight requirement of 3.5 tons.

quantified to evaluate the likelihood of success. Other influencing factors—such as regulatory changes, geopolitical dynamics, customer trends, social acceptance, and economic shocks—were not assessed. Based on this bottleneck analysis, the transformation under the "EU Ambition" scenario was adjusted in time to ease supply chain pressure while maintaining consistency with the original transformation. This scenario is referred to as the "Bottleneck-adjusted" scenario.

The third scenario was developed to assess the industrial potential of eFuels in decarbonizing EU mobility. Industrial limitations were identified through a bottleneck assessment of eFuel supply chains, and the scenario was designed to maximize the eFuel ramp-up speed within these constraints, building on the "Bottleneck-adjusted" scenario. This transformation is referred to as the "Industrial eFuel Potential" scenario.

These three scenarios are introduced in detail in → *Chapters 3, 4, and 5*, respectively. For each, annual CO_2 emission reductions and compliance with the CO_2 budget were evaluated.

Finally, the status quo of the eFuel industry was examined in → *Chapter 6* through a data analysis of announced production capacities, providing transparency on current market challenges. As a result, this study identified both the potential and the limitations of eFuels and outlined the actions required to maximize their contribution to carbon savings in EU mobility.
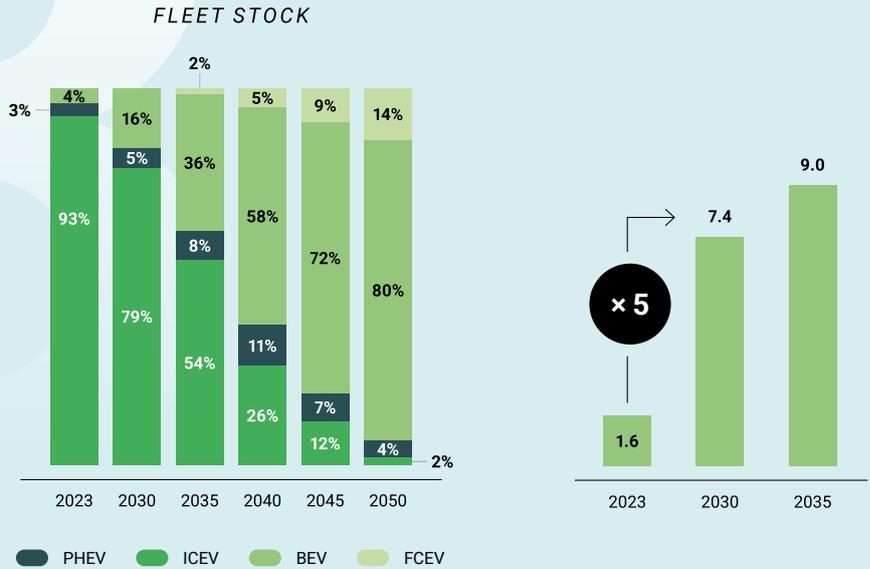
The study was conducted in four phases, as illustrated in Figure 8, and is detailed in → *Chapters 3 to 6*. ●

3 EU mobility transformation

"EU AMBITION" SCENARIO

According to EU plans, a fast power-train & energy & transformation is required

FLEET STOCK

Legend: PHEV, ICEV, BEV, FCEV

2023: 3% PHEV, 93% ICEV, 4% BEV
2030: 4%, 79% ICEV, 16% BEV, 5%
2035: 2%, 54% ICEV, 36% BEV, 8%
2040: 5%, 26% ICEV, 58% BEV, 11%
2045: 9%, 12% ICEV, 72% BEV, 7%
2050: 14%, 2%, 80% BEV, 4%

×5
2023: 1.6
2030: 7.4
2035: 9.0

---

4 Bottleneck analysis

"BOTTLENECK-ADJUSTED" SCENARIO

BEV ramp-up is expected to be delayed, action is required for climate targets

Bottleneck factor		2025–2029	2030–2034	2035–2039	2040–2044	2045–2050
Battery Global	01 Lithium mining & refining					
	02 Nickel mining & refining					
	03 Cobalt mining & refining					
	04 Graphite mining & refining					
	05 AAM production					
	06 CAM production					
	07 Cell production					
Electricity EU	08 Wind power equipment					
	09 PV power equipment					
	10 Wind power installation					
	11 PV power installation					
	12 Transmission grid					
	13 Distribution grid					
	14 Public charging					
Hydrogen EU/Global	15 Wind power equipment					
	16 PV power equipment					
	17 Wind power installation EU					
	18 PV power installation EU					
	19 Electrolysis equipment					
	20 H_2 plant installation EU					
	21 H_2 plant installation global					
	22 H_2 pipeline					
	23 Fuel cell					
eFuels Global	24 Wind power equipment					
	25 PV power equipment					
	26 Electrolysis equipment					
	27 eFuel plant installation					

Callouts: Lithium: ~30% deficit; Nickel: ~20% deficit; Graphite: ~5% deficit; Power grid: ~10–20% deficit; Green hydrogen plants: ~50% deficit; Fuel cell production: ~20% deficit

Supply/demand deviation
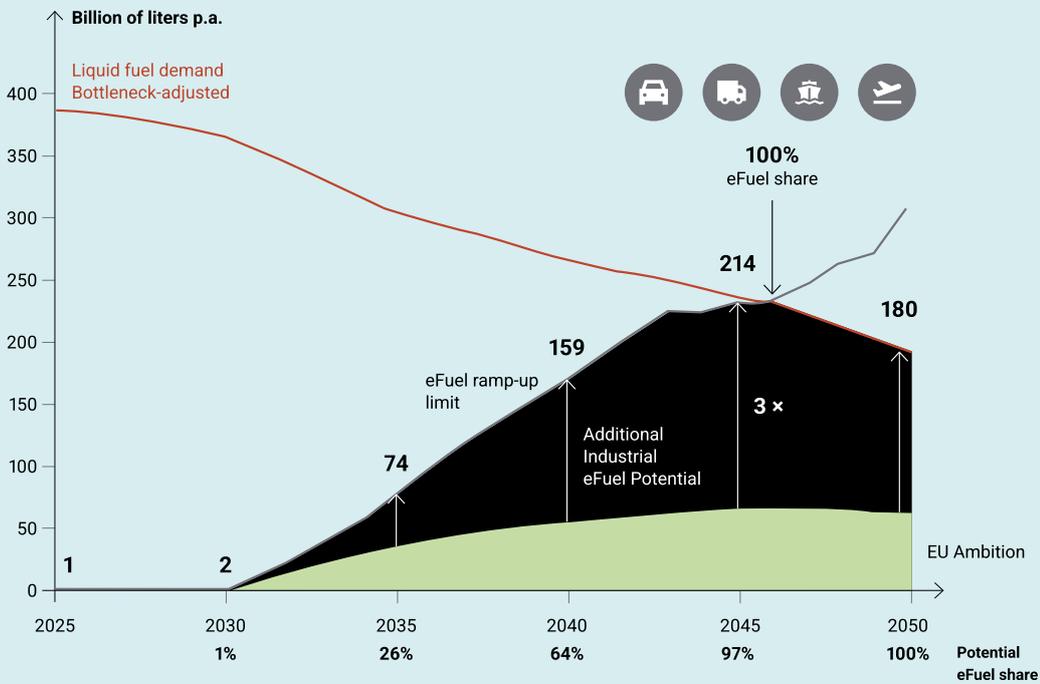−25% or more — 0% — +25% or more

Figure 8: Structure of the study.

5   eFuel market potential

"INDUSTRIAL eFUEL POTENTIAL" SCENARIO

eFuels could potentially ramp-up faster, which could close decarbonization gap

Billion of liters p.a.

Liquid fuel demand
Bottleneck-adjusted

100%
eFuel share

214

159

eFuel ramp-up
limit

74

3 ×

Additional
Industrial
eFuel Potential

180

EU Ambition

2025	2030	2035	2040	2045	2050	Potential eFuel share
1	2					
	1%	26%	64%	97%	100%	

---

6   eFuel status quo

POTENTIALS
AND CHALLENGES

eFuels are on a strong growth path to 2030, but
projects still lack financing
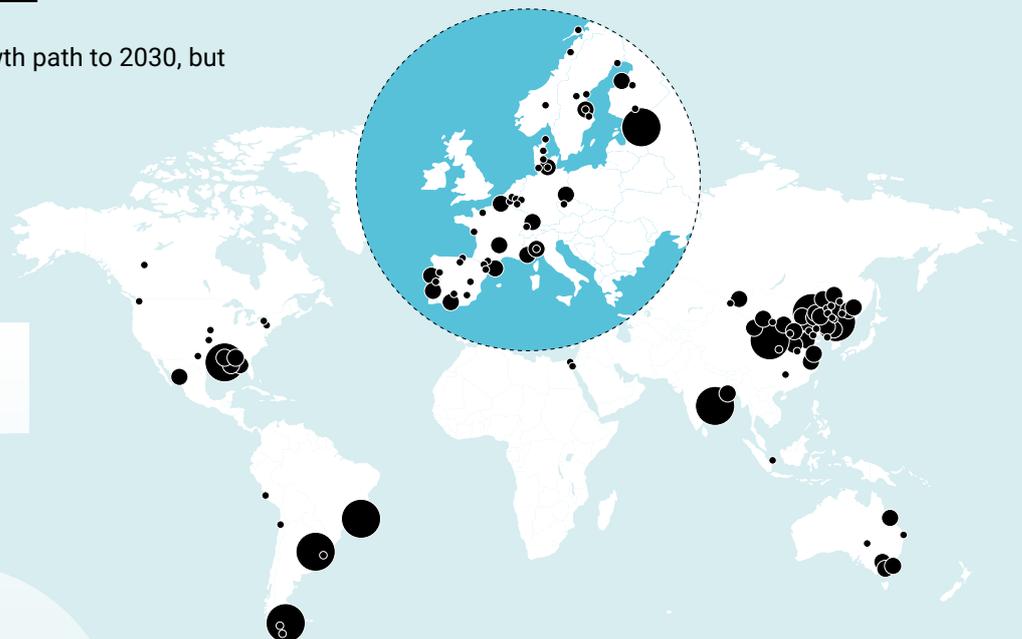
EU mobility transformation: "EU Ambition" scenario

↓

3.1. Introduction to the European Commission's Impact Assessment

The primary goal of this study was to analyze the mobility transformation planned by the European Union through 2050. To align with the EU's climate targets, a reliable and official source of information was required. However, the current state of European regulatory instruments does not allow for a precise transformation forecast beyond 2035. The European Commission's Impact Assessment is a structured process used during the preparation of new EU initiatives—both legislative and non-legislative—to evaluate necessary actions and analyze the potential economic, social, and environmental impacts of available options. It provides an evidence base for decision-making and supports the Commission in designing effective and proportionate policies. Reports are published alongside legislative proposals and shared with the European Parliament and Council. The 2024 Impact Assessment report[1] offers a comprehensive analysis of transformation scenarios across various sectors. Scenario 3 was designed to meet EU climate targets—achieving a 55 percent reduction in CO_2 emissions by 2030 compared to 1990 levels, a 90 percent reduction by 2040, and climate neutrality by 2050. For this reason, Scenario 3 has been set as the basis for understanding the EU's mobility transformation plan and will be referred to as the "EU Ambition" scenario.

3.2. Methodology, modelling and data collection

3.2.1. Fleet & powertrain

To analyze the ramp-up speed of different powertrain technologies, a fleet model was developed. The European Commission's Impact Assessment report does not provide fleet stock sizes in terms of vehicle numbers but specifies powertrain shares for the years 2030, 2040, and 2050 across the following segments: passenger cars, trucks and buses, and national and international navigation. No detailed powertrain forecast is provided for aviation; however, the report includes energy demand data for all four mobility segments examined in this study. Data availability from the European Commission's Impact Assessment report is illustrated in Figure 9.
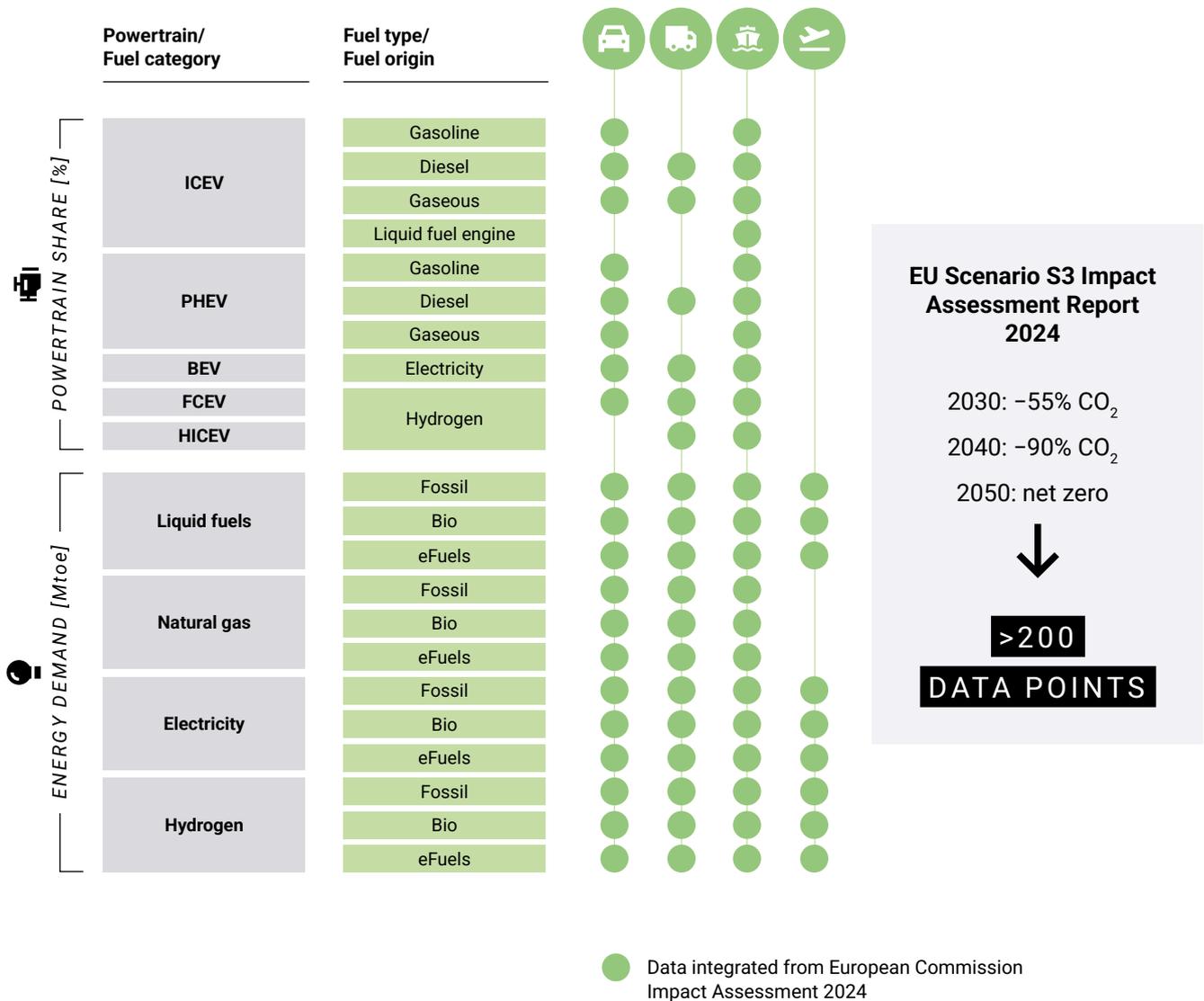

Figure 9: Available data from the European Commission's Impact Assessment report to model powertrain and energy transformation.

In on-road mobility, a fleet model is essential to derive detailed annual CO_2 emissions, which are critical for calculating cumulative emissions—the basis for ensuring compliance with climate targets according to the CO_2 budget. In a life cycle analysis, annual CO_2 emissions are driven by both energy demand and vehicle production. The methodology for CO_2 calculation is detailed in → *Section 3.2.3*. To estimate energy-related and vehicle production-related emissions, a model was developed to simulate the number of vehicles for each powertrain at both fleet stock and new registration levels. In the "EU Ambition" scenario, the model uses fleet stock powertrain shares stated in the Impact Assessment report for the data point years 2030, 2040, and 2050 as targets. For each year until 2050, new registrations were modeled to achieve these targets across all powertrains: gasoline, diesel, and methane ICEV; gasoline, diesel, and methane PHEV; BEV; FCEV; and HICEV. For PHEV passenger cars, the Impact Assessment report does not specify the share of diesel, gasoline, and methane. These shares were aligned with the corresponding shares of the ICEV powertrain.

In the next step, fleet stock size was derived for each powertrain between the data point years. For example, in the passenger car segment, the targeted BEV share is 16 percent in 2030 and 58 percent in 2040. This implies that the BEV fleet stock will grow from 33 million to 120 million vehicles. New BEV registrations were modeled to cover this increase of 87 million vehicles over the decade, based on a linear year-on-year ramp-up. Additionally, new registrations compensate for vehicles exiting the fleet at the end of their natural life cycle.

Since the European Commission's Impact Assessment report does not provide fleet stock sizes in number of vehicles, fleet stock data was aligned by clearly separating two

on-road mobility segments. The passenger car segment includes both individual mobility and light commercial vehicles,* while the truck & bus segment covers medium and heavy commercial vehicles as well as buses. Assuming demand for on-road mobility remains stable in the coming decades, fleet stock size was modeled to remain constant at 2025 levels for the data point years 2030, 2040, and 2050. The 2025 fleet stock size was estimated based on historical new registrations, assuming an average vehicle lifetime of 16 years for passenger cars (according to a recent Umweltbundesamt study[9]) and 8 years for trucks and buses segment. While actual lifetimes vary by use case, applying category-specific averages provides a robust estimate of fleet stock size and the penetration speed of new powertrains. New registration data was sourced from ACEA[10] up to 2023, and values for 2024 and 2025 were defined as the average of annual registrations between 2015 and 2023. Over this period, annual new registrations averaged 12 million passenger cars and 380,000 trucks and buses. Under the assumption that fleet stock size remains stable until 2050, annual new registrations will also remain at similar levels.

* Fulfill a maximum gross vehicle weight requirement of 3.5 tons.

	Annual new registrations	Fleet stock	Average lifetime
🚗	12.3 million	208.7 million	16 years
🚚	379,579	2.7 million	8 years

Figure 10: Assumptions on EU on-road fleet data and average lifetime in 2025.

As a result, the passenger car fleet stock accounts for 208.7 million vehicles and the truck & bus fleet stock for 2.7 million vehicles in 2025, 2030, 2040, and 2050. Between these data point years, the model calculates new registrations and fleet stock sizes to achieve the powertrain share targets defined in the "EU Ambition" scenario.

In the aviation sector, energy demand data from the Impact Assessment report clearly indicates that in the "EU Ambition" scenario, liquid fuels will remain the dominant energy source, accounting for 99 percent in 2040 and 93 percent in 2050. Additionally, aviation fleet renewal occurs much more slowly than in on-road mobility, and CO_2 emission analysis focuses on energy-related emissions, which represent about 90 percent of life cycle emissions. Decarbonization goals in this segment are therefore driven by the energy used rather than the powertrain. Considering these factors, an energy demand model is best suited to analyze the transformation in aviation.

Similar considerations apply to the maritime segment, where fleet renewal has very limited impact on the powertrain transition due to significantly longer lifetimes—over 30 years compared to an average of eight years for trucks and buses and 16 years for passenger cars. Moreover, ship operators already have options to increase flexibility by using dual-fuel engines in new vessels and retrofitting existing vessels with alternative engine technologies. In this segment, the energy transition will also be the key driver of decarbonization.

3.2.2. Energy demand

In the European Commission's Impact Assessment, energy demand is provided for 2015, 2030, 2040, and 2050 for each mobility segment analyzed in this study. The Impact Assessment report specifies the physical form of the fuel—e.g., liquid or gas—but does not explicitly name the fuel type for liquids such as gasoline or diesel. For on-road mobility, the fleet model developed in this study was used to allocate each energy type to the corresponding powertrain and derive demand based on powertrain shares and fuel energy content. In the maritime and aviation segments, no differentiation was made by the European Commission between fuel types; liquid fuel is referred to as marine fuel and jet fuel, respectively. Marine fuel is assumed to include fuel oil, diesel, methanol, and ammonia, while jet fuel includes kerosene.

In this study, energy analyses were conducted using a standardized metric: the liter of gasoline equivalent. This unit was selected because it provides an intuitive and widely recognized reference for energy content among European consumers. Employing the liter of gasoline equivalent as a common basis facilitates a consistent and comprehensive comparison of energy demand across different energy carriers.

In on-road mobility, energy demand is directly correlated with fleet stock size for each powertrain. Therefore, energy demand data points provided by the Impact Assessment report for 2015, 2030, 2040, and 2050 were coupled with the fleet model for each year up to 2050. This approach increases precision in modeling energy demand across all energy types.

For each powertrain and its corresponding energy type in the data point years 2030, 2040, and 2050, average annual energy consumption

per vehicle was calculated by dividing the fleet-level energy demand provided in the Impact Assessment report by the fleet stock size derived from the fleet model. Since no data point exists in the Impact Assessment report for 2025, annual vehicle energy consumption was assumed to be equal to 2030 values for all powertrains and energy types. Between data point years, the evolution of annual energy consumption per vehicle was determined through linear interpolation, enabling a year-by-year estimate for each powertrain technology until 2050.

For example, an average gasoline passenger car shows an increase in annual consumption from 1,102 liters in 2030 to 1,366 liters in 2050. In contrast, the average electricity consumption of BEVs decreases over time—from 2,267 kWh in 2030 to 2,093 kWh in 2050. This opposing trend is not explained in the European Commission's Impact Assessment report and results from the assumption that fleet stock size remains constant. The decrease in BEV energy consumption can be interpreted as a shift in usage: currently, BEVs attract large-size car users with high mileage, but in the long term, they are expected to be used in smaller cars with shorter mileage as well. Conversely, gasoline cars are currently concentrated in smaller vehicles with low annual consumption, but over time, they are expected to serve use cases with higher mileage and range requirements—explaining the increase in average annual consumption.

For each energy type and each year until 2050, fleet-level energy demand was calculated by multiplying the average annual energy consumption per vehicle by the fleet stock size of the corresponding powertrain.

The European Commission's Impact Assessment simulates the deployment of low-carbon energy sources and provides assumed shares

	ICEV gasoline	BEV
🚗	**~1,100 l p.a.**	**~2,250 kWh p.a.**
🚚	**~20,000 l p.a.**	**~67,300 kWh**

Figure 11: Average annual energy consumption of passenger cars, trucks and buses, exemplary for ICEV gasoline and BEV in 2025.

for the data point years 2015, 2030, 2040, and 2050. For example, in passenger car mobility, the share of biofuels is projected to increase from 7 percent in 2030 to 27 percent in 2040 and 30 percent in 2050. However, the European Commission's Impact Assessment does not distinguish between conventional and advanced biofuels; the reported quotas apply to all biofuel types collectively. Furthermore, the assessment differentiates fuel deployment across mobility segments. For example, the projected ramp-up of eMethane is expected to occur more rapidly in the shipping sector compared to trucks and buses—21 percent versus 7 percent by 2040, and 45 percent versus 38 percent by 2050, respectively.

For each energy type, the shares of individual energy sources were determined for every year up to 2050 using linear interpolation between the reference points for 2015, 2030, 2040, and 2050. These shares were then multiplied by the corresponding energy demand for each energy type to calculate the demand by source. This step is essential for assessing CO_2 emissions.

As highlighted in → *Section 3.2.1.*, fleet renewal has minimal impact on energy demand in the maritime and aviation segments, where decarbonization is driven by the energy used rather than the powertrain. For this reason, energy demand in these segments was not coupled with the fleet model. Instead, to model energy demand, a linear interpolation was applied between the years 2015, 2030, 2040, and 2050.

3.2.3. CO$_2$ emissions

To estimate CO$_2$ emissions in the EU mobility segments analyzed in this study—passenger cars, trucks and buses, shipping, and aviation—specific methodological approaches were defined.

In on-road mobility, CO$_2$ emissions were analyzed at the vehicle level across the entire life cycle, followed by modeling at the fleet level. Life cycle emissions include those generated during vehicle production, energy supply, and vehicle use. From this point forward, these will be referred to as "vehicle production," "well-to-tank," and "tank-to-wheel" emissions, respectively. "well-to-wheel" emissions combine both well-to-tank and tank-to-wheel stages. All three emission factors are strongly influenced by the choice of powertrain and the energy source used by the vehicle.

In on-road mobility, CO$_2$ emissions were analyzed at the vehicle level across the entire life cycle, followed by modelling at the fleet level.

The choice of powertrain directly affects CO$_2$ emissions from both vehicle production and tank-to-wheel operation. For instance, for an average truck and bus segment vehicle produced in 2025, production emissions are lower for a diesel ICEV—43 tons of CO$_2$—compared to a BEV, which emits 87 tons of CO$_2$. For each powertrain type, average production emissions were derived from detailed analyses by Umweltbundesamt and IFEU[9]. Over time, the reduction in CO$_2$ intensity of the energy mix decreases production-related emissions. Based on results provided by the study for 2020, 2030, and 2050, interpolations were aligned to the evolution of the European electricity mix assumed in the "EU Ambition" scenario. For example, by 2040, producing an average diesel ICEV in the truck and bus segment results in 22 tons of CO$_2$: half the 2025 level. A similar trend is modeled for BEVs, with emissions dropping to 43 tons of CO$_2$ by 2040.

The powertrain choice also influences lifetime tank-to-wheel emissions, where alternative powertrains offer a clear advantage: 0 tons of CO$_2$ for a BEV versus 432 tons for an average diesel ICEV in the truck and bus segment. Consequently, the evolution of powertrain shares within mobility fleets has a significant impact on both vehicle production and tank-to-wheel emissions at the fleet level.

The second key driver is the energy source used by the vehicle. Life cycle analyses include emissions from energy production and supply, referred to as well-to-tank emissions. This is why the choice of energy source significantly impacts CO$_2$ emissions. For each powertrain, energy-related emissions were calculated using the CO$_2$ intensity factor[11] of the respective energy type, as shown in Figure 12.

Energy type	Gasoline	Diesel	Kerosene	Methanol	Methane	Hydrogen
Well-to-Tank	0.60 kg CO_2/l	0.63 kg CO_2/l	0.56 kg CO_2/l	0.45 kg CO_2/l	0.86 kg CO_2/kg	10.9 kg CO_2/kg
Tank-to-Wheel	2.34 kg CO_2/l	2.70 kg CO_2/l	2.52 kg CO_2/l	1.92 kg CO_2/l	2.56 kg CO_2/kg	
Well-to-Wheel	2.94 kg CO_2/l	3.33 kg CO_2/l	3.08 kg CO_2/l	2.37 kg CO_2/l	3.44 kg CO_2/kg	10.9 kg CO_2/kg

Figure 12: CO_2 intensity factors of conventional fossil energy carriers.

For an average diesel ICEV in the truck and bus segment, well-to-tank emissions are calculated based on a CO_2 intensity factor of 0.63 kg CO_2 per liter and an annual fuel consumption of 20,000 liters. Over an eight-year lifetime, this results in 101 tons of CO_2 if the vehicle uses fossil diesel exclusively. Well-to-wheel emissions amount to 533 tons of CO_2. If the vehicle is powered by green hydrogen-based eFuels, CO_2 emissions are assumed to be reduced by 70 percent compared to conventional fossil diesel on a well-to-wheel basis. This assumption aligns with the minimum requirement of the Delegated Act on Greenhouse Gas Methodology under the Renewable Energy Directive (Art. 28[12]) and applies to biofuels as well. The remaining 30 percent of emissions are allocated to well-to-tank. In other words, eFuels and biofuels are considered zero-emission technologies for vehicle use but not for energy supply. Based on this assumption, an eDiesel-powered vehicle emits 160 tons of CO_2 over its lifetime. In practice, the 70 percent reduction threshold is likely to be exceeded in many cases, offering additional decarbonization potential through eFuels or biofuels.

Similarly, the well-to-wheel approach is applied to measure CO_2 emissions for other energy types, such as electricity. While electricity is carbon-neutral on a tank-to-wheel basis, well-to-tank emissions are not neutral—even when sourcing exclusively from renewable energy. For example, installing onshore wind turbines and using the power grid results in a CO_2 emission factor of 11 g CO_2/kWh. For an average truck and bus segment vehicle, exclusive use of onshore wind-based electricity leads to well-to-tank emissions of six tons of CO_2 over its lifetime. A CO_2 intensity factor was defined for each electricity source[13], as shown in Figure 13.

Cluster	Fossil			Nuclear	Renewable							
Electricity source	**Coal**	**Biomass co-firing**	**Natural gas**	**Nuclear**	**Biomass**	**Solar PV – utility**	**Solar PV – roof**	**Solar-concentr.**	**Geo-thermal**	**Hydro-power**	**Wind offshore**	**Wind onshore**
Intensity factor g CO_2/kWh	820	740	490	12	230	48	41	27	38	24	12	11
Share 2023	12.3%	3.5%	16.8%	22.9%	5.6%	9.1%			0.3%	11.8%	2.0%	15.7%
Share within cluster 2023	37.8%	10.7%	51.5%	100%	12.6%	20.4%			0.7%	26.5%	4.5%	35.3%
Cluster intensity factor g CO_2/kWh	641			12	48							

Figure 13: CO_2 intensity factors and share of electricity sources.
PV: photovoltaic

In the European Commission's Impact Assessment, the electricity mix is grouped into three clusters: fossil-based, nuclear-based, and renewable energy-based. To assign a CO_2 intensity factor to each cluster, the 2023 mix of electricity sources[14] and their respective CO_2 intensities were used, as shown in Figure 13. Within each cluster, the CO_2 intensity factor is assumed to remain constant over time.

In this analysis, it is assumed that for a given powertrain, all vehicles have access to the average EU mix of energy sources, regardless of local variations or individual energy purchase agreements. For example, under the "EU Ambition" scenario, all diesel ICEVs in the truck and bus segment are assumed to use 44 percent fossil diesel, 30 percent biodiesel, and 26 percent eDiesel in 2040. This eFuel quota appears highly ambitious when compared to the current RFNBO target set for 2030 under the Renewable Energy Directive (RED)[15]. In this scenario, the European Commission

outlines the need for a substantial increase in eFuel quotas to align with climate targets. Similarly, all battery-electric passenger cars are assumed to use 3 percent fossil-based electricity, 10 percent nuclear-based electricity, and 87 percent renewable electricity in 2040. CO_2 intensity factors, combined with the shares of the respective energy sources in the EU, form the basis for calculating the CO_2 intensity of the energy used by each powertrain. The increasing share of low-carbon sources assumed in the "EU Ambition" scenario reduces the CO_2 intensity of the energy mix over time, thereby lowering well-to-wheel CO_2 emissions across all powertrains. For instance, annual well-to-wheel emissions of an average gasoline passenger car are projected to decrease from 3.1 tons of CO_2 in 2025 to 2.1 tons by 2040, based on the gasoline mix assumed for 2040: 50 percent fossil gasoline, 27 percent biogasoline, and 23 percent eGasoline. Similarly to eDiesel, the European Commission highlights the requirement to

significantly raise eGasoline quotas to meet climate goals. Each vehicle produced is tracked over its lifetime, and its well-to-wheel emissions are synchronized with the evolution of the CO_2 intensity of the corresponding energy mix.

In the shipping and aviation sectors, CO_2 emissions were calculated directly from energy demand, as it is the primary driver of emissions. Industry analyses[16,17] indicate that emissions from the production of an airplane account for approximately 10 percent of its lifetime emissions—a Figure that also applies to maritime vessels. Assuming annual production of airplanes and vessels is proportional to energy demand in their respective segments, annual fleet-level production emissions were estimated as 10 percent of annual energy-related emissions. Similar to the approach used for on-road mobility, energy-related emissions in shipping and aviation were derived for each energy type based on the CO_2 intensity factor of the fuel and fleet-level energy demand. Fleet stock emissions evolve over time according to changes in these parameters under the "EU Ambition" scenario.

3.3. Fleet stock evolution and required new registrations in on-road mobility

As highlighted in → *Section 3.2.1.*, the energy transition is the primary driver of transformation in the maritime and aviation segments. In contrast, the powertrain transition within fleets has only a minor impact, mainly due to slow fleet renewal and the high energy flexibility of vessels. Consequently, fleet transition was not further analyzed in these segments; instead, the focus is placed on energy demand.

For on-road mobility, the evolution of fleet stock size across different powertrains was examined in detail, as it directly affects energy demand and CO_2 emissions throughout the entire vehicle life cycle.

3.3.1. Passenger car segment

In passenger car mobility, the results of the "EU Ambition" scenario derived from the European Commission's Impact Assessment clearly demonstrate the ambition to scale up new powertrains such as BEVs and FCEVs through 2050.

As shown in Figure 14, the simulation projects that BEVs will surpass a 15 percent fleet stock share by 2030 and reach parity with ICEVs before 2040. This translates to a BEV fleet stock of more than 30 million vehicles by 2030 and over 120 million vehicles by 2040. According to this scenario, BEVs account for 80 percent of the fleet stock by 2050, establishing themselves as the leading powertrain in passenger car mobility. The European Commission projects a later ramp-up for FCEVs, which begin to reach a significant fleet stock size by 2040 with a 5 percent share—equivalent to

more than 10 million vehicles—and approach a 15 percent share, or around 30 million vehicles, by 2050. PHEVs are forecasted to grow to more than 20 million vehicles by 2040, representing 11 percent of the fleet stock, before declining to fewer than 10 million vehicles by 2050 with only a 4 percent share. This indicates that PHEV technology is considered a transitional solution rather than a long-term option. Under the "EU Ambition" scenario, ICEVs are almost completely phased out by 2050, with less than a 2 percent share and a fleet stock of fewer than 5 million vehicles. For comparison, this is roughly half the size of today's BEV fleet stock in the European Union. In summary, to meet climate targets, the European Commission relies on a complete phase-out of ICEVs and a major phase-in of BEVs in passenger car mobility.

The targeted fleet transformation depends on the transition in new car registrations. To achieve the BEV phase-in outlined in the "EU Ambition" scenario designed by the European Commission, the fleet model indicates that high BEV market shares in new registrations are essential—reaching 48 percent by 2030, 62 percent by 2035, and 72 percent by 2040. To secure an 80 percent BEV share in the fleet stock by 2050, powertrain shares in new registrations must peak before 2045. According to this scenario, the BEV ramp-up in new registrations should be successfully implemented within a 25-year timeframe. Additionally, the simulation shows FCEVs beginning their ramp-up around 2030, reaching a 7 percent market share by 2035 and steadily increasing to nearly 20 percent by 2050. PHEVs are projected to gain market share until 2040,
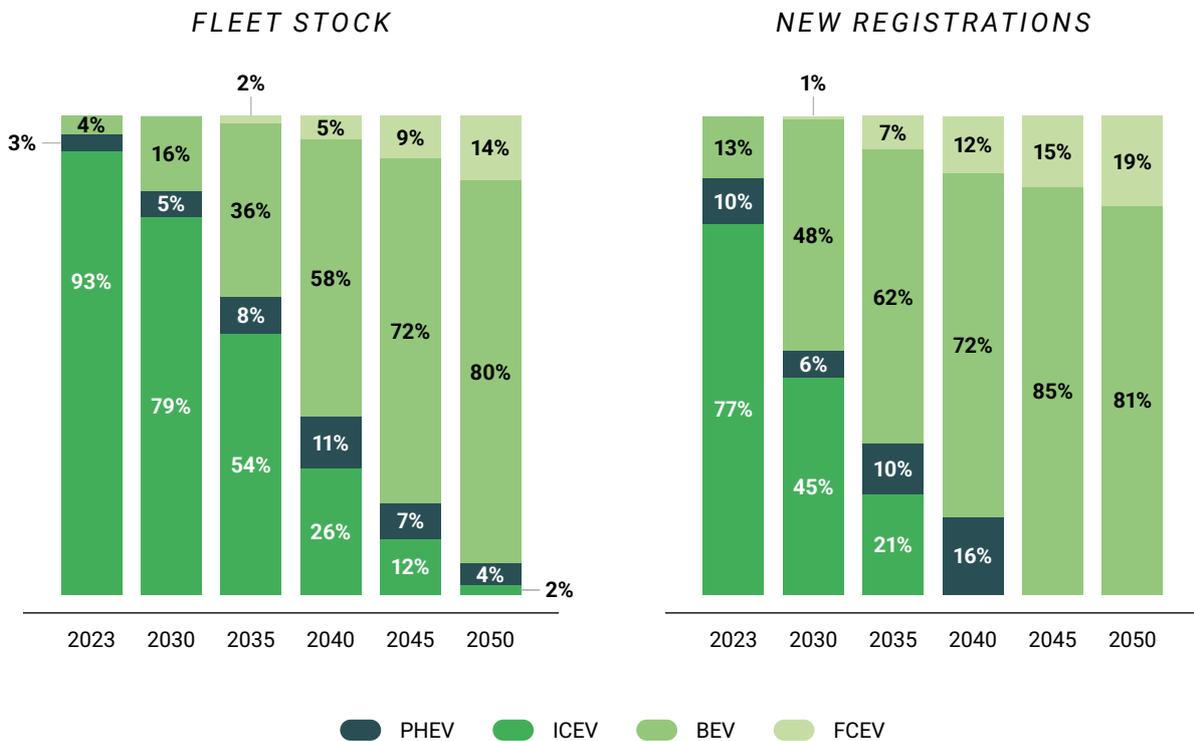
FLEET STOCK

NEW REGISTRATIONS

Figure 14: Powertrain shares in passenger car fleet stock and new registrations: "EU Ambition" scenario.

exceeding 15 percent before being phased out. In the "EU Ambition" scenario, no new PHEV registrations are expected after 2045, confirming their role as a transitional technology. To meet fleet stock targets set by the European Commission's Impact Assessment report, ICEVs must be phased out of new registrations by 2040. However, the model shows ICEVs still holding more than 20 percent market share in 2035. The electrification projected in the European Commission's Impact Assessment is slower than the trajectory set by current EU fleet regulations, which target full electrification of new registrations by 2035. To comply with the European "Fit for 55" package and emission performance standards for new passenger cars and vans from 2035, the introduction of carbon neutral fuel vehicles (CNFVs) will be necessary to address this remaining 20 percent ICEV share, as well as the PHEV share of 11 percent in 2035 and 16 percent in 2040. In the European Commission's scenario, the internal combustion engine remains relevant even after 2040, with a combined share of 37 percent for ICEVs and PHEVs in the vehicle fleet. Sustainable fuels will therefore play a decisive role in achieving climate targets. The energy forecast for the "EU Ambition" scenario was examined in this study and will be analyzed in → *Section 3.4*.

In the European Commission's scenario, the internal combustion engine remains relevant even after 2040, with a combined share of 37 percent for ICEVs and PHEVs in the vehicle fleet. Sustainable fuels will therefore play a decisive role in achieving climate targets.

According to the "EU Ambition" scenario, new registrations are expected to stabilize before 2045, dominated by two technologies: BEVs (85 percent) and FCEVs (15 percent). To illustrate the implications for the BEV market across the value chain, Figure 15 shows the forecasted number of BEV registrations

In the European Commission's scenario, the internal combustion engine remains relevant even after 2040, with a combined share of 37 percent for ICEVs and PHEVs in the vehicle fleet. Sustainable fuels will therefore play a decisive role in achieving climate targets.

through 2035. The results indicate that new registrations must reach 7.4 million vehicles by 2030 and 9 million by 2035. For context, ACEA market data[10] reports that 1.6 million BEVs were sold in the European Union in 2023. This Figure must increase fivefold to meet the 2030 target—just seven years later. Such growth requires proactive planning across the entire BEV supply chain, including critical battery raw materials, cathode and anode materials, battery cells, battery packs, and vehicle production. This ramp-up also places significant pressure on energy infrastructure, including electricity transmission and distribution networks, as well as charging capacity. The feasibility of this scenario has been assessed and will be detailed in → *Chapter 4*.

Another key finding relates to the ambitious phase-out of ICEVs. As shown in Figure 14, ICEVs are projected to disappear from the fleet stock by 2050, with only a 2 percent share remaining. However, the simulation indicates that ICEVs still account for more than 20 percent of new registrations in 2035—equivalent to 6.4 million new ICE vehicles. Fifteen years later, the ICEV fleet stock share is projected to drop to 2 percent, or about 3.6 million vehicles.

This does not align with the average passenger car lifetime of 16 years, as the 6.4 million ICEVs registered in 2035 would still be on the road by 2050 under normal conditions. This discrepancy highlights the need for premature scrapping to meet fleet stock targets, as natural end-of-life alone is insufficient. The fleet model developed in this analysis calculates the number of vehicles subject to early scrapping, prioritizing older vehicles over newer ones. Figure 16 illustrates the approach used to achieve fleet stock targets by 2040 under the "EU Ambition" scenario, considering scrapping requirements.

In 2039, 67.2 million ICEVs remain in the fleet stock, covering all ICE vehicles powered by gasoline, diesel, or methane. The target of reaching a 26 percent ICEV share by 2040—as shown in Figure 14—requires a reduction of 12.1 million vehicles. However, only 4.2 million ICEVs exit the fleet stock through natural end-of-life, meaning that 7.9 million vehicles must be prematurely scrapped to achieve this target. Prioritizing older vehicles for early scrapping, 5.4 million 15-year-old cars are removed by 2040, along with 1.3 million 14-year-old cars and 1.2 million vehicles aged between 11 and 13 years. The fact that only 4.2 million cars exit naturally, despite 9.5 million vehicles entering the market 16 years earlier (in 2024), reflects the impact of premature scrapping in previous years. In other words, some of these vehicles were already removed before 2039. Figure 17 illustrates passenger car exits required to meet fleet stock targets under the "EU Ambition" scenario designed by the European Commission.

The results show that ICEV new registrations remain around 7 million vehicles before phasing out by 2036. From that point onward, natural end-of-life would account for roughly 7 million vehicles over the following 16 years. For instance, the 6 million ICEVs registered in 2035 should naturally exit the market by 2050.
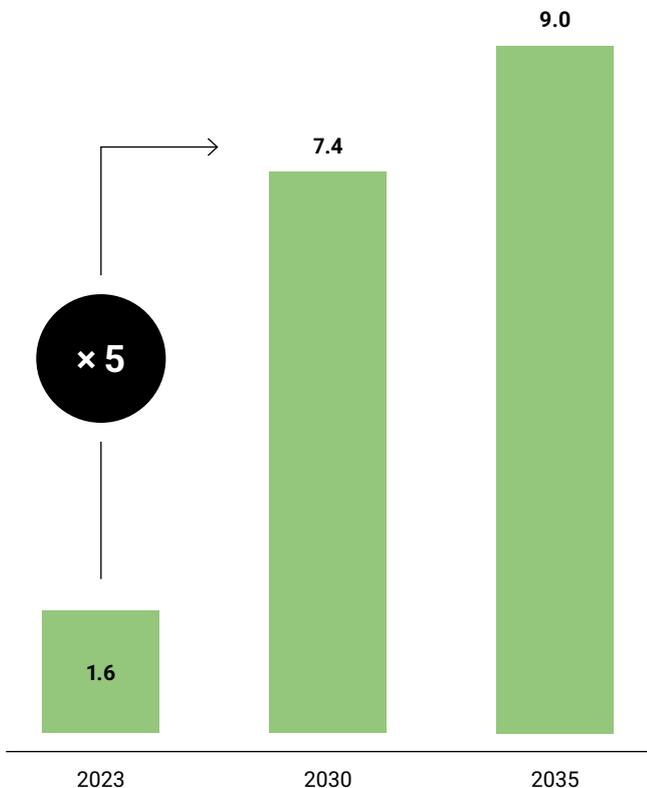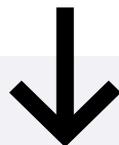

Figure 15: BEV new registrations in million vehicles: "EU Ambition" scenario.

EU Ambition 2039–2040 Fleet stock powertrain shares
[million units]

Calculated 2040 scrapping ICEV
[million units]

Assumptions:
- 16 years lifetime for all technologies
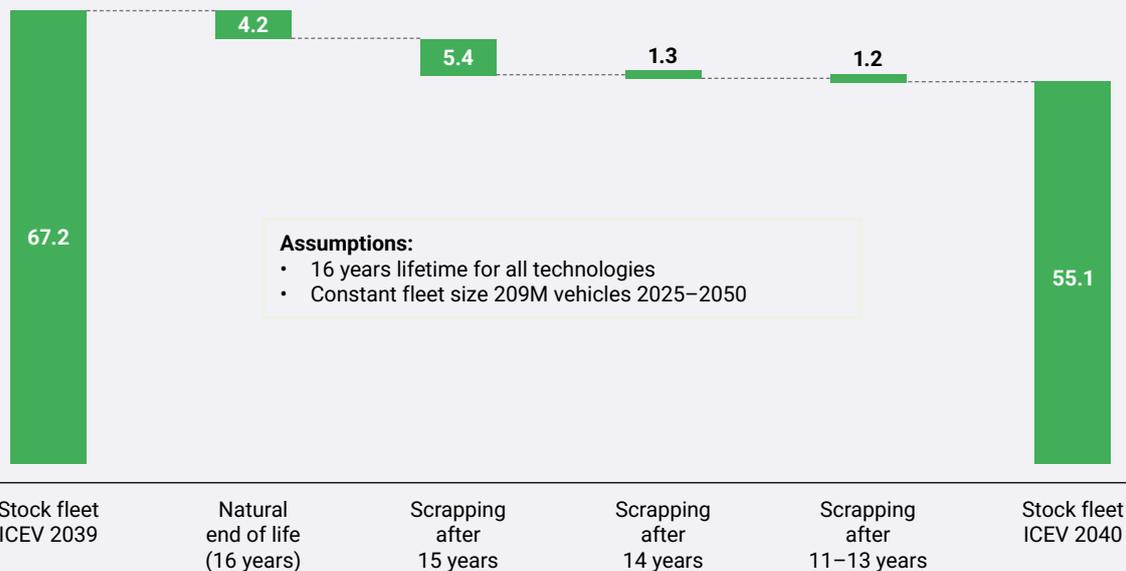- Constant fleet size 209M vehicles 2025–2050

Figure 16: Approach of scrapping calculation for ICEVs between 2039 and 2040: "EU Ambition" scenario.

However, due to premature scrapping starting in 2036, these vehicles will be removed earlier. This accelerates fleet stock exits and requires scrapping even relatively new cars. In total, nearly 75 million vehicles must be prematurely scrapped to meet fleet stock targets. The financial impact of implementing such a scrappage program is estimated to exceed €200 billion, based on the average residual value of scrapped vehicles in relation to their age. Instead of a scrappage scheme, an investment of the same magnitude in eFuel production would be sufficient to finance half of the globally planned capacity for 2030, estimated at approximately 20 billion liters of gasoline equivalent, as outlined in → *Chapter 6*.
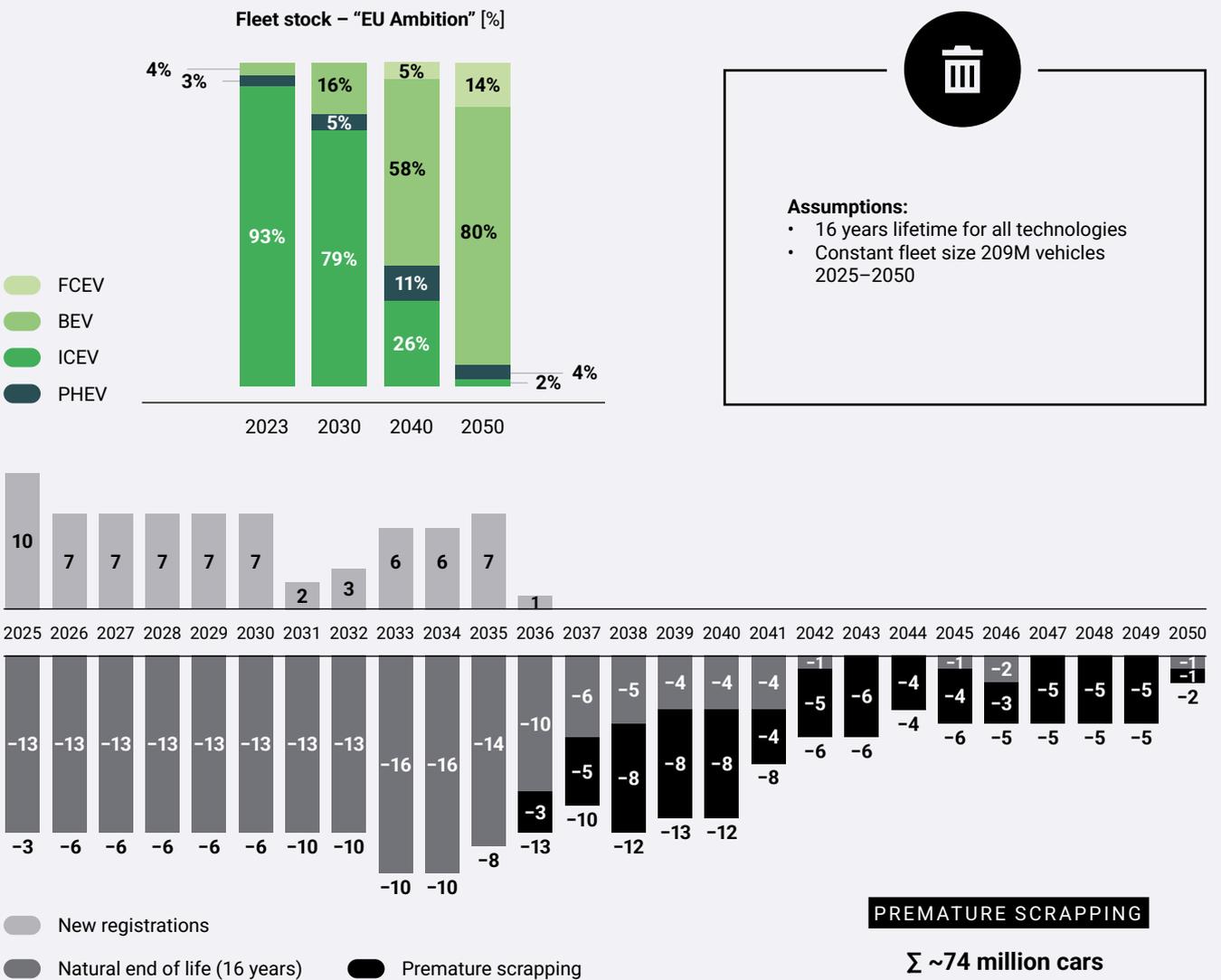
Figure 17: Passenger cars fleet stock exit to fulfill fleet stock targets in million vehicles: "EU Ambition" scenario.

3.3.2. Truck & bus segment

In the truck & bus segment, the "EU Ambition" scenario derived from the European Commission's Impact Assessment reflects a longer transformation process compared to passenger car mobility, as illustrated in Figure 18. Unlike the passenger car segment, this transition is not driven by a single technology but by a diversified mix, where hydrogen-based powertrains play a significant role. BEVs and FCEVs are projected to phase in and capture a major share of the fleet stock by 2050, although ICEVs are expected to maintain a relevant presence beyond 2040. BEVs begin to gain traction in the truck and bus fleet stock by 2035 with a 13 percent share, reaching parity with ICEVs shortly after 2045. This corresponds to approximately 350,000 BEVs in 2035 and 1 million by 2045. By 2050, BEVs are forecasted to represent 48 percent of the fleet stock. Hydrogen powertrains—including FCEVs and HICEVs—are considered key alternatives in the powertrain transition for truck and bus mobility. Together, these technologies will become relevant by 2035 with a 7 percent share, exceeding 150,000 vehicles, and are projected to reach 31 percent by 2050, surpassing conventional ICEVs. This equates to more than 800,000 trucks and buses powered by hydrogen by 2050.

In contrast to passenger cars, PHEVs are not expected to gain significant traction in truck & bus mobility, peaking at a 5 percent share over the 25-year period. Similar to the passenger car segment, PHEVs are treated as a transitional technology, phasing out after 2045 with only a 2 percent share by 2050—less than 70,000 vehicles. According to the "EU Ambition" scenario, ICE powertrains remain relevant in the EU fleet stock, still accounting for 57 percent in 2040 and 19 percent in 2050. In conclusion, to meet climate targets, the European Commission relies on a diverse mix of powertrain technologies, with BEVs leading

Instead of a scrappage scheme, an investment of the same magnitude in eFuel production would be sufficient to finance half of the globally planned capacity for 2030.

the transition and hydrogen-powered vehicles serving as a key complementary solution. Unlike passenger cars, ICEVs are not fully phased out but continue to play a role beyond 2050.

Similar to passenger car mobility, new registrations were analyzed to assess the level of ambition in the powertrain transition. To achieve the 48 percent BEV fleet stock share set in the "EU Ambition" scenario, BEV market shares must begin increasing by 2030, reaching 20 percent by 2035, 30 percent by 2040, and 60 percent by 2050. Because the BEV ramp-up starts later than in passenger car mobility, it must be successfully implemented within a shorter timeframe of 20 years. Likewise, hydrogen powertrains must begin market uptake by 2030, reaching 12 percent by 2035, 17 percent by 2040, and nearly

40 percent by 2050. Despite its planned phase-out, the ICE powertrain is expected to maintain a significant market share until 2045, at around 20 percent. Moreover, the 90 percent tailpipe emission reduction target for 2040 established by EU regulations does not align with the scenario developed by the European Commission and analyzed in this study. However, new registration results indicate a complete phase-out of ICEVs by 2050. Assuming the "EU Ambition" scenario materializes, ICEVs will remain in the fleet stock beyond 2050, but their full phase-out would occur by approximately 2058, considering an average vehicle lifetime of eight years. For truck and bus mobility, the European Commission's intention to use PHEVs only as a transitional technology is confirmed by the model, as no new registrations are planned beyond 2050.

In this scenario, new registrations are projected to stabilize by 2050, split between two categories: BEVs (60 percent) and hydrogen-powered (40 percent). To illustrate the implications across both value chains, Figure 19 shows the forecasted number of BEV and hydrogen-powered vehicle registrations through 2035.

As a result, 10,600 BEV registrations are required in 2030 and 70,000 in 2035 to meet fleet stock targets. This represents a seven-fold increase within just five years, adding to the pressure already exerted by the passenger car segment on battery and energy supply chains. During the same period, hydrogen-powered vehicles must grow from 10,900 units in 2030 to 38,400 units in 2035—a four-fold increase. Although the powertrain
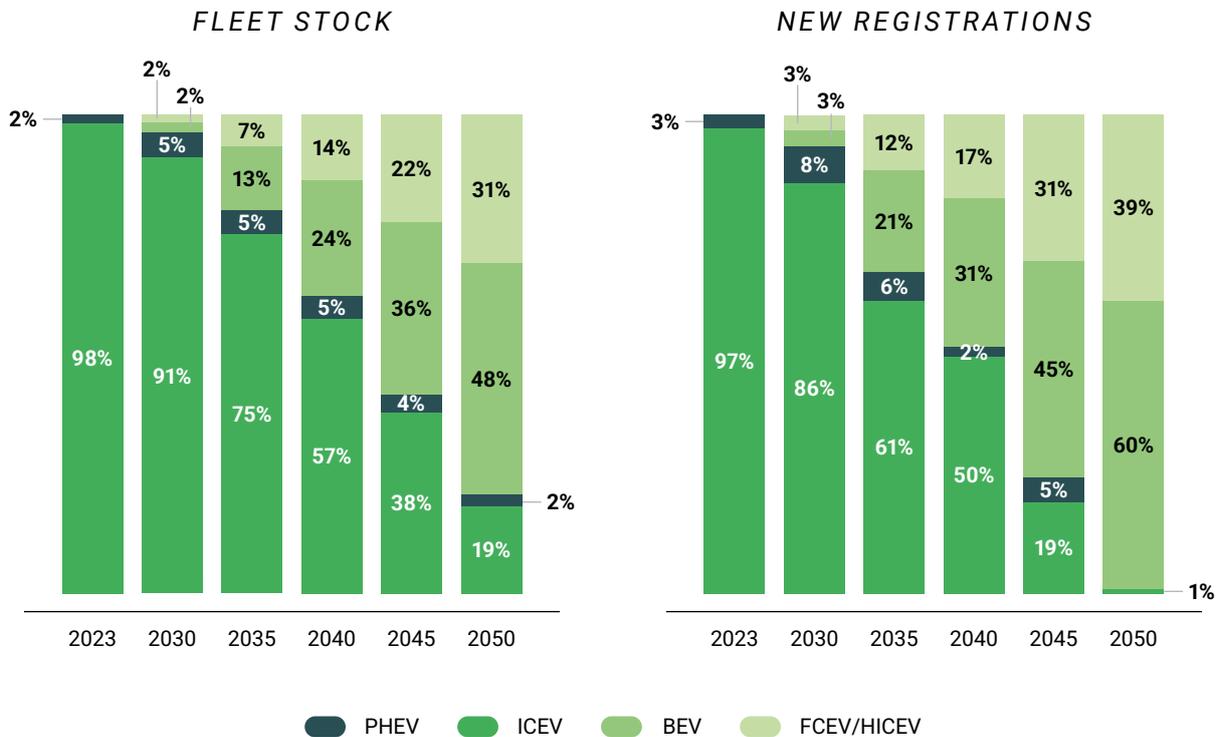

Figure 18: Powertrain shares in truck and bus fleet stock and new registrations: "EU Ambition" scenario.

transition in the truck & bus segment is less aggressive than in passenger cars, its success depends on the same supply chains for both segments. This means that potential bottlenecks could have shared implications, which will be analyzed in → *Chapter 4*.

Similar to the passenger car segment, premature scrapping was assessed for the truck & bus fleet. However, the slower transition pace set by the European Commission for this segment, combined with the shorter average vehicle lifetime, provides greater flexibility for natural fleet renewal. As a result, no significant implications related to premature scrapping were identified for this segment.

While the powertrain transition is a key driver for meeting climate targets in on-road

mobility, the energy transition represents another critical pillar of decarbonization—particularly in the maritime and aviation segments.

3.4. Energy demand

Beyond the powertrain transformation, the energy transition is a key pillar of decarbonization. In on-road mobility, it is closely linked to the powertrain transition and therefore to fleet renewal. As highlighted in → *Section 3.2.1.*, decarbonization in the maritime and aviation segments is not driven by fleet renewal but by the type of energy used. Figure 20 illustrates the forecasted share of energy demand by energy type in these two segments for 2050, based on the European Commission's Impact Assessment.
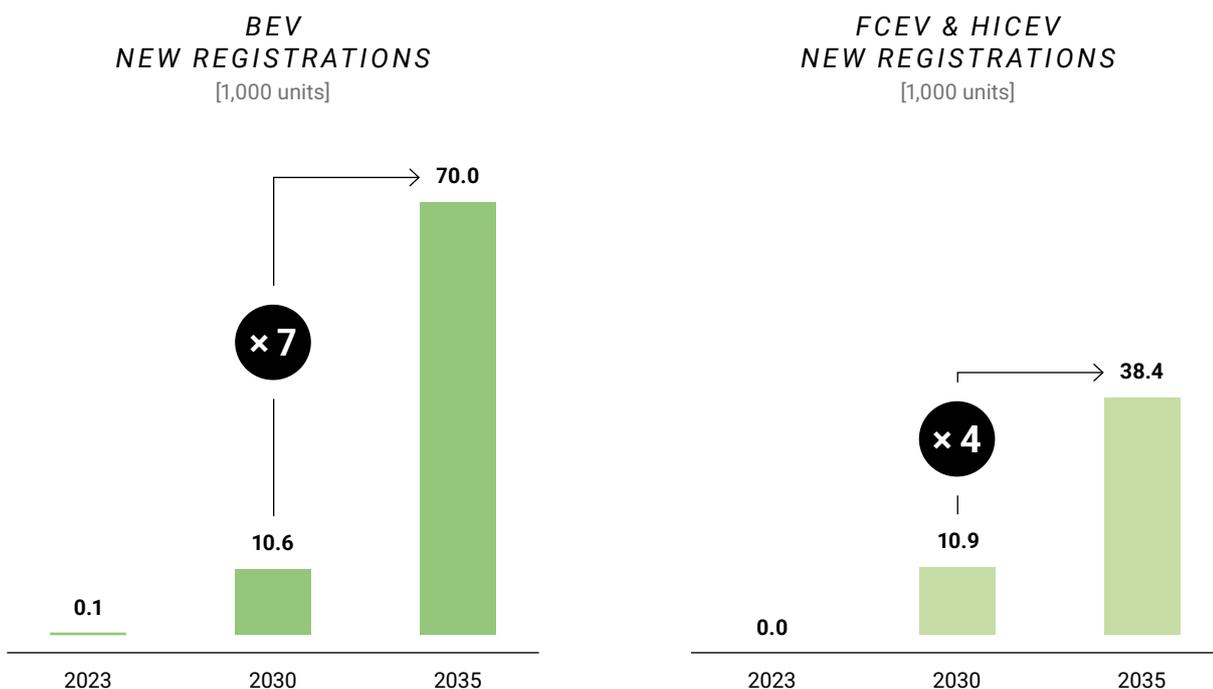
BEV
NEW REGISTRATIONS
[1,000 units]

FCEV & HICEV
NEW REGISTRATIONS
[1,000 units]

Figure 19: BEV and hydrogen-powered new vehicle registrations in thousand vehicles: "EU Ambition" scenario.

In the "EU Ambition" scenario, the results underscore the continued dominance of liquid fuels in both segments by 2050.

* Also called kerosene.

At European ports, liquid marine fuel is expected to account for 60 percent of energy supplied by 2050, including fuel oil, diesel, methanol, and ammonia. Liquefied Natural Gas (LNG) is projected to remain highly relevant with a 22 percent share. According to the European Commission's report, hydrogen will represent 14 percent of energy demand, positioning it as a key option in the maritime energy transition. Electricity, however, is expected to remain marginal with only a 2 percent share by 2050. Due to range limitations, direct electrification will be suitable only for specific applications such as short-sea

shipping, passenger ferries, inland waterways, and shore power use at berth.

In the aviation segment, very few applications allow alternatives to liquid jet fuel.* According to the "EU Ambition" scenario, 93 percent of the energy supplied at European airports will still be jet fuel by 2050. The direct use of hydrogen (6 percent) and electricity (1 percent) will remain limited to niche cases with flexible weight and range requirements. For example, it is technically unlikely that electric or hydrogen-powered aircraft will be suitable for transatlantic flights.

Figure 21 illustrates the evolution of energy demand across the four mobility segments analyzed in this study—passenger cars, trucks
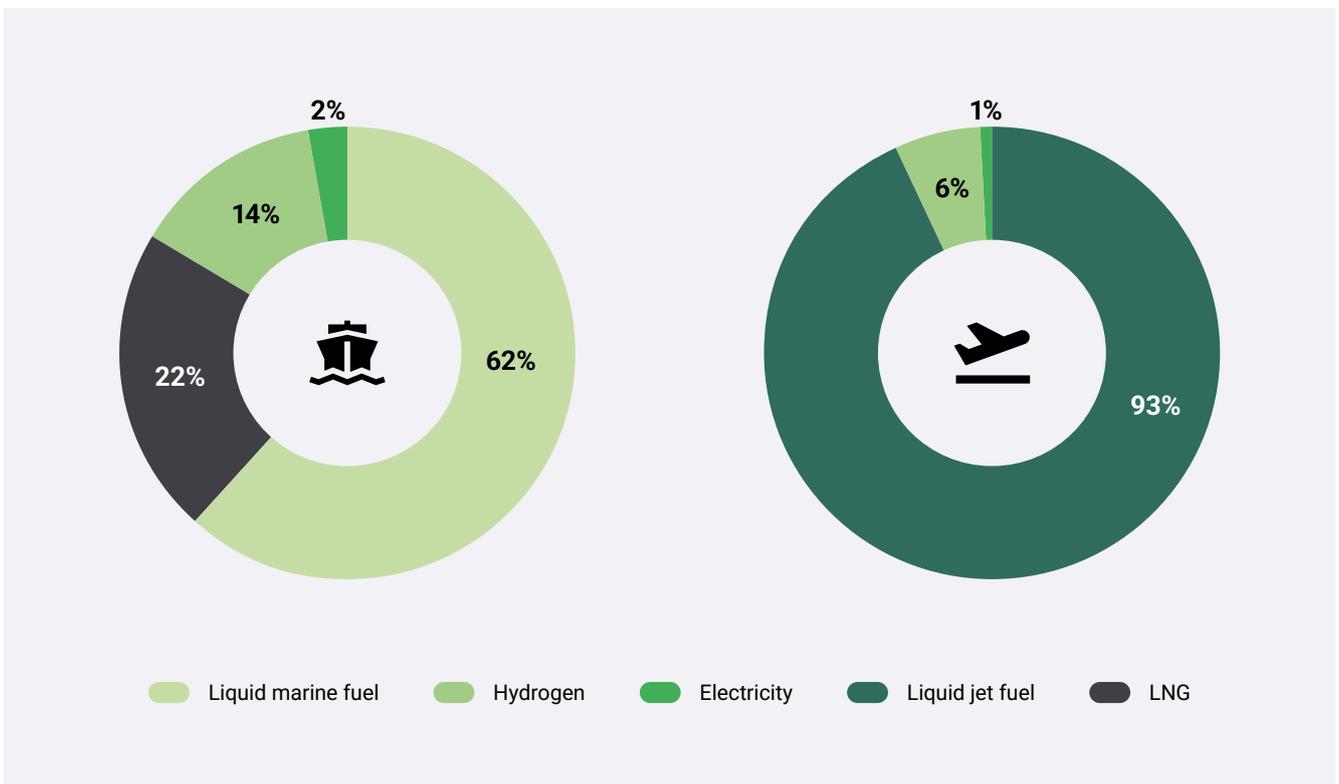

Figure 20: Energy demand share in maritime and aviation segments in 2050: "EU Ambition" scenario.

and buses, maritime, and aviation—broken down by energy type.

The energy forecast derived from the European Commission's Impact Assessment and modeled in this study shows an overall decline in energy demand of 34 percent between 2025 and 2050—from 369 to 244 billion liters of gasoline equivalent. This reduction is primarily driven by the phase-out of liquid fuels in the passenger car and truck & bus segments, resulting from the powertrain transformation detailed in → *Section 3.3*. Electricity and hydrogen phase-in with the ramp-up of BEVs, FCEVs, and HICEVs. Efficiency gains from electric powertrains further contribute to the decrease in total energy demand.

Electricity and hydrogen demand also increase with the energy transition in maritime and aviation, although they remain secondary solutions in these segments. By 2050, electricity demand is expected to reach the equivalent of 53 billion liters of gasoline—or 480 TWh—representing 22 percent of total energy demand across the four mobility segments in the EU. Hydrogen demand will rise to 47 billion liters of gasoline equivalent, or 13 million tons of hydrogen, accounting for nearly 20 percent of mobility energy demand.
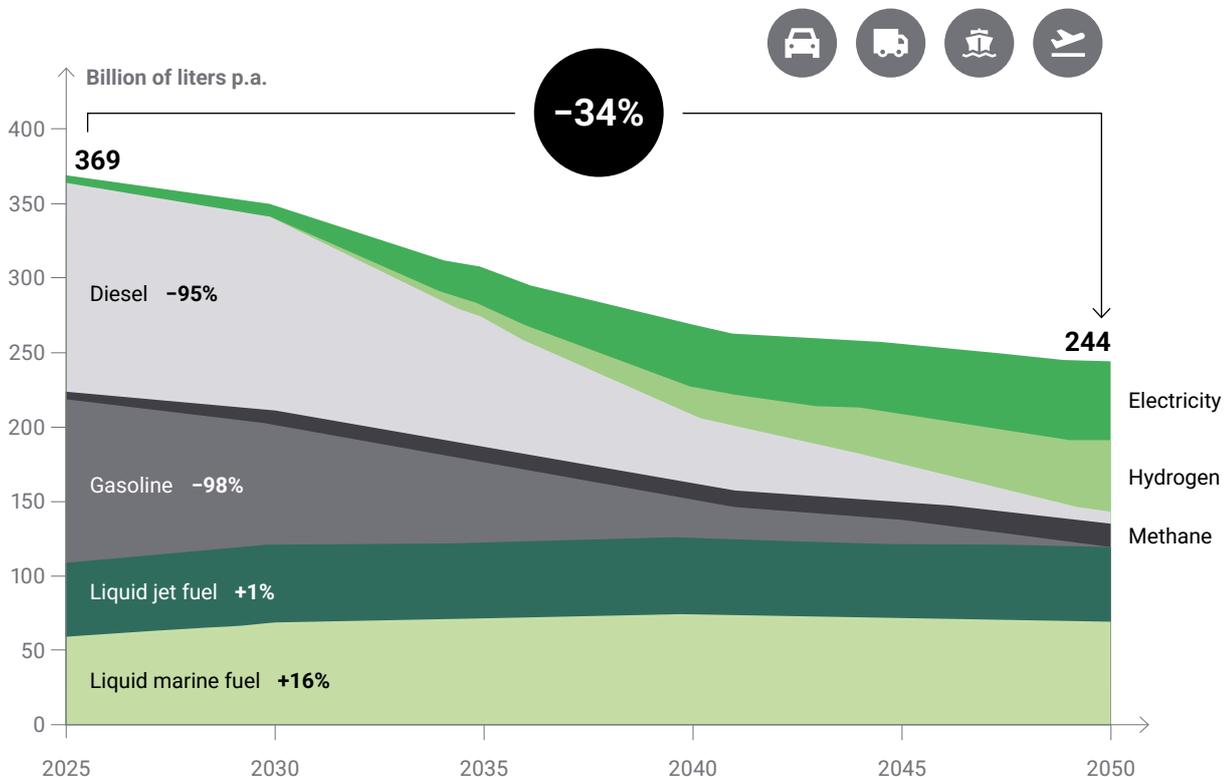

Figure 21: Annual energy demand in EU mobility by energy type: "EU Ambition" scenario.
Results are presented in billion liters of gasoline equivalent | Diesel refers to the use of diesel in on-road mobility, marine fuel refers to fuel oil, diesel, methanol, and ammonia

Driven mainly by the energy transition in the maritime and truck & bus segments, methane demand is forecasted to grow from 3 to 10 million tons—equivalent to 5 to 15 billion liters of gasoline—representing 6 percent of total energy demand by 2050.

According to the "EU Ambition" scenario, diesel and gasoline consumption is projected to decline by 95 percent and 98 percent, respectively. This drastic phase-out is directly linked to the ambitious electrification plan for on-road mobility, where ICEVs and PHEVs together account for only 6 percent of passenger cars and 20 percent of trucks and buses by 2050.

A different trend is expected for jet fuel and marine fuel, given the long-term dominance of liquid fuels in the maritime and aviation sectors. Jet fuel demand is forecasted to remain close to current levels, at about 49 billion liters of gasoline equivalent by 2050. While 7 percent of aviation energy demand will be covered by hydrogen and electricity, as shown in Figure 21, jet fuel consumption will remain stable due to the continued growth in air traffic observed in recent years, which more than offsets efficiency improvements in aircraft engines. Marine fuel demand is projected to increase by 16 percent over the next 25 years, even though 38 percent of maritime energy demand will be met by alternative sources— LNG, hydrogen, and electricity—by 2050, as illustrated in Figure 21. This assumption is based on the expectation that maritime transport demand will continue to rise in the coming decades. Overall, this trend, combined with the general decline in total energy demand, results in higher shares of jet fuel and marine fuel among all energy types by 2050: 20 percent and 29 percent, respectively, as shown in Figure 22.

Overall, liquid fuels account for 53 percent of total energy demand across the four mobility segments by 2050. This corresponds to 128 billion liters of gasoline equivalent that must be supplied annually from zero-emission sources such as advanced biofuels and eFuels. To ensure compliance with climate targets, the European Commission's Impact Assessment defines quotas for different transport segments. In this study, these quotas were allocated to the corresponding fuel types for the data point years 2030, 2040, and 2050. They are labeled as "Ambition" in Figure 23, while quotas aligned with current EU regulations are referred to as "Regulation."
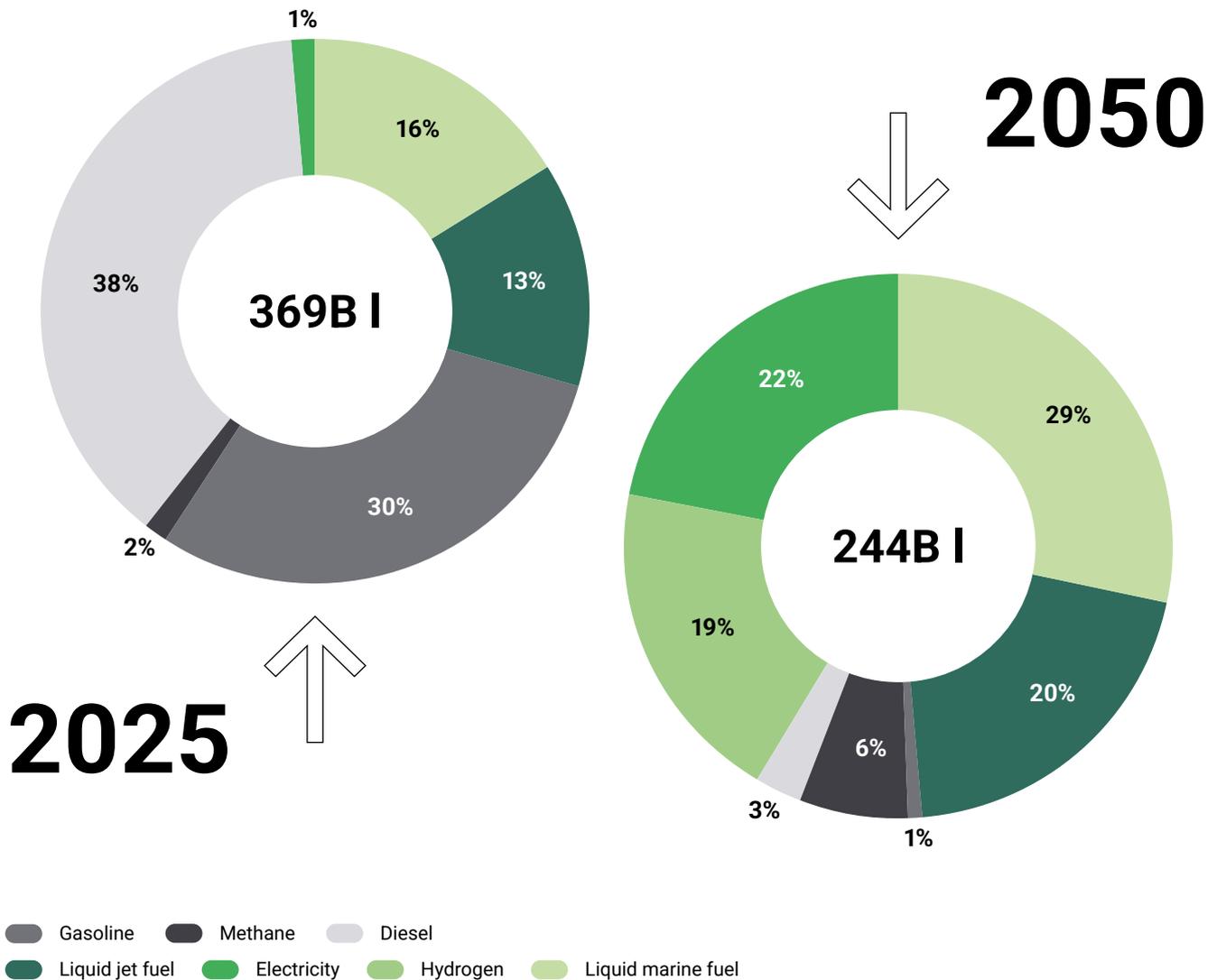
2050

2025

- Gasoline
- Methane
- Diesel
- Liquid jet fuel
- Electricity
- Hydrogen
- Liquid marine fuel

Figure 22: Share of energy demand in EU mobility in 2025 and 2050 by energy type: "EU Ambition" scenario. Results are presented in billion liters of gasoline equivalent | Diesel refers to the use of diesel in on-road mobility; marine fuel refers to fuel oil, diesel, methanol, and ammonia

In on-road mobility, the "Current EU Regulation" scenario is based on the Renewable Energy Directive (RED)[15], which drives the ramp-up of eFuels and advanced biofuels. As of early 2026, 15 Member States have initiated or already completed the implementation of RED III. However, there are substantial differences in national ambitions for RFNBOs. Finland, for example, has adopted a particularly ambitious RFNBO quota of 4 percent in the on-road transport sector for 2030. In Spain and Belgium, quotas of 2.5 percent and 2 percent, respectively, are under discussion. Other Member States are pursuing considerably
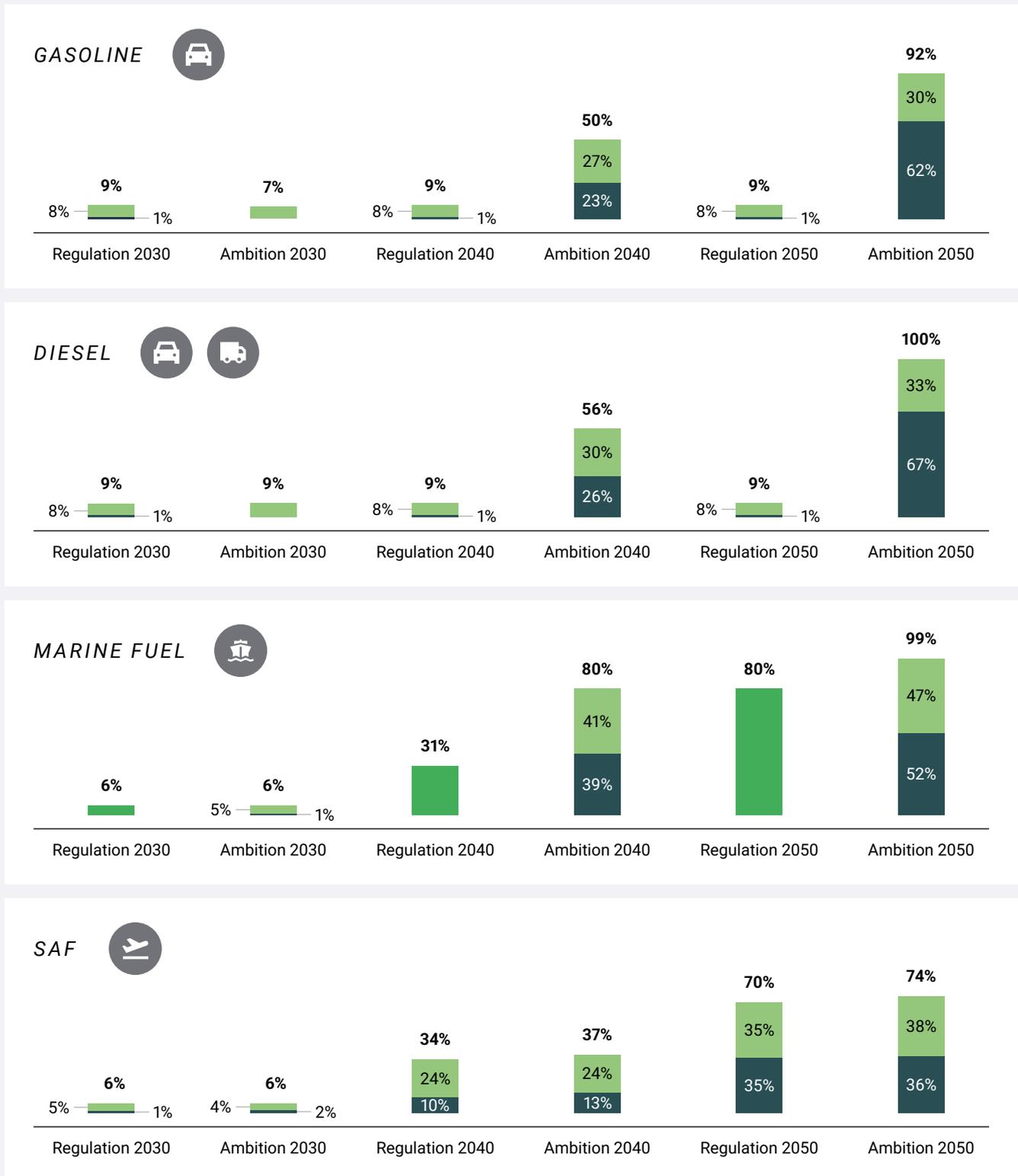
Figure 23: Quotas for eFuels and biofuels: "EU Ambition" scenario vs. "Current EU Regulation" scenario.
Diesel refers to the use of diesel in on-road mobility; marine fuel refers to fuel oil, diesel, methanol, and ammonia | SAF: Sustainable Aviation Fuel | Assumptions for regulation: Quotas for eGasoline and eDiesel based on RED III RFNBO quota 2030, excluding multipliers, assumed constant until 2050; Quotas for biogasoline and biodiesel based on RED III advanced biofuel quota 2030, excluding multipliers, assumed constant until 2050 and current average blending quota of 3.2 percent for 1st generation biofuels in on-road transport based on the SHARES Database; Quotas for marine fuel derived from FuelEU Maritime greenhouse gas intensity reduction quotas, excluding multipliers; Quotas for SAF derived from ReFuelEU Aviation SAF quotas, excluding multipliers

While the targets for 2030 in the current regulation (RED III) are not extended to 2040 and 2050, the European Commission's scenario makes it clear that the quotas for eFuels and biofuels will need to be significantly increased in order to meet climate targets.

lower targets: Germany is proposing a quota of 1.2 percent, while France and Sweden are each aiming for 1 percent. Countries such as Poland, the Czech Republic, and Portugal are limiting themselves to the minimum requirement of 0.5 percent. Overall, this is already resulting in a potential demand of around 30 TWh or 3 billion liters of eFuels. The additional demand from the remaining Member States has not yet been taken into account. As the implementation of RED III has not yet been completed in several Member States, the quotas defined at the EU level were used as the reference basis for this analysis. Quotas are currently defined for 2030 and, in this analysis, assumed constant for 2040 and 2050, as targets for these years are not yet aligned. Accordingly, a 4.5 percent quota is set for advanced biofuels and a sub-quota of 1 percent for eFuels. Multipliers for eFuels and biofuels were excluded from this analysis, assuming a progressive scenario where all

EU member states remove multipliers when implementing RED III. Assuming first-generation biofuels remain at today's average share of 3.2 percent, according to the SHARES Database[18], a regulatory quota of 8 percent for biofuels is set for 2030. For eGasoline and eDiesel, the "EU Ambition" scenario derived from the Commission's Impact Assessment indicates a delayed ramp-up until 2030, with a negligible share of eFuels, compared to 1 percent eFuels under the current regulation. However, while the targets for 2030 in the current regulation (RED III) are not extended to 2040 and 2050, the European Commission's scenario makes it clear that the quotas for eFuels and biofuels will need to be significantly increased in order to meet climate targets. By 2040, the European Commission forecasts eGasoline quotas to reach 23 percent, rising to 62 percent by 2050, while eDiesel quotas are set even higher—26 percent by 2040 and 67 percent by 2050.

In the maritime segment, the "Current EU Regulation" scenario is based on the FuelEU Maritime[19] regulation, which defines greenhouse gas intensity reduction quotas. As zero-emission fuels, eFuels and biofuels can contribute to meeting these targets. Therefore, these intensity reduction quotas can be directly compared with the fuel quotas forecasted in the "EU Ambition" scenario. Similar to on-road mobility, multipliers were excluded from this analysis. In 2030, both scenarios align with a 6 percent quota. In the long term, however, the "EU Ambition" scenario emphasizes the need for a substantial increase in quotas to achieve climate targets—reaching 80 percent sustainable fuels by 2040 versus 31 percent under current regulation, and 99 percent versus 80 percent by 2050.

In the aviation segment, the "Current EU Regulation" scenario is based on the eSAF and bioSAF quotas defined in ReFuelEU Aviation[20]. Similar to on-road and maritime mobility, multipliers were excluded from this analysis. The results show that quotas in both scenarios remain very similar, with only a slight increase in the "EU Ambition" scenario for 2040 and 2050 compared to "Current EU Regulation."

Based on the quotas identified in the European Commission's Impact Assessment report, the detailed ramp-up of eFuels was modeled, and the results are presented in Figure 24.

Across all four segments, eFuel supply is projected to scale up by 2030 and stabilize at an annual production level of 60 billion liters of gasoline equivalent by 2045. The model reflects Europe's ambition to continuously ramp up marine eFuels—including eDiesel,

eMethanol, and eAmmonia—and eSAF, reaching annual supplies of 36 and 18 billion liters of gasoline equivalent by 2050, respectively. In on-road mobility, eGasoline and eDiesel are forecasted to increase until 2040, contributing to fleet decarbonization with an annual supply of nearly 18 billion liters of gasoline equivalent.

Overall, the ramp-up defined by the European Commission in the "EU Ambition" scenario underscores the need to scale eFuel production across all transport segments to meet CO_2 reduction targets.
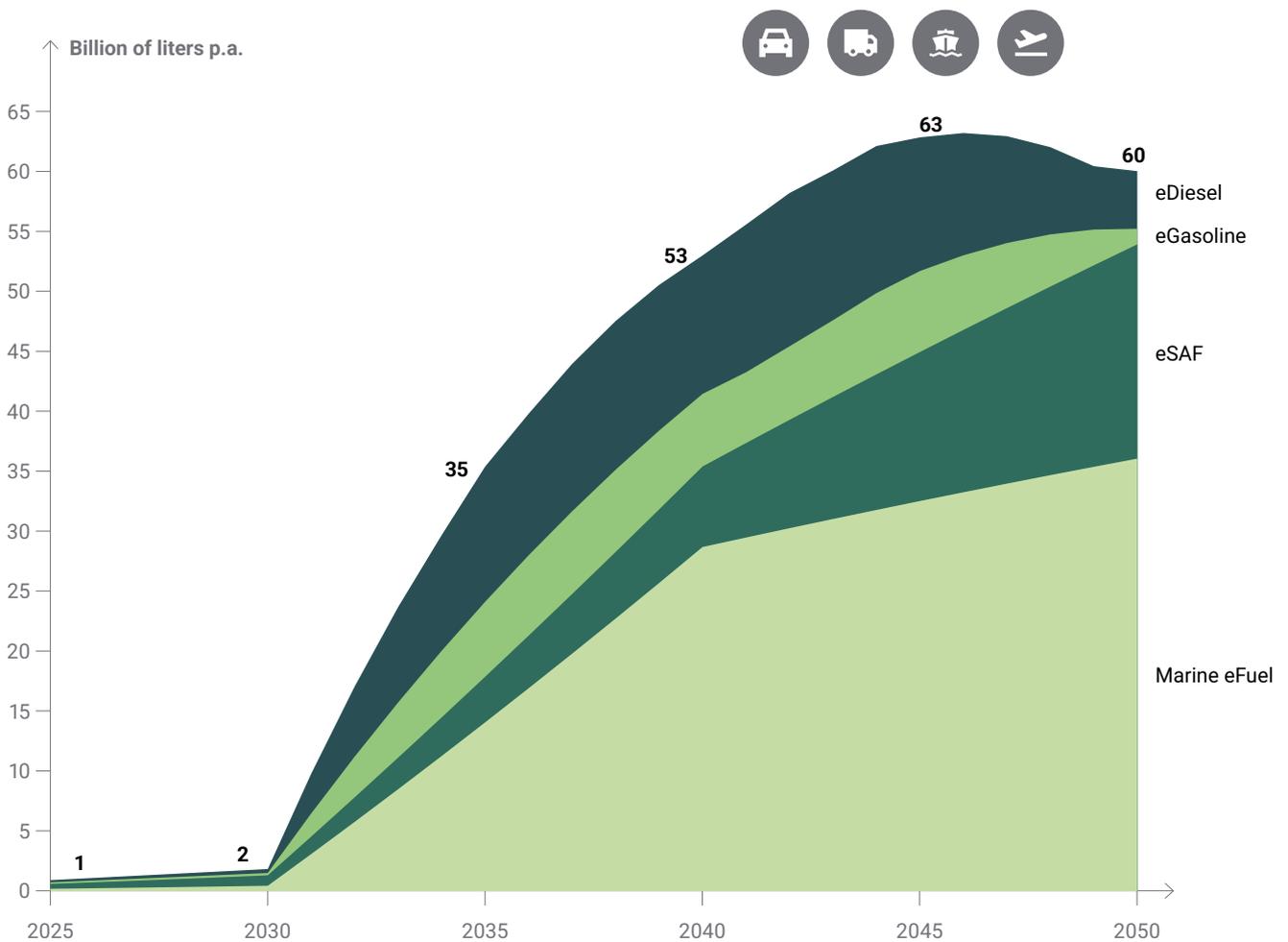

Figure 24: Annual eFuel demand in EU mobility by energy type: "EU Ambition" scenario.
Results are presented in billion liters gasoline equivalent | eDiesel refers to the use of eDiesel in on-road mobility; marine eFuel refers to eDiesel, eMethanol, and eAmmonia | SAF: Sustainable Aviation Fuel

eFuel and green hydrogen demand for agricultural and construction machines

This study focuses on the four mobility segments that currently contribute most significantly to CO_2 emissions in European mobility: passenger cars, trucks and buses, maritime shipping, and aviation. Other mobility sectors will also require renewable fuels to achieve substantial emission reductions. A complementary analysis conducted by Porsche Consulting derived the future powertrain mix for agricultural and construction machines based on a detailed total cost of ownership (TCO) assessment. New vehicle registrations were categorized by powertrain technology and use case, and energy consumption was benchmarked for each category to estimate fleet-level energy demand. The resulting energy mix was evaluated under an ambition level equivalent to the ramp-up targets for on-road eDiesel and green hydrogen defined in the European Commission's Impact

Assessment. In other words, the same quotas for eDiesel and green hydrogen as in the "EU Ambition" scenario for on-road mobility were applied. The results are presented in Figure 25.

This analysis indicates that by 2050, European eFuel and green hydrogen demand for agricultural and construction machines will reach the equivalent of 7 billion liters of gasoline, exceeding 10 percent of the eFuel demand projected by the European Commission for on-road mobility, maritime shipping, and aviation. Although this study concentrates on the most critical mobility segments for achieving EU climate targets, other segments must also be considered in the broader effort to mitigate climate change.
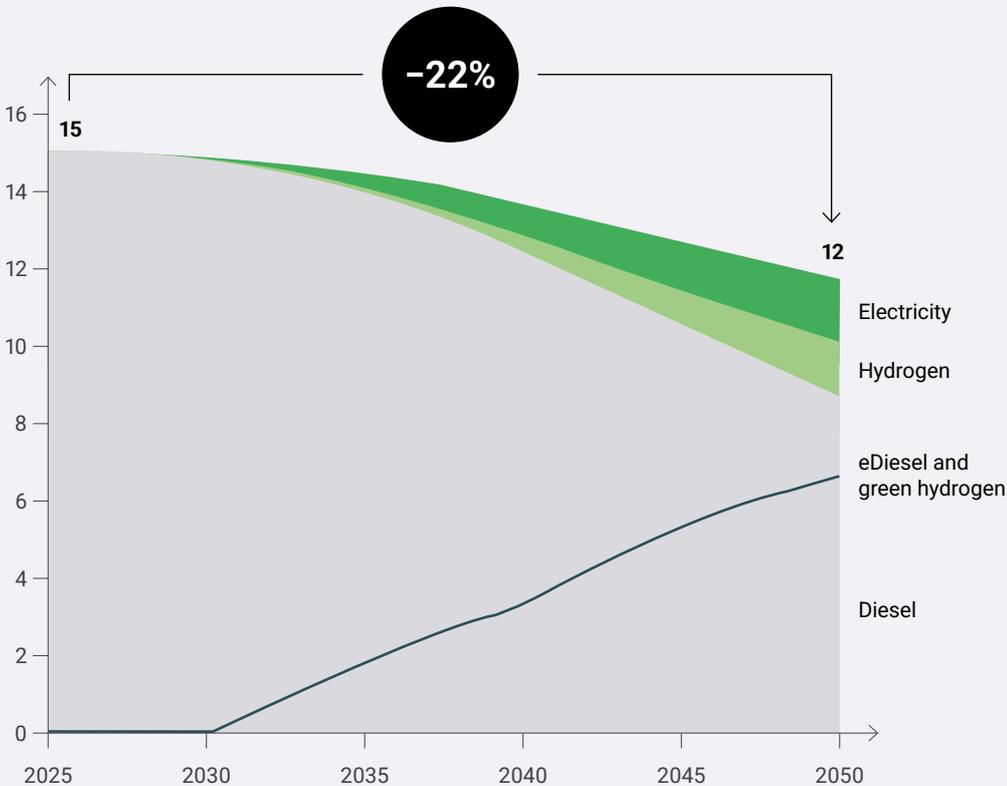

Figure 25: Annual fuel demand of agricultural and construction machines in the EU.
Source: Porsche Consulting Powertrain TCO Model | Results are presented in billion liters gasoline equivalent |
Assumption: eDiesel and green hydrogen ramp-up based on on-road mobility quotas in the "EU Ambition" scenario

3.5. Annual CO_2 emissions

Based on the modeled powertrain transformation in on-road mobility and the energy transition across all four segments, CO_2 emissions were calculated for the European Commission's "EU Ambition" scenario using a life cycle approach. This includes emissions from vehicle production, the entire energy supply chain, and vehicle use. The detailed methodology is explained in → *Section 3.2.3*. For each segment, the resulting annual CO_2 emissions are presented in Figure 26.
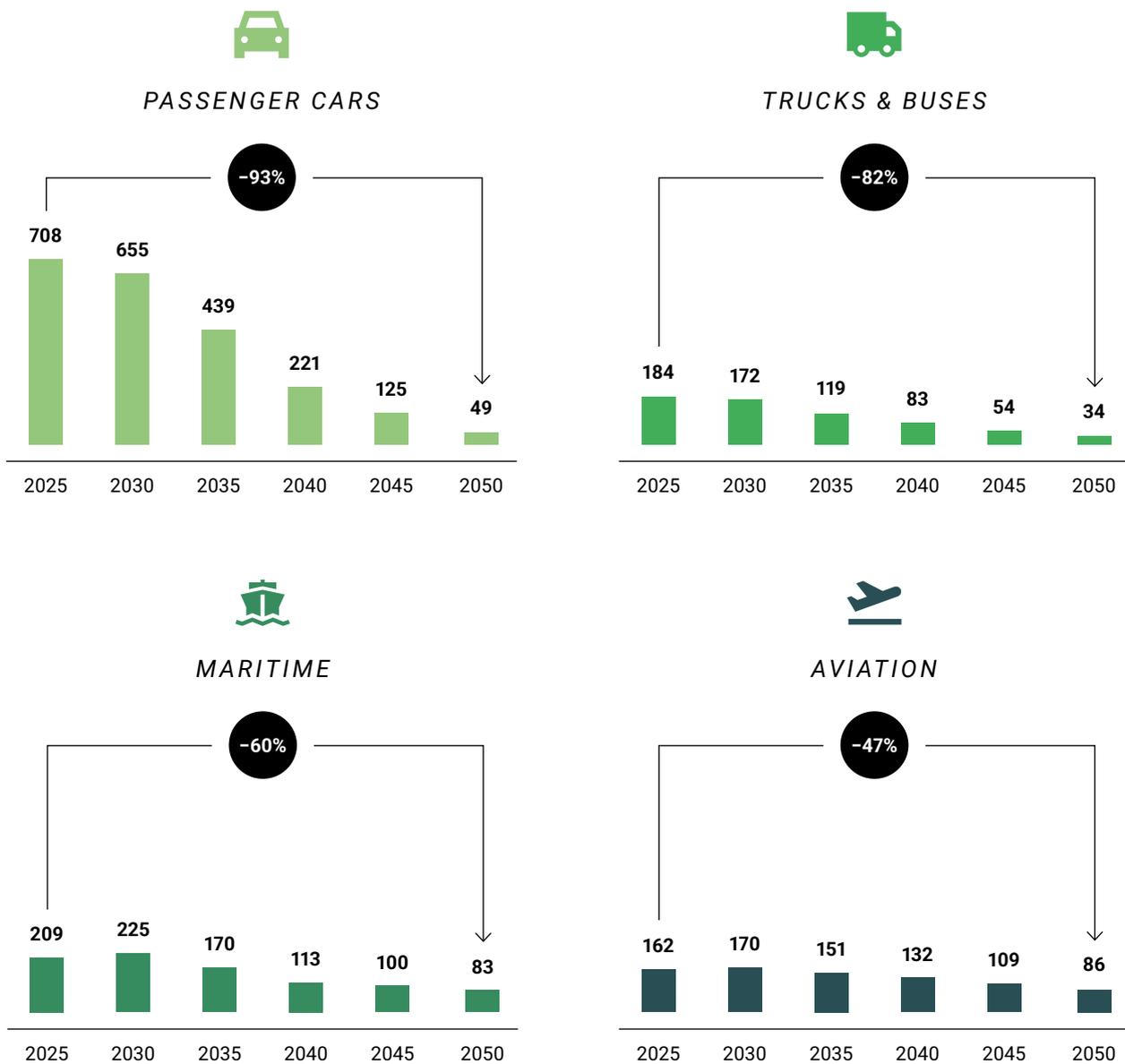

Figure 26: Annual life cycle CO_2 emissions in EU mobility by segment in million tons CO_2/a: "EU Ambition" scenario.

In the maritime and aviation segments, carbon savings are delayed due to rising transport demand and the limited feasibility of direct electrification.

For the year 2025, the simulation indicates the highest CO_2 emissions in passenger car mobility, exceeding 700 million tons of CO_2. This is primarily due to the larger annual energy consumption in this segment. The other three segments currently show similar emission levels, ranging between 160 and 210 million tons of CO_2.

A faster decarbonization is projected for on-road mobility, with passenger cars achieving a 93 percent reduction between 2025 and 2050, and trucks and buses reaching 82 percent. This ambition aligns with the assumed high electrification rates for 2050: 94 percent for passenger cars (80 percent BEV and 14 percent FCEV) and 79 percent for trucks and buses (48 percent BEV and 31 percent hydrogen powertrains). The resulting efficiency gains, illustrated in Figure 21, combined with the assumption that 89 percent of electricity will come from renewable sources and 8 percent from nuclear energy by 2050, maximize decarbonization potential.

In the maritime and aviation segments, carbon savings are delayed due to rising transport demand and the limited feasibility of direct electrification. This results in a stronger reliance on the ramp-up of eFuels and biofuels. Consequently, a carbon peak is expected around 2030 in these two sectors, before renewable fuels begin contributing significantly by 2035. By 2050, CO_2 reductions compared to 2025 are projected to reach 60 percent in maritime mobility and 47 percent in aviation. Although the combined 2050 quota for renewable fuels is expected to reach 99 percent and 74 percent, respectively—as shown in Figure 23—the conservative assumption that these fuels have 70 percent lower CO_2 intensity than conventional fossil fuels (see → *Section 3.2.3.*) limits carbon savings to a maximum of 70 percent. In practice, eFuels and biofuels often achieve reductions exceeding 80 percent, offering additional decarbonization potential for maritime and aviation.

CO_2 emissions were analyzed across all phases of the vehicle life cycle for each of the four mobility segments. Life cycle emissions include those generated during vehicle production, energy supply, and vehicle use. From now on, these will be referred to as "vehicle production," "well-to-tank," and "tank-to-wheel" emissions, respectively. "Well-to-wheel" emissions combine both well-to-tank and tank-to-wheel phases. While tank-to-wheel is specific to on-road mobility and other terms apply to different segments—such as "tank-to-wake" for maritime mobility—the analysis is simplified by using on-road terminology for all segments. Overall progress toward emission targets is shown in Figure 27.
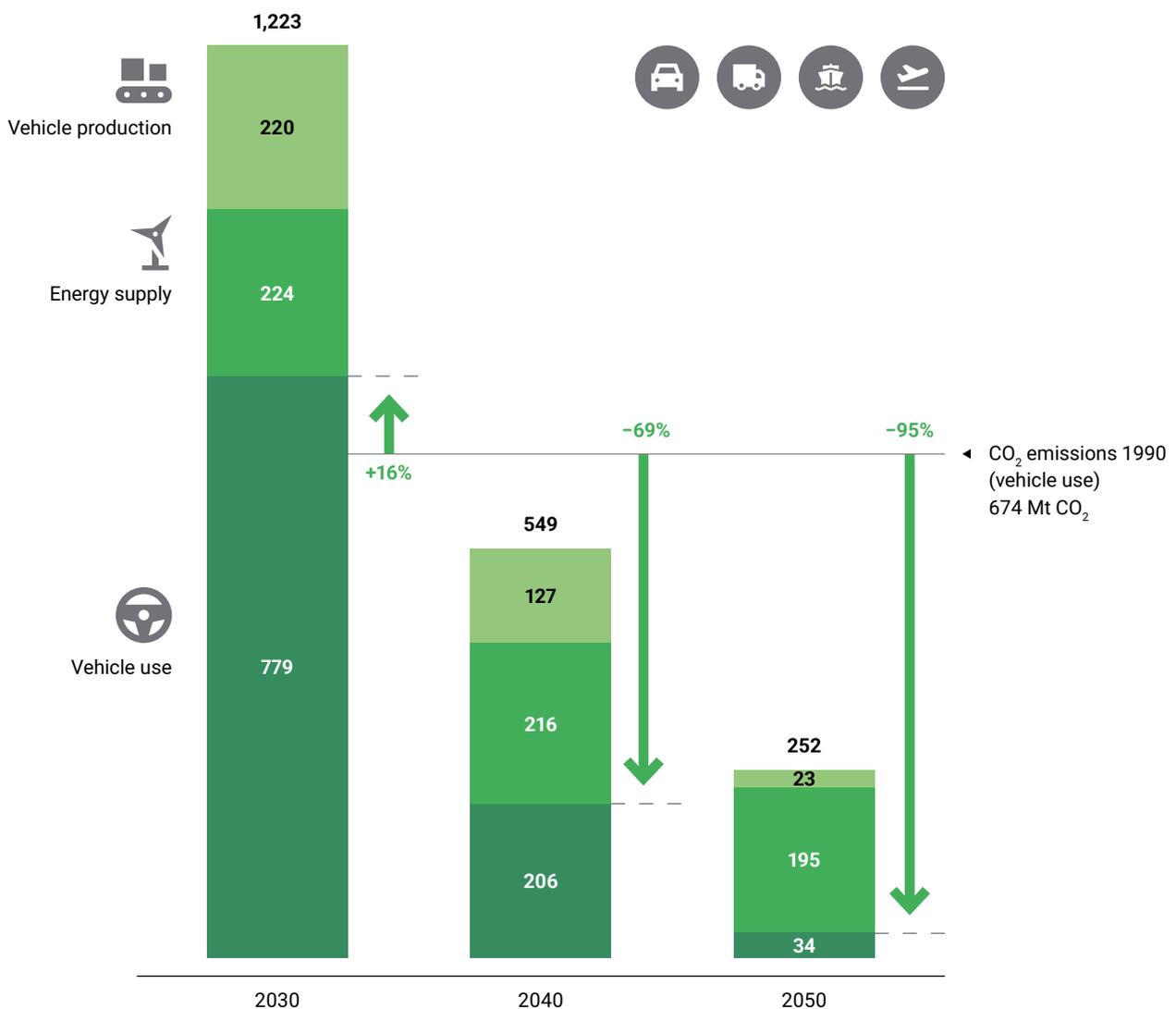

Figure 27: Annual CO_2 emissions by phase of the vehicle life cycle in EU mobility in million tons CO_2/a: "EU Ambition" scenario.

In mobility, CO_2 emission targets set by the European Union are limited to the tank-to-wheel scope. Therefore, tank-to-wheel emissions are highlighted and compared with 1990 levels under the same scope. In 2030, the powertrain and energy transformations defined in the "EU Ambition" scenario are not sufficient to achieve a 55 percent reduction compared to 1990. Instead, emissions remain higher than 40 years earlier due to increased mobility demand and the inertia of the transition. From 2030 onward, the shift to electric on-road mobility combined with the scale-up of renewable fuels across all segments drives a steep decline in tank-to-wheel CO_2 emissions—by a factor of four between 2030 and 2040, and six between 2040 and 2050. This results in reductions of up to 70 percent by 2040 and 95 percent by 2050 compared to 1990 levels. Meeting the 90 percent reduction target by 2040 and achieving climate neutrality by 2050, as outlined in the "EU Ambition" scenario, will require additional effort—either within the mobility sector or through compensation in other sectors. It is also important to note that rail transport, off-road transport, motorcycles, and recreational boating are outside the scope of this analysis; including them would increase CO_2 emissions beyond the results shown in Figure 27.

Reducing CO_2 emissions within the tank-to-wheel scope can impact emissions in other life cycle phases, such as vehicle production or well-to-tank. For example, BEVs have zero emissions on a tank-to-wheel basis but generate higher emissions during vehicle production compared to conventional ICEVs, primarily due to battery manufacturing and its energy-intensive supply chain. The electricity source also influences well-to-tank emissions. In the "EU Ambition" scenario, the assumption of renewable electricity use significantly reduces both vehicle production and well-to-tank CO_2 emissions. This assumption is critical for

electrification to effectively contribute to climate targets. As explained in → *Section 3.2.3.*, a 70 percent CO_2 reduction factor compared to conventional fossil fuels is assumed for eFuels and biofuels on a well-to-wheel basis. The remaining 30 percent is allocated to well-to-tank emissions. In other words, eFuels and biofuels are considered zero-emission technologies in the vehicle use scope but not in the energy supply scope. In practice, the 70 percent reduction threshold for eFuels and biofuels is likely to be exceeded in many cases, enabling further reductions in energy supply emissions. Under the current assumption, these emissions will stagnate at around 200 million tons of CO_2 by 2050, making them the primary emission driver.

To conclude, the transformation outlined by the European Commission as the "EU Ambition" scenario establishes a strong decarbonization pathway on a tank-to-wheel basis. However, additional emission drivers, such as vehicle production and energy supply (well-to-tank), must also be addressed in the race against climate change. Ensuring the successful rollout of this ambitious powertrain and energy transition requires a quantitative feasibility analysis, which is examined in → *Chapter 4*.

Meeting the 90 percent reduction target by 2040 and achieving climate neutrality by 2050, as outlined in the "EU Ambition" scenario, will require additional effort—either within the mobility sector or through compensation in other sectors.

4

Bottleneck analysis: "Bottleneck-adjusted" scenario

The "EU Ambition" scenario, derived from scenario 3 of the European Commission's Impact Assessment, raises questions about the industrial feasibility of the assumed powertrain and energy transition across passenger car, truck & bus, maritime, and aviation mobility segments. Such an ambitious ramp-up of new powertrains and energy sources could place significant pressure on global and European supply chains. To evaluate the feasibility of the transition speed proposed in the Commission's Impact Assessment, a comprehensive bottleneck analysis was conducted. This analysis examined 27 critical supply chain factors that strongly influence the pace of the mobility transition. The objective was to compare demand and supply in order to identify potential shortages or additional capacities.

→ 4.1. Methodology, modelling and data collection

4.1.1. Scope of the bottleneck analysis

To define a technology-neutral decarbonization path for EU mobility, this study's bottleneck analysis focused on industrial feasibility factors. Additional dimensions that could delay the transformation of powertrain and energy supply chains—such as regulation, geopolitical dynamics, customer trends, social acceptance, and unforeseeable economic events—were not assessed. For the industrial feasibility assessment, the analysis was organized into four main supply chain areas: batteries, renewable electricity, green hydrogen, and eFuels. Within these categories, 27 critical supply chain factors—referred to as "bottleneck factors"—were identified and evaluated. Some were assessed at a global level, where supply is shared with other markets, while others were analyzed at the European level.

Across the battery supply chain, global mining and refining capacities for lithium, nickel, cobalt, and battery-grade graphite were identified as critical for scaling up battery production. In addition, global manufacturing capacities for anode active material, cathode active material, and battery cells were closely examined, as delays in their ramp-up could significantly impact the adoption of BEVs. Battery

pack and vehicle manufacturing capacities were not considered potential bottlenecks for BEV ramp-up, as automotive OEMs have demonstrated their ability to scale these capacities. Disruptions in this area typically result from delays in upstream supply chains or from hesitant demand. The battery supply chain was analyzed on a global scale due to its international distribution. For example, a major share of lithium used in batteries for European mobility is sourced from countries such as Chile, Bolivia, Argentina, and Australia. Refining capacities, however, are primarily concentrated in China, which also dominates the production of anode and cathode active materials. Most battery cells are currently imported from China and South Korea, although the European Union is planning to expand its own production capacities. This illustrates the global nature of the battery supply chain and underscores the need to consider worldwide market dynamics in the bottleneck analysis.

In the renewable electricity supply chain, the manufacturing of wind and photovoltaic power equipment was analyzed at a global level due to the international nature of this market. The speed of installing wind and photovoltaic power plants was assessed at the European level, excluding intercontinental electricity imports because of technical and financial constraints. Similarly, the pace of installing transmission and distribution grids was evaluated at the European level, along with the roll-out speed of public charging points.

Similar to renewable electricity, the feasibility of scaling green hydrogen depends on global manufacturing capacities for wind and photovoltaic power equipment. In addition, global manufacturing capacities for electrolysis equipment were assessed. Considering the European Union's ambition to expand green hydrogen supply from both European and

global sources[21] the speed of installing green hydrogen production capacities was evaluated at both European and global levels. For European green hydrogen projects, the availability of renewable energy within the EU is a key enabler, as these projects typically source electricity from the grid combined with power purchase agreements (PPAs). For this reason, the installation pace of wind and photovoltaic power plants in Europe was assessed as an additional limiting factor. For global green hydrogen projects, dedicated stand-alone power plants are generally the preferred option due to remote conditions. Therefore, potential limitations in renewable power plant installation were already considered within the global green hydrogen installation assessment. The speed of installing hydrogen

pipelines was analyzed at the European level, as constraints in this area could affect green hydrogen availability within the EU. Finally, global fuel cell manufacturing capacities were evaluated to identify potential limitations in the ramp-up of FCEV.

Moreover, eFuel supply chains were assessed at a global scale, as eFuels are expected to be traded internationally—not only due to capacity limitations within Europe, but also because production in regions with high renewable energy potential should be prioritized to achieve cost reductions. Similar to renewable electricity and green hydrogen, global manufacturing capacities for wind and photovoltaic power equipment were analyzed, along with global manufacturing of electrolysis equipment. The global installation speed of eFuel production plants is critical to securing the eFuel ramp-up in the European Union and was examined in detail. Since hydrogen and renewable power generation are integral parts of eFuel plants, potential limitations related to their installation speed were already considered within the assessment of global eFuel production plant installation.

As highlighted in → *Section 3.2.1.*, the energy transition is the primary driver of transformation in the maritime and aviation segments. In contrast, powertrain transitions within these fleets have a relatively low impact, mainly due to slow fleet renewal and the high energy flexibility of vessels. Furthermore, as noted in → *Section 3.4.*, fuel cell and battery-based powertrains will remain limited to a few applications.

For this reason, potential industrial bottlenecks in fuel cell and battery supply chains were not further investigated for maritime and aviation. Instead, the feasibility assessment focused on energy supply chains—specifically renewable electricity, green hydrogen, and eFuels.

4.1.2. Methodology and modelling for EU mobility supply

The approach involves comparing demand and supply in EU mobility for all 27 bottleneck factors for each year through 2050. EU mobility demand was quantified under the "EU Ambition" scenario for each bottleneck factor in critical powertrain and energy supply chains, based on fleet and energy models. The approach and data collection used to derive EU demand curves will be detailed in → *Section 4.1.3*. To quantify supply, a method was developed to allocate an available share of global supply to EU mobility, since most supply chains are shared with other sectors and markets. In this method, EU mobility receives a proportional share of global supply corresponding to its share of global demand. This mechanism is structured in four steps, as illustrated for lithium mining in Figure 28.

The approach began at the global level, where demand data was collected for all bottleneck factors. To reflect the ambition of other markets in meeting their climate commitments, global demand was derived from the International Energy Agency's (IEA) "Announced Pledges" scenario (APS). Introduced in 2021, the APS models how the global energy system would evolve if all governments fully and on time implemented their announced climate and energy pledges. This includes the latest national announcements for short- and long-term carbon reduction targets, regardless of whether they are legally binding.

The APS corresponds to limiting global warming to approximately 1.7°C above pre-industrial levels. This target aligns with the Paris Agreement objective of keeping global warming "well below 2°C," but it does not achieve global climate neutrality by 2050. In contrast, the "EU Ambition" scenario assessed in this study was designed by the European Commission to reach climate neutrality by 2050, making it more progressive than the global trajectory under APS. The higher ambition announced by the European Union was factored into APS and offsets more conservative pledges in other markets.

The purpose of this study was to evaluate the feasibility of the transformation based on the announced ambitions of the EU and other global markets—not on a scenario assuming global climate neutrality by 2050. The fact that global ambitions are generally less aggressive than those of the EU eases pressure on critical powertrain and energy supply chains. Assuming the EU receives a proportional share of global supply corresponding to its share of global demand, this creates more flexibility for the European transition in case of bottlenecks. Conversely, if global ambitions increase, bottlenecks could intensify or new ones could emerge, directly impacting the EU mobility transition. Similarly, bottlenecks could diminish or disappear if global ambitions weaken.

The bottleneck assessment in this study reflects current global announcements, but future changes in global trajectories could alter the results. The IEA derived global demand under APS across powertrain and energy supply chains in several detailed reports, which will be referenced later in this study. For each bottleneck factor, EU mobility demand was calculated based on the "EU Ambition" scenario, and its share of global demand was used to allocate the same proportion of global supply to EU mobility.

In the second step, global supply was forecasted based on existing capacities and industry announcements. Data collection and quantitative results are detailed in → *Section 4.2.* for lithium, wind power equipment, electrolysis equipment, and eFuel production capacities, and in Appendix E for all other
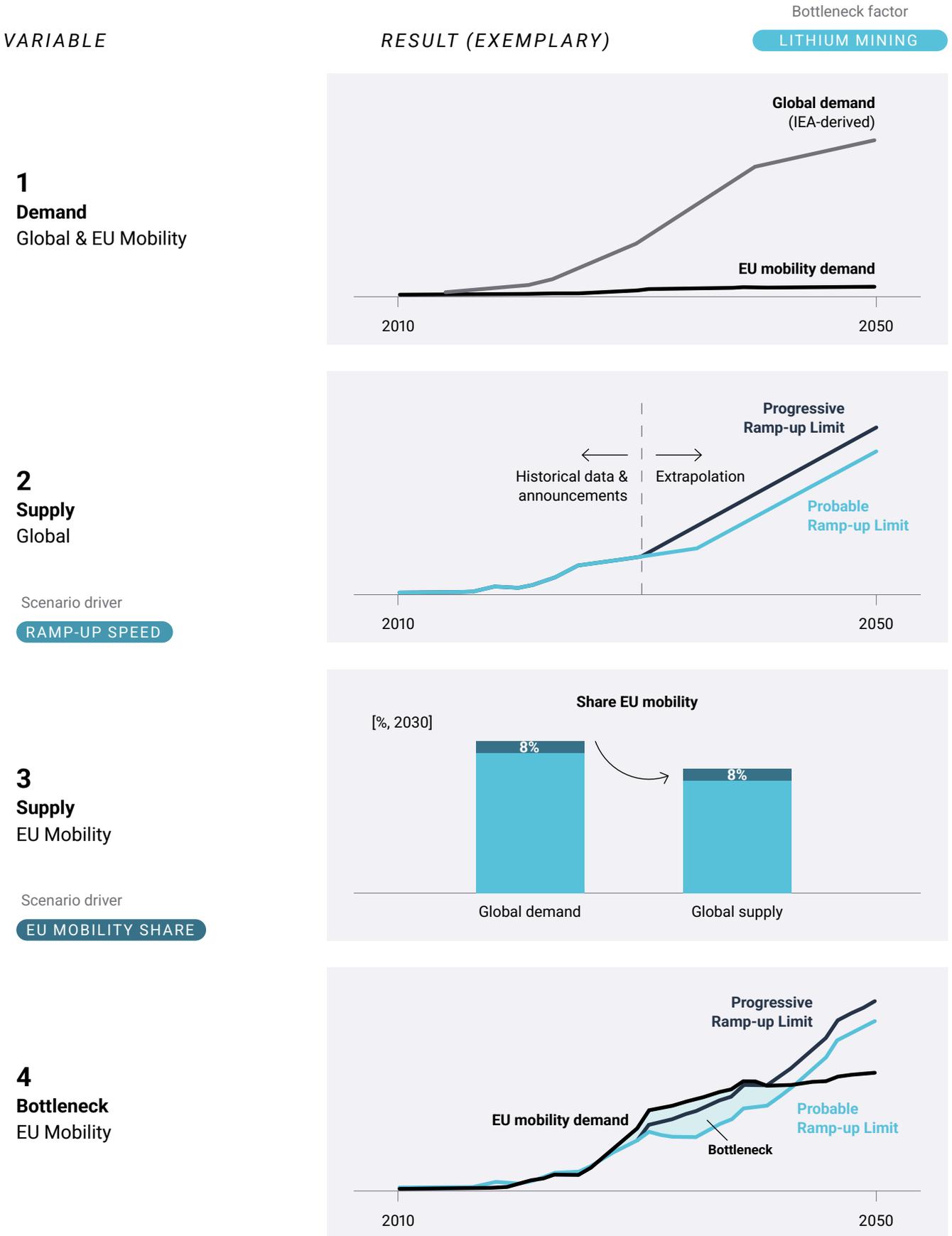
VARIABLE

RESULT (EXEMPLARY)

Bottleneck factor

LITHIUM MINING

1

Demand
Global & EU Mobility

Global demand
(IEA-derived)

EU mobility demand

2010
2050

2

Supply
Global

Scenario driver

RAMP-UP SPEED

Progressive
Ramp-up Limit

Historical data &
announcements | Extrapolation

Probable
Ramp-up Limit

2010
2050

3

Supply
EU Mobility

Scenario driver

EU MOBILITY SHARE

Share EU mobility

[%, 2030]

8%

8%

Global demand

Global supply

4

Bottleneck
EU Mobility

Progressive
Ramp-up Limit

EU mobility demand

Probable
Ramp-up Limit

Bottleneck

2010
2050

Figure 28: Approach of the bottleneck analysis illustrated for lithium mining: "EU Ambition" scenario.

bottleneck factors in critical powertrain and energy supply chains.

For emerging supply chains such as batteries, green hydrogen, and eFuels, historical data alone is insufficient to predict future capacity ramp-up. Therefore, announced capacities were tracked and projected through 2030. Announcements beyond 2030 were excluded due to their low implementation likelihood at present. Industry plans within a five-year horizon typically involve stronger stakeholder commitments, increasing confidence in their feasibility.

Until 2030, it is unlikely that capacity ramp-up will exceed the sum of existing capacities and current industry announcements, as lead times for new capacity additions generally exceed five years for nearly all bottleneck factors. Consequently, the sum of existing capacities and announced capacities for 2030 was set as the ramp-up limit for the period 2025–2030. An exception was made for the installation speed of wind and photovoltaic power plants, as lead times are typically shorter than five years and the industry's maturity allows future ramp-up limits to be derived from historical trends.

For the period 2030–2035, longer lead times create room for new projects. Therefore, the ramp-up limit from 2030 was projected based on accelerated capacity additions using the compound annual growth rate (CAGR) from 2025–2030. By 2035, all supply chains are expected to reach their maximum ramp-up speed, so the ramp-up limit from 2035 onward was defined as the highest annual capacity addition achieved before 2035, applied as a constant thereafter. This supply scenario is referred to as the "Probable Ramp-up Limit". It does not represent a realistic industry forecast, as additional external factors influence the ramp-up across powertrain and energy

supply chains—such as regulatory frameworks, geopolitical developments, consumer behavior, social acceptance, and unforeseen economic events. Instead, it reflects the maximum achievable ramp-up considering industrial limitations.

A sensitivity analysis was conducted to simulate a more aggressive supply scenario from 2030, referred to as the "Progressive Ramp-up Limit". In this scenario, annual capacity additions from 2030 to 2038 are set as the maximum between a CAGR-based* addition and the best year's addition from previous years. From 2039 onward, the highest annual addition achieved by 2038 is applied as a constant.

* CAGR from 2025–2030.

After projecting demand and supply curves at the global level, implications were derived for EU mobility. The share of global supply allocated to EU mobility was assumed to be proportional to its share of global demand. For example, in 2030, lithium demand from EU mobility is forecasted to represent 8 percent of global lithium demand, as calculated in step 1. Accordingly, the same share of global lithium supply was allocated to EU mobility. This approach was applied consistently for each year from 2025 to 2050.

This assumption implies no preferential access for the EU over other regions, meaning that supply for EU mobility depends not only on the global capacity ramp-up speed but also on demand from other regions. In other words, if global demand rises sharply, the share of supply available to EU mobility decreases, even if global supply capacities continue to grow during that period. Conversely, if global demand declines, the share of supply allocated to EU mobility increases.

As the final step, demand and supply curves were compared at the EU mobility level to identify potential bottlenecks and opportunities to accelerate the transformation.

4.1.3. Methodology, modelling and data collection for EU mobility demand

Based on the "EU Ambition" scenario, demand curves for mobility were derived from fleet and energy models and later compared with supply curves for each bottleneck factor in critical powertrain and energy supply chains. The methodology for generating demand curves is detailed in this Section.

4.1.3.1. Battery

In the battery supply chain, battery cell demand was calculated based on new BEV and PHEV registrations and the corresponding average battery capacity per vehicle for each on-road mobility segment—passenger cars and trucks & buses. The evolution of average

	PHEV	BEV
🚗	**20 kWh** 2025–2050	**55 kWh** in 2025 **80 kWh** 2035+
🚚	**100 kWh** 2025–2050	**500 kWh** in 2025 **600 kWh** 2030+

Figure 29: Average battery capacity per vehicle.

battery capacity over time was considered, and Figure 29 provides an overview of these assumptions. For passenger cars, battery capacity assumptions were derived from the detailed life cycle analysis by Umweltbundesamt[9]. For trucks and buses, assumptions were based on a study by Link et al. (2024)[22]. In both segments, the average BEV battery capacity is projected to increase over time due to technical improvements and rising range expectations. As BEV adoption grows, attracting range-sensitive users who remain hesitant to switch to battery-electric mobility will require offering greater range flexibility. Linear interpolations were applied between the data points shown in Figure 29.

Annual battery cell demand in the "EU Ambition" scenario was calculated for on-road mobility based on new BEV and PHEV registrations and average battery capacity. The results, shown in Figure 30, indicate that the battery supply chain ramp-up should be completed by 2040 to achieve the "EU Ambition" scenario.

Demand for critical raw materials, as well as anode active material (AAM) and cathode active material (CAM), depends on battery cell demand and the cell chemistry used in vehicles. The battery cell chemistry forecast developed by Porsche Consulting was applied to model the evolution of each chemistry's market share. For passenger cars, the model predicts that LFP and LMFP chemistries will dominate the volume market in the long term, followed by LNMO and NCA. Nickel-rich NMC chemistries are expected to serve the performance segment, while other standard NMC chemistries are forecasted to phase out. In the truck & bus segment, LFP and LMFP chemistries are projected to dominate in the mid-term, with other chemistries limited to specific use cases. For each cell chemistry, the gravimetric content of critical raw materials—lithium, nickel, cobalt, and graphite—was
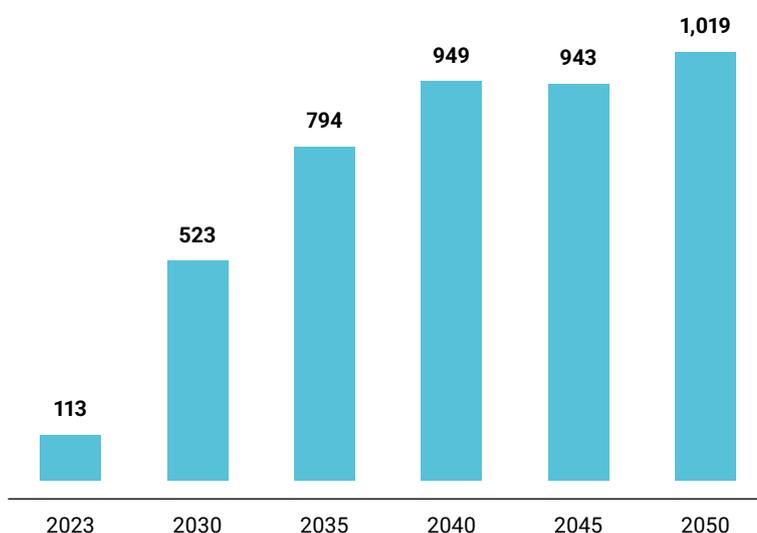

Figure 30: Annual battery cell demand in EU on-road mobility in GWh: "EU Ambition" scenario.

assessed. Combining annual battery cell demand, the cell chemistry forecast, and raw material content per chemistry, annual raw material demand was calculated for both passenger car and truck & bus segments. Similarly, specific demand for AAM and CAM was evaluated for each battery cell chemistry, with annual demand derived from battery cell demand and the chemistry forecast across both on-road mobility segments.

4.1.3.2. Renewable electricity

For each bottleneck factor in the renewable electricity supply chain, demand curves were derived from the energy demand model.

Electricity demand was modeled across three power source clusters: fossil, nuclear, and renewable. However, the evolution of the electricity mix within these clusters was not provided in the European Commission's Impact Assessment report. To specifically

assess demand for wind and solar photovoltaic capacities, the electricity mix was further refined in the model. The detailed 2023 electricity mix served as the baseline[14], while projections for 2030 and 2050 were derived from the IEA "Announced Pledges" scenario as outlined in the World Energy Outlook 2023[23]. Demand for wind and solar photovoltaic power generation was calculated for the period 2025–2050, and the corresponding installed capacity required each year was modeled based on annual capacity load factors: an average of 2,730 hours for wind power plants and 1,130 hours for solar photovoltaic, according to average European 2019 climate data[24].

Demand for power transmission and distribution was derived from overall electricity demand in EU mobility and the average grid length required for electricity transmission and distribution within the EU. Electricity demand for EU mobility was taken directly from the energy model for each year through 2050.

Based on the 2020 ENTSO-E TYNDP Report[25] and historical trends in EU electricity transmission, specific demand for transmission grid capacity was estimated at 130 km/TWh. Similarly, specific demand for distribution grid capacity was set at 5,000 km/TWh, as derived from the IEA Electricity Grids and Secure Energy Transition report (2023)[26]. Using these factors, EU mobility demand for transmission and distribution grids was calculated in kilometers for each year until 2050.

Demand for public charging capacity was calculated based on the BEV and PHEV fleet stock size and the average charging capacity required per vehicle. In the passenger car segment, the average charging capacity requirement was assumed to be 1.3 kW for BEVs and 0.8 kW for PHEVs, according to the IEA Global EV Outlook 2024[27]. For trucks and buses, the requirement specified in the Alternative Fuel Infrastructure Regulation (AFIR) for Heavy Duty[28] served as the basis, resulting in a charging capacity requirement of 22.4 kW for BEVs. The PHEV average capacity requirement was estimated at 13.8 kW, assuming the same proportional relationship to BEVs as in the passenger car segment.

4.1.3.3. Green hydrogen

The European Union plans to produce and import 10 million tons of green hydrogen each by 2030 to supply all sectors, according to the EU Hydrogen Strategy (2022)[21] and the REPowerEU Plan (2022)[29]. This adds complexity to the bottleneck assessment, as both supply chains were evaluated separately under the assumption that each contributes 50 percent of total supply. For EU mobility in the "EU Ambition" scenario, demand was split between European and global sources based on this assumption.

The approach begins by assessing the demand for electrolysis capacity. For each supply chain and each year, the required electrolysis capacity was calculated based on annual capacity load and the green hydrogen demand derived from the energy model. European production sites were assumed to operate at an average annual capacity load of 2,500 hours, while global production sites benefit from more favorable conditions, achieving 4,000 annual full-load hours. These values were derived using the Porsche Consulting Green Hydrogen Cost Model, based on average climate data[24] in regions currently hosting large-scale green hydrogen projects, such as the Portuguese or the Danish coastlines in Europe, as well as selected areas within the MENA region globally. This reduces the installed capacity requirement for global plants compared to European plants for the same production volume. For example, in the "EU Ambition" scenario, the electrolysis

capacity dedicated to EU mobility's green hydrogen supply in 2040 is projected to reach 11.2 GW in the EU and 7.0 GW in global regions.

The second step involves quantifying demand for wind and photovoltaic power capacities for both European and global production sites. European production plants are assumed to source electricity from renewable power available in the grid. Therefore, the required electricity capacity for green hydrogen production was allocated to each renewable source according to its share and projected evolution, as defined in → *Section 4.1.3.2.* For example, photovoltaic power is forecasted to represent 47 percent of total installed renewable capacity in 2040. Given that the required electrolyzer capacity for European green hydrogen production is projected at 11.2 GW in 2040, 47 percent of this capacity—approximately 5.2 GW—should be powered by photovoltaic sources. Using this approach, required installed capacities for wind and solar photovoltaic power were derived for European green hydrogen projects for each year until 2050. For global green hydrogen projects, it is assumed that electrolysis capacities are powered by dedicated stand-alone wind and photovoltaic plants, with installed capacities equally distributed between the two sources. For instance, to meet the "EU Ambition" scenario in 2040, global green hydrogen production is forecasted to require 3.5 GW of installed wind capacity and an equal 3.5 GW of photovoltaic capacity.

To quantify demand for hydrogen pipelines in the European Union, industry announcements on new or repurposed pipeline projects were analyzed using the IEA Hydrogen Infrastructure Database[6]. Based on the technical data of these projects, specific demand for pipeline capacity was estimated at 13,750 km per Mt of hydrogen. It was assumed that hydrogen transport via pipelines in the EU will be required for all hydrogen types, regardless of energy source. At the start of the planned transformation under the "EU Ambition" scenario, hydrogen-powered vehicles are unlikely to refuel exclusively with green hydrogen. Since the ramp-up of green hydrogen

For global green hydrogen projects, it is assumed that electrolysis capacities are powered by dedicated stand-alone wind and photovoltaic plants, with installed capacities equally distributed between the two sources.

is expected to take several decades, other hydrogen types—such as fossil-based hydrogen—will also be supplied to EU mobility through the pipeline network. The pipeline network is assumed to serve on-road and aviation mobility, but not maritime mobility. Imported hydrogen will transit through ports, where vessels can refuel directly. The hydrogen pipeline capacity required under the "EU Ambition" scenario was calculated based on hydrogen demand in the on-road and aviation segments and the specific demand factor of 13,750 km/Mt.

Annual fuel cell demand was calculated for on-road mobility, while maritime and aviation were not further analyzed, as noted in → *Section 4.1.1*. Fuel cell demand was derived from FCEV new registrations and the average fuel cell capacity per vehicle, assumed to be 104 kW for passenger cars and 245 kW for trucks and buses, based on an industry benchmark analysis across several brands in both segments.

4.1.3.4. eFuels

Similar to the green hydrogen supply chain, the eFuel supply chain was assessed by focusing on the required capacities for eFuel production plants, electrolysis equipment, and wind and solar photovoltaic power. Unlike green hydrogen, the European Union has not defined a clear sourcing strategy for eFuels, leaving global imports as a viable option for mobility supply. Due to significant cost advantages in producing eFuels in regions with high renewable energy potential, eFuel supply for EU mobility is assumed to occur at a global scale. This assumption is critical for considering efficiency gains and their implications on required capacities for renewable power and electrolysis equipment.

The required annual capacity for eFuel production plants was derived directly from eFuel demand calculated in the energy model across all mobility sectors analyzed in this study. To determine the installed capacity for methanol

and Fischer-Tropsch (FT) synthesis routes, it was assumed that eGasoline and eMethanol are produced via methanol synthesis, while eDiesel and eSAF are produced via the FT route. Although variations to this assumption may occur in practice, current projects indicate a clear trend in this direction. For each synthesis path, eFuel demand was calculated based on detailed fuel-type volumes provided by the energy model. Global eFuel production sites were assumed to operate at an average annual capacity load of 5,000 hours. This value was derived using the Porsche Consulting eFuel Cost Model, based on average climate data[24] in global regions currently hosting large-scale eFuel projects, such as Patagonia (Chile) or Inner Mongolia (China). Using this assumption and annual eFuel demand, required methanol and FT synthesis capacities were projected over time. By 2040, the "EU Ambition" scenario designed by the European Commission is projected to require a methanol synthesis capacity equivalent to approximately 104 billion liters of gasoline, alongside an additional capacity of 55 billion liters via the Fischer-Tropsch route.

For each synthesis path, the required installed electrolysis capacity was calculated using efficiency data from the Porsche Consulting eFuel Cost Model. In the next step, the required installed wind and solar photovoltaic capacities were derived under the assumption that electrolysis plants are powered by dedicated stand-alone wind and photovoltaic installations, with equal capacity distribution between both sources—similar to global green hydrogen production plants, as described in → *Section 4.1.3.3*. For example, to meet the "EU Ambition" scenario, global eFuel production in 2040 is projected to require 59 GW of installed wind power capacity for the methanol route and 32 GW for the Fischer-Tropsch route. The same capacities are required for photovoltaic power.

4.1.4. Methodology and modelling of "Bottleneck-adjusted" scenario

After modeling the supply and demand curves for each bottleneck factor in EU mobility, based on the methodology described in → *Sections 4.1.2. and 4.1.3.*, potential bottlenecks are identified when demand exceeds supply in the "EU Ambition" scenario. Conversely, opportunities to accelerate the transformation are identified when supply exceeds demand. Using the supply curves from the "Probable Ramp-up Limit" scenario, new vehicle registrations and low-carbon energy quotas were calculated through a bottom-up approach, ensuring consistency with previous assumptions. In several cases, multiple bottleneck factors affect the supply chain. For each year, the most restrictive bottleneck factor is used to build the "Bottleneck-adjusted" scenario. The resulting scenario does not represent a realistic industry forecast, as multiple external factors influence the ramp-up across powertrain and energy supply chains—such as regulatory frameworks, geopolitical developments, consumer behavior, social acceptance, and unforeseen economic events. Instead, the "Bottleneck-adjusted" scenario reflects the maximum achievable ramp-up considering industrial limitations.

For example, the 2032 passenger car BEV new registration quota is forecasted to reach 65 percent in the "EU Ambition" scenario. In comparison, the "Bottleneck-adjusted" scenario shows a maximum of 40 percent. This value is derived from the most restrictive bottleneck factor in 2032: lithium supply.

The model first sets the maximum lithium supply, forecasted at 34 kt for EU mobility according to the "Probable Ramp-up Limit" scenario. This supply is then allocated between passenger car mobility and truck and bus mobility, maintaining consistency with

This capacity is then distributed between BEVs and PHEVs, maintaining consistency with battery cell demand shares for the same year under the "EU Ambition" scenario. Consequently, BEVs receive 96 percent of the available battery cell capacity: approximately 380 GWh. With an average BEV battery capacity of 73 kWh in 2032, this translates into 5.2 million BEV new registrations, corresponding to a 40 percent market share. This calculation assumes annual new passenger car registrations remain constant at about 13 million vehicles to keep the fleet stock size aligned with the "EU Ambition" scenario over the entire 2025–2050 period—approximately 209 million vehicles. Subsequently, the fleet model takes over to derive fleet stock sizes and powertrain shares.

The same approach is applied to determine the feasible ramp-up of other powertrains in both the passenger car segment and the truck & bus segment. On the energy side, the method for deriving energy quotas follows an analogous process and is implemented after adjusting the powertrain transformation.

Typically, adjusting the powertrain transition reduces pressure on energy supply chains, meaning that most low-carbon energy quotas are more likely to increase rather than be constrained by bottlenecks in the "Bottleneck-adjusted" scenario. Finally, CO_2 emissions are modeled based on the adjusted powertrain and energy transitions.

lithium demand shares for the same year under the "EU Ambition" scenario. As a result, passenger car mobility receives 94 percent of the lithium supply in 2032, equivalent to 32 kt. For comparison, the share of supply is higher for nickel—98 percent—since NMC chemistries play a secondary role in the truck & bus segment.

Based on the cell chemistry forecast introduced in the "EU Ambition" scenario and the gravimetric lithium content of each type of chemistry, the average lithium content for the passenger car segment in 2032 is calculated at 82 g/kWh. Combined with the 32 kt lithium supply, the maximum battery cell capacity based on lithium availability is 395 GWh. Following a similar process, the cell capacity based on nickel availability reaches 461 GWh. The same approach applies to cobalt and graphite supply, as well as anode active material, cathode active material, and cell production capacities. At this point, lithium is identified as the limiting factor, and the maximum cell capacity is assumed to be 395 GWh.

4.2. Detailed approach for exemplary bottleneck factors

In this chapter, the methodology presented in → *Section 4.1.* will be illustrated with one example from the battery supply chain—lithium—and three examples from the eFuel supply chain: wind power equipment, electrolysis equipment, and eFuel plant installation. The results of the industrial bottleneck assessment for additional factors are provided in Appendix E. → *Section 4.1.* introduced a sensitivity analysis using the "Progressive Ramp-up Limit" scenario. In this chapter, the method will be detailed for the baseline scenario, referred to as the "Probable Ramp-up Limit" scenario, while the sensitivity results will be presented in → *Section 4.3.*

4.2.1. Lithium

Lithium is a critical raw material for the ramp-up of BEVs and PHEVs, as it is used in both the passenger car and truck & bus segments and in most battery cell chemistries through 2050. Lithium supply has been identified as the most limiting factor for the expansion of electric mobility, alongside nickel supply. Since nickel plays a secondary role in truck and bus mobility, this chapter will focus on the approach for lithium.

Figure 31 shows the forecasted global annual primary lithium supply limit, taking into account both mining and refining capacities.

01 LITHIUM MINING & REFINING
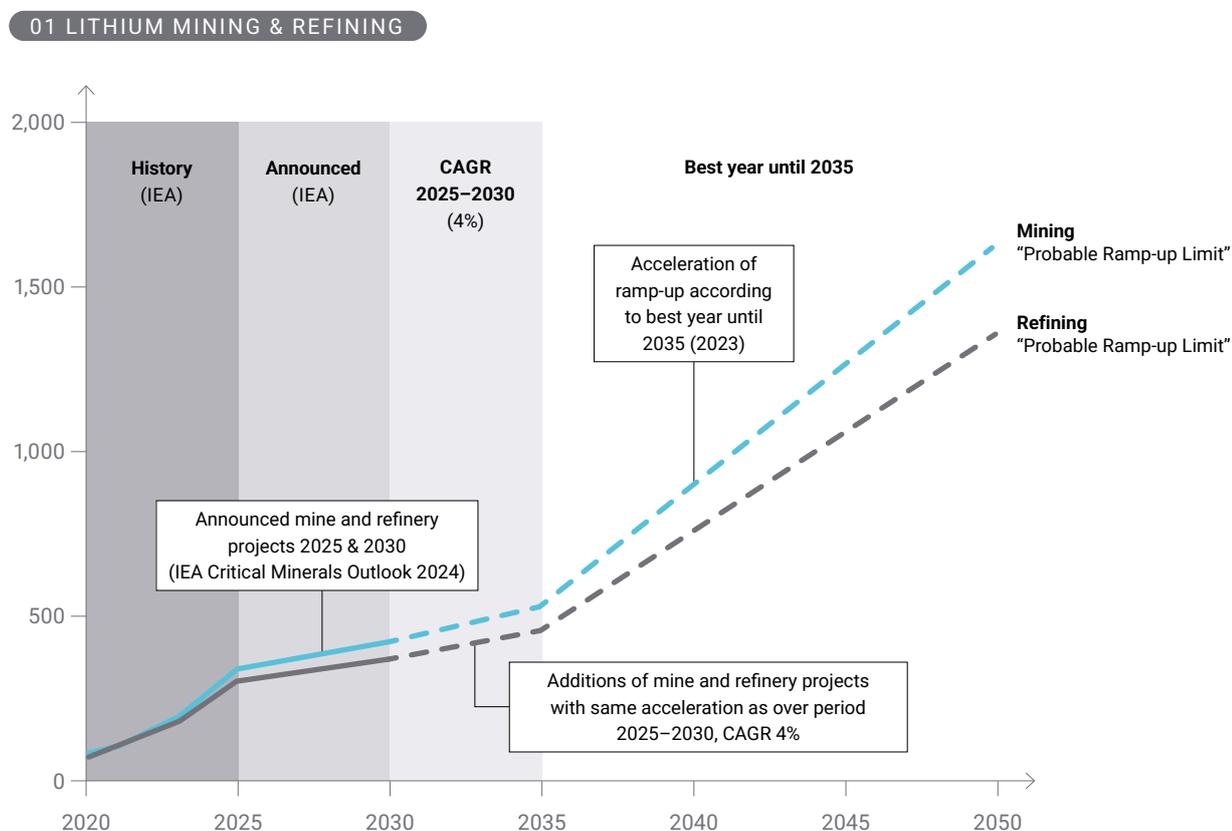
Figure 31: Global annual primary supply of lithium in kt/a: "Probable Ramp-up Limit" scenario.
Source: IEA Global Critical Minerals Outlook 2024[30]

Following the approach detailed in → *Section 4.1.*, the ramp-up was forecasted based on historical mining and refining capacities, combined with the International Energy Agency (IEA)[31] forecast of capacity announcements for 2025 and 2030. Between these data points, capacity was interpolated linearly.

Beyond 2030, announced capacities were excluded due to their low implementation likelihood at present. Short-term plans—typically within five years—are generally backed by stronger commitments from lithium mining companies, increasing confidence in their feasibility. Including long-term announcements would artificially reduce the projected ramp-up speed.

Until 2030, it is unlikely that capacity ramp-up will exceed the sum of existing capacities and current industry announcements, as lead times for new lithium mining projects exceed five years according to the IEA report The Role of Critical Minerals in Clean Energy Transitions[30]. For the period 2030–2035, lead times allow room for new projects again.

The ramp-up limit from 2030 was projected based on an acceleration of new capacity additions, using the compound annual growth rate (CAGR) from 2025 to 2030. For example, in 2030, global lithium mining capacity is forecasted at 423 kt based on announcements. Applying a CAGR of 4 percent—derived from the 2025–2030 period—results in a capacity of 442 kt in 2031.

By 2035, lithium mining and refining capacities are expected to reach their maximum ramp-up speed. Therefore, the ramp-up limit from 2035 onward is defined by the highest annual capacity addition observed before 2035. The best year for lithium mining until 2036 is forecasted to be 2025, with a capacity addition of 73 kt compared to 2024. Assuming this "best year" occurs again in 2036 leads to a capacity of 599 kt in 2036, starting from 526 kt in 2035. The same annual capacity addition is assumed for each year from 2036 to 2050.

The resulting supply ramp-up does not represent a realistic industry forecast, as multiple external factors influence the ramp-up of the supply chain—such as regulatory frameworks, geopolitical developments, consumer behavior, social acceptance, and unforeseen economic events. Instead, it reflects the maximum achievable ramp-up considering industrial limitations.

Lithium supply for EU mobility was derived following the approach presented in → *Section 4.1.* and is illustrated for lithium in Figure 32.
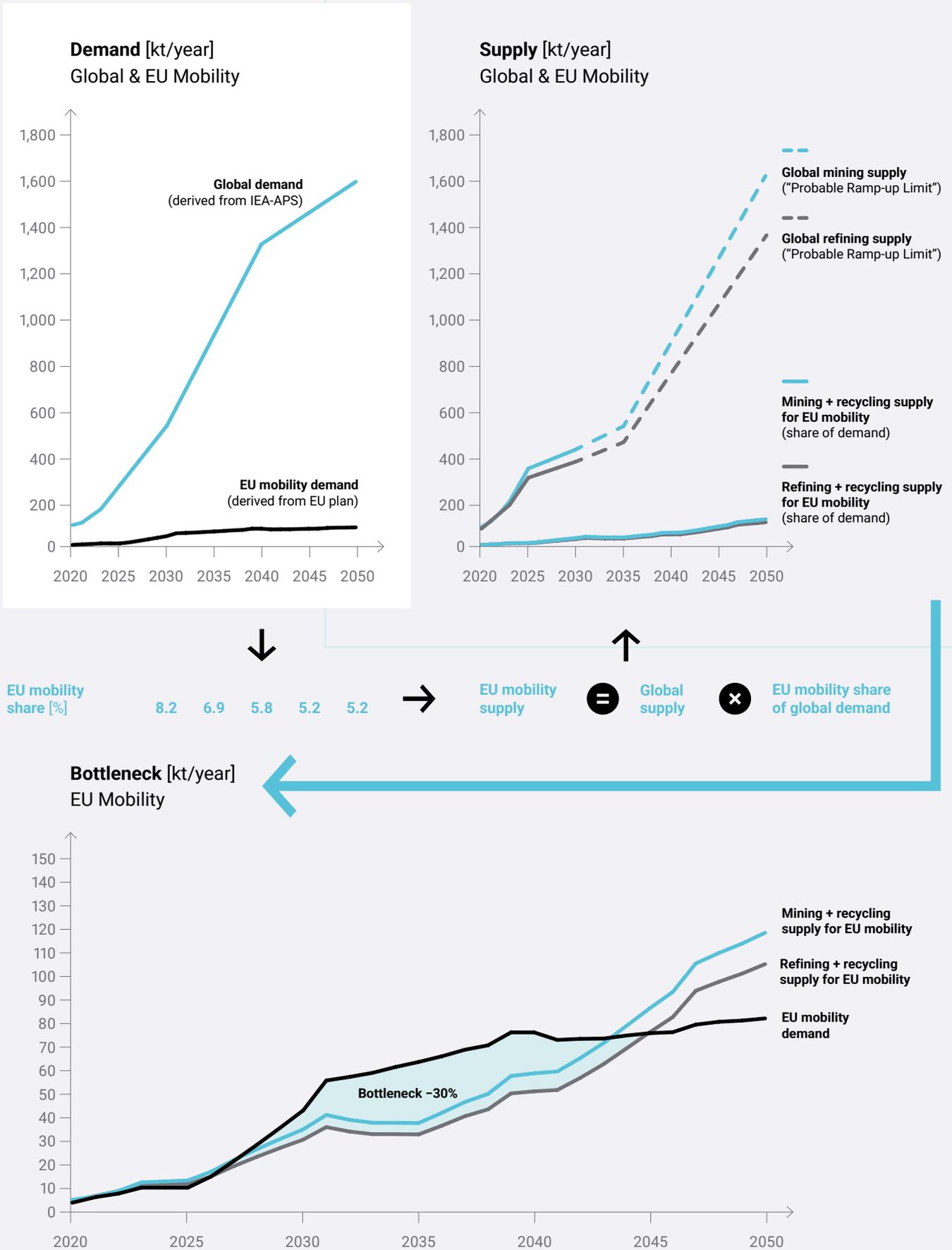
Demand [kt/year]
Global & EU Mobility

Global demand
(derived from IEA-APS)

EU mobility demand
(derived from EU plan)

Supply [kt/year]
Global & EU Mobility

Global mining supply
("Probable Ramp-up Limit")

Global refining supply
("Probable Ramp-up Limit")

Mining + recycling supply
for EU mobility
(share of demand)

Refining + recycling supply
for EU mobility
(share of demand)

EU mobility
share [%]   8.2   6.9   5.8   5.2   5.2   →

EU mobility
supply   =   Global
supply   ×   EU mobility share
of global demand

Bottleneck [kt/year]
EU Mobility

Mining + recycling
supply for EU mobility

Refining + recycling
supply for EU mobility

EU mobility
demand

Bottleneck −30%

Figure 32: Approach to identify battery bottlenecks in EU mobility, annual lithium availability in kt/a.
Source: IEA Global Critical Minerals Outlook 2024[30]

Global primary lithium demand was sourced from the IEA Global Critical Minerals Outlook 2024[31] under the "Announced Pledges" (APS) scenario to account for the ambitions of other nations. The demand includes global clean technologies such as BEVs, as well as all other lithium uses.

In 2023, global demand was estimated by the IEA at 165 kt—92 kt for clean technologies and 73 kt for other uses. Global secondary supply and reuse were estimated at 5 kt. Therefore, global primary lithium demand was set at 160 kt. Additional data points from the IEA report were available for 2030, 2040, and 2050, with linear interpolation applied between them.

As described in → *Section 4.1.3.1.*, lithium demand for EU mobility was modeled under the "EU Ambition" scenario. For each year until 2050, the share of global demand attributed to EU mobility was calculated—for example, 6.9 percent in 2035—and applied to the global primary lithium supply derived in Figure 31. This assumption implies no preferential access to primary lithium for EU mobility compared to other regions and sectors. Consequently, supply for EU mobility depends not only on global capacity ramp-up speed but also on demand from other regions. Since global lithium demand and EU mobility demand follow different trajectories, the share of supply allocated to EU mobility is not constant over time. It decreases after 2030 due to other nations' ambitions to accelerate EV adoption. Based on this logic, primary lithium supply for EU mobility is projected to decline between 2030 and 2035, even though global mining and refining capacities continue to increase during that period.

For battery raw materials, an additional source of supply complements the EU mobility supply curve derived from this approach. While the bottleneck assessment focused on the primary supply of critical raw materials, the availability of secondary materials was also modelled to capture both primary and secondary supply. The current regulation on battery material recycling[32] served as the basis for modelling battery collection and recovery rates for lithium, nickel, and cobalt. For graphite, the average collection and recovery rates of lithium, nickel, and cobalt were assumed. For all four critical raw materials, the collection rate is planned to reach 70 percent by 2030, while recovery rates are expected to range between 80 percent and 95 percent in the medium term, depending on the material.

Assuming that the resulting secondary material remains within the European market and can be integrated into new battery cells for the EU market, secondary material availability was modelled based on the average vehicle lifetime. Quotas for recycled material in new batteries for passenger cars, trucks, and buses were then calculated. The results, illustrated in Figure 33, show that recycled material in EU batteries begins to have a significant impact by 2040, with up to 27 percent secondary lithium in new cars, trucks, and buses. In the lithium bottleneck assessment, this amount adds to primary supply and helps alleviate potential bottlenecks in the raw material supply chain.

Finally, lithium supply was compared with lithium demand in EU mobility to identify industrial bottlenecks or opportunities to accelerate the BEV ramp-up. The results are shown in Figure 34.

According to the "EU Ambition" scenario, lithium demand is projected to rise sharply between 2025 and 2032, driven by ambitious new BEV registrations in the passenger car segment. This results in a bottleneck situation starting in 2027 under the "Probable Ramp-up Limit" scenario, with an average annual supply deficit of around 30 percent.
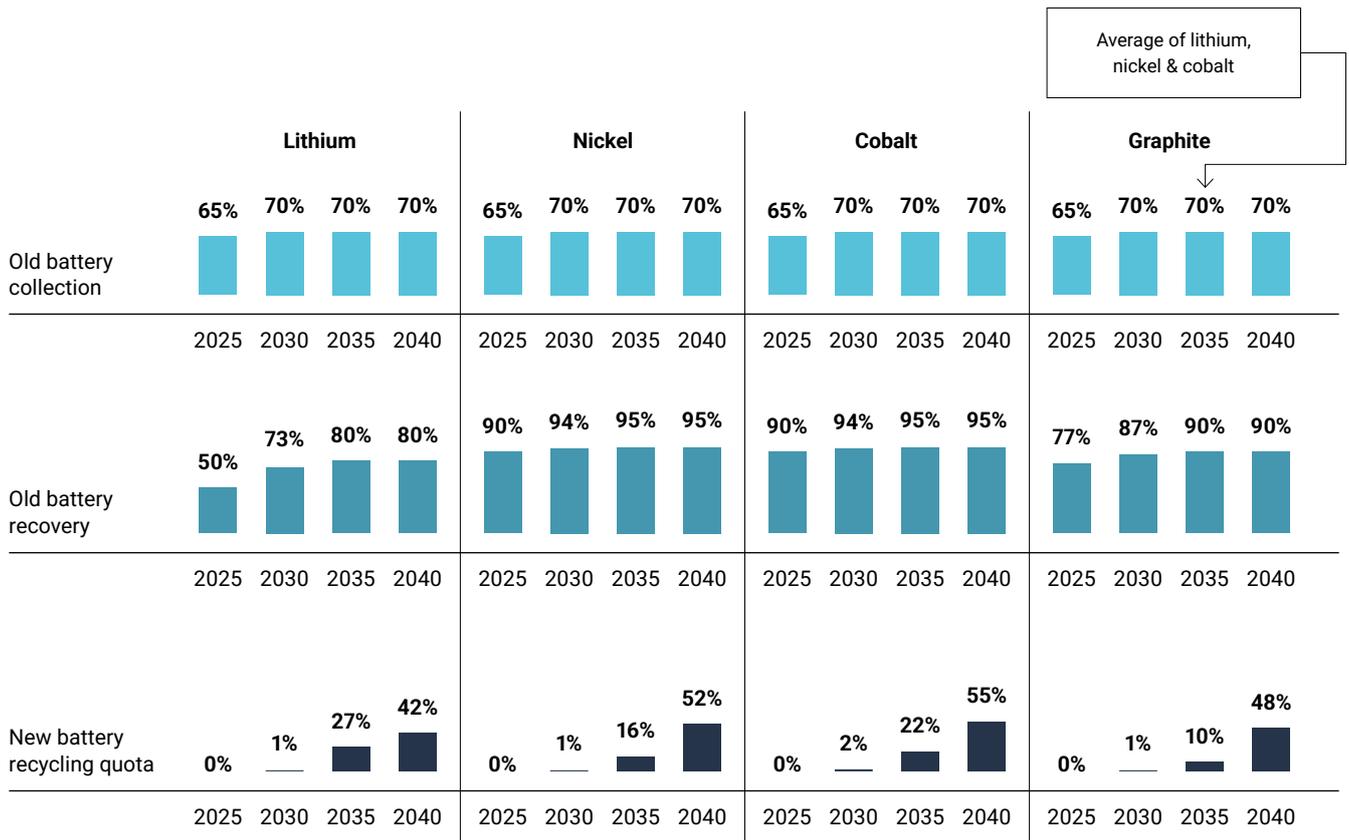
	Lithium				Nickel				Cobalt				Graphite			
Old battery collection	65%	70%	70%	70%	65%	70%	70%	70%	65%	70%	70%	70%	65%	70%	70%	70%
	2025	2030	2035	2040	2025	2030	2035	2040	2025	2030	2035	2040	2025	2030	2035	2040
Old battery recovery	50%	73%	80%	80%	90%	94%	95%	95%	90%	94%	95%	95%	77%	87%	90%	90%
	2025	2030	2035	2040	2025	2030	2035	2040	2025	2030	2035	2040	2025	2030	2035	2040
New battery recycling quota	0%	1%	27%	42%	0%	1%	16%	52%	0%	2%	22%	55%	0%	1%	10%	48%
	2025	2030	2035	2040	2025	2030	2035	2040	2025	2030	2035	2040	2025	2030	2035	2040

Average of lithium, nickel & cobalt

Figure 33: Battery material collection and recovery rates in the EU for passenger cars and trucks and buses.
Source: European Regulation on Batteries and Waste Batteries[32]

01 LITHIUM MINING & REFINING
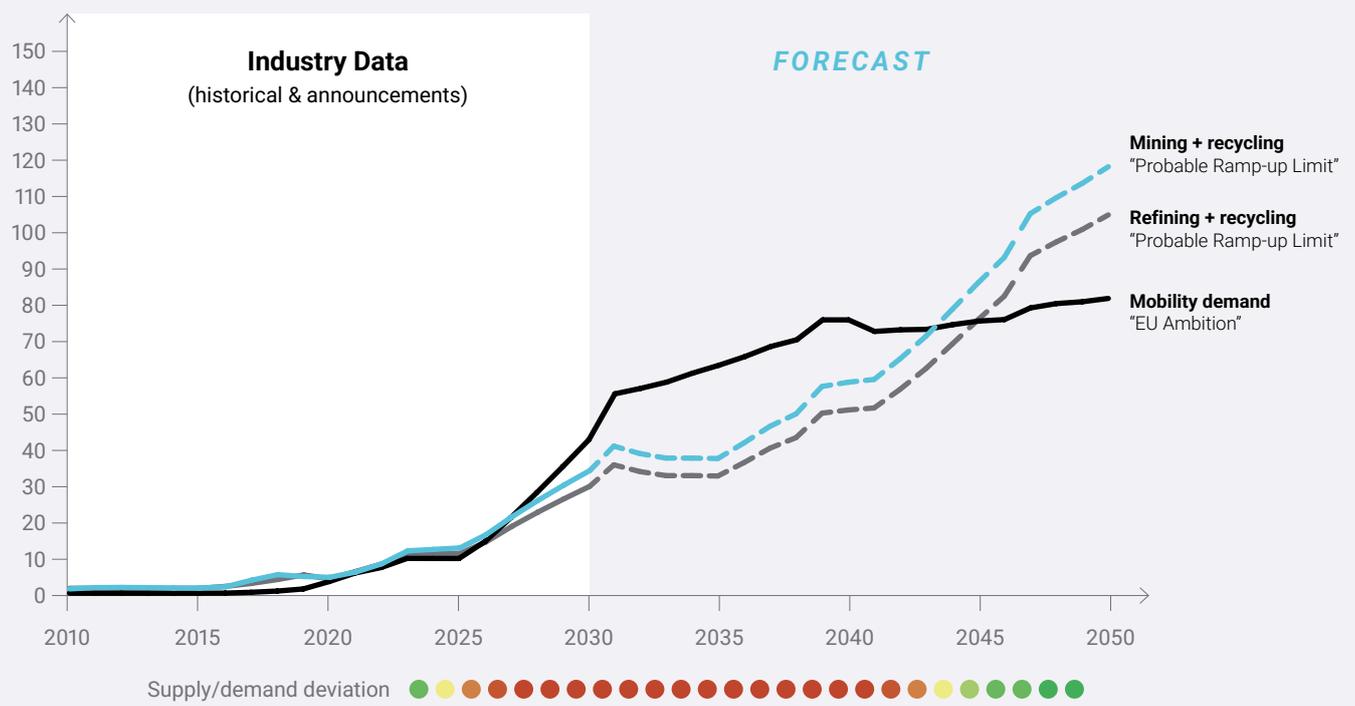
Figure 34: Comparison of annual lithium supply and demand in kt/a in EU mobility: "EU Ambition" scenario.

After 2032, the growth in lithium demand is expected to slow as a large share of new registrations has become electrified. However, the later ramp-up of BEVs in the truck & bus segment sustains high demand until 2040. Beyond 2040, lithium demand for EU mobility is forecasted to stagnate as the BEV ramp-up is completed and FCEVs gain market share.

By 2040, recycling begins to have a significant impact, and as global BEV adoption advances, overall lithium supply for EU mobility increases. Bottlenecks are expected to ease by 2047. From that point onward, provided other bottleneck factors allow, new BEV registrations could exceed the levels assumed in the "EU Ambition" scenario.

The lithium bottleneck forecasted in this analysis—and its intensity—has direct implications for the ramp-up of electric vehicles in the EU, which will be assessed in the "Bottleneck-adjusted" scenario in → *Section 4.3*.

4.2.2. Wind power equipment for eFuel production

In the bottleneck assessment, the availability of wind power equipment was evaluated as a potential limiting factor for the ramp-up of renewable power in the EU, as well as for the production of green hydrogen and eFuels. While global supply is identical for all three applications, the impact of wind power equipment availability depends on the severity of other bottlenecks. For example, wind power equipment could limit the ramp-up of eFuels if other bottleneck factors in the eFuel supply chain are less critical. Conversely, it may not be a limiting factor for green hydrogen if other constraints are more significant. For this reason, the assessment was conducted for all three applications simultaneously. This example emphasizes on wind power equipment availability for eFuel production.

For the period 2025–2030, the ramp-up limit for most bottleneck factors was derived from the sum of existing capacities and current industry announcements. An exception was made for the availability of wind and photovoltaic power equipment, as well as for the installation speed of wind and photovoltaic power plants in the EU. These supply chains have reached sufficient maturity to project future ramp-up limits based on historical trends.

Historical availability of wind power equipment—such as rotor blades, hubs, nacelles, towers, power electronics, and grid connections—was assumed to correlate directly with global wind power plant installations. Global historical installed wind power capacity data from the International Renewable Energy Agency (IRENA)[33] was used to forecast the ramp-up limit for wind power equipment.

According to the database, global installed capacity was estimated at 1,017 GW in 2023, including both onshore and offshore wind power. Between 2024 and 2035, new additions were assumed to grow at the same pace as during 2012–2023, following a CAGR of 13 percent. From 2036 onward, the ramp-up is assumed to align with the maximum annual capacity addition observed before 2035, which is 500 GW in 2035.

Figure 35 illustrates the quantitative results for global installed wind power equipment capacity under the "Probable Ramp-up Limit" scenario.

Wind power equipment supply for EU mobility was derived following the approach presented in → *Section 4.1.* and is illustrated in Figure 36.

Global installed wind power capacity demand was derived from the IEA World Energy Outlook 2023[23] under the "Announced Pledges" (APS) scenario, reflecting the ambition of other nations to scale up wind energy to meet climate targets. Starting from the installed capacity in 2023 provided by IRENA, data points for 2030, 2035, 2040, and 2050 were extracted from IEA data, with linear interpolation applied between them.

24 WIND POWER EQUIPMENT
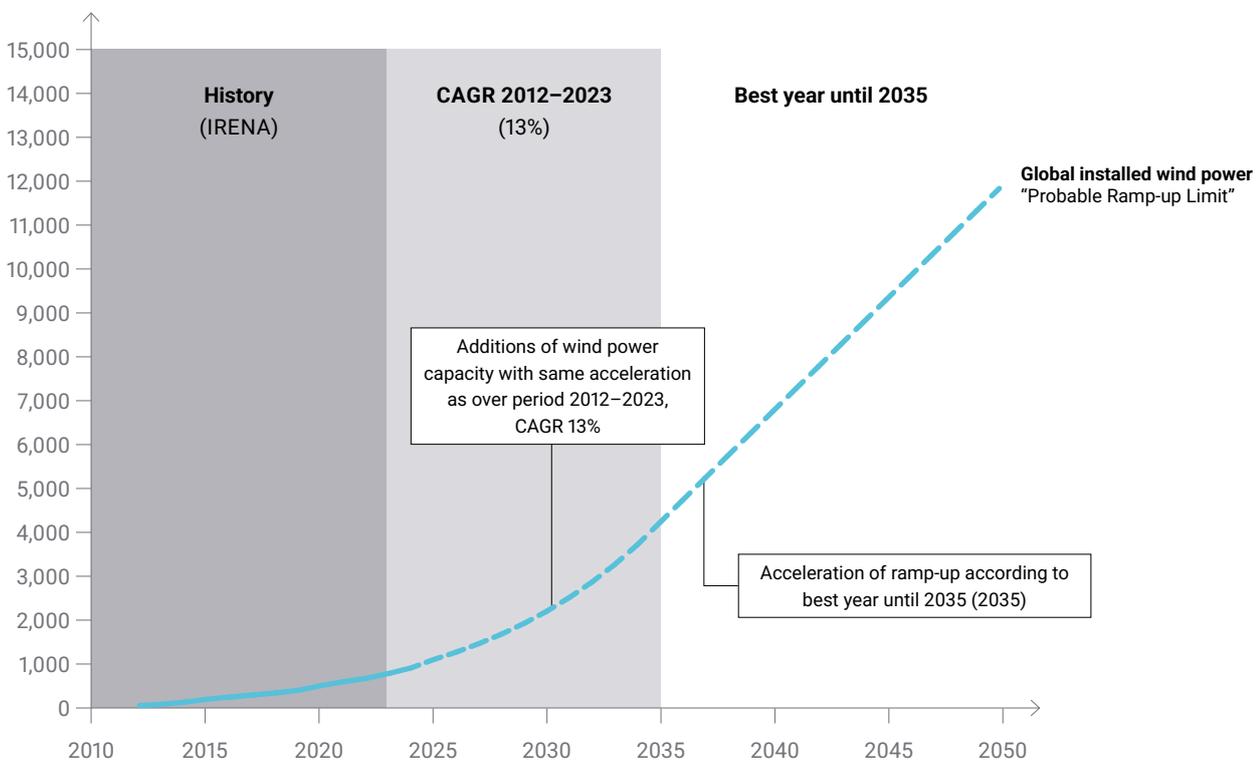
Figure 35: Global installed wind power equipment capacity in GW: "Probable Ramp-up Limit" scenario.
Source: IRENA Wind Energy Data 2024[33]

Demand [GW]
Global & EU Mobility

Global demand
(derived from IEA-APS)

Wind capacity demand for
EU mobility eFuels
(derived from EU plan)

Supply [GW]
Global & EU Mobility

Global installed wind power
("Probable Ramp-up Limit")

Installed wind power
for EU mobility eFuels
(share of demand)

EU mobility
share [%]   0.1   1.8   2.1   2.1   1.7   →   EU mobility
supply   =   Global
supply   ×   EU mobility share
of global demand

Bottleneck [GW]
EU Mobility eFuels

Installed wind power for
EU mobility eFuels

Wind capacity demand for
EU mobility eFuels

Bottleneck −10%

Figure 36: Approach to identify bottlenecks for eFuels in EU mobility, installed wind power equipment capacity in GW.
Source: IEA World Energy Outlook 2023[23]

As described in → *Section 4.1.3.4.*, installed wind power demand was modeled for eFuel use in EU mobility according to the "EU Ambition" scenario. For each year, the share of global demand attributed to EU mobility was calculated—for example, 2.1 percent in 2040—and applied to the supply derived in Figure 35.

This assumption implies no preferential access for EU mobility over other regions and sectors, nor for eFuel production over other applications such as green hydrogen or renewable power generation. Until 2030, eFuel demand in EU mobility remains marginal under the "EU Ambition" scenario, which explains the low share of wind power equipment supply allocated to this application. Starting in 2030, eFuel demand begins to ramp up, increasing the share of wind power equipment dedicated to this use.

Overall, the need for wind power capacity across multiple markets and sectors limits the share of equipment available for eFuel production in EU mobility.

Finally, wind power equipment supply was compared with demand for the eFuel application in EU mobility to identify industrial bottlenecks or opportunities to accelerate the eFuel ramp-up. The results are shown in Figure 37.

24 WIND POWER EQUIPMENT
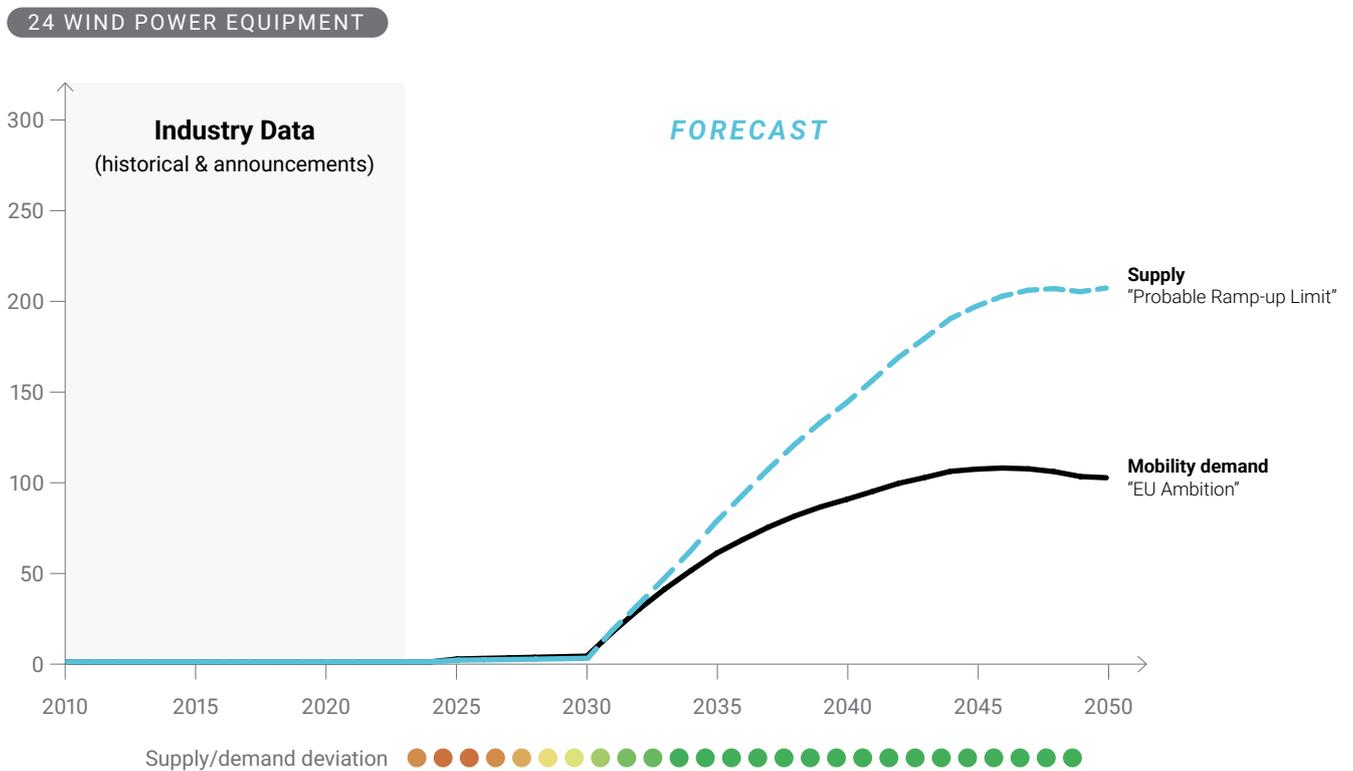
Figure 37: Comparison of supply and demand for eFuels in EU mobility, installed wind power equipment in GW: "EU Ambition" scenario.

From 2030 onward, no further limitations are expected from wind power equipment availability, meaning the eFuel ramp-up could be intensified—provided other bottleneck factors allow it.

According to the "EU Ambition" scenario, wind power equipment capacity demand for eFuel production in EU mobility is expected to remain low over the next five years. During this period, a moderate supply deficit of around 10 percent is anticipated under the "EU Ambition" scenario, driven by a sharp increase in global renewable energy demand. Since eFuel production shares the same supply chain, this bottleneck could affect its ramp-up.

After 2030, eFuel demand in EU mobility accelerates, but global wind power equipment availability grows even faster than global demand, easing supply constraints across all markets and sectors. From 2030 onward, no further limitations are expected from wind power equipment availability, meaning the eFuel ramp-up could be intensified—provided other bottleneck factors allow it.

The moderate bottleneck identified between 2025 and 2030 will influence the ramp-up of eFuels in EU mobility. The potential contribution of an accelerated eFuel ramp-up after 2030 will be analyzed in → *Chapter 5* under the "Industrial eFuel Potential" scenario. While this bottleneck analysis focuses on industrial feasibility, additional limiting factors such as investment security and regulation will be addressed in → *Chapter 6*.

4.2.3. Electrolysis equipment for eFuel production

In the bottleneck assessment, the availability of electrolysis equipment was evaluated as a potential limiting factor for the ramp-up of green hydrogen and eFuels. While global supply is identical for both applications, the impact of electrolysis equipment availability depends on the severity of other bottlenecks. For example, electrolysis equipment may not limit the ramp-up of eFuels if other bottleneck factors in the eFuel supply chain are more critical. Conversely, it could become a limiting factor for green hydrogen if other constraints are less significant. For this reason, the assessment was conducted for both applications simultaneously. This example emphasizes electrolysis equipment availability for eFuel production.

Following the approach detailed in → *Section 4.1.*, the ramp-up was forecasted based on historical electrolyzer manufacturing capacity up to 2024 and industry announcements for 2030, as reported in the IEA Global Hydrogen Review 2024[34]. Between these data points, manufacturing capacity was interpolated linearly. To ensure comparability with the installed electrolysis capacity required for eFuel production, global electrolyzer manufacturing capacity was converted into global installed electrolysis capacity. The results are illustrated in Figure 38.

For the period 2030–2035, the "Probable Ramp-up Limit" was projected based on accelerated capacity additions, using the CAGR from 2025 to 2030. For example, in 2030, global installed electrolysis capacity is forecasted at 628 GW according to announcements. Applying a CAGR of 39 percent—derived from the 2025–2030 period—results in 873 GW in 2031.

From 2036 onward, the ramp-up limit is defined by the maximum annual capacity addition observed before 2035. The best year for global electrolyzer manufacturing is projected to be 2035, with an addition of 916 GW compared to 2034. Assuming this "best year" repeats in 2036, this leads to an installed electrolysis capacity of 4,178 GW in 2036, starting from 3,262 GW in 2035. The same annual addition is assumed for each year from 2036 to 2050.

The identification of potential bottlenecks in eFuel supply for EU mobility due to electrolysis equipment availability was assessed following the approach illustrated in Figure 39.

The analysis was conducted by comparing demand and supply, focusing on installed electrolysis capacity. Global demand for installed electrolysis capacity was derived from the forecasted green hydrogen demand in the IEA "Announced Pledges" scenario[23], with linear interpolation applied between the provided data points for 2022, 2030, and 2050.

26 ELECTROLYSIS EQUIPMENT
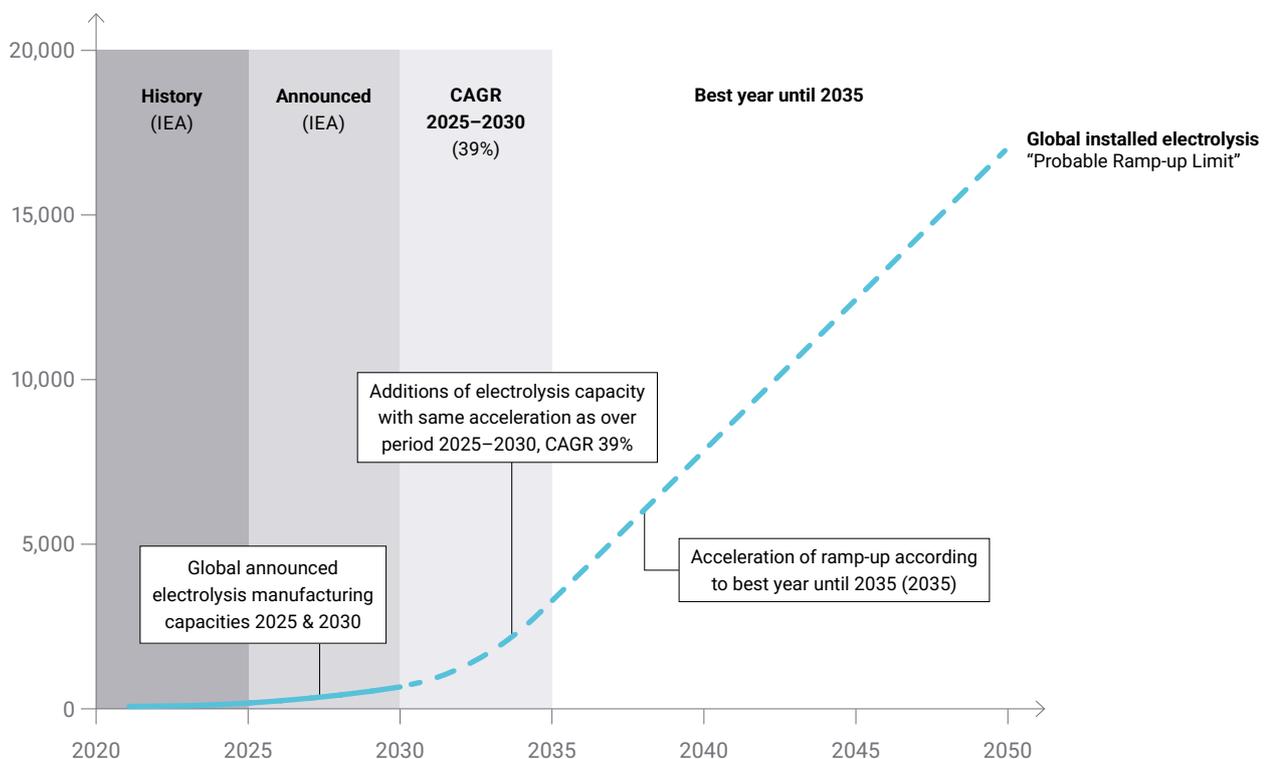
Figure 38: Global installed electrolysis equipment capacity in GW: "Probable Ramp-up Limit" scenario.
Source: IEA Global Hydrogen Review 2024[34]

Demand [GW]
Global & EU Mobility

Global demand
(derived from IEA-APS)

Electrolysis capacity demand for EU mobility eFuels
(derived from EU plan)

Supply [GW]
Global & EU Mobility

Global installed electrolysis
("Probable Ramp-up Limit")

Installed electrolysis for EU mobility eFuels
(share of demand)

EU mobility share [%]   2.1   13   11   9.5   7

→ **EU mobility supply** = **Global supply** ✕ **EU mobility share of global demand**

Bottleneck [GW]
EU Mobility eFuels

Installed electrolysis for EU mobility eFuels

Electrolysis capacity demand for EU mobility eFuels

Figure 39: Approach to identify bottlenecks for eFuels in EU mobility, installed electrolysis equipment capacity in GW.
Source: IEA World Energy Outlook 2023[23]

As described in → *Section 4.1.3.4.*, installed electrolysis demand was modeled for eFuel use in EU mobility according to the "EU Ambition" scenario. Each year, the share of global demand determines the share of global supply, ensuring proportional access to electrolysis equipment across nations and sectors.

As a result, the evolution of electrolysis equipment supply dedicated to eFuel production for EU mobility is closely linked to eFuel demand under the "EU Ambition" scenario.

Finally, electrolysis equipment supply was compared with demand for the eFuel application in EU mobility to identify industrial bottlenecks or opportunities to accelerate the eFuel

ramp-up. The results, based on installed electrolysis capacity, are shown in Figure 40.

According to the "EU Ambition" scenario, electrolysis equipment capacity demand for eFuel production in EU mobility is expected to remain low until 2030, then accelerate in line with the increase in eFuel demand modeled in the same scenario. The stagnation in eFuel demand forecasted by the European Commission from 2045 leads to a plateau in installed electrolysis capacity.

From the perspective of electrolyzer manufacturing, this means that no additional electrolysis equipment will be required for eFuel production in EU mobility—except for plant

26 ELECTROLYSIS EQUIPMENT
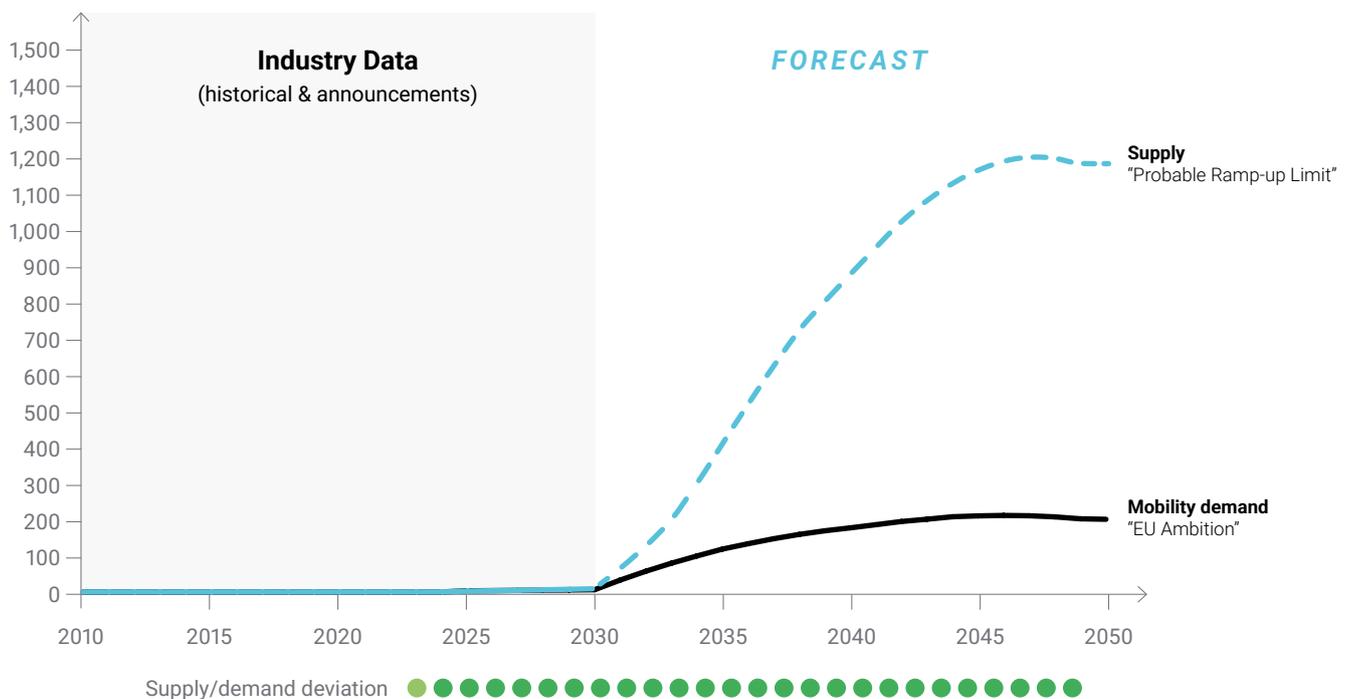
Figure 40: Comparison of supply and demand for eFuels in EU mobility, installed electrolysis equipment in GW: "EU Ambition" scenario.

renovations—as existing plants will be sufficient to meet demand. The electrolyzer manufacturing capacity ramp-up modelled in the "Probable Ramp-up Limit" scenario does not create bottlenecks for eFuel production in EU mobility. On the contrary, it provides room for accelerating eFuel production starting in 2030.
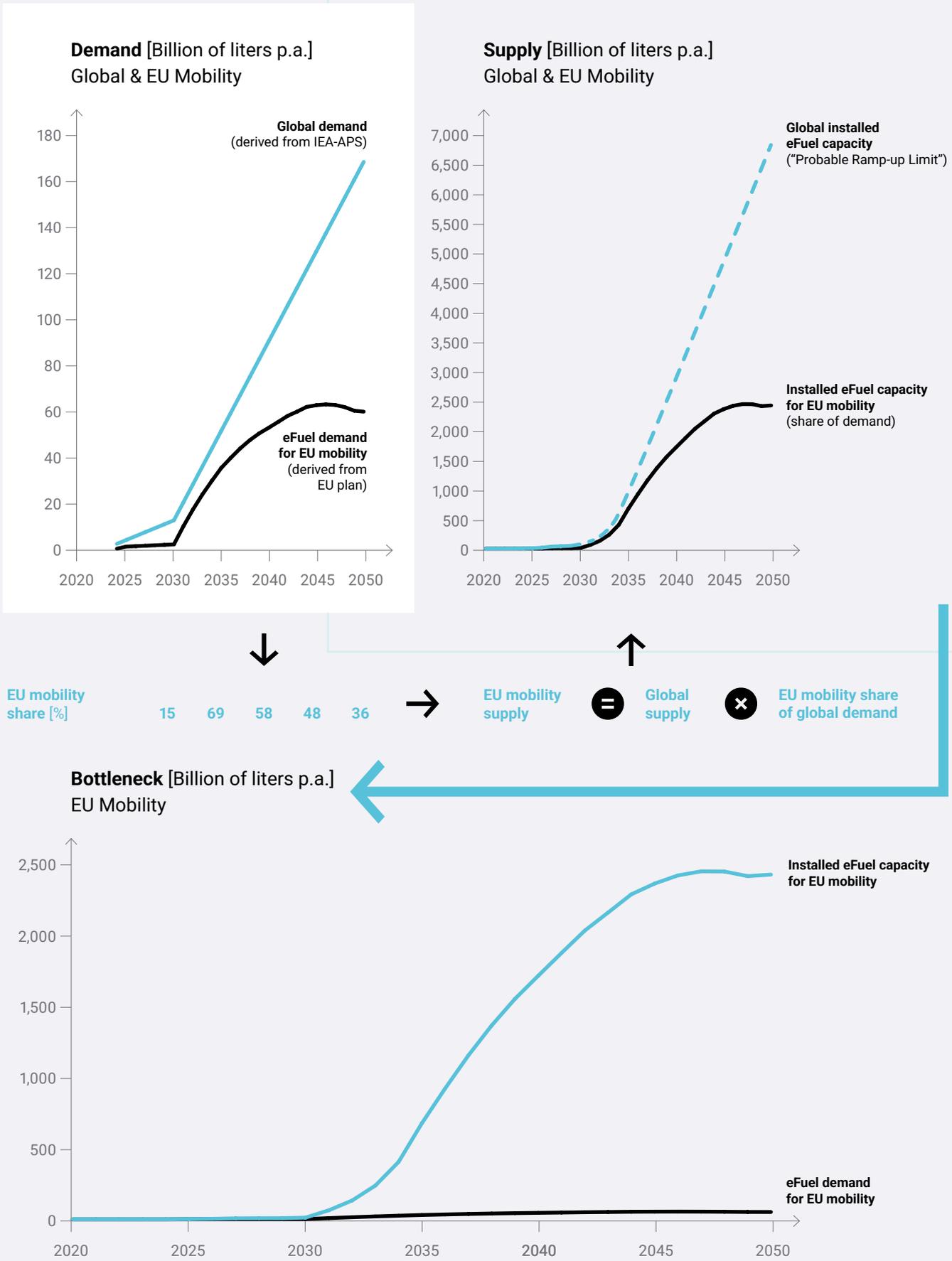
This aspect and its implications will be examined in detail in → *Chapter 5* under the "Industrial eFuel Potential" scenario. While the bottleneck analysis focuses on industrial feasibility, additional limiting factors such as investment security and regulation will be addressed in → *Chapter 6*.

4.2.4. Installation of eFuel plants

In addition to renewable energy and electrolysis equipment availability, the speed of global eFuel production plant installation was assessed as a potential limiting factor for the ramp-up of eFuel production for EU mobility. Following the methodology presented in → *Section 4.1.*, the ramp-up limit

The electrolyzer manufacturing capacity ramp-up modelled in the "Probable Ramp-up Limit" scenario does not create bottlenecks for eFuel production in EU mobility.

for this bottleneck factor was forecasted at a global level based on historical eFuel production capacities up to 2024 and industry announcements through 2030, derived from the Porsche Consulting eFuel Project Tracker. These announcements were validated against industry data from the eFuel Alliance[5], IEA[6], and Methanol Institute[7]. Identified activities were analyzed in detail, with results presented in → *Chapter 6*.

By 2030, eFuel production is announced to reach 80 billion liters gasoline-equivalent, including both power-to-liquid and power-to-gas activities. Between 2030 and 2035, the ramp-up limit is assumed to follow the CAGR of the 2025–2030 period—66 percent—resulting in a global production capacity of 990 billion liters gasoline equivalent by 2035, equivalent to 16 percent of global oil consumption in 2023 according to FuelsEurope data[35].

Beyond 2035, the ramp-up limit is defined by the maximum annual capacity addition observed before 2035. The fastest eFuel production ramp-up is forecasted for 2035, with an addition of 392 billion liters gasoline equivalent. From 2036 onward, the ramp-up limit assumes this annual addition repeats each year. The global supply results for the "Probable Ramp-up Limit" scenario are illustrated in Figure 41.

The identification of potential bottlenecks in eFuel supply for EU mobility due to eFuel plant installation speed was assessed following the approach illustrated in Figure 42.

The quantitative bottleneck assessment was based on comparing the pace of global eFuel plant installation with global eFuel demand. Global eFuel demand was projected using the IEA "Announced Pledges" scenario[23] and a linear interpolation between the available data points. As outlined in → *Section 4.1.3.4.*, the required eFuel production plant capacity for

27 eFUEL PLANT INSTALLATION
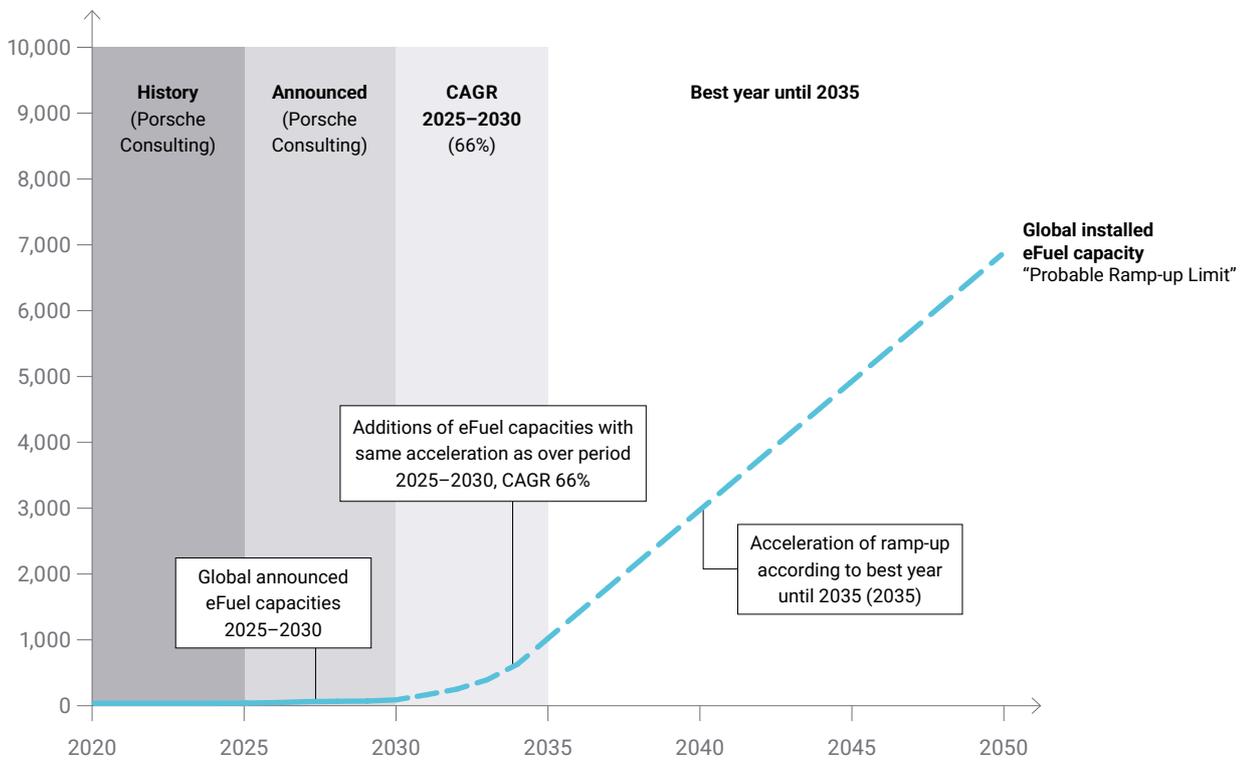
Figure 41: Global installed eFuel production plant annual capacity in billion liters gasoline equivalent: "Probable Ramp-up Limit" scenario.
Source: Porsche Consulting eFuel Project Tracker, eFuel Alliance[5], Methanol Institute[7], IEA Hydrogen Infrastructure Database[6]

EU mobility was modelled annually in the energy model across all mobility sectors analyzed in this study, according to the "EU Ambition" scenario. Each year, the EU mobility share of global demand determines the corresponding share of global eFuel supply. This approach ensures that access to eFuel production plants is proportional to demand, enabling a fair distribution of capacity across nations and sectors.

Based on global announcements derived from the IEA APS, global ambition to ramp up eFuel production remains low until 2040.

Consequently, EU mobility would require more than 50 percent of global demand to meet the "EU Ambition" scenario outlined in the European Commission's Impact Assessment. After 2040, the EU mobility demand share declines as other nations accelerate their ramp-up plans and EU mobility demand stagnates, assuming successful reductions in liquid fuel consumption through electrification. As a result, the EU mobility share of global supply is expected to remain high until 2040 and then decrease thereafter.

Demand [Billion of liters p.a.]
Global & EU Mobility

Global demand (derived from IEA-APS)

eFuel demand for EU mobility (derived from EU plan)

Supply [Billion of liters p.a.]
Global & EU Mobility

Global installed eFuel capacity ("Probable Ramp-up Limit")

Installed eFuel capacity for EU mobility (share of demand)

EU mobility share [%]   15   69   58   48   36   →   **EU mobility supply**   =   **Global supply**   ✕   **EU mobility share of global demand**

Bottleneck [Billion of liters p.a.]
EU Mobility

Installed eFuel capacity for EU mobility

eFuel demand for EU mobility

Figure 42: Approach to identify bottlenecks for eFuels in EU mobility, installed eFuel production plant annual capacity in billion liters gasoline equivalent.
Source: IEA World Energy Outlook 2023[23]

The resulting available eFuel production capacity for EU mobility was compared with EU mobility demand to identify potential industrial bottlenecks or opportunities to accelerate the eFuel ramp-up. The results are shown in Figure 43.

According to the "EU Ambition" scenario, the feasible pace of eFuel plant installation dedicated to EU mobility is projected to remain low until 2030, then accelerate as eFuel demand increases under the same scenario. From an industrial feasibility perspective, no bottlenecks are expected to prevent achieving the "EU Ambition." The availability of renewable power equipment is anticipated to be the most limiting factor in the eFuel supply chain until 2030, as detailed in → *Section 4.2.2.* This creates room for accelerating eFuel production

after 2030, the implications of which are thoroughly examined in → *Chapter 5* under the "Industrial eFuel Potential" scenario. While the bottleneck analysis focuses on industrial feasibility factors, additional constraints such as investment security and regulatory frameworks will be addressed in → *Chapter 6*.

4.3. Overview of results and sensitivities

After completing the industrial bottleneck assessment for all 27 factors, the results were analyzed to identify implications within each supply chain area. Figure 44 illustrates potential supply deficits across all industrial bottleneck factors, based on the "EU Ambition" scenario for demand and the "Probable Ramp-up Limit" scenario for supply.

27 eFUEL PLANT INSTALLATION
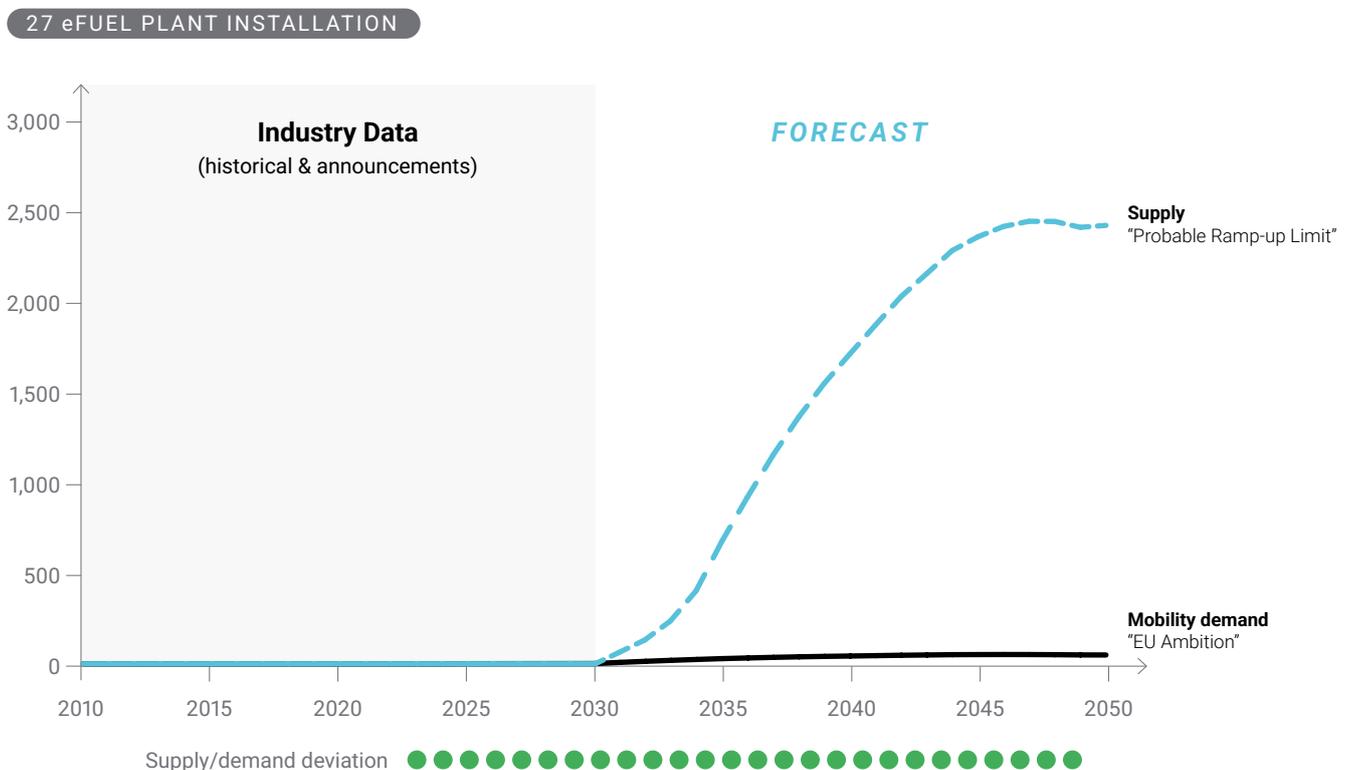
Figure 43: Comparison of supply and demand for eFuels in EU mobility, installed eFuel production plant annual capacity in billion liters gasoline equivalent: "EU Ambition" scenario.

In the battery supply chain, bottlenecks are expected under the "EU Ambition" scenario until 2044, primarily due to limited lithium and nickel mining capacities, with deficits of approximately 30 percent and 20 percent over the period, respectively. As highlighted in → *Section 4.2.* for lithium, ambitious ramp-up road maps for PHEVs and BEVs across the EU and globally drive a steep increase in raw material demand along the battery supply chain. Due to long lead times and limited project announcements in the mining industry, primary supply ramp-up is expected to remain constrained until 2035. After 2035, additional capacities could come online, while nickel demand is projected to decline with the transition toward nickel-free cell chemistries. By 2040, the growing importance of secondary material supply and widespread electrification in several global regions, including the EU, further ease supply chain pressure by 2045. After 2047, availability of lithium and nickel could exceed demand levels assumed in the "EU Ambition" scenario.

To achieve the "EU Ambition" scenario, cobalt and battery-grade graphite supply chains will also face pressure, though only moderate bottlenecks are forecasted, with up to a 5 percent supply deficit. Anode and cathode active materials are not expected to limit the pace of electrification in EU mobility. Similarly, battery cell production capacity is unlikely to pose an industrial feasibility constraint, although other factors such as investment security may slow the ramp-up. In summary, lithium and nickel supply chains could delay the ramp-up of BEVs and PHEVs until 2047. Implications for fleet transformation and climate targets are analyzed in → *Section 4.4.*

In the renewable electricity supply chain, moderate ramp-up limitations are expected across several bottleneck factors. In the short term, equipment supply for renewable power plants may come under pressure to meet the European Commission's ambitious scenario, until new manufacturing capacities ease the situation—by 2027 for photovoltaic power and by 2030 for wind power. Until 2035, wind power plant installation is projected to be the most limiting factor for renewable electricity expansion in the EU. These constraints cannot be offset by a faster ramp-up of photovoltaic power, as installation capacity will also remain under pressure until 2031. Since electricity is shared across multiple sectors, this will affect the share of renewable electricity available for mobility until 2035, and therefore the pace of decarbonization.

In the long term, power grid capacity may struggle to keep up with rising electricity demand driven by mobility and the electrification of other sectors such as heating and industry. Without significant improvements in ramp-up speed and efficiency, a capacity deficit of up to 20 percent is expected. Due to short lead times and the high ambition of announced activities, industrial limitations for public charging infrastructure are not anticipated.
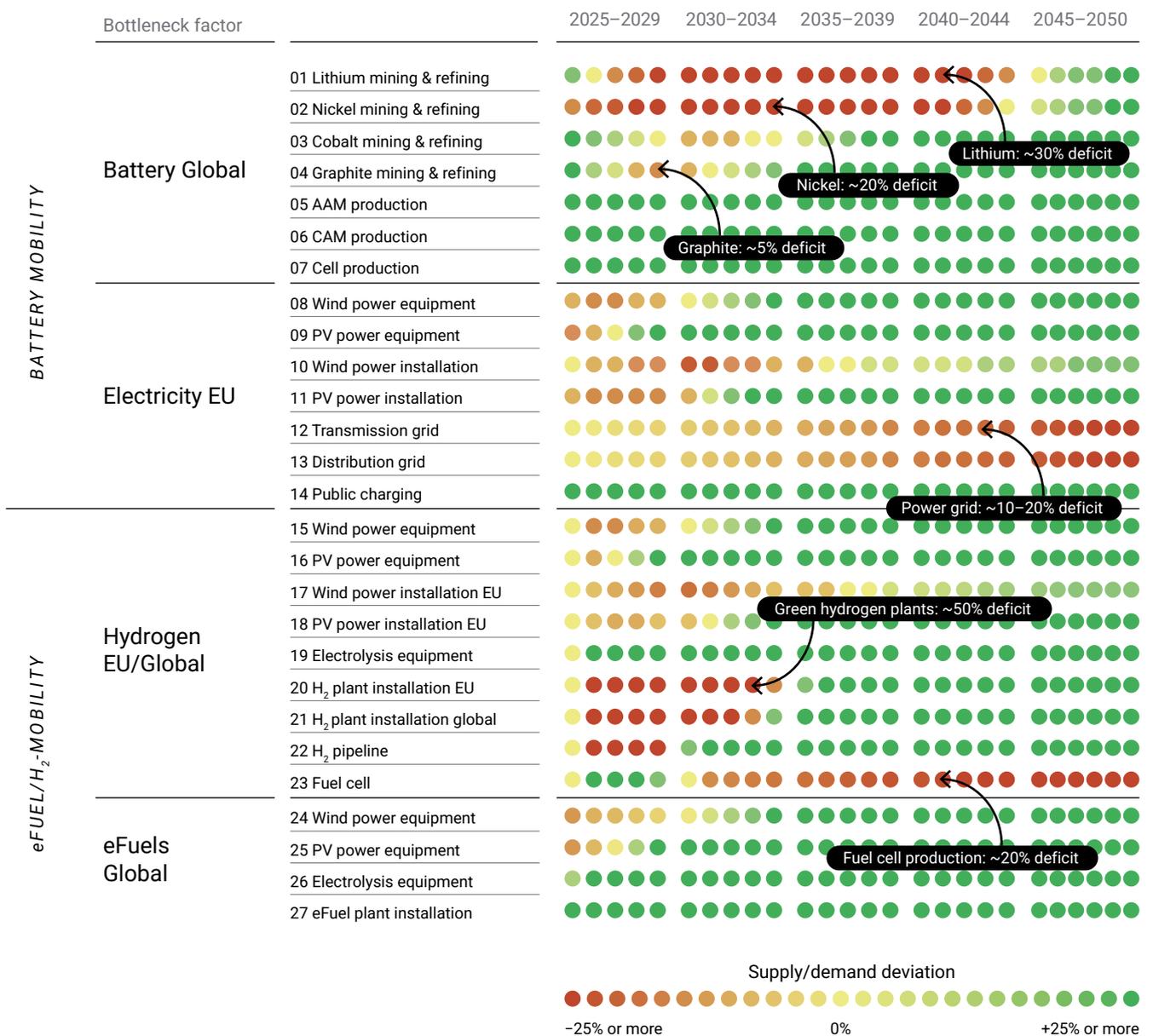
Figure 44: Supply and demand deviations of bottleneck factors in %: "EU Ambition" and "Probable Ramp-up Limit" scenario.
AAM: Anode Active Material | CAM: Cathode Active Material | PV: Photovoltaic

In the battery supply chain, bottlenecks are expected under the "EU Ambition" scenario until 2044, primarily due to limited lithium and nickel mining capacities, with deficits of approximately 30 percent and 20 percent over the period, respectively. […] After 2047, availability of lithium and nickel could exceed demand levels assumed in the "EU Ambition" scenario.

The bottleneck analysis indicates that green hydrogen supply chains will face significant pressure, primarily due to the slower ramp-up of green hydrogen production plants in both the EU and other regions compared to the pace required under the "EU Ambition" scenario. This results in an estimated 50 percent green hydrogen supply deficit until 2033. Approximately half of the planned green hydrogen production capacity is expected to rely on European wind and photovoltaic power plants, creating additional limitations until 2035, similar to the constraints identified for renewable electricity supply. Furthermore, hydrogen transport is projected to be restricted by the pace of pipeline infrastructure deployment within the EU until 2029. While this may not impact hydrogen-powered vessels, which can access imported green hydrogen more easily, it could significantly delay adoption in other mobility segments. If global electrolysis manufacturers execute their plans as announced and maintain the projected pace, electrolysis equipment is not expected to cause limitations to the EU's green hydrogen ramp-up.

Current industry announcements suggest that the fuel cell supply chain is not yet prepared to deliver the capacities required to meet the "EU Ambition" scenario.

The bottleneck assessment of the global eFuel supply chain indicates that meeting EU mobility demand for eFuels will be challenging until 2030, primarily due to the scarcity of renewable energy equipment and limited additions to eFuel production capacity. From 2030 onward, additional plant installations and increased responsiveness from renewable power equipment manufacturers are expected to accelerate the ramp-up. The availability of electrolysis equipment is not anticipated to hinder implementation of the "EU Ambition" scenario, particularly because other nations plan a later ramp-up of eFuels and green hydrogen. The current "EU Ambition" scenario

leaves room for accelerating eFuel deployment through 2050. Implications are evaluated in detail in → *Chapter 5* under the "Industrial eFuel Potential" scenario.

To ensure the robustness of the bottleneck analysis, sensitivity analyses were conducted focusing on two dimensions. The first dimension is the industrial ramp-up limit, for which two scenarios were examined for each bottleneck factor, as introduced in → *Section 4.1.*: the "Probable Ramp-up Limit" and the "Progressive Ramp-up Limit" scenarios. The second dimension addresses the share of supply allocated to EU mobility. It was assumed that EU mobility's dedicated supply is proportional to its share of demand. This sensitivity analysis considers a potential deviation from this assumption by ±30 percent. The results are presented in Figure 45.

The sensitivity analysis confirms the persistence of key bottlenecks identified under the baseline scenario, "Probable Ramp-up Limit" and "fair share".

In the most conservative case, where EU mobility receives 30 percent less supply within the "Probable Ramp-up Limit" scenario, bottlenecks intensify and persist longer. For example, lithium and nickel deficits reach up to 60 percent in the 2030s, while graphite and cobalt become critical for the BEV ramp-up until 2040, with supply shortfalls of up to 30 percent in the most constrained years. The supply of anode and cathode active materials, as well as battery cell manufacturing, remains bottleneck-free in this scenario. In the renewable electricity supply chain, global wind power equipment shortages intensify, with deficits of up to 30 percent until 2035. Throughout the period, wind power plant installation speed in the EU is forecasted to be a critical factor for renewable energy use in BEVs, leading to wind power supply deficits of up to 40 percent. Similar challenges appear in

Figure 45: Sensitivities in supply and demand deviations of bottleneck factors in %: "EU Ambition" scenario.
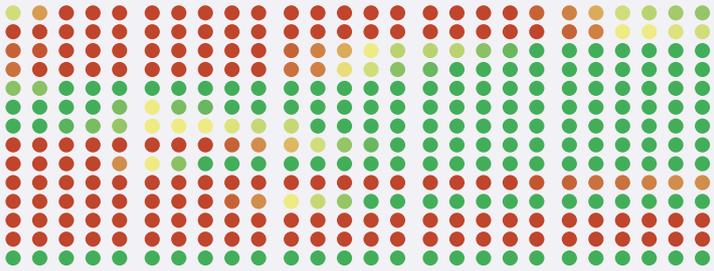
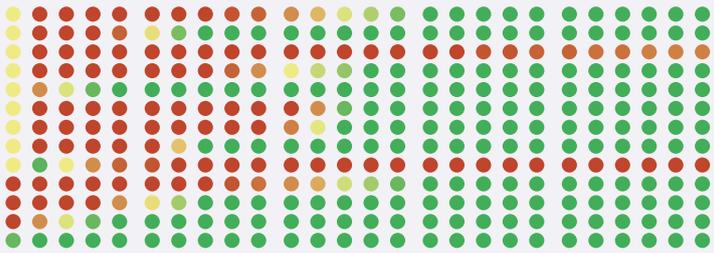**PROGRESSIVE**

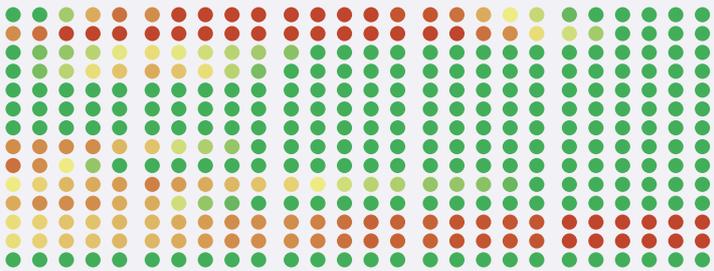2025–2029 2030–2034 2035–2039 2040–2044 2045–2050

−30%

BATTERY MOBILITY

eFUEL/H$_2$-MOBILITY

FAIR SHARE

BATTERY MOBILITY

eFUEL/H$_2$-MOBILITY

+30%
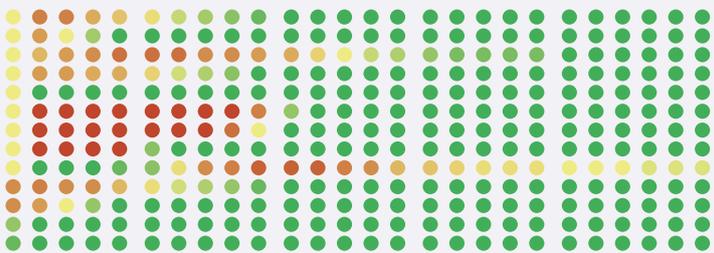
BATTERY MOBILITY
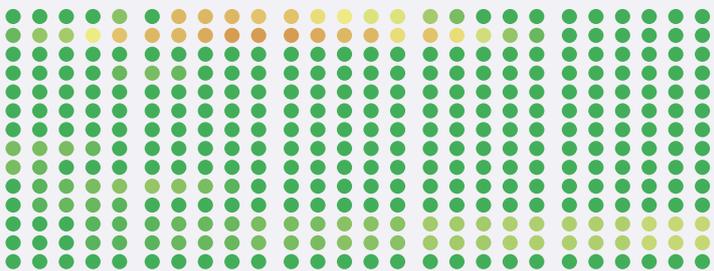
eFUEL/H$_2$-MOBILITY

Supply/demand deviation

−25% or more   0%   +25% or more
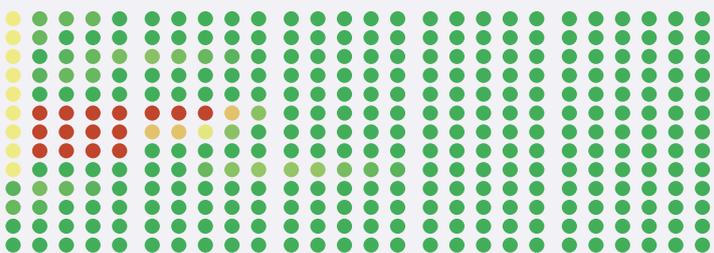
the green hydrogen supply chain, driven by global wind power equipment constraints and slow power plant ramp-up in the EU. Bottlenecks in green hydrogen plant installation are more severe than in the baseline scenario, resulting in an 80 percent supply deficit during the early ramp-up years before easing by 2038. For eFuels, the ramp-up could be limited by global wind and photovoltaic equipment availability until 2036—compared to 2030 in the baseline scenario—with supply deficits exceeding 30 percent by 2030.

Conversely, in a highly progressive scenario where EU mobility receives 30 percent more supply and industrial capacity evolves according to the "Progressive Ramp-up Limit" scenario, several bottlenecks ease compared to the baseline. For instance, cobalt and graphite availability no longer pose risks to electrification timelines. However, lithium and nickel supply chains remain under pressure, with deficits of 5–10 percent between 2030 and 2035. In this scenario, all bottlenecks in the renewable electricity and eFuel supply chains disappear, while green hydrogen plant installation speed remains critical for EU mobility until 2032.

Overall, the sensitivity analysis confirms the robustness of industrial bottlenecks identified under the "Probable Ramp-up Limit" scenario with a "fair share" of supply for EU mobility. While additional limiting factors—such as regulation, geopolitical dynamics, customer trends, social acceptance, and unforeseeable economic events—could delay the transformation assumed in the "EU Ambition" scenario, industrial bottlenecks have been quantified, and their implications for powertrain and energy transition in EU mobility are evaluated in the following sections.

4.4. Adjusted new registrations and fleet stock evolution for on-road mobility

The "Bottleneck-adjusted" scenario was developed to assess the EU transition speed if industrial bottlenecks cannot be mitigated. In this scenario, the pace of transformation is adapted to reduce pressure on supply chains while maximizing their utilization. Supply chains identified as having additional potential are ramped up to their maximum capacities, except for eFuels, for which opportunities for acceleration are detailed in → *Chapter 5*. This scenario does not represent a realistic industry forecast, as additional external factors influence the ramp-up across powertrain and energy supply chains—such as regulatory frameworks, geopolitical developments, consumer behavior, social acceptance, and unforeseen economic events. Instead, the "Bottleneck-adjusted" scenario reflects the maximum achievable ramp-up considering industrial limitations. Figure 46 illustrates the powertrain shares within the passenger car fleet stock and new registrations under the "EU Ambition" and "Bottleneck-adjusted" scenarios. In the "Bottleneck-adjusted" scenario, new registrations for each powertrain were determined based on supply chain availability, following the approach described in → *Section 4.1.4.*, and the resulting fleet stock shares were calculated accordingly.

Due to industrial bottlenecks in battery raw material supply, new BEV registrations are projected to grow significantly slower than in the European Commission's scenario, particularly between 2030 and 2045. Additional factors—such as regulatory developments, geopolitical dynamics, consumer behavior, societal acceptance, and unforeseeable economic events—could further delay the ramp-up along the supply chains. The largest gap is

expected in 2035, with BEVs capturing less than 40 percent market share versus more than 60 percent under "EU Ambition." By 2040, a 20 percent gap in new registrations persists between the two scenarios. This slowdown is driven by industrial bottlenecks caused by the simultaneous BEV ramp-up planned by the EU and other global regions. In terms of fleet
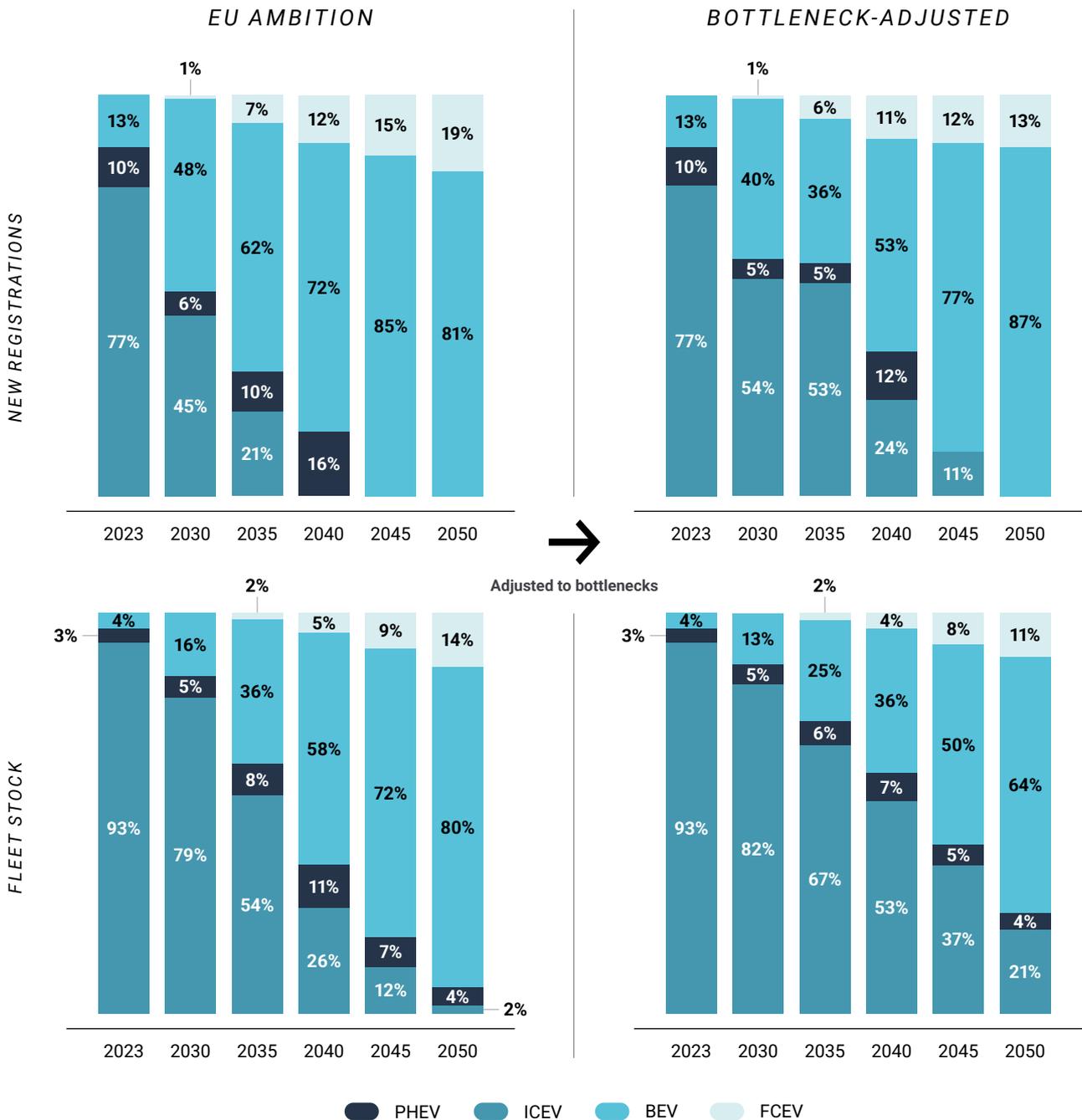

Figure 46: Powertrain shares in passenger car fleet stock and new registrations: "EU Ambition" vs. "Bottleneck-adjusted" scenario.

stock composition, the BEV ramp-up in the passenger car segment is likely to be delayed by approximately five years. Assuming mobility needs—and therefore fleet stock size—remain consistent with current levels, this delay is offset by other powertrain technologies, such as ICEVs.

While new BEV registrations are expected to remain constrained until 2045, an accelerated ramp-up could occur thereafter, reaching 87 percent of new registrations by 2050 compared to 81 percent in the "EU Ambition" scenario. Despite this long-term potential, BEV fleet stock share is forecasted to reach only 64 percent by 2050, falling short of the targeted 80 percent. Similarly, limitations in the fuel cell supply chain result in a lower FCEV fleet stock share in 2050: 11 percent versus 14 percent under "EU Ambition." Consequently, the share of ICEVs and PHEVs in the fleet stock remains higher than planned, at approximately 60 percent in 2040 and 25 percent in 2050, compared to 37 percent and 6 percent in the "EU Ambition" scenario.

Similarly, the feasible penetration of new powertrains was adjusted to ease pressure on powertrain supply chains in the truck and bus segment, as shown in Figure 47.

In the truck and bus segment, the powertrain transformation modeled in the "EU Ambition" scenario follows a similar pattern to the passenger car segment. Bottlenecks across global battery supply chains put pressure on the ramp-up of BEVs in truck and bus mobility. This results in a delayed dominance of electric vehicles in this segment, with up to a five-year lag in new registrations under the "Bottleneck-adjusted" scenario. Considering supply chain limitations reduces BEV shares in new registrations from 21 percent to 11 percent in 2035 and from 31 percent to 23 percent in 2040. Consequently, the same delay is

expected in BEV fleet stock penetration, with 14 percent versus 24 percent in 2040 and 27 percent versus 36 percent in 2045.

However, the truck and bus transformation benefits from specific advantages that reduce pressure on the BEV ramp-up. While BEVs are forecasted to dominate market shares in the long term, hydrogen-powered vehicles play a significant role as well, reaching nearly 40 percent of new registrations by 2050. Moreover, the BEV transition occurs later than in the

Due to industrial bottlenecks in battery raw material supply, new BEV registrations are projected to grow significantly slower than in the European Commission's scenario. […] Additional factors—such as regulatory developments, geopolitical dynamics, consumer behavior, societal acceptance, and unforeseeable economic events—could further delay the ramp-up along the supply chains.

passenger car segment. This means the ramp-up of battery trucks and buses is less affected by the critical period for battery supply chains: between 2025 and 2035. In other words, this segment requires intensive access to battery supply chains when other segments and global markets have already completed their BEV ramp-up. This dynamic could change if other segments revise their ambitions and delay BEV adoption.
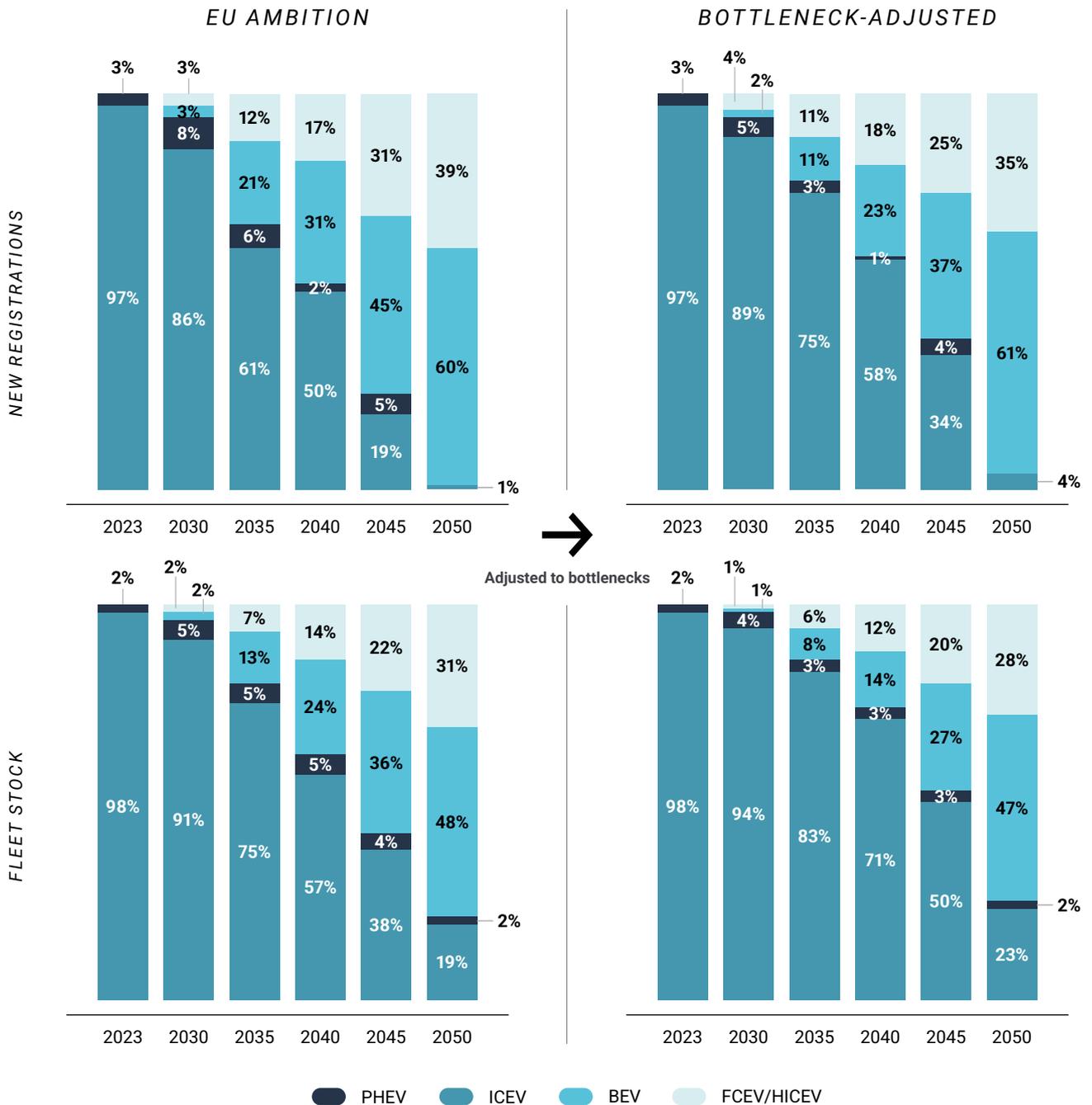

Figure 47: Powertrain shares in truck and bus fleet stock and new registrations: "EU Ambition" vs. "Bottleneck-adjusted" scenario.

Additionally, as nickel-based cell chemistries do not represent a major share of the battery market in this segment, limitations stem primarily from the lithium supply chain. The growing availability of secondary materials by 2040, enabled by the early BEV ramp-up in passenger car mobility, further reduces pressure on primary material supply chains for trucks and buses. After 2045, the BEV ramp-up can accelerate again as supply chain pressure eases. Leveraging these advantages and fast fleet renewal—an average vehicle lifetime of eight years—the delay accumulated until 2045 can be recovered by 2050, when BEV fleet stock share is nearly as high in the "Bottleneck-adjusted" scenario as in the "EU Ambition" scenario. Limitations in the fuel cell supply chain are reflected in a lower FCEV fleet stock share in 2050—28 percent versus 31 percent in the "EU Ambition" scenario.

Even if the truck and bus segment recovers faster, a delayed phase-out of ICEVs inevitably leads to a slower phase-out of liquid fuels than planned by the European Commission to meet climate targets.

Even if the truck and bus segment recovers faster, a delayed phase-out of ICEVs inevitably leads to a slower phase-out of liquid fuels than planned by the European Commission to meet climate targets.

4.5. Resulting energy demand in the transport sector

Similar to the energy demand forecast in the European Commission's "EU Ambition" scenario illustrated in Figure 21, energy demand projections were modelled based on the "Bottleneck-adjusted" scenario for the four mobility sectors: passenger cars, trucks and buses, shipping, and aviation. The "Bottleneck-adjusted" scenario indicates that the delay in the BEV ramp-up is offset by continued reliance on liquid fuel-based internal combustion engines in on-road mobility. Consequently, the phase-out of liquid fuels progresses more slowly than projected by the European Commission. To quantify this effect, Figure 48 compares both scenarios with a focus on liquid fuel demand, excluding electricity, hydrogen, CNG, and LNG. In the "EU Ambition" scenario, energy demand projections were derived from the European Commission's Impact Assessment. In contrast, the "Bottleneck-adjusted" scenario accounts for a slower fleet transition resulting from industrial bottlenecks in the battery and fuel cell supply chains.

As detailed in → *Chapter 3*, the "EU Ambition" scenario derived by the European Commission targets a significant reduction in liquid fuel use in on-road mobility by 2050, driven by an ambitious BEV ramp-up planned before 2040. According to the EU plan, liquid fuel demand is expected to slightly increase in the shipping and aviation segments, as ICEVs remain the dominant powertrain and mobility demand in these sectors is projected to rise. In the "Bottleneck-adjusted" scenario, overall liquid fuel demand is forecasted to be 14 percent higher than in the "EU Ambition" scenario, cumulated over the 25-year period, with the gap widening until 2045 before easing as battery supply chain bottlenecks reduce. Since maritime and aviation segments are not affected by delays in electrification, the increase in liquid fuel demand compared to the "EU Ambition" scenario is driven by the BEV delay in on-road mobility, where cumulative liquid fuel demand is expected to be 23 percent higher than in the EU plan. If the powertrain transformation does not progress as swiftly as planned by the European Commission, liquid fuel demand will remain significantly above expectations—exceeding 60 billion liters of gasoline equivalent in on-road mobility by 2050, versus less than 10 billion liters planned. This could result in delayed carbon savings.
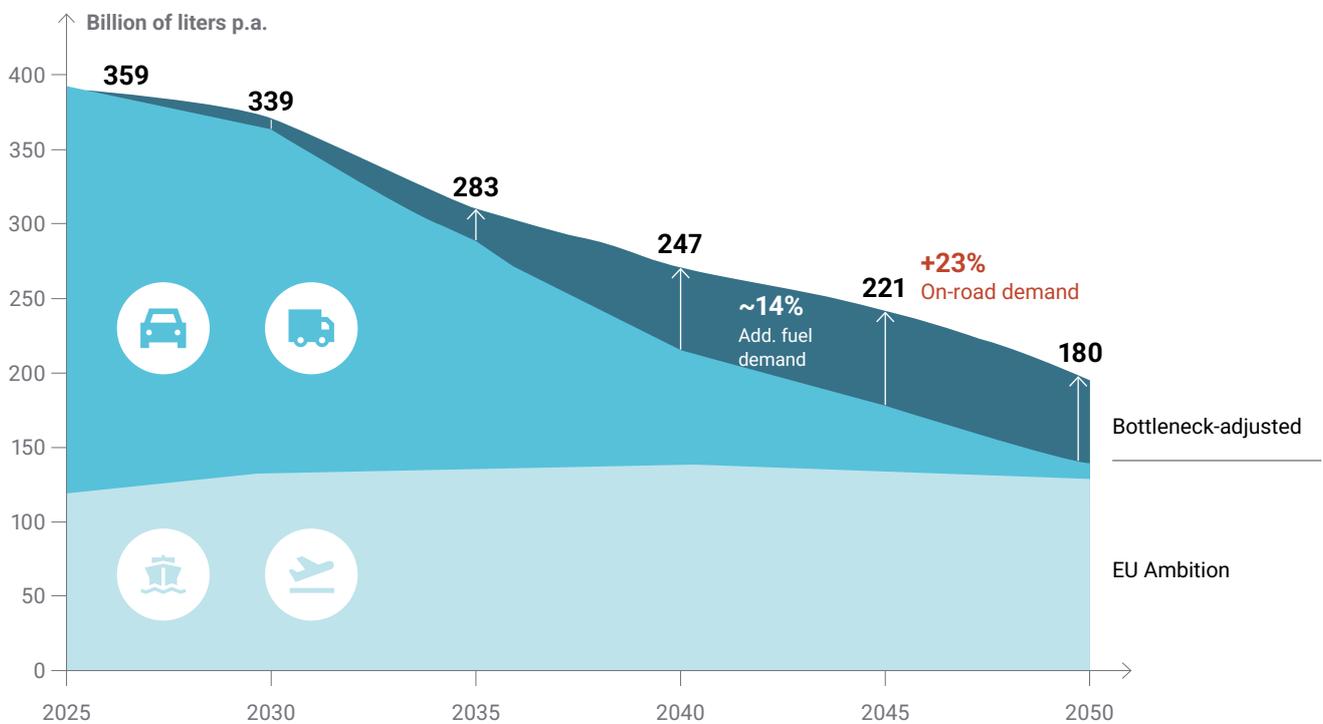
Figure 48: Annual liquid fuel demand in EU mobility: "EU Ambition" vs "Bottleneck-adjusted" scenario.
Scope: gasoline, diesel, fuel oil, methanol, ammonia, and jet fuel | Fuel volume in billion liters gasoline-equivalent

4.6. Resulting annual CO_2 emissions in the transport sector

Following the life cycle approach described in → *Section 3.2.3.*, emissions were calculated for both the "EU Ambition" scenario and the "Bottleneck-adjusted" scenario. This includes emissions from vehicle production, the entire energy supply chain, and vehicle use. Annual CO_2 emissions for the four mobility fleets analyzed in this study are compared for both scenarios in Figure 49. In the "Bottleneck-adjusted" scenario, the additional industrial potential of eFuels identified in the bottleneck analysis was not considered; this aspect was examined in detail in → *Chapter 5*.
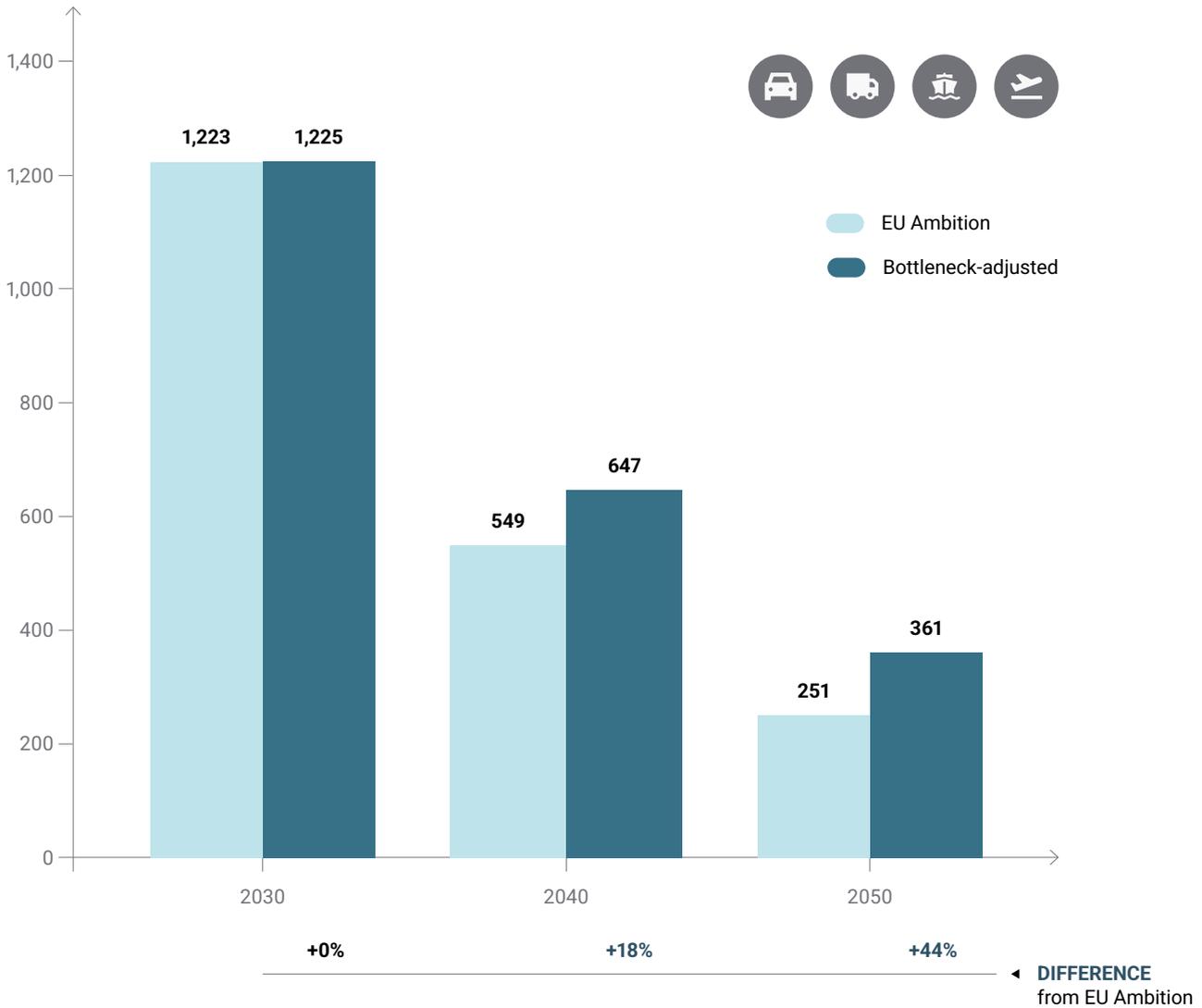
Figure 49: Annual life cycle CO_2 emissions in EU mobility in million tons CO_2/a: "EU Ambition" vs. "Bottleneck-adjusted" scenario.
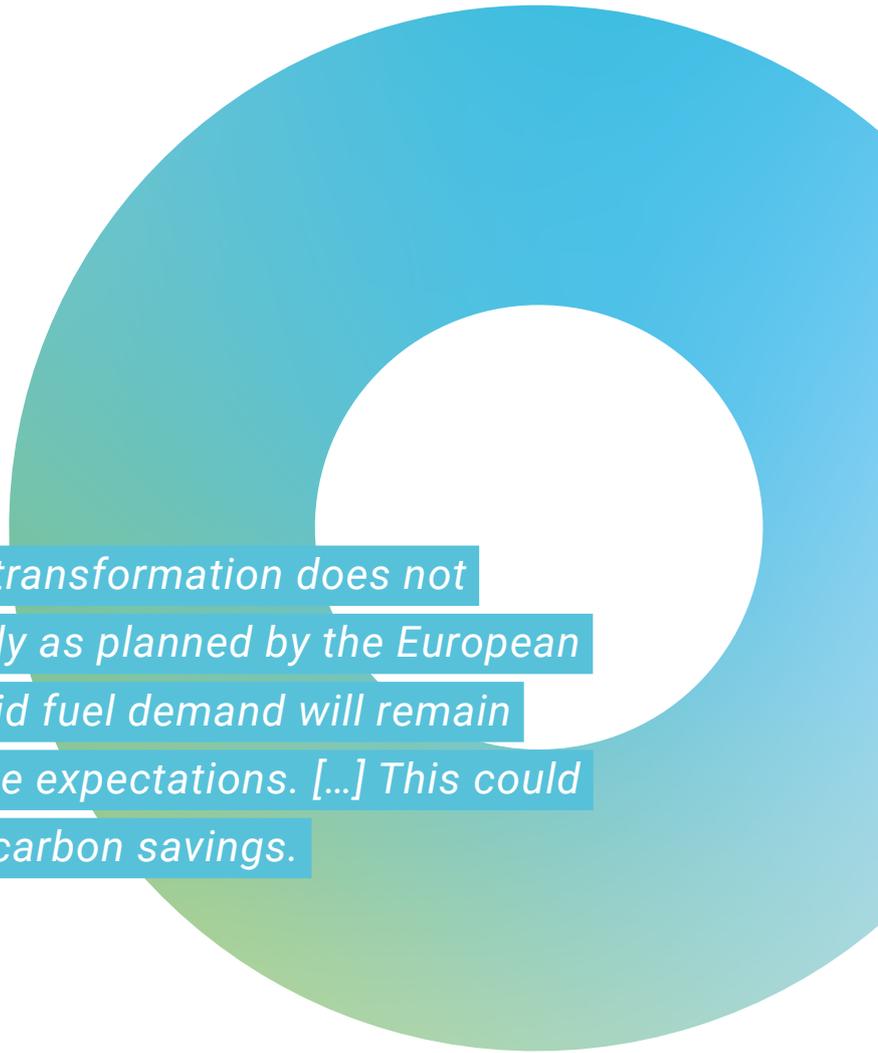
If the powertrain transformation does not progress as swiftly as planned by the European Commission, liquid fuel demand will remain significantly above expectations. […] This could result in delayed carbon savings.

As a result, the increased liquid fuel demand highlighted in → *Section 4.5.* under the "Bottleneck-adjusted" scenario leads to slower CO_2 savings compared to the "EU Ambition" scenario, with emissions exceeding the target by 18 percent in 2040 and by 44 percent in 2050. These additional emissions stem from the prolonged use of ICEVs in EU mobility, directly impacting tank-to-wheel emissions. This further complicates achieving the 90 percent reduction target by 2040 and climate neutrality by 2050, as additional effort requirements were already identified in → *Section 3.5.* for the transformation modeled in the "EU Ambition" scenario.

To conclude, the industrial bottleneck assessment of the transformation designed by the European Commission and referred to as the "EU Ambition" scenario highlights a potential delay in the powertrain and energy transition, with direct implications for CO_2 savings and the achievement of climate targets. However, the industrial feasibility evaluation also reveals opportunities to accelerate the eFuel ramp-up compared to the "EU Ambition" scenario. The contribution of this additional potential was quantified and analyzed in → *Chapter 5*. 💧

eFuel market potential: "Industrial eFuel Potential" scenario

The "Bottleneck-adjusted" scenario was developed to outline a feasible pathway for powertrain and energy transformation while accounting for industrial constraints. This scenario reflects both potential slowdowns and accelerations in the transition for each bottleneck factor—except those within the eFuel supply chain. To date, the analysis has primarily highlighted limitations and possible acceleration in the battery, renewable electricity, and green hydrogen supply chains.

In this chapter, we assess how bottlenecks in the eFuel supply chain influence the overall energy transition. The objective is to clarify the role of eFuels in decarbonizing EU mobility, assuming they scale according to the "Probable Ramp-up Limit" scenario introduced in → *Section 4.1.2.* While sustainable biofuels will also play a significant role—and financial and political factors remain critical for the successful ramp-up of both markets—this scenario focuses on the full utilization of the industrial ramp-up potential of eFuels within EU mobility.

5.1. Methodology, modelling and data collection

To evaluate the potential contribution of eFuels to EU mobility decarbonization, the "Industrial eFuel Potential" scenario was introduced. This scenario builds on the "Bottleneck-adjusted" scenario described in → *Section 4.1.4.* and assumes that the eFuel ramp-up in EU mobility follows the "Probable Ramp-up Limit" scenario outlined in → *Section 4.1.2.*

Based on the supply curves in the "Probable Ramp-up Limit" scenario, eFuel quotas were calculated using a bottom-up approach while maintaining consistency with general assumptions of the "EU Ambition" scenario. Several bottleneck factors influence the eFuel supply chain—such as the availability of wind and photovoltaic power equipment, electrolysis equipment, and the installation speed of eFuel production plants. Each year, the most limiting bottleneck factor is used to build the "Industrial eFuel Potential" scenario.

For example, in 2032, the eGasoline quota is projected to be 5 percent in the "EU Ambition" scenario, while the "Industrial eFuel Potential" scenario indicates it could reach a maximum of 9 percent. This figure is derived from the most restrictive bottleneck in the eFuel supply chain for that year: the availability of wind and photovoltaic power equipment. Compared with the minimum quota of 1 percent for eFuels/RFNBO specified for 2030 under the Renewable Energy Directive (RED)[15], the projections for 2032 in the "EU Ambition" and "Industrial eFuel Potential" scenarios deviate significantly. Under optimal regulatory framework conditions, however, the "Industrial eFuel Potential" scenario demonstrates that such a scale-up is industrially feasible. Recommendations for optimizing the regulatory framework conditions are discussed in detail in → *Chapter 7.* It is important to note that the "Industrial eFuel Potential" scenario does not represent a realistic industry forecast, as external factors—such as regulatory developments, geopolitical dynamics, consumer behavior, social acceptance, and unforeseen economic events—significantly influence ramp-up across supply chains.

Taking wind power equipment as an example, the model first determines the maximum feasible installed wind capacity dedicated to eFuel production for EU mobility, based on equipment availability as described in → *Section 4.2.2.* After accounting for the share of global supply allocated to other markets and applications, the installed wind capacity for eFuels in EU mobility is set at 31 GW in 2032. Adding the installed photovoltaic capacity calculated using the same method results in a total renewable power capacity of 85 GW dedicated to eFuel production for EU mobility.

According to the "Probable Ramp-up Limit" for electrolysis equipment, installed electrolysis capacity could reach 127 GW_{el} in 2032. Since this exceeds the available renewable power capacity, renewable power becomes the limiting factor for eFuel production in that year. The installed capacity is then allocated between Fischer-Tropsch and methanol synthesis routes, consistent with the fuel demand shares in the "EU Ambition" scenario. Under this assumption, eGasoline and eMethanol are produced via methanol synthesis, while eDiesel and eSAF are produced via Fischer-Tropsch. Although variations are possible, current projects indicate a clear trend toward this approach.

Based on these assumptions, eGasoline and eMethanol together account for 53 percent of eFuel demand in 2032 in the "EU Ambition" scenario. Therefore, the same share is applied to the methanol route in the "Industrial eFuel Potential" scenario. Next, eFuel volumes are calculated using plant efficiency data from the Porsche Consulting

eFuel Cost Model and assuming an average annual operating load of 5,000 hours, as introduced in → *Section 4.1.3.4.* Production is split between eMethanol and eGasoline according to demand shares derived from the "EU Ambition" scenario: 53 percent eGasoline and 47 percent eMethanol in 2032. Similarly, eDiesel and eSAF volumes are derived from the Fischer-Tropsch route. The resulting eFuel volume in 2032 is higher when considering the "Probable Ramp-up Limit" for eFuel plant installation speed; therefore, renewable power becomes the limiting factor for eFuel production in that year. This process is repeated annually to construct the "Industrial eFuel Potential" scenario.

5.2. eFuel ramp-up: "Industrial eFuel Potential" vs. "EU Ambition" scenarios

To quantify the feasible industrial ramp-up of eFuel capacities, several factors were assessed on a global scale. Based on projections for eFuel capacity installations and equipment supply for renewable energy and production processes such as electrolysis, the ramp-up of eFuels was modelled using the approach detailed in → *Section 5.1.* This is referred to as the "Industrial eFuel Potential" scenario in Figure 50.
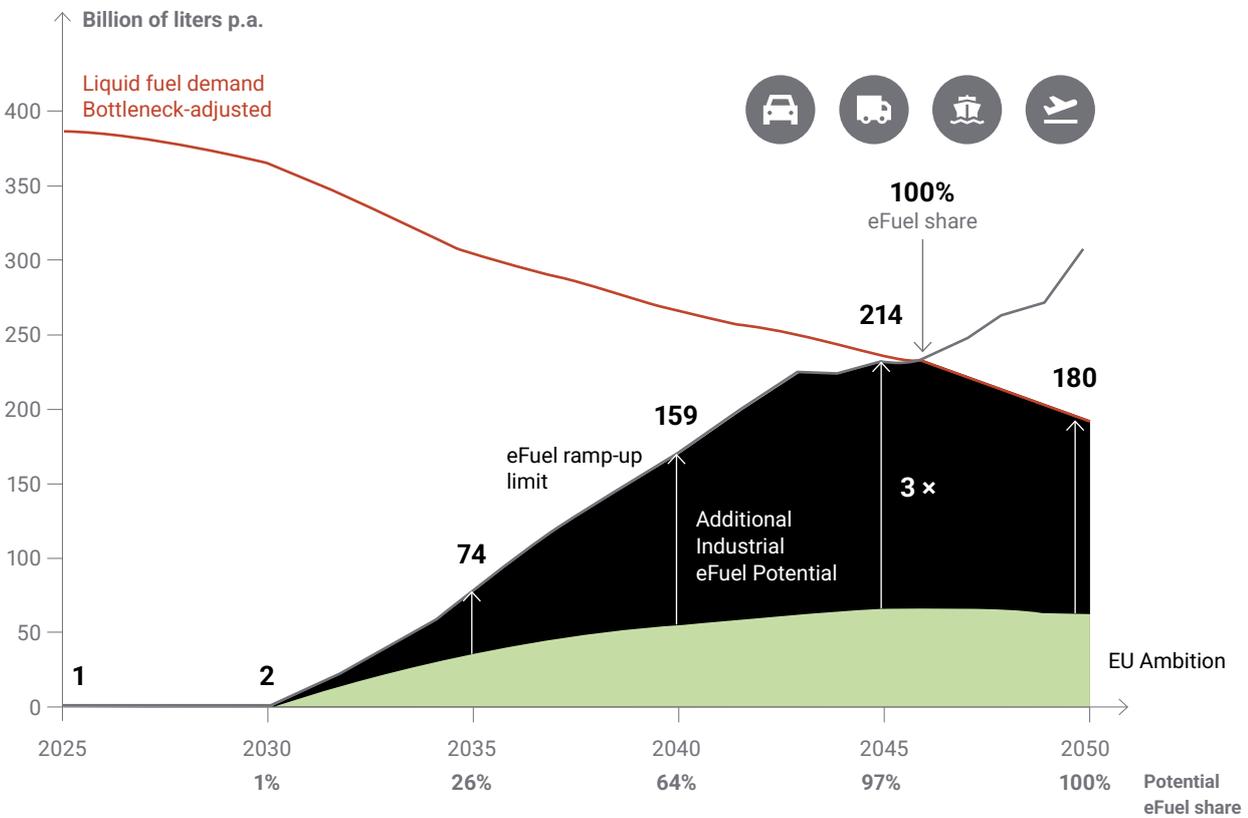
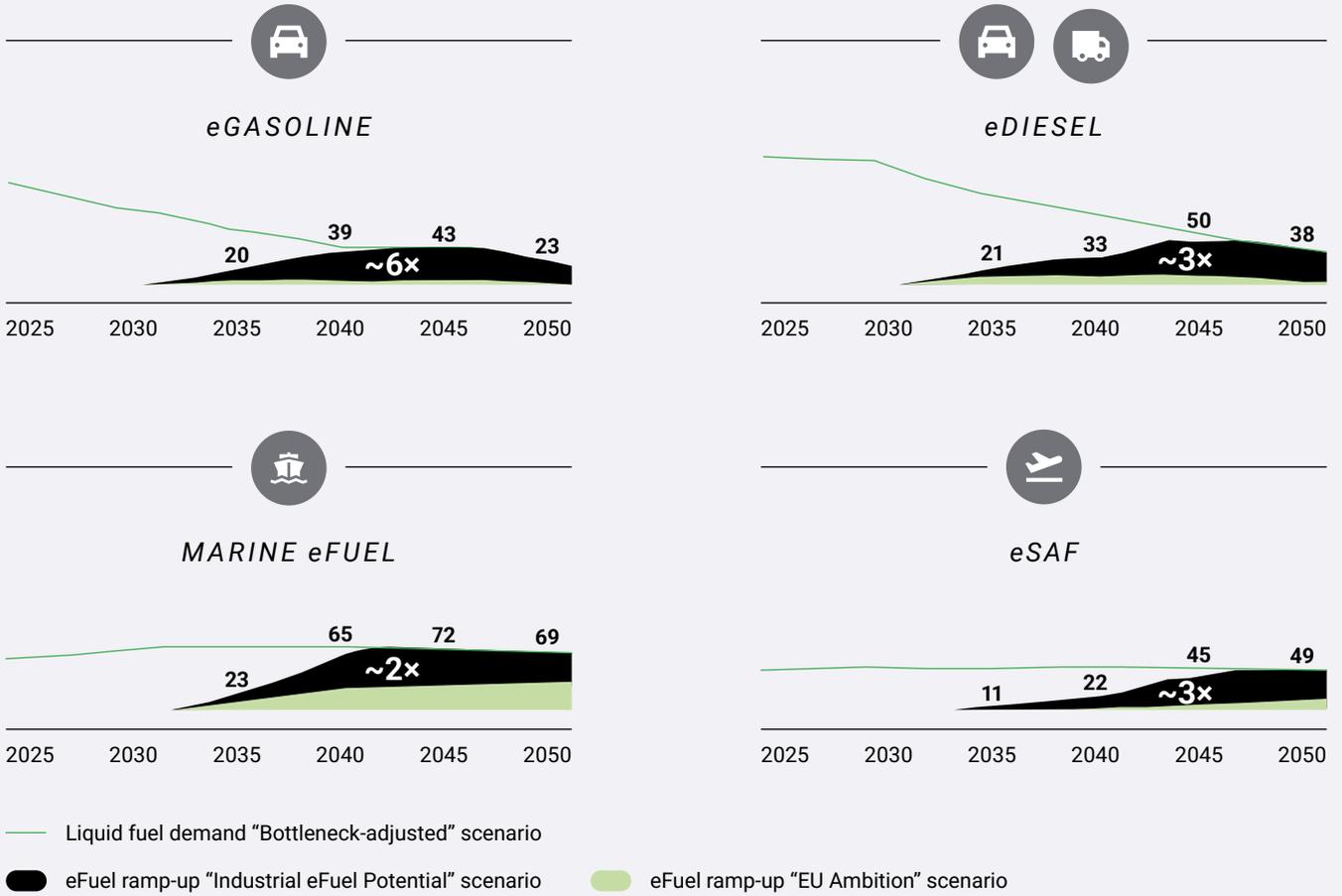**Figure 50:** Annual liquid fuel demand in EU mobility in the "Bottleneck-adjusted" scenario and eFuel ramp-up: "EU Ambition" vs. "Industrial eFuel Potential" scenario.
Scope: gasoline, diesel, fuel oil, methanol, ammonia, and jet fuel | Fuel volume in billion liters gasoline equivalent

The disclosed ramp-up represents the share of global eFuel supply allocated to EU mobility, proportional to its share of global eFuel demand. Capacities allocated to other sectors and markets were excluded. For EU mobility, Figure 50 compares the eFuel ramp-up in the "Industrial eFuel Potential" scenario with the "EU Ambition" scenario, as derived from the European Commission's Impact Assessment.

According to the "EU Ambition" scenario, a significant ramp-up of eFuels in mobility is expected between 2030 and 2040, with demand rising to more than 50 billion liters of gasoline equivalent across the four mobility segments. After 2045, eFuel demand is projected to stagnate, based on the assumption that the powertrain transition accelerates, leading to minimal liquid fuel demand for on-road mobility beyond that point. Additionally, sustainable biofuels (not shown here) are anticipated to play a substantial role in reducing CO_2 emissions within the "EU Ambition" scenario.

The "Industrial eFuel Potential" scenario indicates that, compared with the European Commission's scenario, roughly three times higher eFuel potential could be unlocked. As a result, the eFuel market could grow to 200 billion liters of gasoline equivalent by 2045, achieving a 100 percent eFuel quota the following year—assuming a delayed phase-out of liquid fuels in on-road mobility, consistent with the "Bottleneck-adjusted" scenario described in → *Section 4.5.*

As explained in → *Section 5.1.*, the eFuel ramp-up was calculated for each fuel type while maintaining consistency with their respective demand shares in the "EU Ambition" scenario. The results are summarized for eGasoline, on-road eDiesel, marine eFuel,* and eSAF in Figure 51.

The "Industrial eFuel Potential" scenario indicates that, compared with the European Commission's scenario, roughly three times higher eFuel potential could be unlocked.

The "Industrial eFuel Potential" scenario shows a stronger ramp-up across all fuel types compared to the "EU Ambition" scenario. Until 2030, limitations in renewable energy equipment availability prevent eFuel production from accelerating beyond the "EU Ambition" scenario. After 2030, supply chain constraints ease, allowing the ramp-up to accelerate.

According to the industrial feasibility assessment, marine eFuels and eGasoline could fully replace fossil fuels by 2042, while eDiesel and eSAF reach a 100 percent quota by 2046. The delay for eDiesel and eSAF is primarily due to the European Commission's prioritization of the maritime sector for the ramp-up of eFuels, which shifts capacity allocation toward eMethanol and eMethanol-based products according to the approach described in → *Section 5.1*. As a result, cumulative volumes increase sixfold for eGasoline, threefold for on-road eDiesel and eSAF, and twofold for marine eFuels, which include eDiesel, eMethanol, and eAmmonia.

* Marine eFuel includes eDiesel, eMethanol, and eAmmonia.

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EU liquid fuel demand vs. eFuel ramp-up
[Billion of liters p.a.]

eGASOLINE

20   39   43   23   ~6×

2025   2030   2035   2040   2045   2050

eDIESEL

21   33   50   38   ~3×

2025   2030   2035   2040   2045   2050

MARINE eFUEL

23   65   72   69   ~2×

2025   2030   2035   2040   2045   2050

eSAF

11   22   45   49   ~3×

2025   2030   2035   2040   2045   2050

— Liquid fuel demand "Bottleneck-adjusted" scenario

⬛ eFuel ramp-up "Industrial eFuel Potential" scenario   🟩 eFuel ramp-up "EU Ambition" scenario

Figure 51: Annual liquid fuel demand by fuel type in EU mobility in the "Bottleneck-adjusted" scenario and eFuel ramp-up: "EU Ambition" vs. "Industrial eFuel Potential" scenario.
Fuel volume in billion liters gasoline equivalent | eDiesel refers to the use of eDiesel in on-road mobility, marine eFuel refers to eDiesel, eMethanol, and eAmmonia | SAF: Sustainable Aviation Fuel

The significant increase in eGasoline volumes is driven not only by additional industrial potential across the supply chain but also by the longer presence of ICEVs in the "Bottleneck-adjusted" scenario, which sustains higher liquid fuel demand in the passenger car fleet compared to the "EU Ambition" scenario. Similar findings apply to eDiesel, reflecting delayed transformation in the truck and bus segment, though with a more moderate lag. From 2045 onward, declining liquid fuel demand in on-road mobility leads to reduced eFuel demand. However, excess eFuel

capacities are not considered stranded investments, as they are expected to supply other sectors and markets, especially given that the EU mobility ramp-up is significantly ahead of plans announced in other regions.

To conclude, the industrial feasibility assessment clearly shows that the eFuel ramp-up could be accelerated compared to the "EU Ambition" scenario, potentially increasing their contribution to achieving climate targets—a highly beneficial outcome if the powertrain transition is delayed.

5.3. Resulting annual CO_2 emissions in the transport sector

The industrial bottleneck analysis suggests that powertrain transformation in on-road mobility could be delayed by about five years due to battery supply chain constraints. In contrast, eFuels may expand at a rate three times higher than projected in the "EU Ambition" scenario. These insights call for a detailed assessment of their impact on CO_2 emissions and the ability to meet climate targets.

CO_2 emissions were calculated for four mobility fleets: passenger cars, trucks and buses, shipping, and aviation. The calculation covers the entire vehicle life cycle, as outlined in → *Section 3.2.3.* Figure 52 compares the resulting annual CO_2 emissions across the following scenarios: "EU Ambition," "Bottleneck-adjusted," and "Industrial eFuel Potential.*"

The analysis indicates that accelerating the eFuel ramp-up to its full industrial potential can drive faster decarbonization of EU mobility, even compared to the "EU Ambition" scenario. Until 2030, ramp-up constraints limit opportunities for additional CO_2 savings through eFuels. However, the impact of accelerated ramp-up after 2030 becomes evident by 2040, with 170 million tons of CO_2 saved compared to the "Bottleneck-adjusted" scenario. In the "Industrial eFuel Potential" scenario, a 14 percent CO_2 reduction is achievable versus the "EU Ambition" scenario. In other words, leveraging the full potential of eFuels more than offsets the 18 percent increase in CO_2 emissions caused by the delayed powertrain transformation. By 2050, the "EU Ambition" and "Industrial eFuel Potential" scenarios converge at the same emission level, as most energy demand in both cases is met by renewable sources. The remaining emissions are primarily linked to energy supply, specifically Well-to-Tank emissions.

* Derived from the "Bottleneck-adjusted" scenario and considering the additional industrial potential of eFuels, as introduced in → *Section 5.1.*
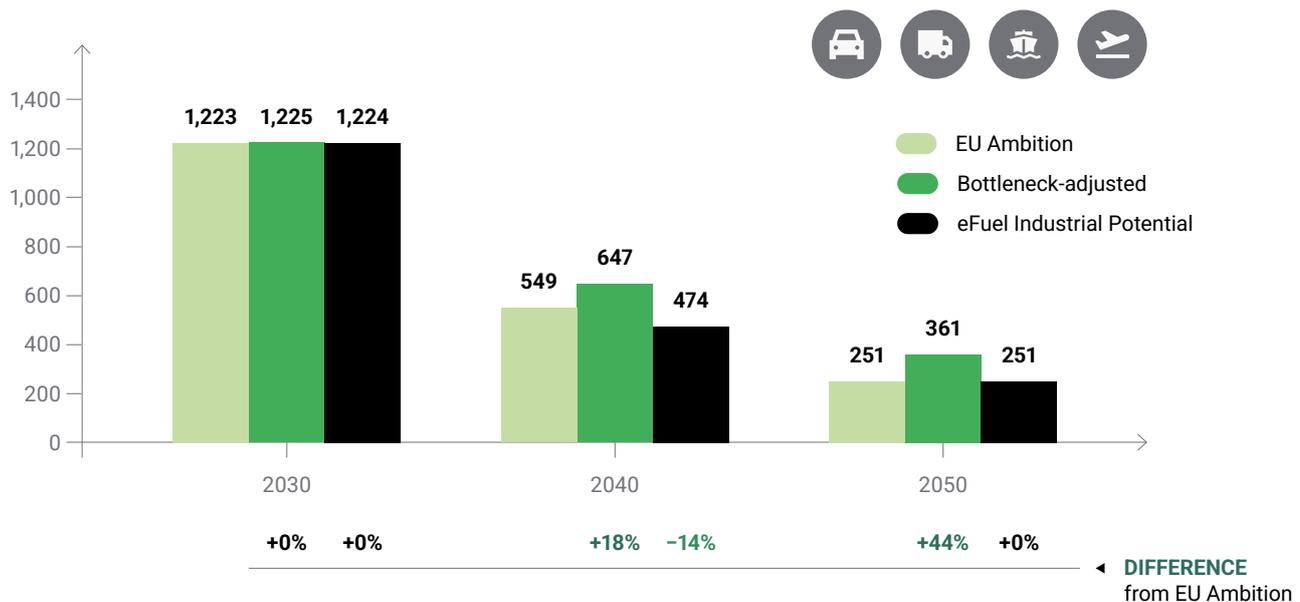
Figure 52: Annual life cycle CO_2 emissions in EU mobility in million tons CO_2/a: "EU Ambition" vs. "Bottleneck-adjusted" vs. "Industrial eFuel Potential" scenario.

5.4. CO_2 budget compliance across the analyzed scenarios

The Paris Climate Conference in 2015 established a global target to limit warming to 1.75°C (or well below 2°C) above pre-industrial levels. To achieve this, the Intergovernmental Panel on Climate Change (IPCC) highlighted in its 2018 report[2] that the rise in global temperature is directly linked to atmospheric CO_2 concentration. This means that setting annual emission targets alone is insufficient to meet a temperature goal; instead, cumulative anthropogenic CO_2 emissions must be monitored.

Accordingly, the IPCC derived a global CO_2 budget that accounts for natural carbon sinks and potential climate tipping points. The report estimated that approximately 1,400 Gt CO_2 remained available from January 1, 2018, to avoid exceeding the 1.75°C threshold with a 50 percent probability. After deducting global CO_2 emissions up to 2024[3], the residual budget is about 700 Gt CO_2 as of early 2025.

Allocating a proportional share of this budget to the EU based on population, and then to EU mobility based on its emission share among EU sectors[4], results in roughly 19 Gt CO_2 available for EU mobility starting in 2025. This allocation includes life cycle emissions: vehicle production, energy supply (well-to-tank), and vehicle use (tank-to-wheel).

To evaluate progress toward climate targets in EU mobility, cumulative CO_2 emissions were calculated and compared with the allocated residual CO_2 budget starting in 2025. Three scenarios were analyzed and are shown in Figure 53: the "EU Ambition" scenario, the "Bottleneck-adjusted" scenario, and the "Industrial eFuel Potential" scenario.*

The "EU Ambition" scenario approximately meets the CO_2 budget for the 1.75°C target, assuming carbon neutrality is achieved by 2050 in line with the European climate goal. However, annual life cycle CO_2 emissions indicate that reaching climate neutrality by 2050 will require additional measures—either within

* Derived from the "Bottleneck-adjusted" scenario and considering the additional industrial potential of eFuels, as introduced in → *Section 5.1.*

Accelerating the eFuel ramp-up to its full industrial potential can offset additional emissions resulting from the delayed powertrain transition and thus enable compliance with the CO_2 budget.

EU MOBILITY: CUMULATIVE EMISSIONS
2025–2050
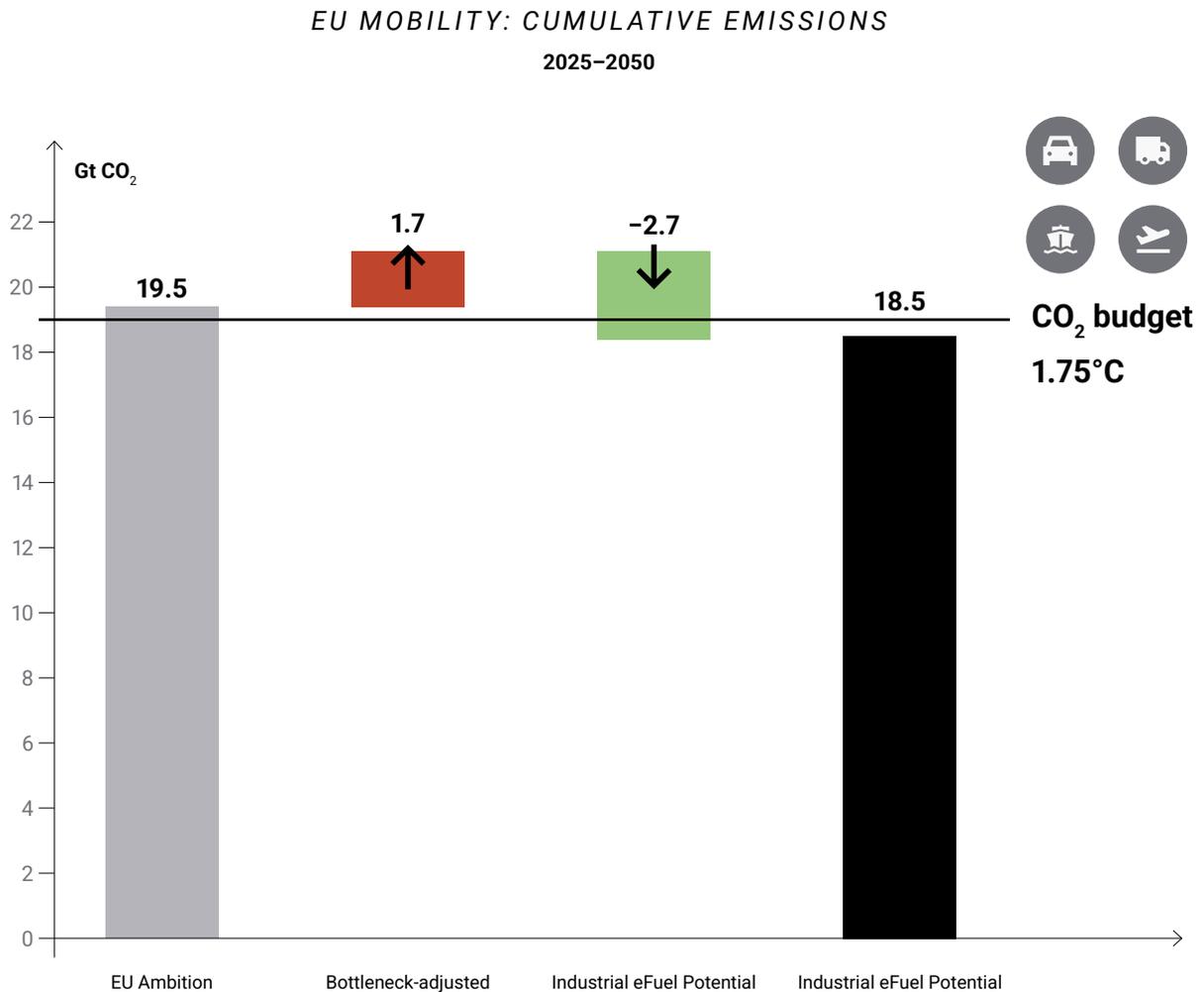
Figure 53: Cumulative life cycle CO_2 emissions in EU mobility in billion tons CO_2 (Gt): "EU Ambition" vs. "Bottleneck-adjusted" vs. "Industrial eFuel Potential" scenario.

the mobility sector or through offsets in other sectors. In the "Bottleneck-adjusted" scenario, increased liquid fuel demand in on-road mobility due to the delayed powertrain transformation could raise cumulative emissions by up to 1.7 Gt CO_2, exceeding the EU mobility budget. Accelerating the eFuel ramp-up to its full industrial potential can offset additional emissions resulting from the delayed powertrain transition and thus enable compliance with the CO_2 budget.

In conclusion, from an industrial feasibility perspective, eFuels can serve as a key lever for achieving climate targets, even if the powertrain transformation in EU mobility is delayed. These findings are based solely on the industrial feasibility of the eFuel ramp-up and do not account for additional limiting factors such as regulatory frameworks or economic developments. → *Chapter 6* provides an overview of current industry plans and the challenges that must be addressed. ⚡

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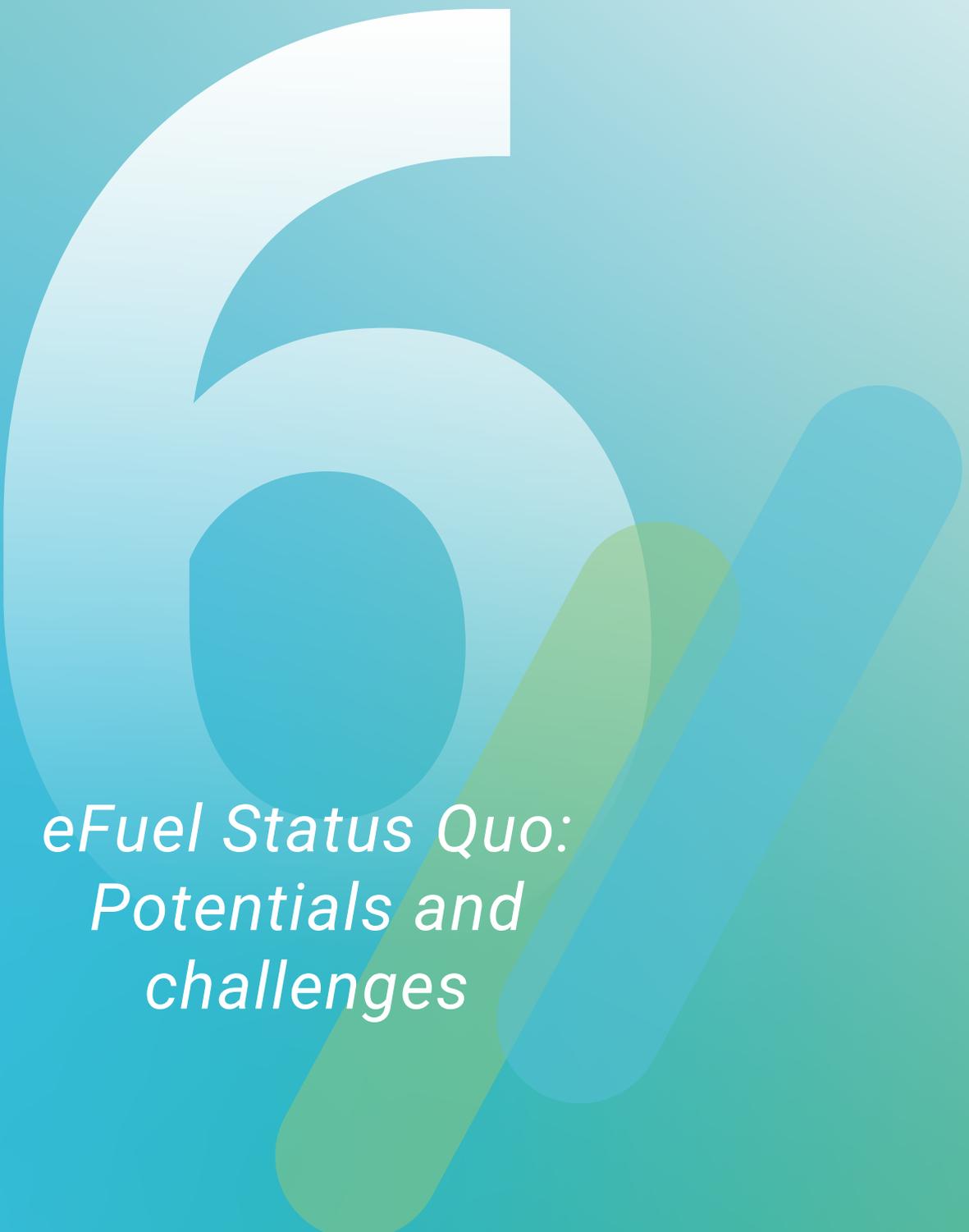
eFuel Status Quo: Potentials and challenges

According to the findings in → *Chapter 5*, eFuels—alongside other solutions—can significantly contribute to meeting climate targets in EU mobility. Unlocking this potential, however, requires substantial action at a global scale. This chapter evaluates the current status of the global eFuel industry based on the identification and assessment of announced production projects.

→ **6.1. Methodology and data collection**

In recent years, global announcements for eFuel production projects have increased significantly. To track these developments, Porsche Consulting created a database to analyze project data, focusing on fuel types, regional differences, involved stakeholders, and stages of advancement. These announcements were validated against industry data from the eFuel Alliance[5], IEA[6], and Methanol Institute[7].

For this analysis, eFuels are defined exclusively as green hydrogen-based* fuels; projects using other hydrogen sources—such as blue, pink, grey, brown, or black hydrogen**— are excluded. Among more than 500 projects reviewed, the focus was on those planning to start production by 2030 and on fuel types most relevant to EU mobility in that timeframe: eAmmonia, eMethanol, eSAF, eGasoline/ eNaphtha, eMethane, and eDiesel.

The data presented in this chapter are based on official announcements from eFuel project developers, and the actual ramp-up will depend on the successful execution of these projects. Figure 54 illustrates the level of detail captured in the database developed for this analysis.

* Derived from renewable electricity.

** Respectively derived from: natural gas via steam reforming combined with Carbon Capture and Storage (CCS), nuclear-based electricity, natural gas via steam reforming, lignite (brown coal), black coal.

500	**6**	**5**	**5**	**>150**
PROJECTS	*eFUEL TYPES*	*REGIONS*	*PROJECT STATUS*	*SOURCES*
Including location, capacity, status	eMethanol, eGasoline/ eNaphtha, eSAF, eDiesel, eMethane, eAmmonia	Europe, North America, South America, China, Rest of the World	Concept, Feasibility, FEED, Construction, Operation	Porsche Consulting, IEA Hydrogen, Methanol Institute, eFuel Alliance

Figure 54: Overview of dimensions analyzed in the eFuel project database.
Source: Porsche Consulting eFuel Project Tracker | SAF: Sustainable Aviation Fuel | FEED: Front-End Engineering Design

Current project announcements indicate strong growth in eFuel supply over the next five years, with 76 billion liters of gasoline equivalent planned by 2030. Figure 55 shows the projected global production share by fuel type in 2030, based on official announcements.

The results show a clear dominance of projects planning to produce eAmmonia, accounting for 73 percent of the projected volume, followed by eMethanol with a 21 percent share. Other fuels are expected to represent up to 2 percent of the market. This strong dominance of eAmmonia is largely due to the Haber-Bosch process, which is already widely used for conventional ammonia production. As a result, technical maturity is higher compared to other eFuels, and the cost competitiveness of eAmmonia production depends primarily on the price of green hydrogen relative to other hydrogen sources—a condition achievable in regions with abundant low-cost renewable energy.

While planned eAmmonia production by 2030 outpaces other fuel types, demand is not expected to be driven by the mobility sector before 2030. In 2022, fertilizer production represented the largest ammonia demand pool, followed by industrial applications such as textiles, refrigeration, and pharmaceuticals. Marine fuel accounted for less than 1 percent of ammonia demand, as shown in Figure 56.

Among the four mobility segments analyzed in this study, eAmmonia is expected to become relevant primarily in the maritime sector. However, ammonia engines are still under development, and large-scale adoption is not anticipated before 2030. In contrast, other powertrains are already being phased into the maritime fleet. Therefore, eAmmonia was not further examined in this chapter, as the analysis focuses on the mobility sector up to 2030.

Current project announcements indicate strong growth in eFuel supply over the next five years.

6.2. Announced eFuel ramp-up by fuel and region

Based on current announcements, eFuel supply is expected to scale significantly by 2030, with around 300 projects relevant to mobility. A global annual capacity of 20 billion liters of gasoline equivalent has been announced, with all regions contributing to the ramp-up—particularly China and Europe. Figure 57 provides a geographical overview of announced production projects, highlighting capacities exceeding 30 million liters* per year.

* Gasoline equivalent.

The map reveals a wide variation in production scale. European projects currently target small to medium-scale output, while regions such as China and South America aim for large-scale production, with several projects exceeding annual capacities of 300 million liters of gasoline equivalent. These regions benefit from
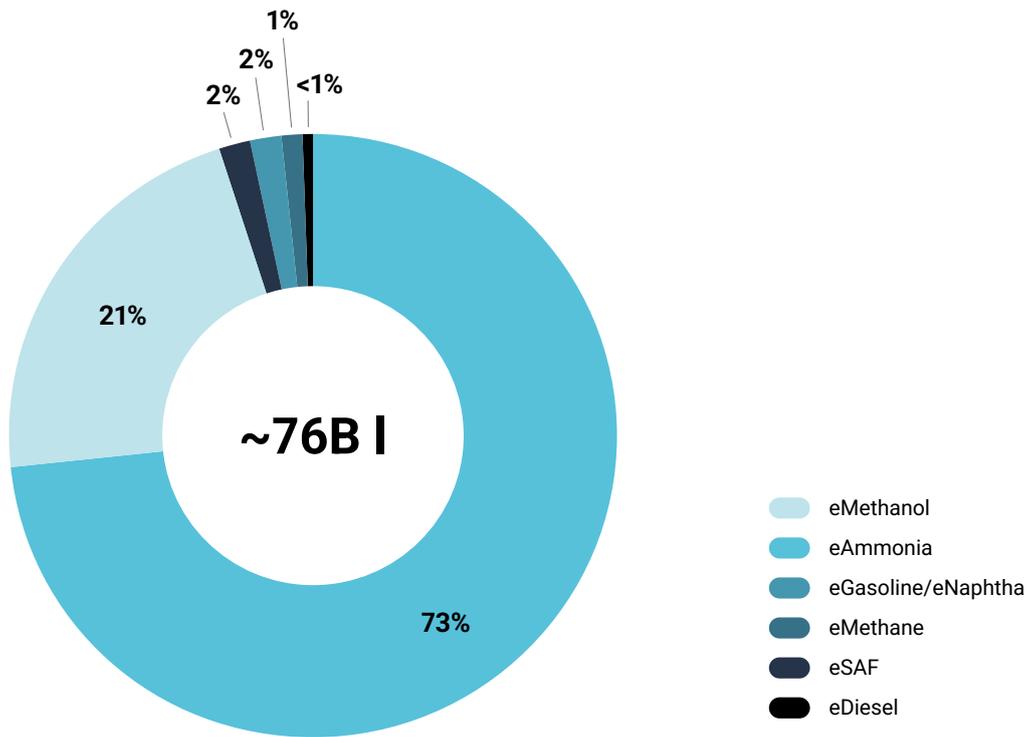
Figure 55: Share of global announced eFuel production by fuel in 2030.
Source: Porsche Consulting eFuel Project Tracker, eFuel Alliance[5], IEA[6], and Methanol Institute[7] | Fuel volume in billion liters gasoline-equivalent | SAF: Sustainable Aviation Fuel
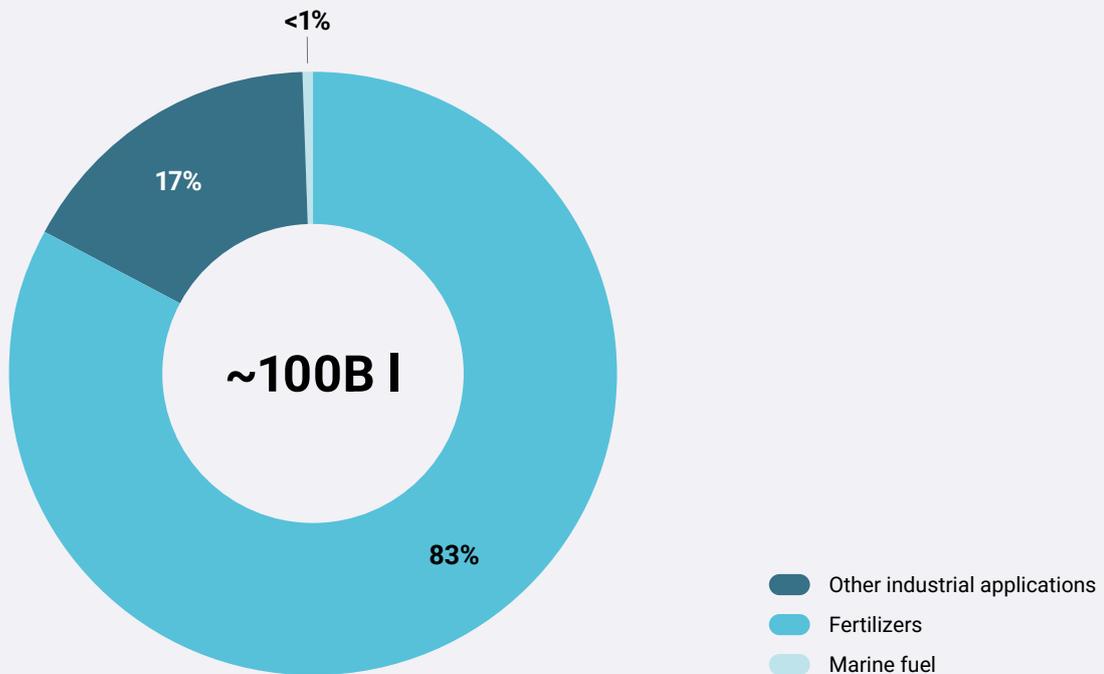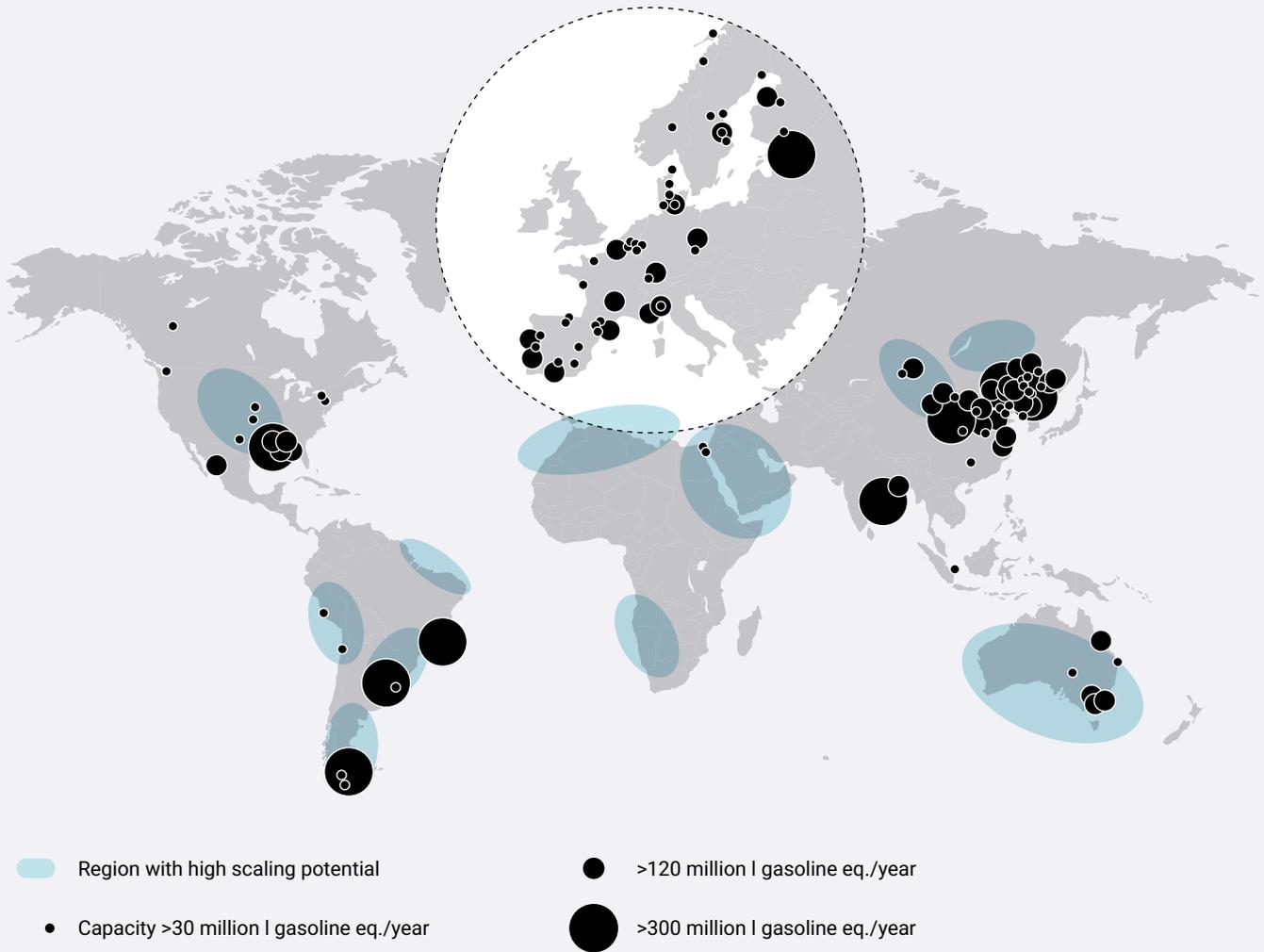

Figure 56: Share of global ammonia demand by application in 2022.
Source: IRENA Innovation Outlook 2022: Renewable Ammonia[36] | Fuel volume in billion liters gasoline equivalent | Other industrial applications include textiles, refrigeration, explosives or pharmaceuticals

Figure 57: Global announced eFuel production projects in 2030 by capacity.
Source: Porsche Consulting eFuel Project Tracker, eFuel Alliance[5], IEA[6], and Methanol Institute[7] | Scope: eMethanol, eSAF, eGasoline/eNaphtha, eMethane, eDiesel, map disclosing projects with annual production capacities above 30 million liters gasoline equivalent | Fuel volume in billion liters gasoline equivalent | SAF: Sustainable Aviation Fuel

more favorable renewable energy conditions, making low-cost production feasible at large scale. In contrast, the land required for renewable power plants at this scale poses a critical constraint in densely populated areas where land availability is limited.

By 2030, many new players are expected to enter the eFuel market. Figure 58 provides an overview of their projected market shares, along with the distribution of fuel types planned for ramp-up by 2030.

According to industry announcements, HIF Global is projected to lead eFuel production, accounting for 12 percent of global capacity by 2030, with several large-scale projects planned in South America, the USA, and Australia. Key players in China are planning—and in some cases already constructing—large-scale eMethanol plants in Inner Mongolia, leveraging low-cost renewable energy and representing 18 percent of global announced production by 2030. Other emerging players include Denmark-based European Energy,

BY COMPANY

2030
eFuel project capacities

~20B l

- 12% HIF
- 5% MINGYANG
- 5% 内蒙古源源能源集团有限责任公司 Inner Mongolia Yuanyuan Energy Group Co., Ltd.
- 4% CGN
- 3% CARBON RECYCLING INTERNATIONAL
- 2% CEEC
- 2% EUROPEAN ENERGY
- 2% GOLDWIND
- 2% ReNew POWER
- 2% Elyse

INERATEC · Aalborg Forsyning · INFINIUM · ABEL ENERGY · Liquid Wind · Arcadia eFuels · MADOQUA · TOKYO GAS · CRRC · Nordic Electrofuel · Ørsted · SPIC · SunGas RENEWABLES · BIO GASCLEAN

25% Others

BY FUEL TYPE

- eMethanol
- eGasoline/eNaphtha
- eMethane
- eSAF
- eDiesel

82%
6%
5%
5%
2%
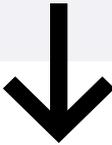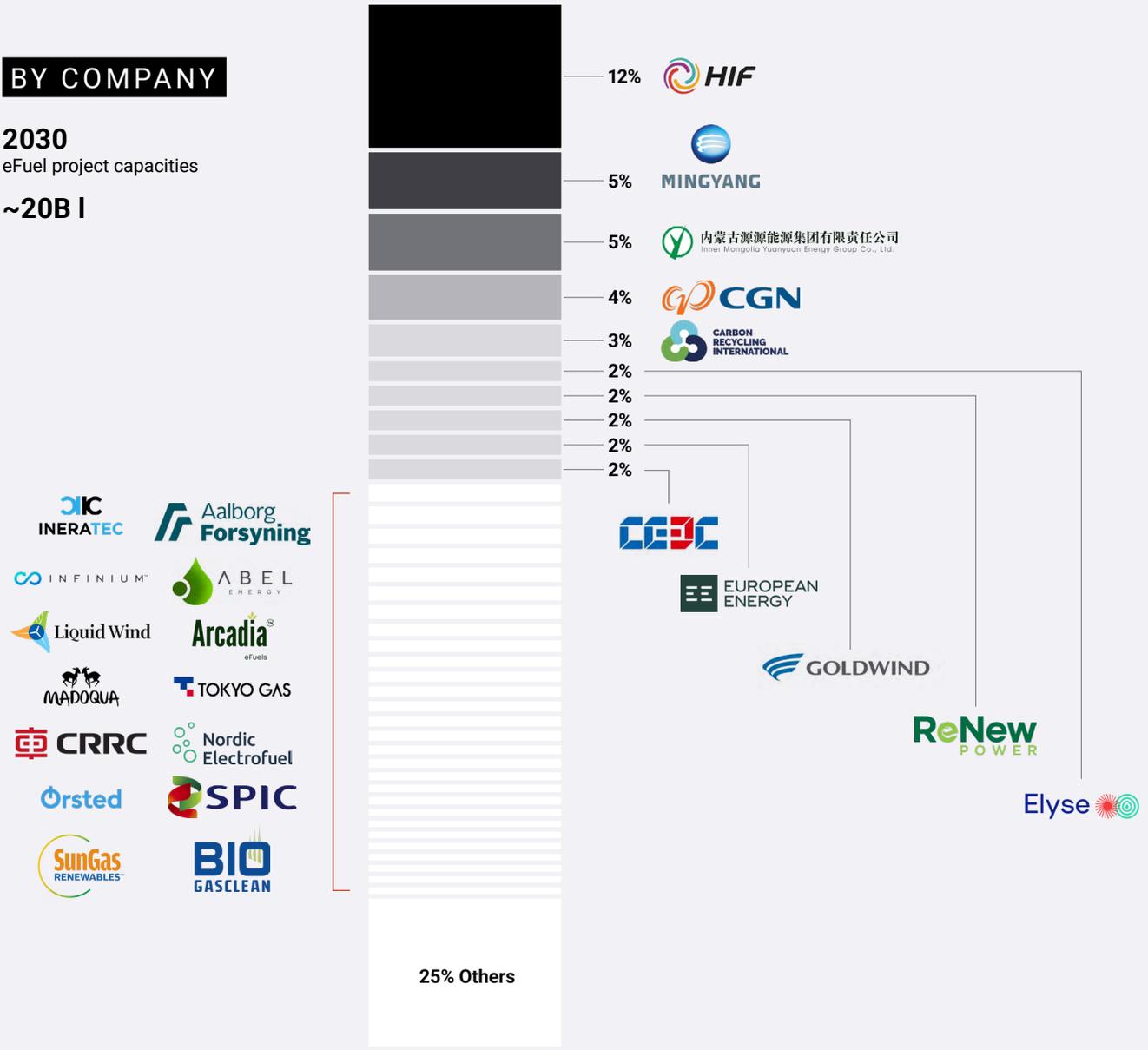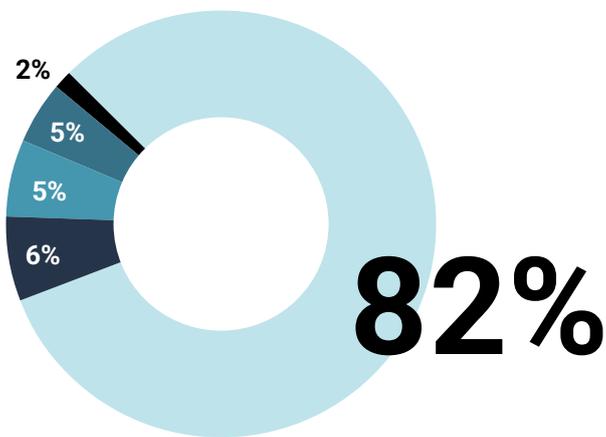
Figure 58: Market share of eFuel production by company and by fuel type based on global announced production in 2030.
Source: Porsche Consulting eFuel Project Tracker, eFuel Alliance[5], IEA[6], Methanol Institute[7] | Scope: eMethanol, eSAF, eGasoline/eNaphtha, eMethane, eDiesel | Fuel volume in billion liters gasoline equivalent | SAF: Sustainable Aviation Fuel

which has large-scale projects planned in Europe. In total, more than 120 companies have been identified with eFuel scaling plans through 2030, resulting in a highly fragmented supply landscape.

The database reveals a strong focus on eMethanol, which accounts for 82 percent of announced capacity by 2030—particularly in China, where methanol is viewed as a means to reduce oil dependency and decarbonize on-road mobility and shipping. Additionally, eMethanol serves as a flexible platform fuel for all mobility segments.

Other fuels—such as eSAF, eGasoline/eNaphtha, and eMethane—are also planned for scale-up, each representing roughly 5 percent of projected eFuel production by 2030, while eDiesel is not prioritized and mainly appears as a byproduct in announced projects. Significant growth is expected for eSAF through 2030, and the market balance could shift in its favor over the long term. Furthermore, eMethanol can be converted into eGasoline or eSAF, a detail not always specified in current announcements, which could influence the fuel-type market share by 2030.

Figure 59 estimates the potential share of EU mobility that could be powered by the globally announced annual capacity of 20 billion liters in 2030. For each mobility segment, only relevant fuel types were considered when calculating potential supply across global projects. For example, only announced capacities of eGasoline and eDiesel were included for the passenger car fleet.

Additionally, the analysis assumes that all globally announced capacities are dedicated to EU mobility—a scenario that does not reflect reality, as global production will also serve other sectors and markets. For instance, eMethanol will be used not only in European

A global annual capacity of 20 billion liters of gasoline equivalent has been announced, with all regions contributing to the ramp-up—particularly China and Europe. […] By 2030, many new players are expected to enter the eFuel market.

maritime transport but also in the chemical industry. Nevertheless, this assumption provides an indication of the scale of announced production within the eFuel industry.

Based on this approach, approximately 1 percent of EU passenger car mobility could be powered by eFuels from global announcements. If projects materialize, global eDiesel and eSAF production could theoretically cover 2.5 percent of fuel demand in both truck and bus and aviation fleets. The contribution of eMethanol could be significantly higher, with more than 16 billion liters of gasoline equivalent forecasted by 2030—enough to meet nearly 24 percent of liquid fuel demand in the maritime sector, as derived from the "EU Ambition" scenario. These estimates indicate that the scale of current production announcements for 2030 could make a meaningful contribution to decarbonizing mobility, particularly in the shipping sector.

As shown in Figure 57, eFuel production is being planned on a global scale, with multiple regions contributing to the ramp-up. Figure 60 details the regional shares of announced production for each fuel type. Overall, China is projected to lead with 43 percent of global capacity, followed by Europe at 28 percent, North America at 13 percent, and South America at 8 percent.

With 16.3 billion liters of annual production, eMethanol is forecasted to dominate the market by 2030, driven primarily by China—where more than half of the announced capacity is concentrated—and Europe, which accounts for roughly one-quarter of global production. For eSAF projects, Europe leads with 84 percent of global announced capacity. South America emerges as the key region for scaling

eGasoline, holding 77 percent of the market share by 2030. Regions such as Patagonia and the Atacama Desert offer vast potential for wind and solar power, enabling low-cost eFuel production. Since eGasoline demand is less incentivized than other fuels in most import regions, the lower willingness to pay increases the need for low-cost energy locations, making South America a strategic hub for eGasoline exports in 2030. Announced eMethane production is dominated by Europe, with a 56 percent share, though its regional distribution is more diversified than other fuel types, involving North America, South America, and additional global regions. eDiesel production is split between Europe (69 percent) and North America (30 percent), primarily as a byproduct of the hydrocracking process in eSAF facilities.

|				
Global eFuel supply (2030)	**~1.5 billion l** eGasoline/eNaphtha + eDiesel	**~1.2 billion l** eDiesel + eMethane	**~1.3 billion l** eSAF	**~16.3 billion l** eMethanol
Max. share of fuel demand	**0.9%** ~161B l fuel consumption within EU fleet	**2.4%** ~49B l fuel consumption within EU fleet	**2.5%** ~52B l fuel consumption within EU fleet	**23.6%** ~69B l fuel consumption within EU fleet
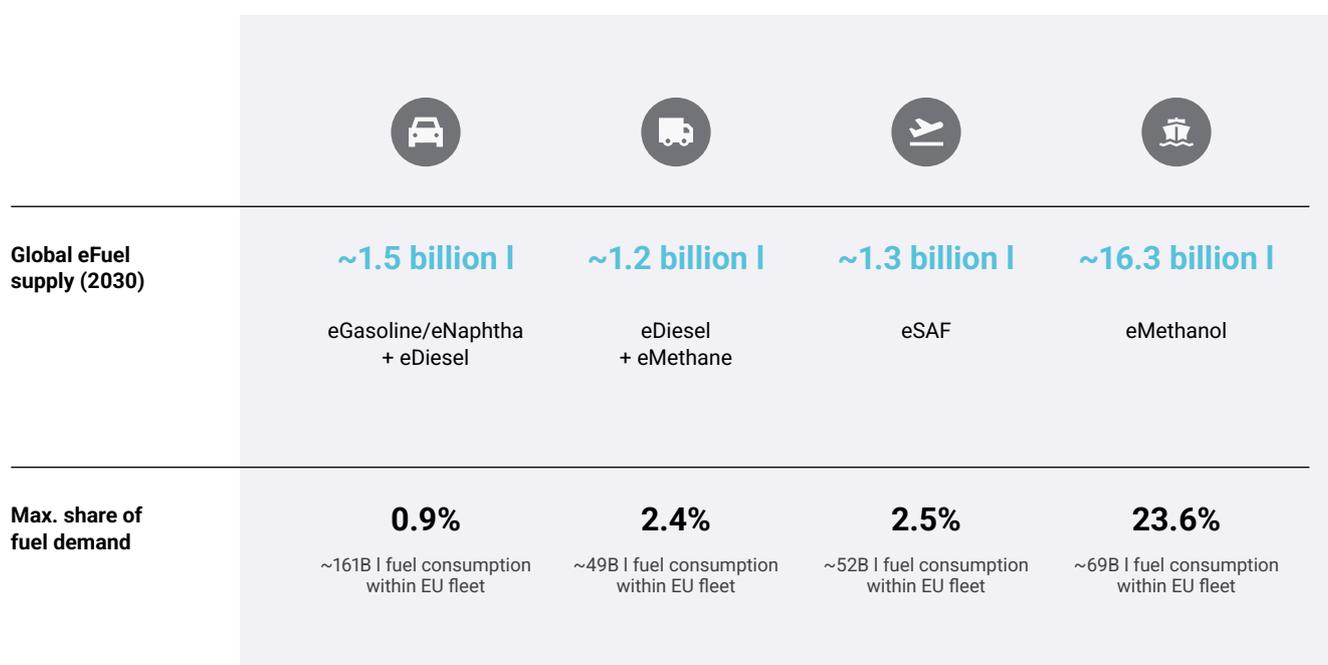
Figure 59: Transformation potential in EU mobility based on global announced eFuel production in 2030.
Source: Porsche Consulting eFuel Project Tracker, eFuel Alliance[5], IEA[6], Methanol Institute[7], European Commission's Impact Assessment Report[1] | Scope: eMethanol, eSAF, eGasoline/eNaphtha, eMethane, eDiesel | Assumption: all global announced capacities dedicated to supply EU mobility | Fuel volume in billion liters gasoline equivalent | SAF: Sustainable Aviation Fuel

These results highlight varying regional priorities in fuel type selection. Figure 61 illustrates the production portfolio for each region.

China is planning an exclusive and large-scale ramp-up of eMethanol, with 8.7 billion liters of annual capacity announced for 2030. Beyond supporting carbon reductions in on-road and maritime transport, eMethanol offers China an opportunity to reduce oil import dependency through local sourcing while leveraging its renewable energy potential.

Europe, with a 28 percent production share and 5.7 billion liters announced for 2030, is pursuing a more diversified strategy: 65 percent of capacity for eMethanol, 19 percent for eSAF, and 9 percent for eMethane. Announced eGasoline and eDiesel capacities remain marginal. This portfolio reflects Europe's
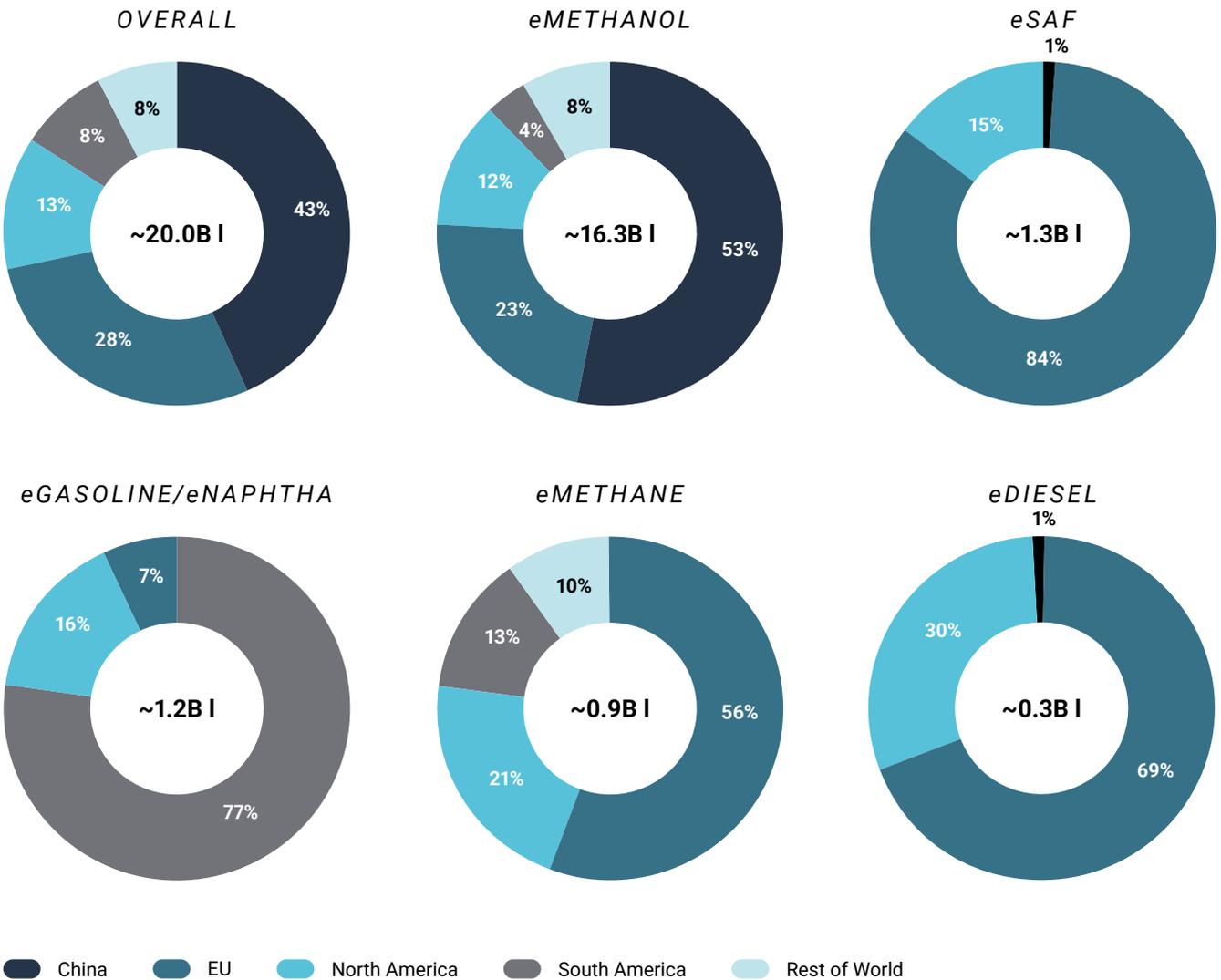
Figure 60: Announced eFuel production share by region in 2030.
Source: Porsche Consulting eFuel Project Tracker, eFuel Alliance[5], IEA[6], and Methanol Institute[7] | Scope: eMethanol, eSAF, eGasoline/eNaphtha, eMethane, eDiesel | Fuel volume in billion liters gasoline equivalent | SAF: Sustainable Aviation Fuel

With 16.3 billion liters of annual production, eMethanol is forecasted to dominate the market by 2030, driven primarily by China—where more than half of the announced capacity is concentrated—and Europe, which accounts for roughly one-quarter of global production.
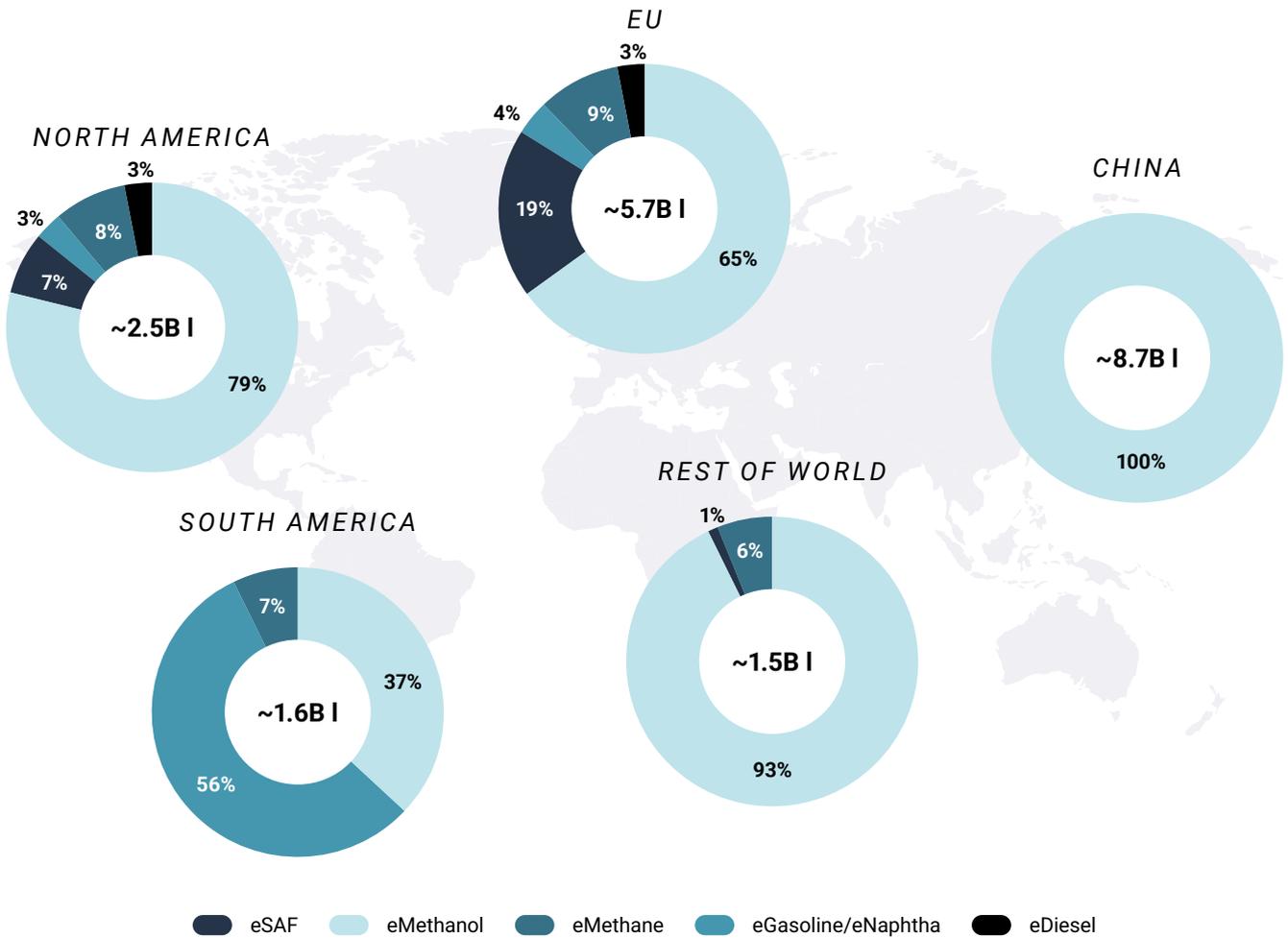
Figure 61: Announced eFuel production share by fuel type in 2030.
Source: Porsche Consulting eFuel Project Tracker, eFuel Alliance[5], IEA[6], and Methanol Institute[7] | Scope: eMethanol, eSAF, eGasoline/eNaphtha, eMethane, eDiesel | Fuel volume in billion liters gasoline equivalent | SAF: Sustainable Aviation Fuel

regulatory focus on decarbonizing maritime and aviation sectors, where eMethanol, eMethane, and eSAF will play key roles.

North America, the third-largest region with a 13 percent share and 2.5 billion liters planned, concentrates 79 percent of its capacity on eMethanol, while scaling plans for eSAF, eMethane, eGasoline, and eDiesel lag behind.

South America is strategically positioned to leverage low-cost renewable energy for competitive eGasoline production, dedicating 56 percent of announced capacity to this fuel type.

In the rest of the world, eMethanol dominates with 93 percent of announced capacity by 2030.

In each region, announced production reflects prevailing market demand trends, such as the priorities set by the European Commission to ramp-up eFuels in the maritime and aviation mobility segments. However, intercontinental trade will be essential to achieve cost efficiencies and secure the global ramp-up of eFuels. While announcements for global eFuel production have surged and ambitious scaling projects could enable decarbonization across multiple sectors and markets, the path to 2030 remains uncertain.

6.3. Market challenges

While numerous stakeholders have announced plans to scale up eFuel production by 2030, several challenges could delay these projects. Their advancement stages have been monitored, ranging from concept or feasibility studies to front-end engineering design (FEED), final investment decision (FID), construction, and operation. Figure 62 illustrates the status of global eFuel capacity planned to begin production by 2030, showing the share of total announced capacity by project stage.

Status of announced eFuel capacities for 2030

Share of eFuel capacity	4%	76%	14%	6%	<0.1%
	Status unknown	Concept/Feasibility	FEED	FID/Construction	Operation

Project execution likelihood

94% — MEDIUM   6% — VERY HIGH

€

FINAL INVESTMENT DECISION
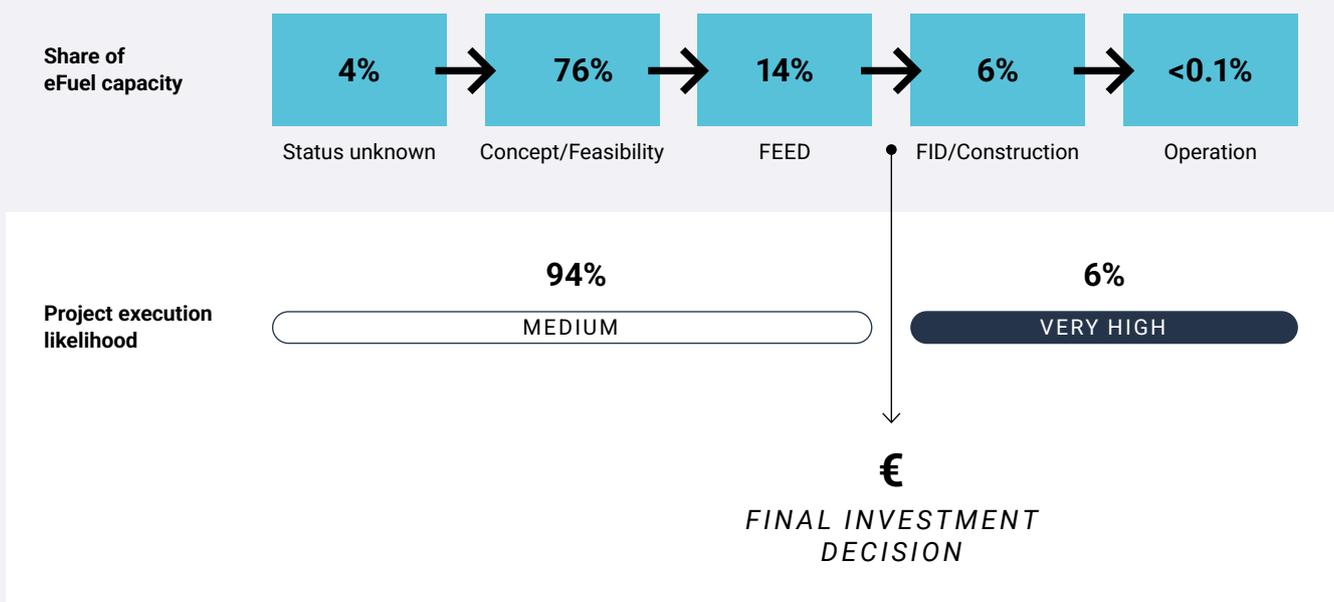
Figure 62: Current status of global announced eFuel capacities for 2030.
Source: Porsche Consulting eFuel Project Tracker, eFuel Alliance[5], IEA[6], and Methanol Institute[7] | Scope: eMethanol, eSAF, eGasoline/eNaphtha, eMethane, eDiesel | SAF: Sustainable Aviation Fuel | FEED: Front-End Engineering Design

OVERALL

BY ASSESSMENT CATEGORY

By fuel type

7.3%	4.5%	0.9%	1.2%	3.8%
eMethanol	eSAF	eGasoline/eNaphtha	eMethane	eDiesel

By region

12.8%	0.8%	4.8%	<0.1%	<0.1%
China	EU	North America	South America	Rest of World

6%
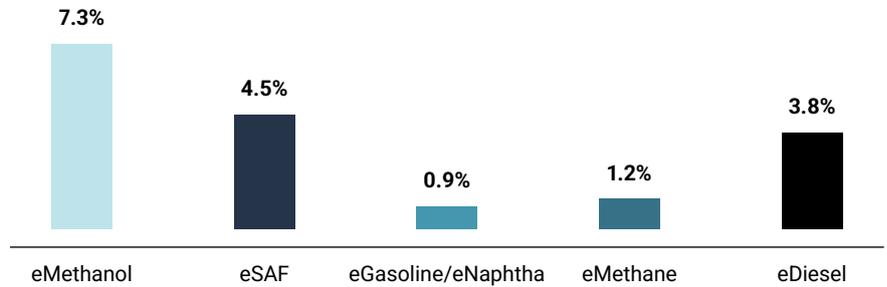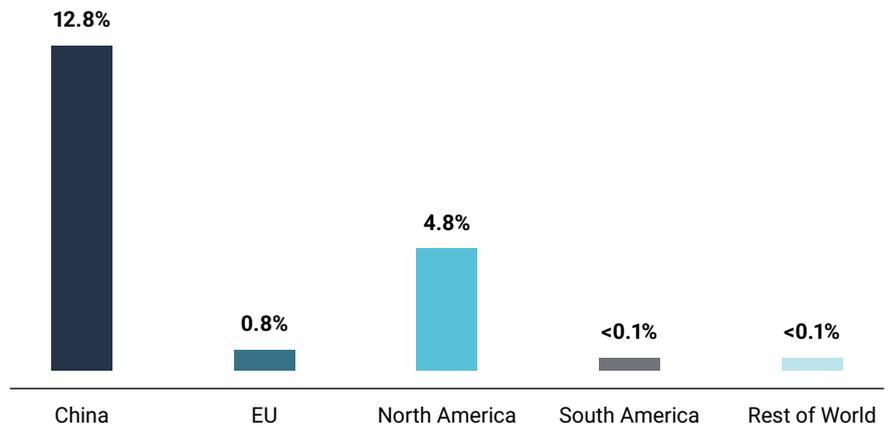
Figure 63: Current FID rate of global announced eFuel capacities for 2030 by fuel type and by region.
Source: Porsche Consulting eFuel Project Tracker, eFuel Alliance[5], IEA[6], and Methanol Institute[7] | Scope: eMethanol, eSAF, eGasoline/eNaphtha, eMethane, eDiesel | SAF: Sustainable Aviation Fuel | FID: Final Investment Decision

So far, financing has been secured for only 6 percent of the eFuel capacity planned for 2030. Most of this capacity is currently under construction, with a small portion already in operation. Conversely, 94 percent of the announced capacity has not yet reached the final investment decision (FID). A significant share—76 percent of total capacity—remains in the concept phase or under feasibility studies, while 14 percent is in the engineering and

design phase or awaiting commitments from offtakers and investors to secure financing.

The financial status of announced projects was analyzed by fuel type and region to identify potential market dynamics. Figure 63 compares the final investment decision (FID) rate of announced capacities across these two dimensions.

The overall FID rate for announced capacities planned to be operational by 2030 is currently 6 percent, but significant differences exist between fuel types. eMethanol is leading the way, with the highest FID rate at 7.3 percent, followed by eSAF at 4.5 percent and eDiesel at 3.8 percent. eGasoline/eNaphtha and eMethane each have an FID rate of around 1 percent. These figures indicate stronger financial security for eMethanol and eSAF projects, driven by greater political and regulatory support in global markets. The FID rate for eDiesel reflects successful financing of eSAF facilities, where eDiesel is a byproduct.

Regional disparities are also notable. Chinese capacities have the highest FID rate at 12.8 percent, followed by North America at 4.8 percent, while less than 1 percent of European capacities for 2030 have secured financing. Other regions remain below 0.1 percent.

In China, strong renewable energy potential and long-term financial planning security are reinforced by political motivation to reduce CO_2 emissions and enhance energy independence through eMethanol. Consequently, 87 percent of the globally financed eFuel capacity is currently planned in China. Conversely, Europe's low FID rate reflects a lack of long-term regulatory certainty.

To conclude, the final investment decision remains a critical barrier for the eFuel industry. The coming months will be decisive for initiating operations before 2030, given that construction and commissioning can take up to four years. Regulatory uncertainty is a major factor deterring offtakers and investors from making long-term commitments. A supportive regulatory framework and robust ramp-up strategies are essential to unlock eFuel investments.

So far, financing has been secured for only 6 percent of the eFuel capacity planned for 2030. Currently, 87 percent of the globally financed eFuel capacity is planned in China.

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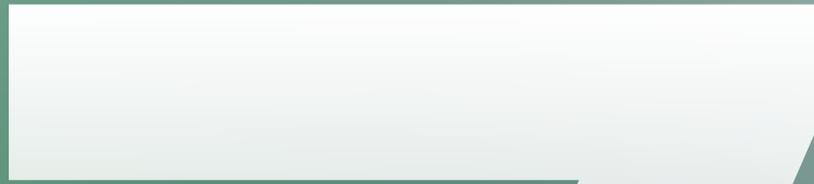
Conclusions and recommendations for a successful eFuel ramp-up

The mobility transformation modeled in Scenario 3 of the European Commission's 2024 Impact Assessment report—referred to as the "EU Ambition" scenario—is likely to be delayed due to battery supply chain bottlenecks. However, the industrial feasibility assessment of eFuels indicates the potential to accelerate the eFuel ramp-up from 2030 to help meet climate targets. Despite this potential, the current status of the eFuel industry reveals significant weaknesses, particularly a lack of financing for European projects.

→ The European Union has established a comprehensive regulatory framework for eFuels, incorporating multiple instruments to stimulate demand and supply in the mobility sector, particularly in maritime and aviation transport. However, challenges remain in unlocking project financing, even with these instruments in place. On the supply side, long-term project risk is elevated due to restrictions on eFuel production and evolving requirements that create uncertainty about future compliance for initial projects. On the demand side, long-term offtake commitments are lacking because current demand projections remain low, driven by insufficient quotas. Furthermore, regulation primarily targets aviation and maritime segments, for example by setting mandates for aircraft operators, who have limited ability to commit to long-term volume contracts. As a result, risk levels for production and offtake do not align with investor expectations, creating a major barrier to project financing.

Figure 64 illustrates several measures that can help mitigate project risks on both the supply and demand sides.

On the supply side, aligning long-term eFuel production criteria is essential. In particular, the requirements for temporal correlation with renewable electricity supply should be made

MEASURE	**Define long-term eFuel production criteria**	**Review eFuel quotas & conditions**	**Introduce eFuel credits in on-road transport**
	↓	↓	↓
GOAL	Mitigate long-term project risk	Increase long-term offtake commitment	Stimulate demand across industries

Figure 64: Required regulatory measures in the European Union to promote financing of eFuel projects.

more flexible to strengthen market development. Introducing grandfathering provisions for initial projects—should production standards change—could reduce long-term supply risks for offtakers and revenue risks for investors. Additionally, integrating unavoidable industrial CO_2 sources into eFuel production standards could accelerate the ramp-up, especially in regions with limited access to biogenic sources. The adoption of internationally recognized sustainability certificates for CO_2 sources would ensure the sustainability of imported eFuels and support imports from regions with low-cost renewable energy.

On the demand side, long-term offtake commitments can be secured by increasing eFuel quotas with clear long-term projections and defined conditions for non-compliance. Rewarding overfulfillment of quotas through additional multipliers and credit banking could further incentivize commitments.

Leveraging existing funding schemes—such as SAF Allowances, the EU Innovation Fund, and the European Hydrogen Bank—is essential. Specifically, competition with other eligible technologies can be reduced by introducing dedicated maritime and aviation budgets in European Hydrogen Bank auctions. Within the EU Emissions Trading System (ETS), increasing the number of Allowances specifically for eSAF projects would help airlines offset eSAF costs, reducing competition with bioSAF and enhancing the attractiveness of eSAF offtake. Additionally, allocating eSAF Allowances for the full duration of the offtake agreement, rather than annually, would provide long-term revenue certainty under the ETS. Furthermore, recognizing eFuel use in other mobility sectors can stimulate demand. For example, introducing eFuel crediting in CO_2 standards for on-road mobility—already implemented in Switzerland—would be effective. Overall, this measure would promote economies of scale, lower investment costs, and mitigate investment and offtake risks through cross-industry risk-sharing.

In addition, robust ramp-up strategies are essential to close financing gaps.

First, reducing eFuel production costs is essential to align with the willingness to pay of potential offtakers. In the case of eMethanol, potential cost reductions exceed 80 percent,

as shown in Figure 65. This can be achieved by scaling up production to benefit from more favorable capital expenditures (Capex). Plant location plays a critical role: higher availability of renewable energy enables smaller plant capacity for the same annual output, lowering Capex. An optimal location also supports

	Small-scale player	Scale	Location	Technology	Future market leader
eMETHANOL COST [€/t]	4,093 Moderate attractiveness	2,474	645	284	COST REDUCTION POTENTIAL €3,403/t (−83%) 690 High attractiveness
Production scale	10 kt eMethanol p. a.	500 kt eMethanol p. a.			
Location	Germany		South America		
Heat source	Purchased heat			Heat recovery	
Electrolyzer & catalysts	Conventional			Advanced	
Storage management	Conventional			AI-optimized management	

Figure 65: eFuel cost reduction levers to become a market leader by 2040, in €/t eMethanol.
Source: Porsche Consulting eFuel Cost Model | Assumptions for market leader 2040: 3.6 MW onshore wind power turbines with 5,872 full-load hours; 10 percent weighted average cost of capital (WACC); CO_2 source: direct air capture (DAC); Transport and distribution costs to Hamburg included

stable plant operations by providing a constant energy load for synthesis processes, reducing energy storage requirements and further decreasing Capex. Additional cost reductions can come from integrating advanced technologies into production. For example, heat recovery systems are crucial to avoid high heat purchasing costs in remote areas, significantly improving the economics of direct air capture (DAC) at low energy costs. More efficient and flexible synthesis processes allow better utilization of fluctuating renewable energy. Likewise, flexible storage management can enhance plant efficiency and reduce energy and material storage needs, creating further Capex advantages. Access to these advanced technologies requires robust partnering strategies and vertical integration within the equipment value chain.

Second, optimizing scale, location, and technology can introduce higher project risks due to additional uncertainties compared to standard setups. Intelligent scaling should leverage economies of scale, location, and technology while managing investment risk by identifying the optimal balance between risk and return. Technology phase-in must be anticipated within the scaling strategy, and modular plant design should be adopted to provide flexibility in plant configuration.

Third, securing offtake is critical to ensuring long-term revenue for investors. This can be strengthened through cross-industry offtake alliances, which create risk-sharing structures by limiting individual offtake volumes while benefiting from production cost advantages at scale. Cross-industry offtake also enables full utilization of all products, minimizing additional refining costs for target products. Long-term regulatory uncertainty can be mitigated by adapting production to industry-specific demand over time, in line with regulatory developments. This requires plant designs

with flexible product outputs. Additionally, a multi-plant supply strategy can reduce technology and cost-performance risks for offtakers. New plants can be added to the supply pool later to capture future technology improvements and cost reductions.

Fourth, eFuel plants should be strategically located to maximize renewable energy potential while minimizing geopolitical risks. Global subsidy opportunities should be leveraged, and eligibility for subsidy programs ensured to improve profitability. Establishing synergies with existing infrastructure—such as commercial ports, maritime routes, and refineries—is critical to securing eFuel supply and supporting the overall scale-up plan.

In conclusion, increasing the attractiveness of eFuel projects and stimulating offtake and financing commitments requires leveraging existing regulatory instruments. Pragmatic production standards, strengthened demand through ambitious quotas in the RED, ReFuelEU Aviation, and FuelEU Maritime, as well as a technology-neutral CO_2 fleet regulation for new vehicles are essential. Investment appeal can be strengthened through collaboration between eFuel producers and cross-industry offtakers, combining cost reductions with scaling strategies and implementing risk-sharing structures. Together with a robust and reliable regulatory framework, these measures are key to unlocking the eFuel ramp-up in Europe and maximizing their contribution to achieving climate targets.

Pragmatic production standards, strengthened demand through ambitious quotas in the RED, ReFuelEU Aviation, and FuelEU Maritime, as well as a technology-neutral CO_2 fleet regulation for new vehicles are essential.

Appendix A – Literature

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Appendix B – Authors

Study coordinators
Ralf Diemer, eFuel Alliance e. V.,
Chief Executive Officer
diemer@efuel-alliance.eu

Dr. Tobias Block, eFuel Alliance e. V.,
Chief Strategy Officer
block@efuel-alliance.eu

Co-authors
Dr. Lukas Mauler, Porsche Consulting GmbH,
Associate Partner

Corentin Prié, Porsche Consulting GmbH,
Manager

Appendix C – Peer Review

A detailed review of the methodology and data assumptions was conducted by SFA (Oxford), a consultancy renowned for its expertise in critical raw minerals and metals essential for the energy transition and renewable energies, including green hydrogen. SFA (Oxford) maintains proprietary databases and offers strategic analyses across the entire raw material value chain. Their clientele spans major mining companies and explorers on the supply side, automotive and battery manufacturers on the offtake side, and investment banks on the financial side. Furthermore, SFA (Oxford) provides specialized knowledge in the green hydrogen value chain, primarily to equipment providers.

For this analysis, the relevant data and assumptions were meticulously reviewed and cross-verified against SFA (Oxford)'s internal sources on a sample basis. Additionally, the methodology was scrutinized for logical sequence and consistency. SFA (Oxford) validated that the conclusions drawn from the analysis are generally reasonable and robust.

Appendix D – Abbreviations

AAM: Anode Active Material
CAGR: Compound Annual Growth Rate
CAM: Cathode Active Material
CCS: Carbon Capture and Storage
CNFV: Carbon-Neutral Fuel Vehicle
CNG: Compressed Natural Gas
BEV: Battery Electric Vehicle
FCEV: Fuel Cell Electric Vehicle
FEED: Front-End Engineering Design
FID: Final Investment Decision
FT: Fischer-Tropsch
GT: Gross Tonnage
HICEV: Hydrogen Internal Combustion Engine Vehicle
ICEV: Internal Combustion Engine Vehicle

IPCC: Intergovernmental Panel on Climate Change
LFP: Lithium Iron Phosphate
LMFP: Lithium Iron Manganese Phosphate
LNG: Liquefied Natural Gas
LNMO: Lithium Nickel Manganese Oxide
NCA: Nickel Cobalt Aluminum
NMC: Nickel Manganese Cobalt
PHEV: Plug-in Hybrid Electric Vehicle
PV: Photovoltaic
RED: Renewable Energy Directive
RFNBO: Renewable Fuel of Non-Biological Origin
SAF: Sustainable Aviation Fuel
TCO: Total Cost of Ownership
WACC: Weighted Average Cost of Capital

Appendix E – Detailed results of bottleneck analysis
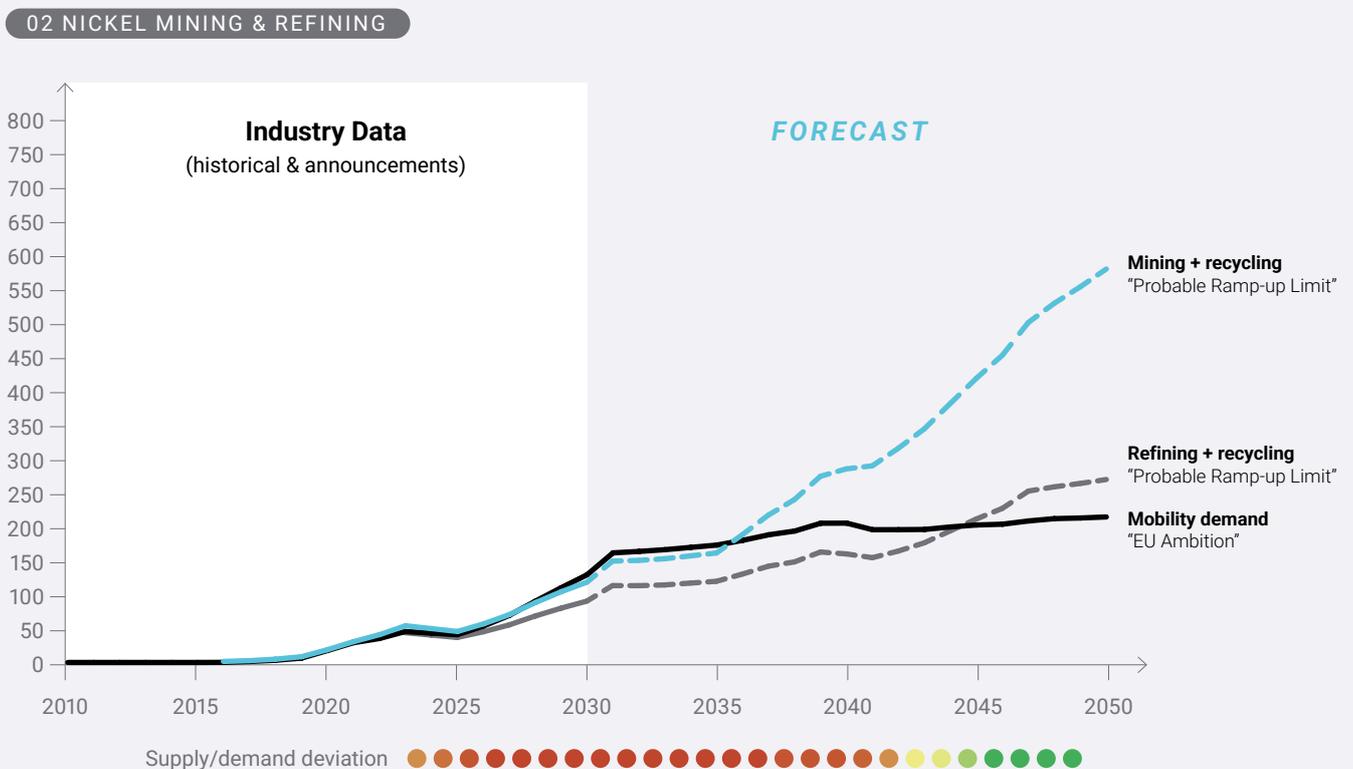
Figure 66: Comparison of annual nickel supply and demand in kt/a in EU mobility: "EU Ambition" scenario.
Source: IEA Global Critical Minerals Outlook 2024[30]

03 COBALT MINING & REFINING
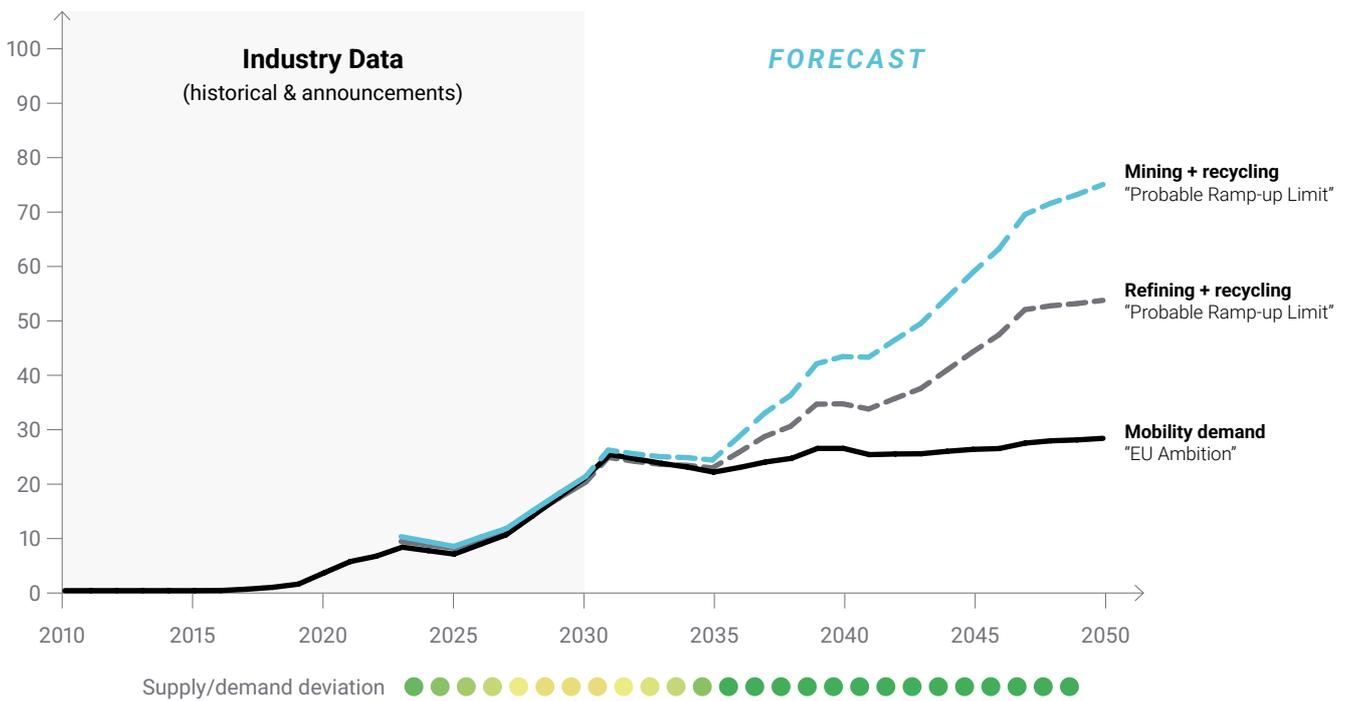
Figure 67: Comparison of annual cobalt supply and demand in kt/a in EU mobility: "EU Ambition" scenario.
Source: IEA Global Critical Minerals Outlook 2024[30]

04 GRAPHITE MINING & REFINING
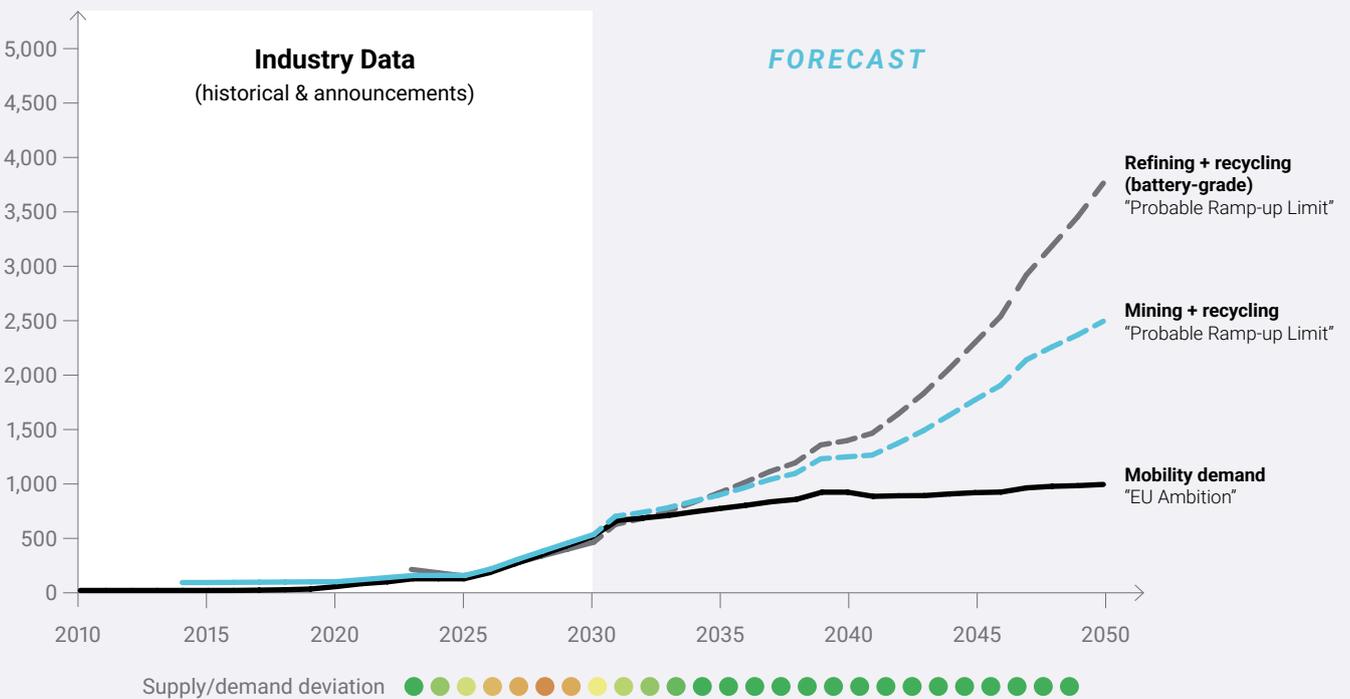
Figure 68: Comparison of annual graphite supply and demand in kt/a in EU mobility: "EU Ambition" scenario.
Source: IEA Global Critical Minerals Outlook 2024[30]

05 AAM PRODUCTION
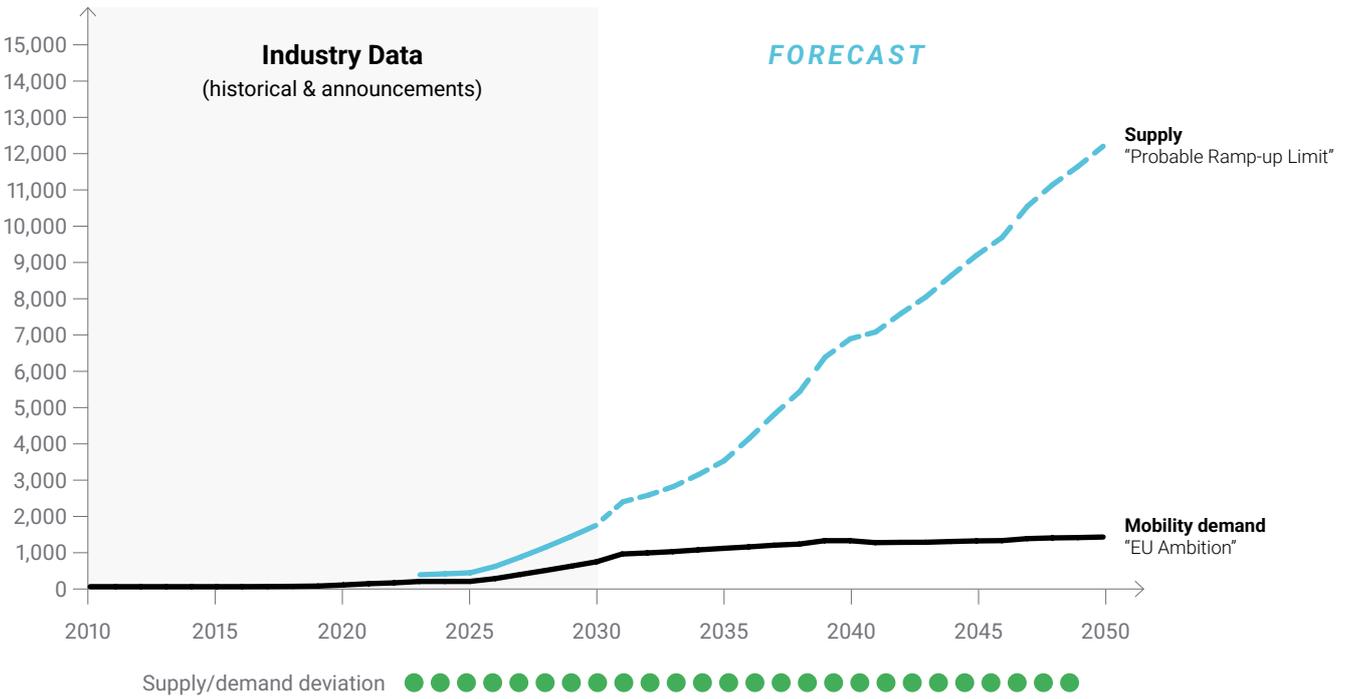
Figure 69: Comparison of annual AAM supply and demand in kt/a in EU mobility: "EU Ambition" scenario.
Source: Benchmark Mineral Intelligence Anode Supply Data[37], Electric Vehicles Battery Demand IEA 2024[38] | AAM: Anode Active Material

06 CAM PRODUCTION
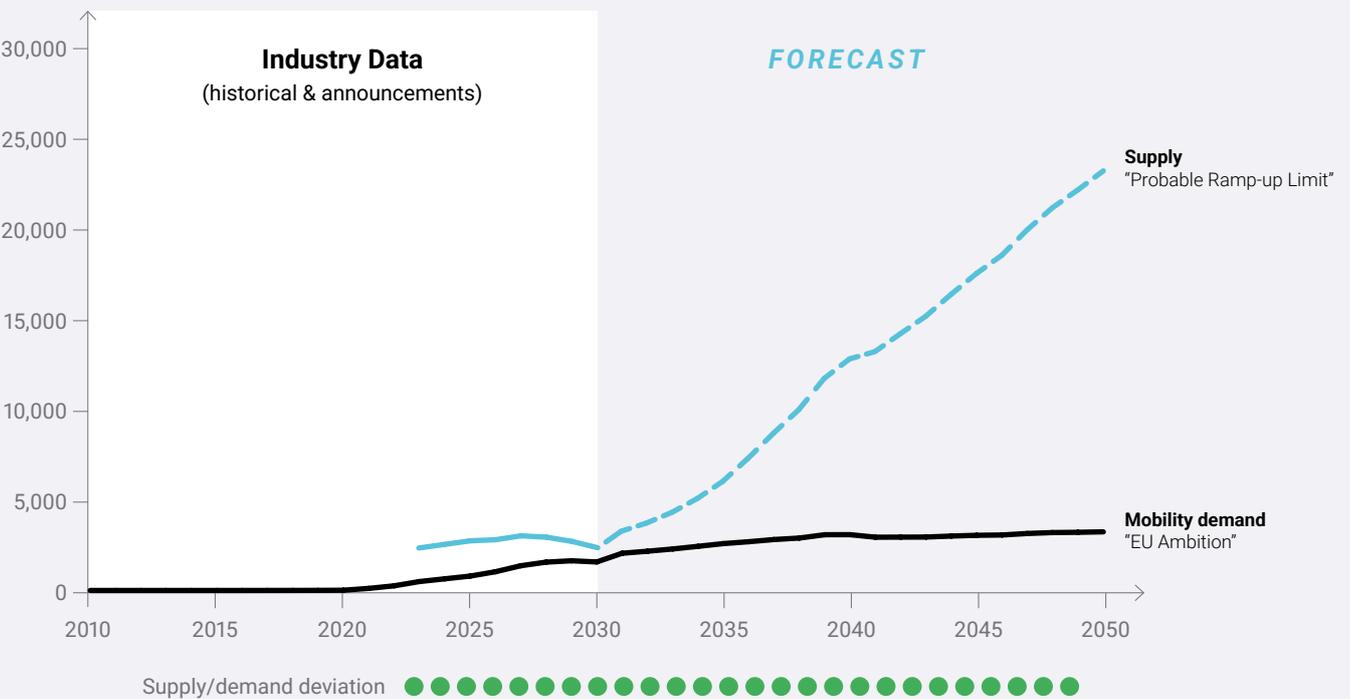
Figure 70: Comparison of annual CAM supply and demand in kt/a in EU mobility: "EU Ambition" scenario.
Source: Wood Mackenzie Cathode Supply Data[39], Electric Vehicles Battery Demand IEA 2024[38] | CAM: Cathode Active Material

07 CELL PRODUCTION
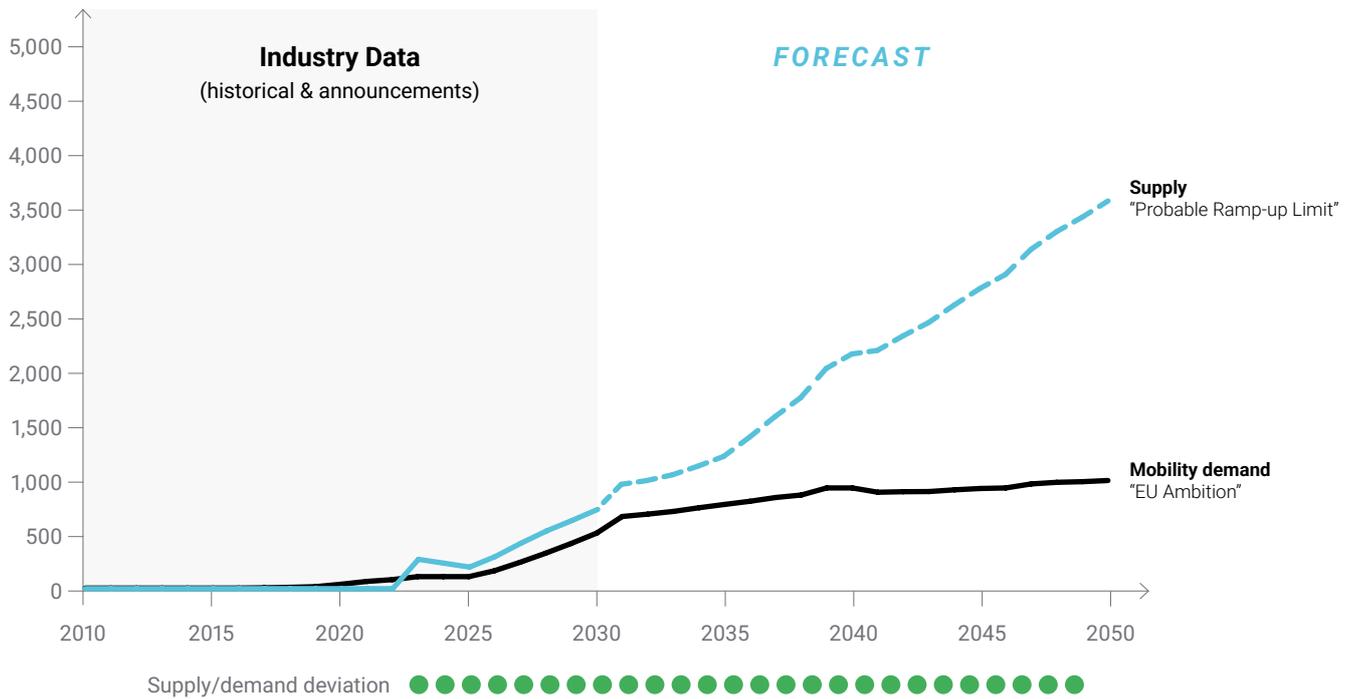
Figure 71: Comparison of annual battery cell supply and demand in GWh/a in EU mobility: "EU Ambition" scenario.
Source: Porsche Consulting Battery Cell Supply Data[40], PEM RWTH Aachen Battery Cell Supply Data[41], Electric Vehicles Battery Demand IEA 2024[38]

08 WIND POWER EQUIPMENT
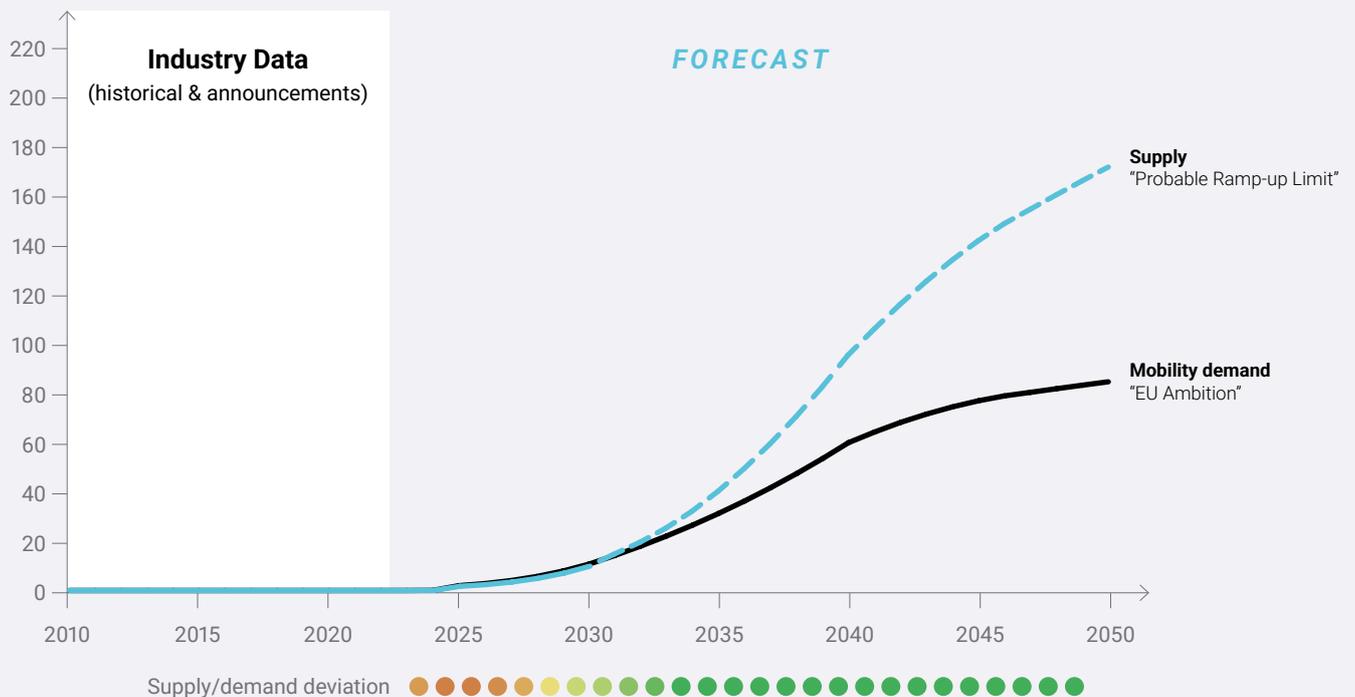
Figure 72: Comparison of supply and demand for renewable electricity in EU mobility, installed wind power equipment in GW: "EU Ambition" scenario.
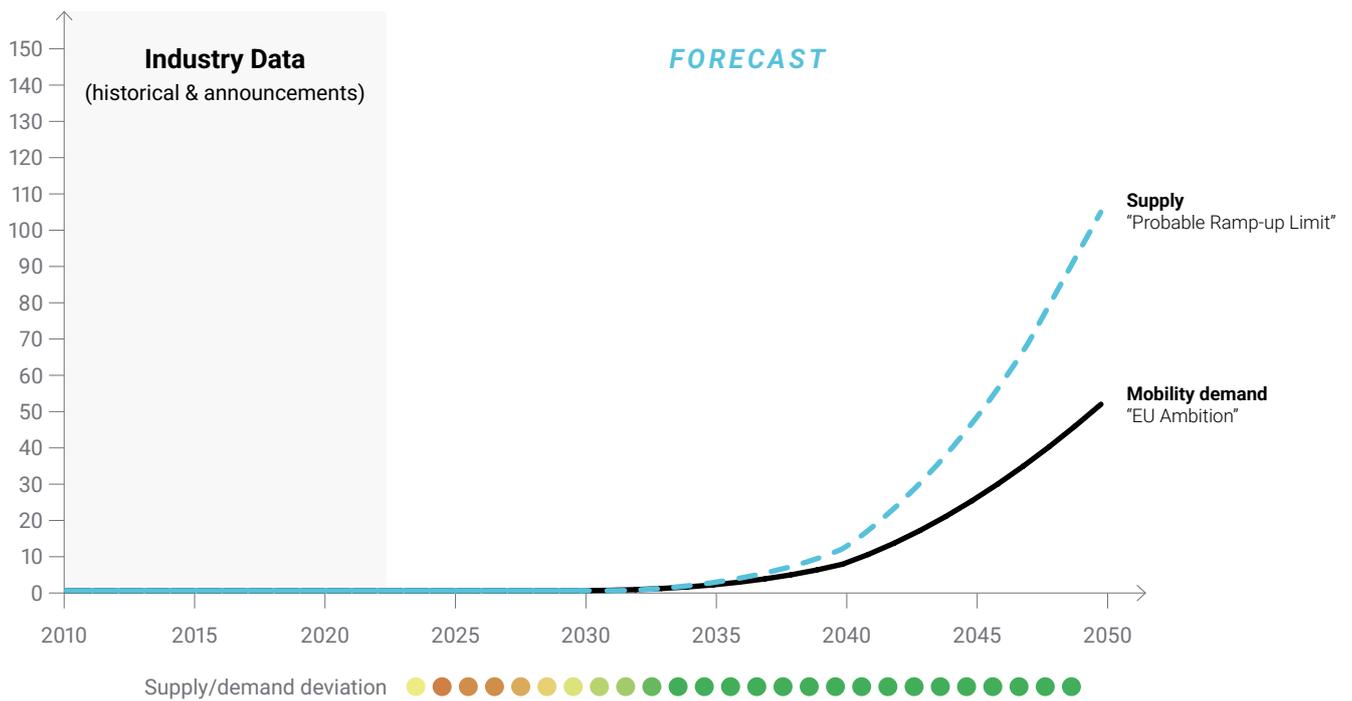Source: IRENA Wind Energy Data 2024[33], IEA World Energy Outlook 2023[23]
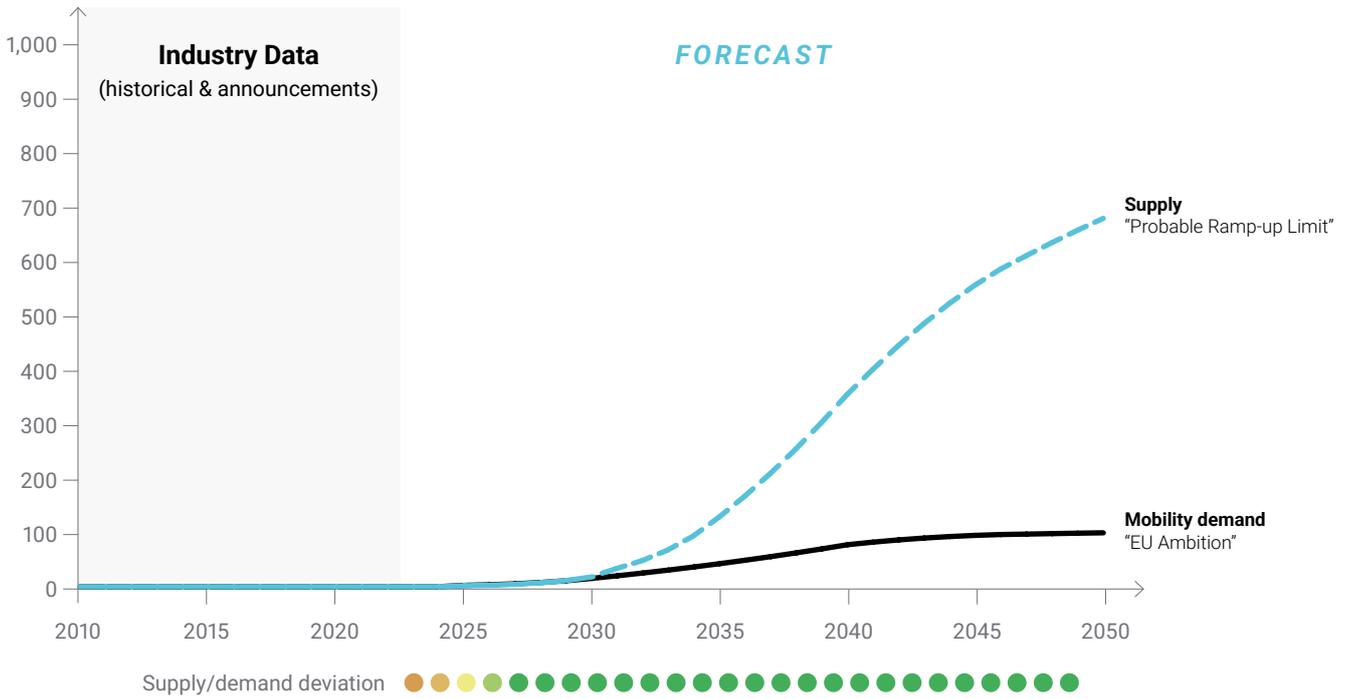
Figure 73: Comparison of supply and demand for renewable electricity in EU mobility, installed PV power equipment in GW: "EU Ambition" scenario.
Source: IRENA Wind Energy Data 2024[33], IEA World Energy Outlook 2023[23] | PV: Photovoltaic
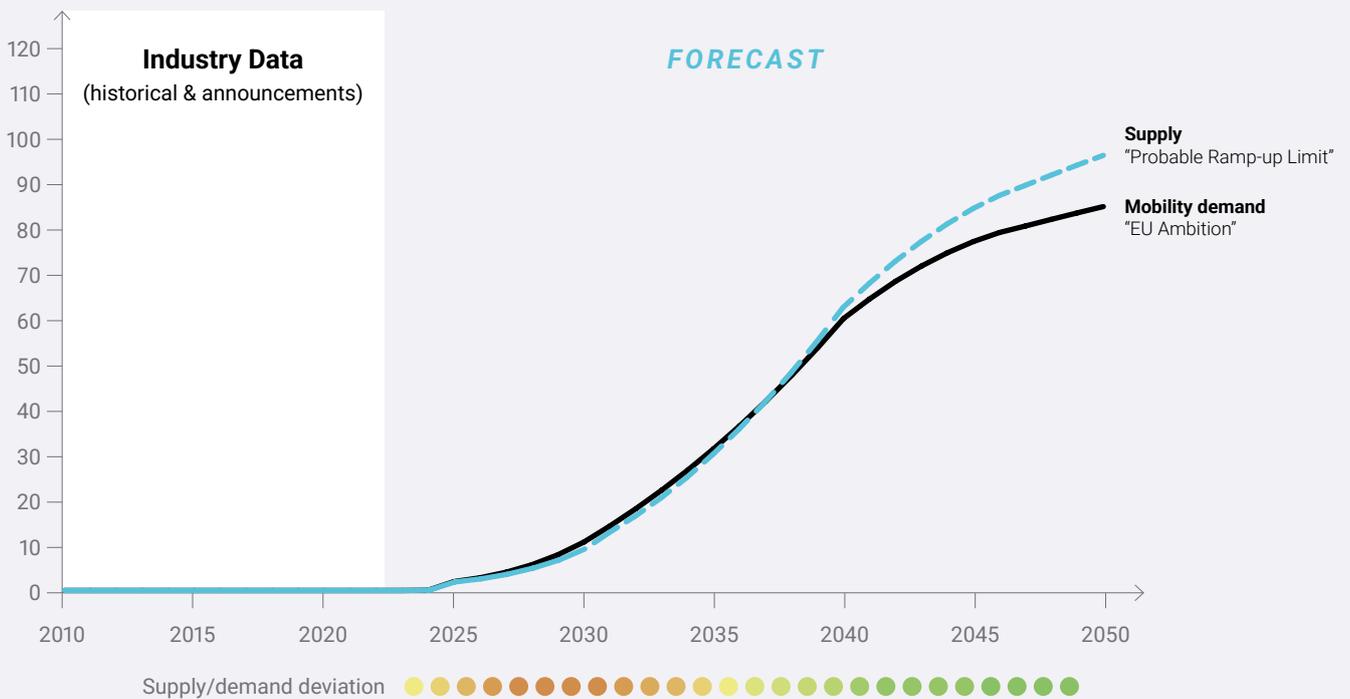
Figure 74: Comparison of supply and demand for renewable electricity in EU mobility, installed wind power plant capacity in GW: "EU Ambition" scenario.
Source: IRENA Wind Energy Data 2024[33], IEA World Energy Outlook 2023[23]
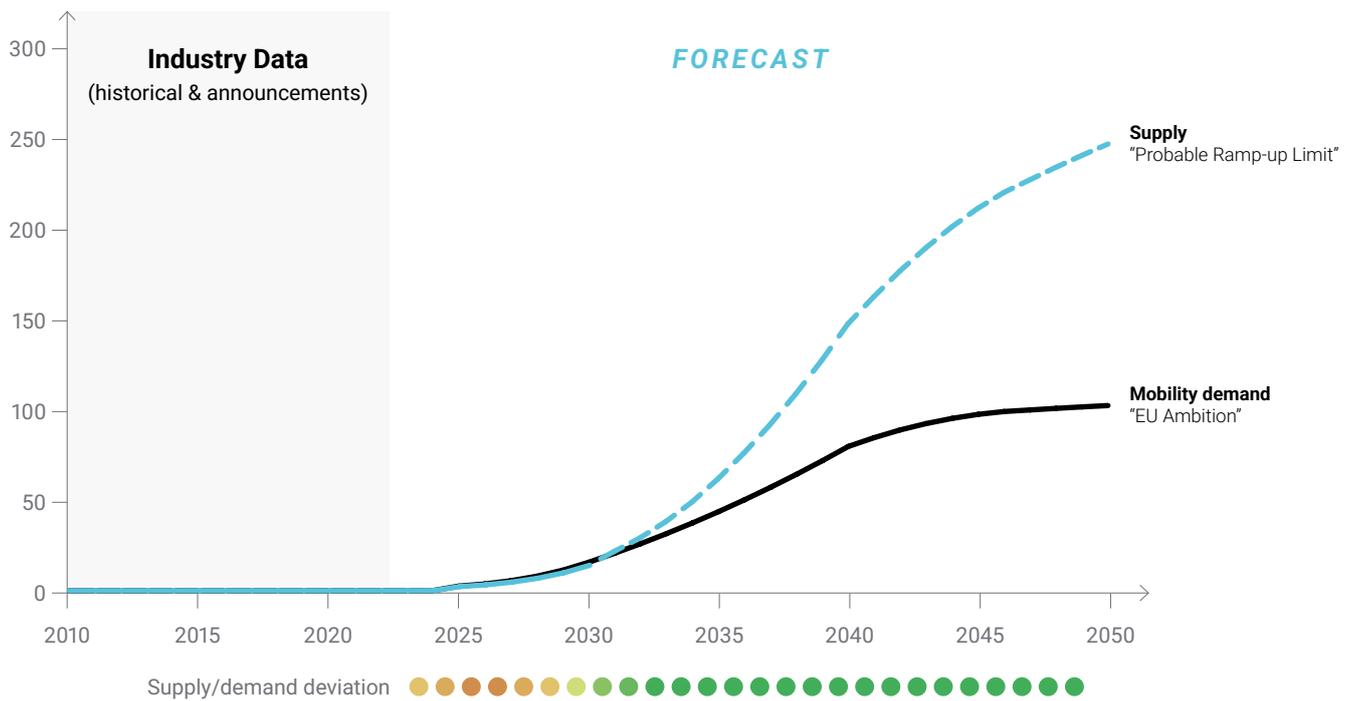
Figure 75: Comparison of supply and demand for renewable electricity in EU mobility, installed PV power plant capacity in GW: "EU Ambition" scenario.
Source: IRENA Wind Energy Data 2024[33], IEA World Energy Outlook 2023[23] | PV: Photovoltaic
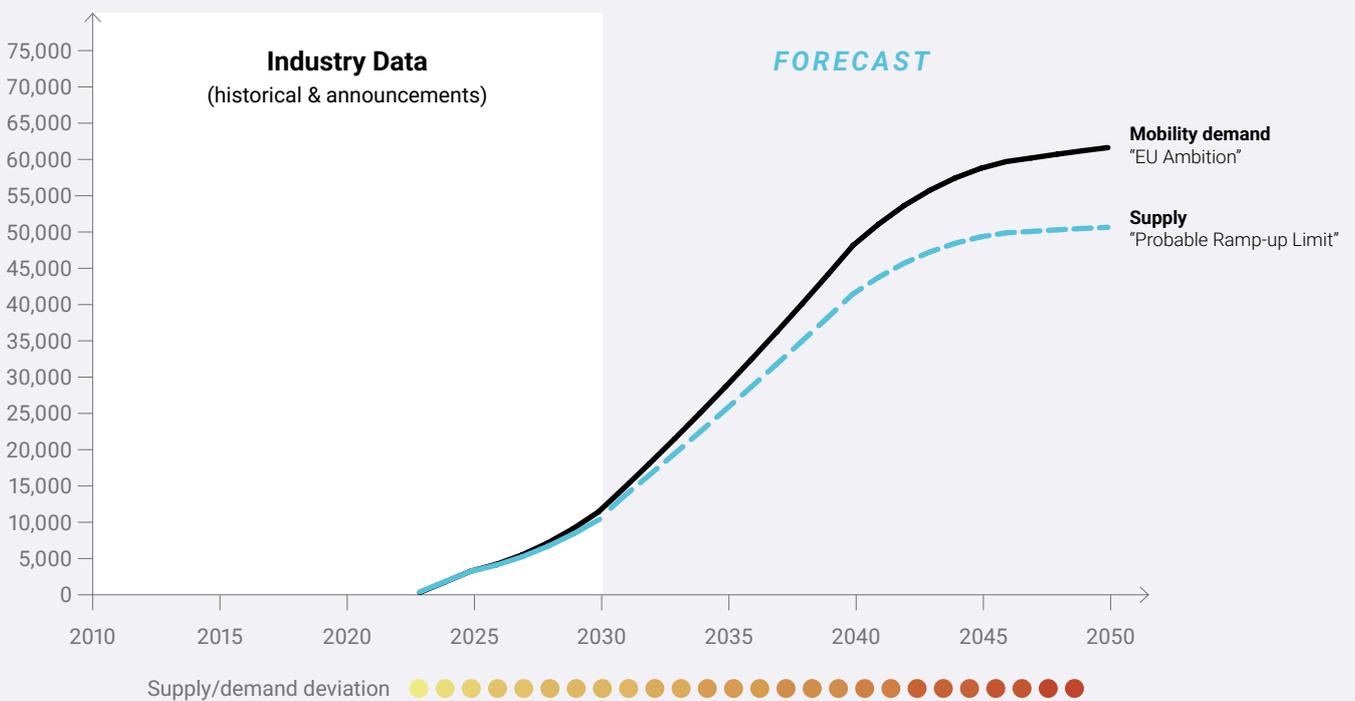
Figure 76: Comparison of supply and demand for electricity in EU mobility, installed transmission grid length in km: "EU Ambition" scenario.
Source: FVV Fuel Study IVb[42], ENTSOE TYNDP Report of 2020[25], IEA World Energy Outlook 2023[23]
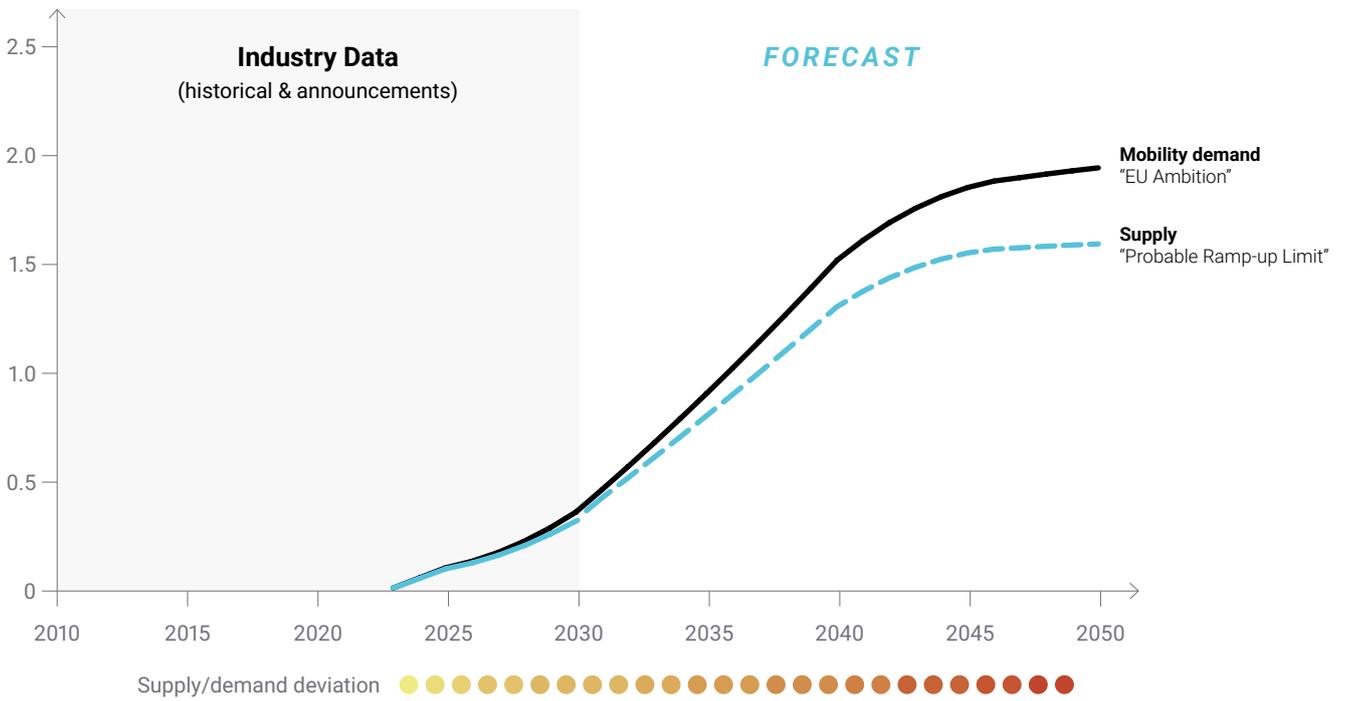
Figure 77: Comparison of supply and demand for electricity in EU mobility, installed distribution grid length in million km: "EU Ambition" scenario.
Source: FVV Fuel Study IVb[42], IEA Electricity Grids and Secure Energy Transition Report 2023[26], IEA World Energy Outlook 2023[23]

14 PUBLIC CHARGING
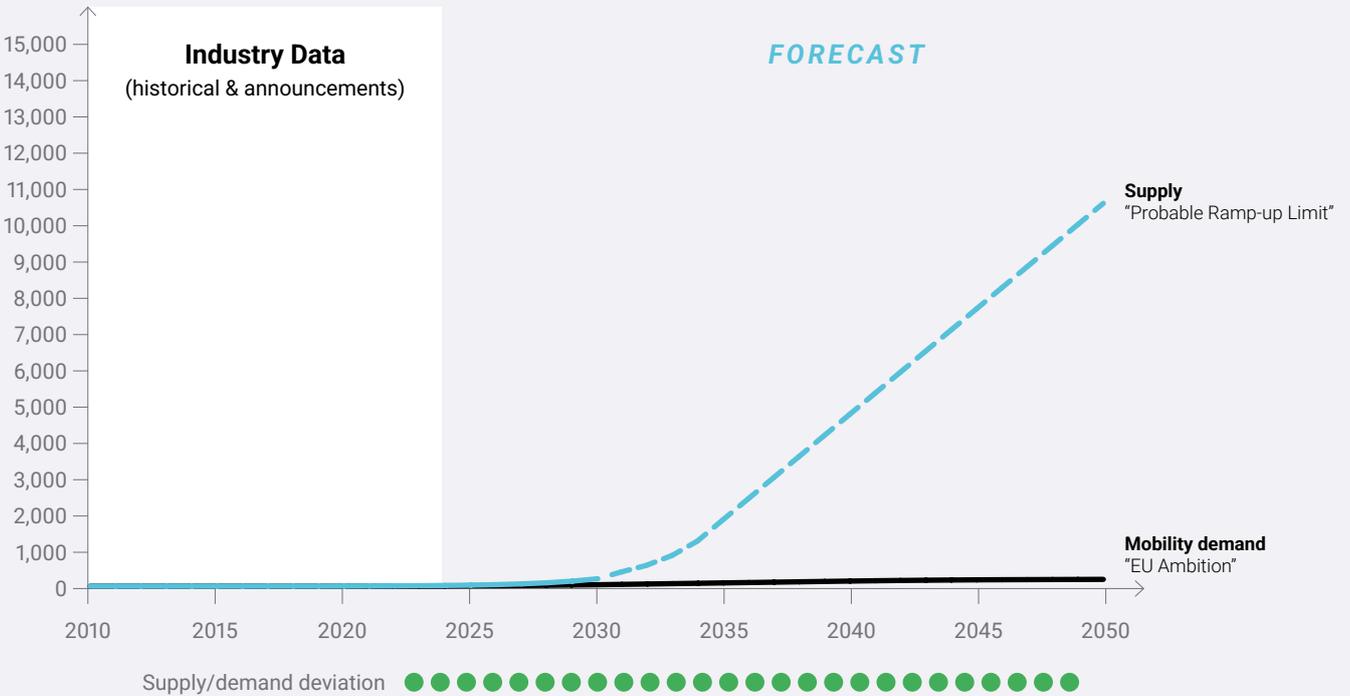
Figure 78: Comparison of supply and demand for electricity in EU mobility, installed public charging capacity in GW: "EU Ambition" scenario.
Source: Bundesnetzagentur Öffentliche Ladeinfrastruktur 2024[43], European Commission 2024[44], IEA Global EV Outlook 2024[27], Alternative Fuel Infrastructure Regulation (AFIR) for Heavy Duty 2021[28]

15 WIND POWER EQUIPMENT

Industry Data (historical & announcements)

FORECAST

Supply "Probable Ramp-up Limit"
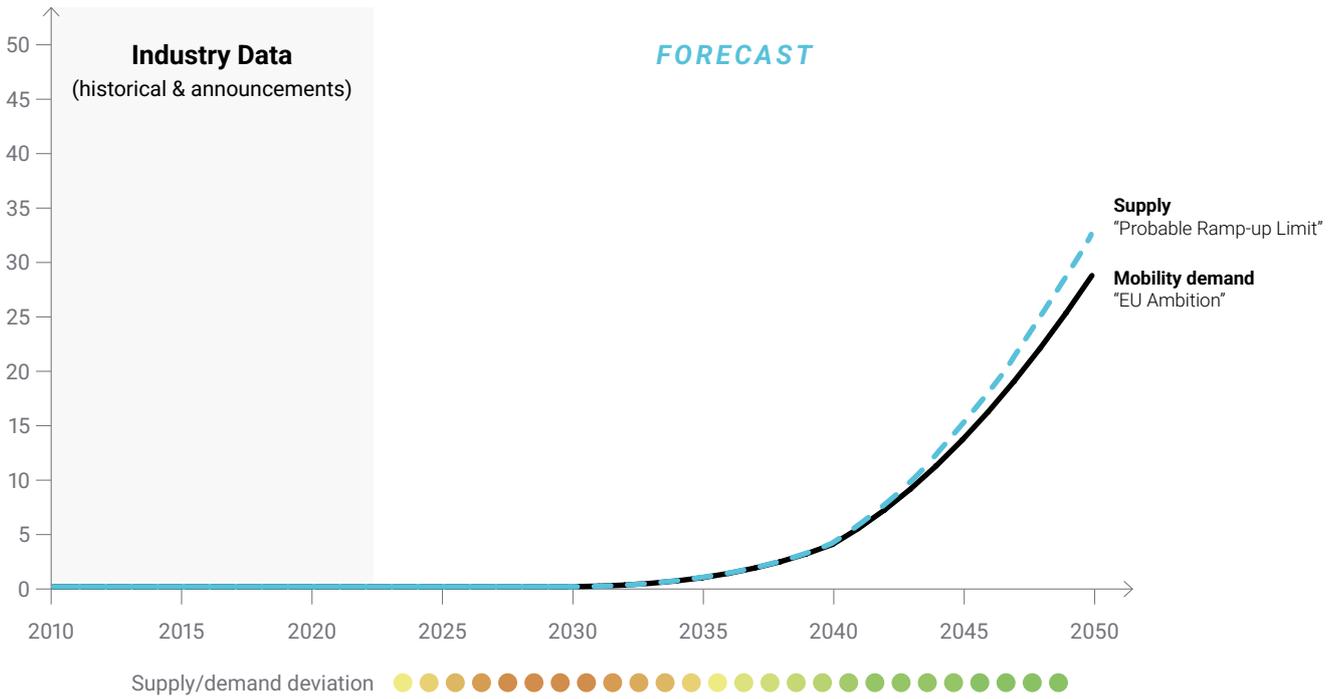
Mobility demand "EU Ambition"

Supply/demand deviation

Figure 79: Comparison of supply and demand for green hydrogen in EU mobility, installed wind power equipment in GW: "EU Ambition" scenario.
Source: IRENA Wind Energy Data 2024[33], IEA World Energy Outlook 2023[23]

16 PV POWER EQUIPMENT

Industry Data (historical & announcements)

FORECAST

Supply "Probable Ramp-up Limit"
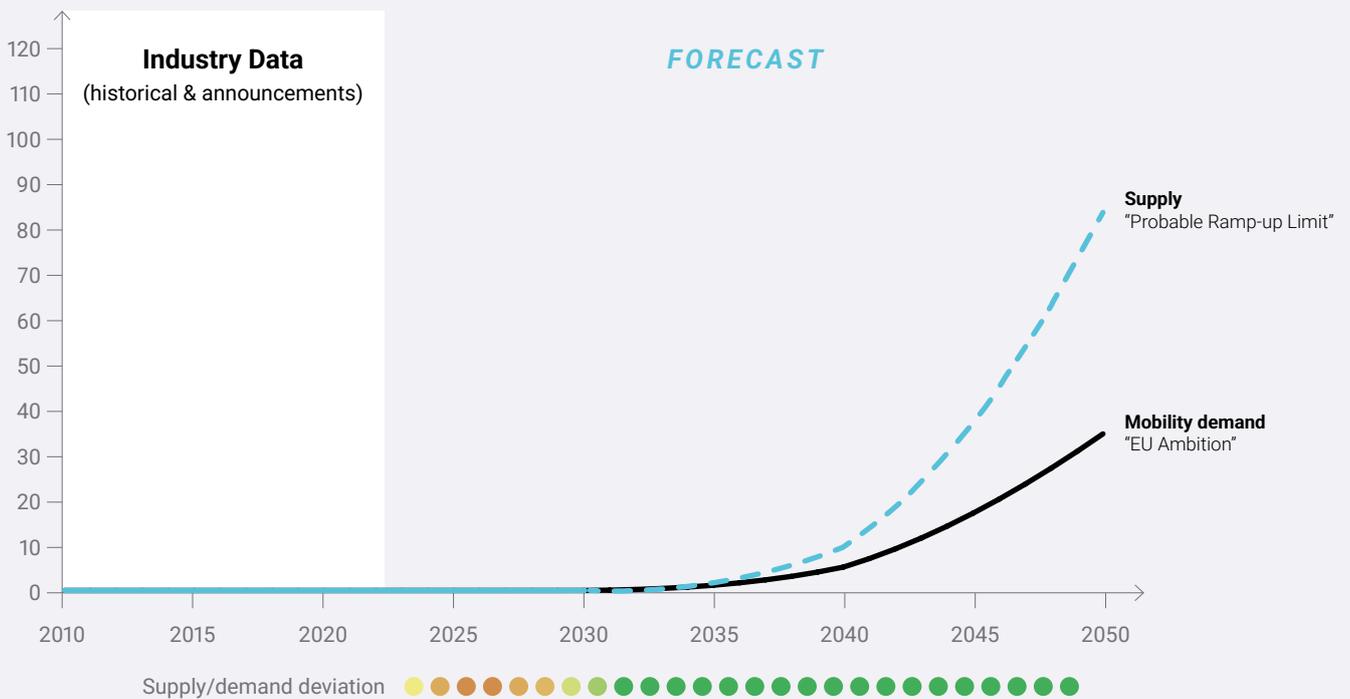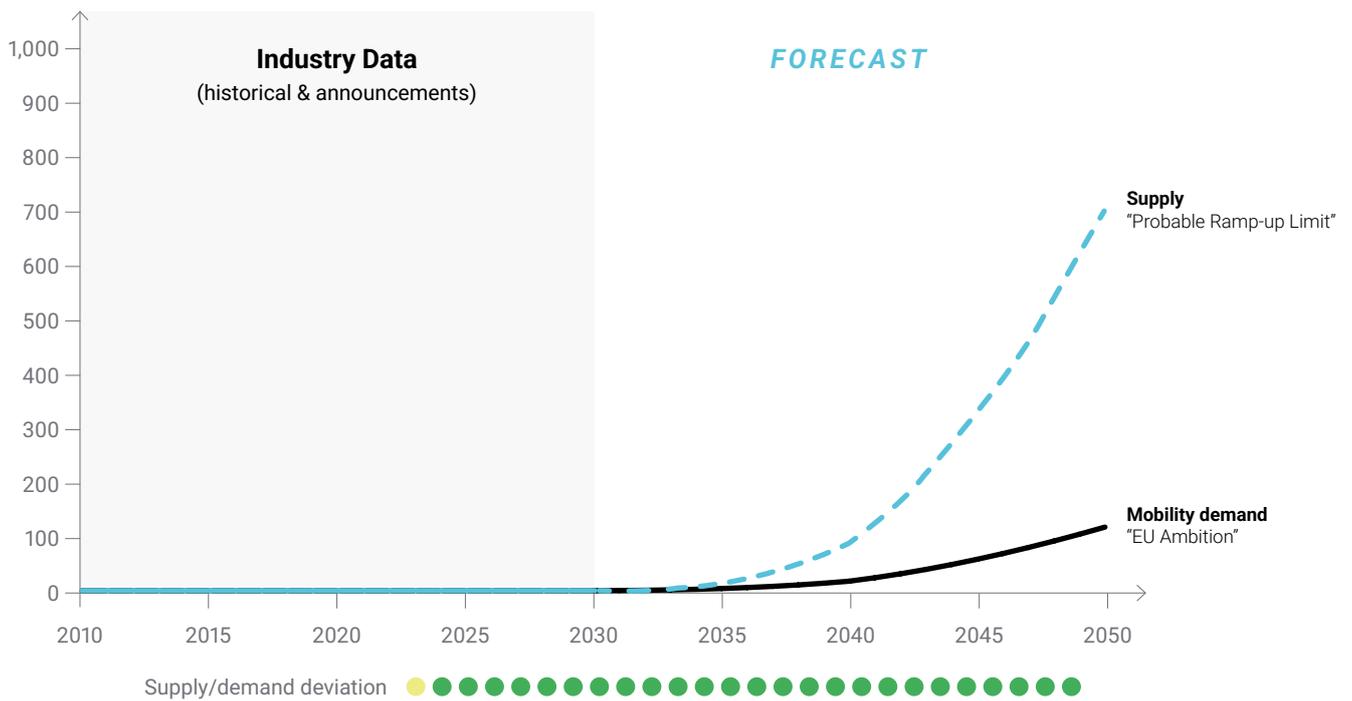
Mobility demand "EU Ambition"

Supply/demand deviation
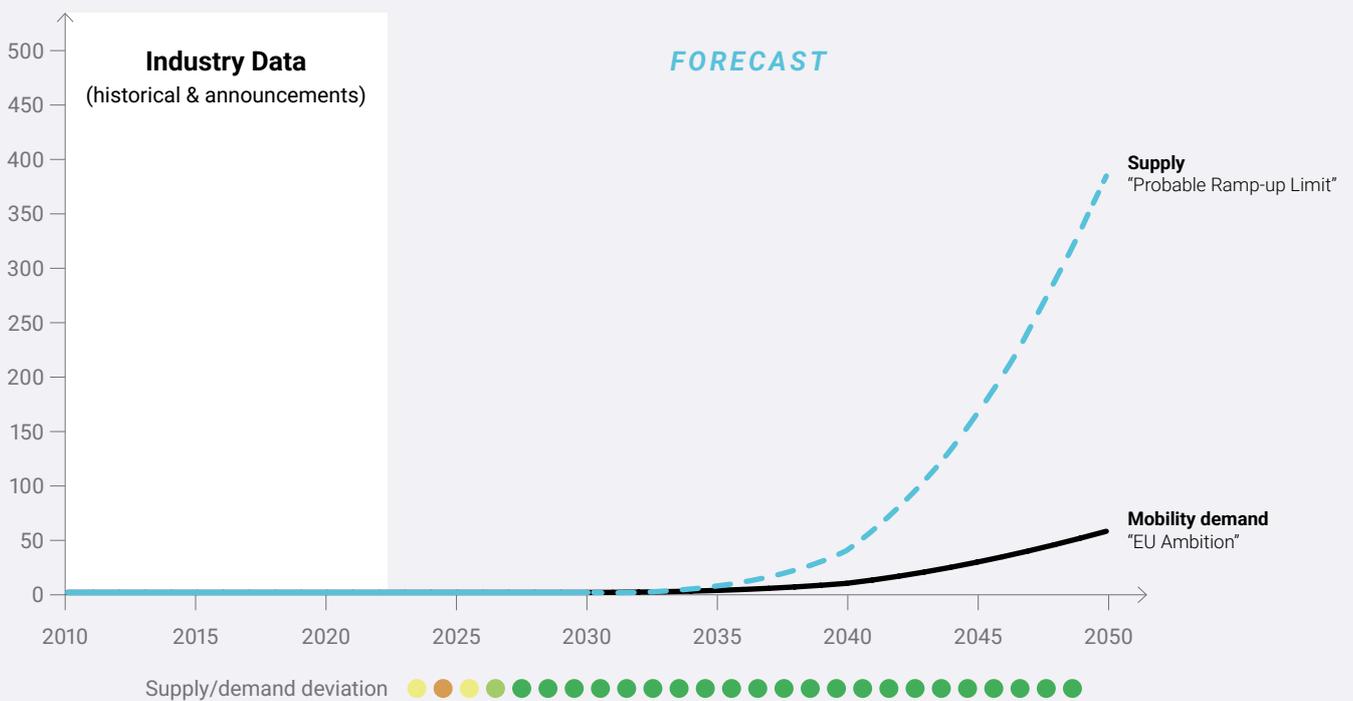
Figure 80: Comparison of supply and demand for green hydrogen in EU mobility, installed PV power equipment in GW: "EU Ambition" scenario.
Source: IRENA Wind Energy Data 2024[33], IEA World Energy Outlook 2023[23] | PV: Photovoltaic

17 WIND POWER INSTALLATION EU

Figure 81: Comparison of supply and demand for green hydrogen in EU mobility, installed wind power plant capacity in GW: "EU Ambition" scenario.
Source: IRENA Wind Energy Data 2024[33], IEA World Energy Outlook 2023[23]

18 PV POWER INSTALLATION EU

Figure 82: Comparison of supply and demand for green hydrogen in EU mobility, installed PV power plant capacity in GW: "EU Ambition" scenario.
Source: IRENA Wind Energy Data 2024[33], IEA World Energy Outlook 2023[23] | PV: Photovoltaic

19 ELECTROLYSIS EQUIPMENT

Figure 83: Comparison of supply and demand for green hydrogen in EU mobility, installed electrolysis equipment in GW: "EU Ambition" scenario.
Source: IEA Global Hydrogen Review 2024[34], IEA World Energy Outlook 2023[23]
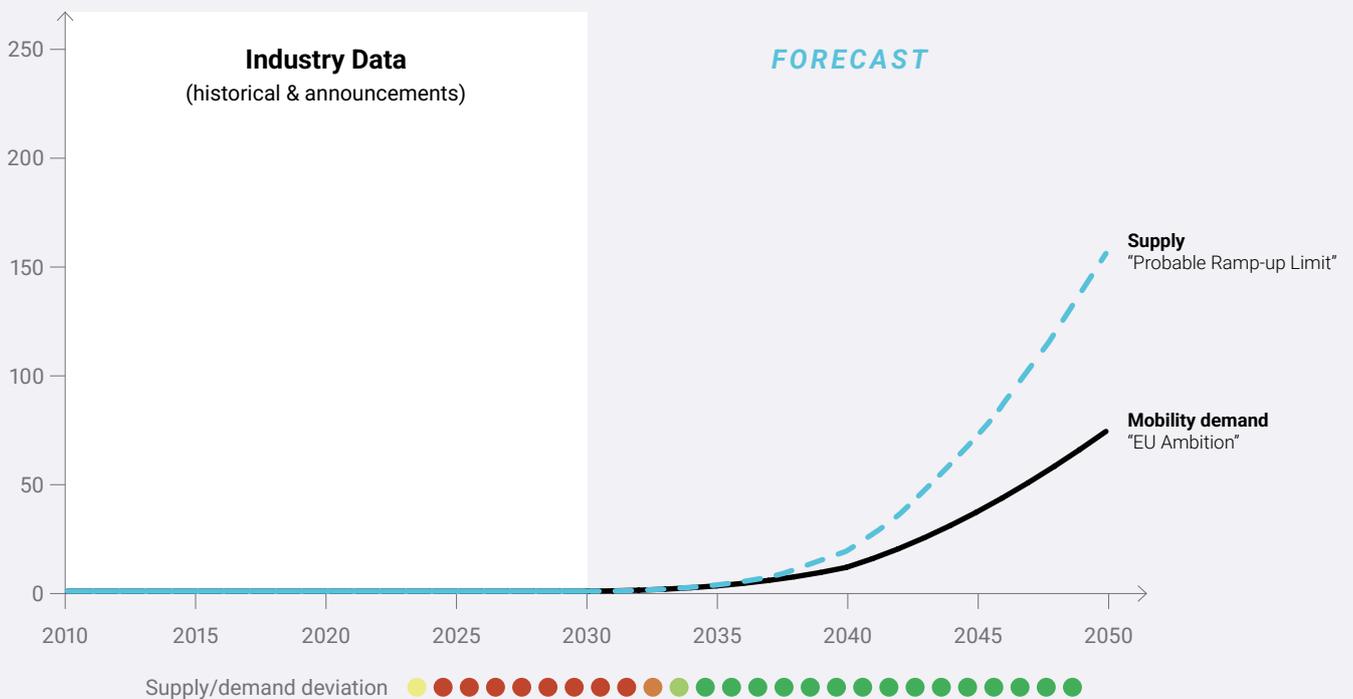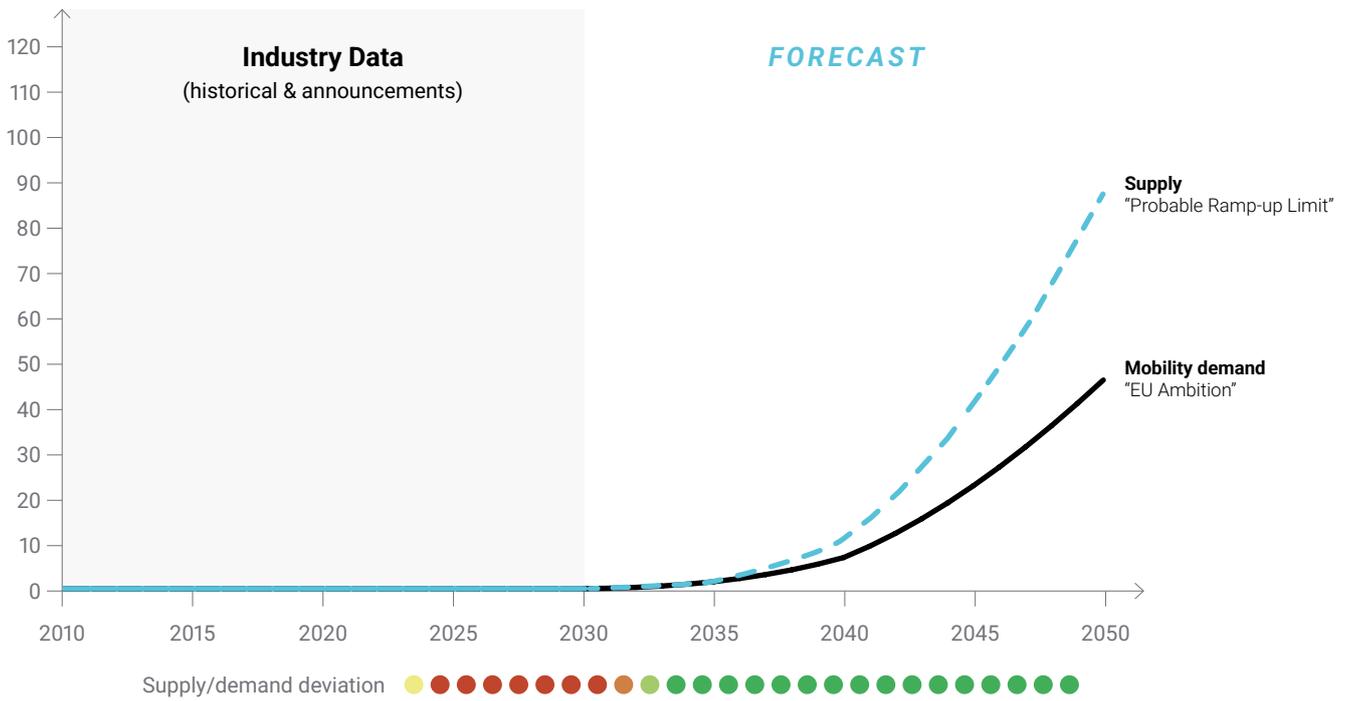
20 H$_2$ PLANT INSTALLATION EU

Figure 84: Comparison of supply and demand for green hydrogen in EU mobility, EU installed green hydrogen production plant capacity in GW: "EU Ambition" scenario.
Source: Porsche Consulting Green Hydrogen Project Tracker, IEA Hydrogen Infrastructure Database[6], EU Hydrogen Strategy 2022[21], REPowerEU Plan 2022[29], IEA World Energy Outlook 2023[23]

21 H₂ PLANT INSTALLATION GLOBAL

Figure 85: Comparison of supply and demand for green hydrogen in EU mobility, global installed green hydrogen production plant capacity in GW: "EU Ambition" scenario.
Source: Porsche Consulting Green Hydrogen Project Tracker, IEA Hydrogen Infrastructure Database[6], IEA World Energy Outlook 2023[23]
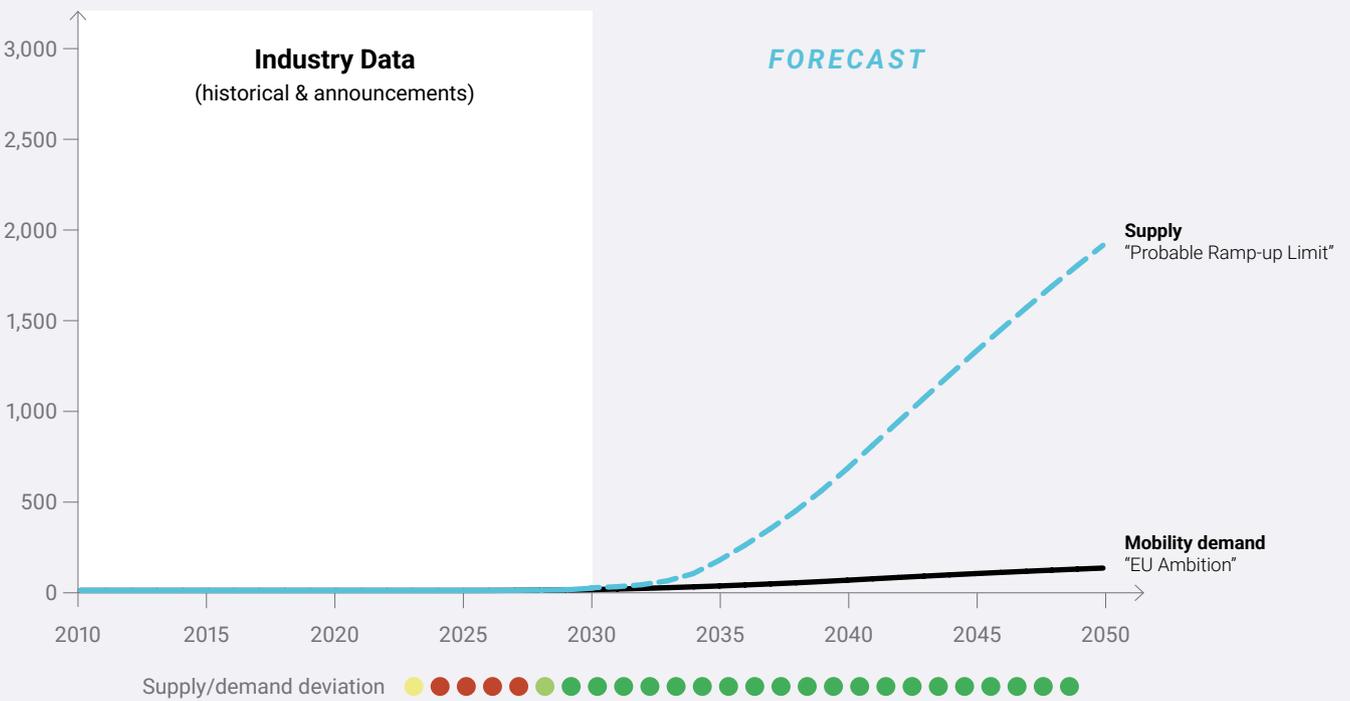
22 H₂ PIPELINE

Figure 86: Comparison of supply and demand for green hydrogen in EU mobility, global installed hydrogen pipeline length in thousand km: "EU Ambition" scenario.
Source: IEA Hydrogen Infrastructure Database[6], EU Hydrogen Strategy 2022[21], REPowerEU Plan 2022[29], IEA World Energy Outlook 2023[23]
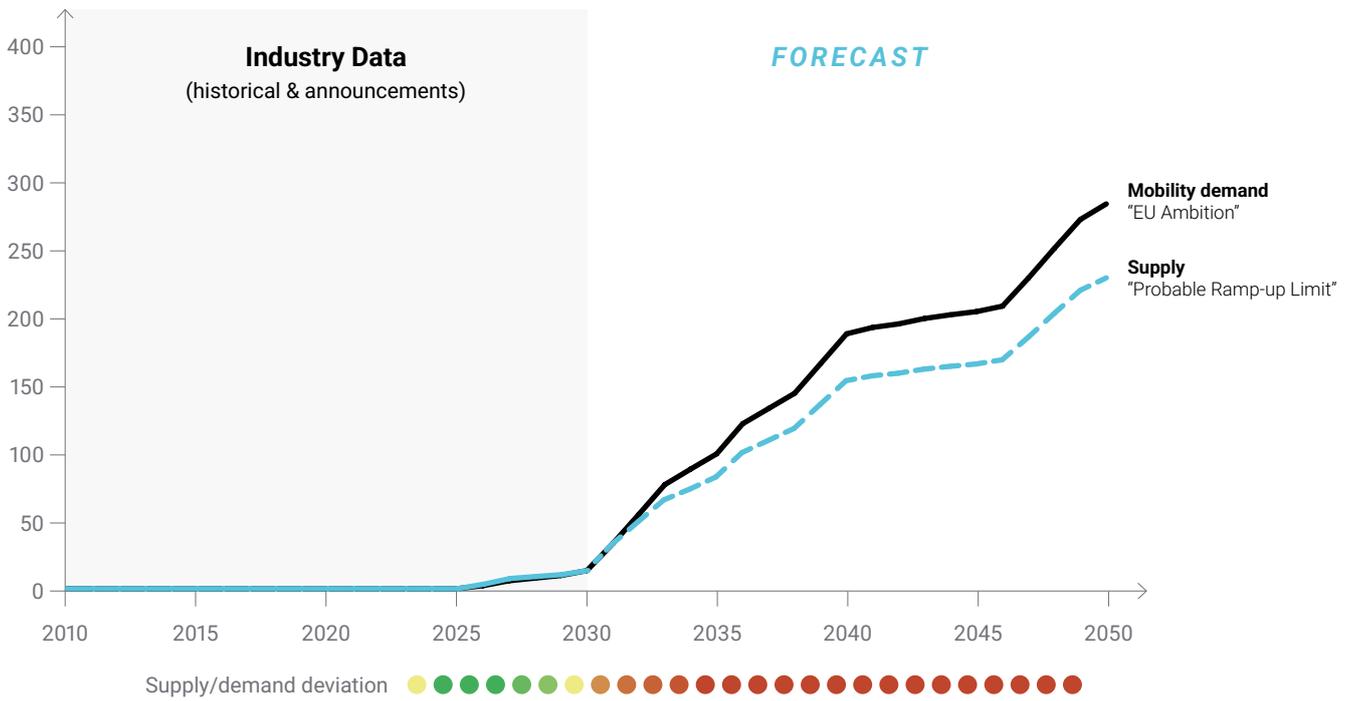
23 FUEL CELL

Figure 87: Comparison of supply and demand for fuel cell in EU mobility, cumulated fuel cell equipment in GW: "EU Ambition" scenario.
Source: OEM industry benchmarks, IEA Global EV Data Explorer 2024[45], IEA Global Hydrogen Review 2023[46]
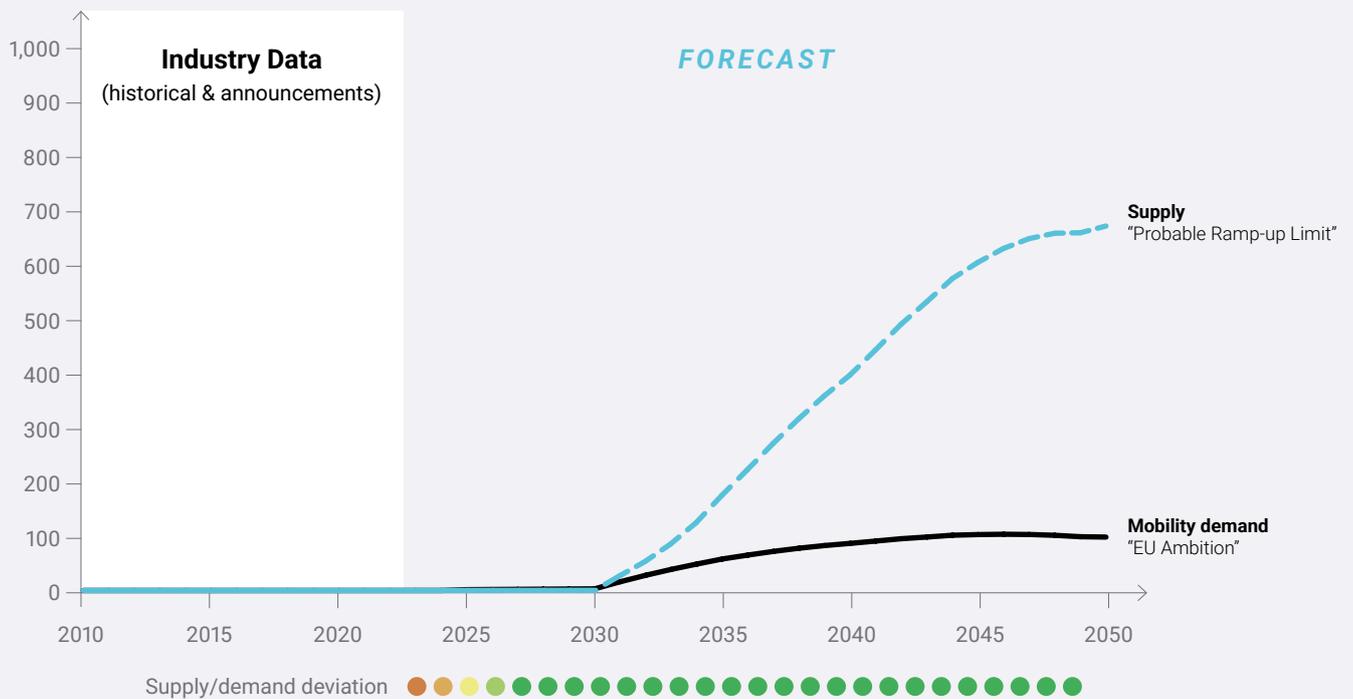
25 PV POWER EQUIPMENT

Figure 88: Comparison of supply and demand for eFuels in EU mobility, installed PV power equipment in GW: "EU Ambition" scenario.
Source: IRENA Wind Energy Data 2024[33], IEA World Energy Outlook 2023[23] | PV: Photovoltaic

IN BRIEF

▶ Internal combustion engines (ICEs) are expected to remain relevant across all mobility fleets until 2040, particularly in shipping and aviation.

▶ The EU Commission's ambitious plans for widespread adoption of battery electric vehicles (BEVs) in on-road mobility exert significant pressure on battery and energy supply chains. Simultaneous ramp-up initiatives in other regions may lead to shortages, underscoring the need for strategic planning and long-term investments.

▶ If the powertrain transformation in mobility does not progress as swiftly as planned by the EU, liquid fuel demand will remain higher than anticipated, potentially delaying carbon savings.

▶ From an industrial feasibility perspective, the ramp-up of eFuels can be accelerated to achieve climate targets, even if the mobility powertrain transition is delayed.

▶ Numerous projects are preparing to enter the eFuel market; however, they currently face financing challenges. Reaching final investment decision (FID) in the coming months will be crucial to enable operations by 2030. Unlocking eFuel project financing will require regulatory support and robust ramp-up strategies.

▶ To increase the attractiveness of eFuel projects and stimulate offtake and financing commitments, existing regulatory instruments can be leveraged. Aligning eFuel production standards can mitigate long-term compliance risk, while increasing eFuel quotas and introducing eFuel crediting across industries can secure demand.

▶ Moreover, eFuel offtake and financing commitments can be further stimulated through collaboration between eFuel producers and cross-industry offtakers, leveraging unit cost reductions synchronized with scaling strategies, while providing risk-sharing structures.