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ALLIANZ RESEARCH

TRANSPORT IN A ZERO CARBON EU: PATHWAYS AND OPPORTUNITIES

03 November 2021

EULER HERMES

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EXECUTIVE SUMMARY

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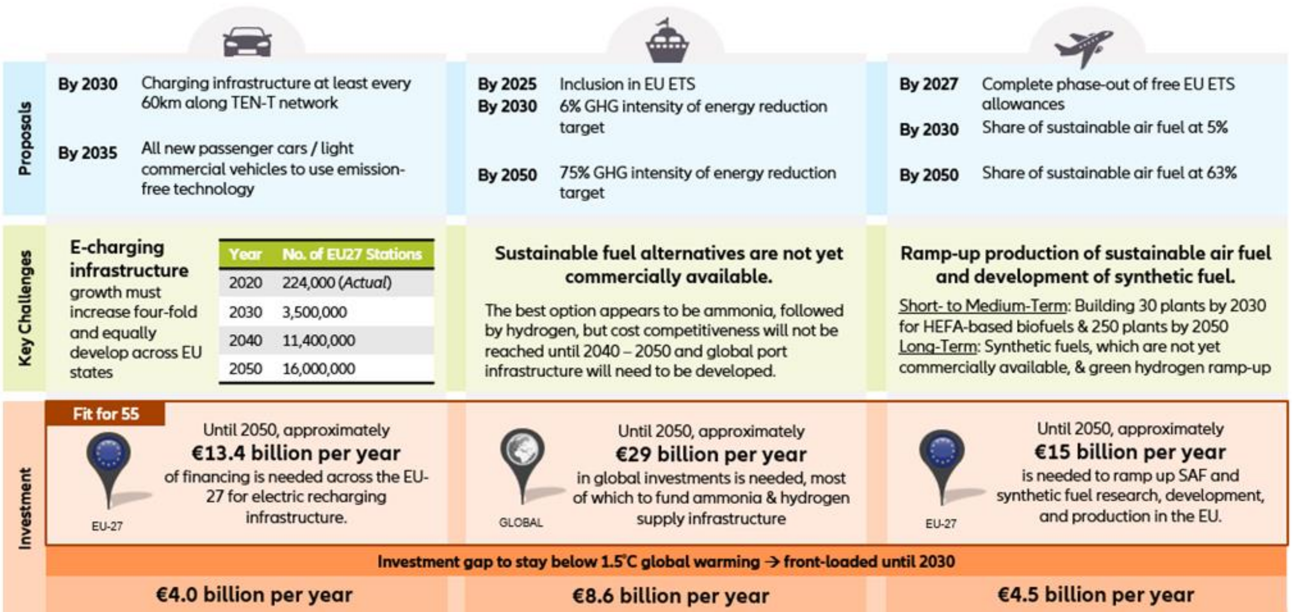
- **Fit for 55 – but missing the 1.5˚C target.** The transportation sector, including domestic transport, international shipping and aviation, accounts for almost 30% of the EU's annual carbon emissions. In this context, the newly proposed Fit for 55 legislation aims at cutting the cord between the transport sector and fossil-fuel dependence, emphasizing the use of cleaner, emission-free technologies and alternative fuels. But comparing the resulting transport emissions pathway with science-based sector pathways from the Network for Greening the Financial System or the One Earth Climate Model, we find that the EU could face an implementation gap of up to 14 years, and around EUR75bn of investment would be needed per year until 2030 to achieve its aspirations to limit global warming to 1.5°C (see figure right hand side).
- **For road transport, this would mean an additional EUR4bn per year of front-loading investments until 2030.** Road transportation is a sector that has high potential for decarbonization in the short and medium-term, accounting for 71% of overall EU transportation emissions in 2018. Low-emission technology, such as hybrid cars, and zero-emission technology, such as battery electric vehicles and hydrogen-fueled vehicles, will play a key role in this transition but electric charging infrastructure needs to increase four-fold to meet the expected growth of electric vehicles.
- **The shipping industry would need EUR8.6bn per year until 2030.** While maritime transport is a critical component of EU external and internal trade volumes, as well as passenger travel, the sector needs significant CO2 reduction through increasing energy efficiency and the use of cleaner energy sources. However, the development of suitable alternative fuels for shipping is challenging due to energy density, technological maturity and commercial readiness, flammability on board and emissions such as methane and nitrous oxide. Alternative fuels (synthetic and biofuels) are not yet commercially available and require substantial investment in research and development to be ready for deployment by 2030. Yet, action is needed now: Ships ordered in the next five years will impact sector emissions for decades to come.
- **Finally, the aviation industry would need EUR4.5bn per year.** In 2018, the EU aviation industry connected 1.2bn passengers but also contributed to 3.6% of total greenhouse gas emissions, with emission growth likely to continue if left uninterrupted. To comply with the 1.5˚C target, the EU needs not only a much quicker ramp-up of sustainable air fuels but also an increase of the fuel efficiency of the air fleet, both of which will result in higher air fares.
- In short, the road to net-zero is rocky, paved with high costs and high uncertainty. Most of necessary technologies require substantial research and investment funding and will not be ready for market deployment until 2030, which means that they will not actively contribute to the emissions reductions needed in the next 10 years. Therefore, short-term solutions that already exist and can help reduce emissions over the next decade must be used in parallel – but with a clear understanding of their "bridge" character to avoid lock-ins into unsustainable pathways that are only partially decarbonized.



Investment needs for the EU transport sector transition

FIT FOR 55 - BUT MISSING THE 1.5° TARGET

The transportation sector (including domestic transport, international shipping and aviation), accounts for almost 30% of the EU's annual carbon emissions, with aviation and shipping even experiencing increasing emissions since 2010. The newly proposed EU climate legislation ("Fit for 55") aims at cutting the cord between the transport sector and fossil-fuel dependence, emphasizing the use of cleaner, emission-free technologies and alternative fuels. Although there is relatively high certainty in alternative fuels, i.e. electrification and infrastructure for road transportation, the path is not as well paved for aviation and one could even say it is unpaved for shipping. As a consequence, the greenhouse gas emission share of these two transportation subsectors will sharply increase over time to almost 50% of all transport-related emissions (see Figure 1). More detailed information about the energy balance flows and the relation to other sectors in the economy is included in the appendix.

Figure 1: Share of transportation emissions, 2020 – 2050

Source: Allianz Research

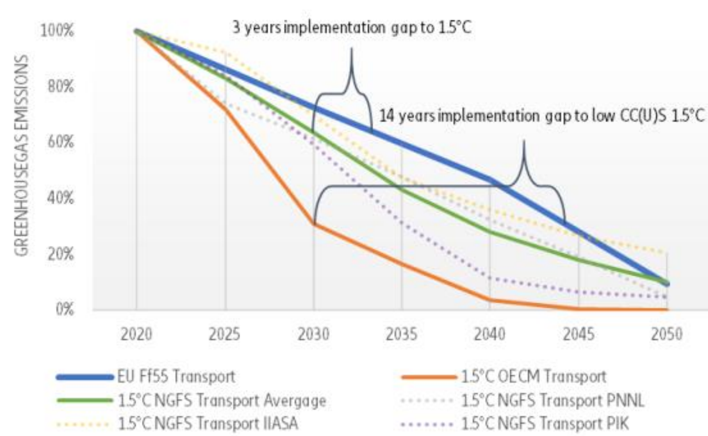
[1] These are initial results. To deepen our understanding of climate literacy we plan to have follow-up studies, covering more countries and respondents.

However, comparing the EU Ff55 transport emissions pathway with science-based sector pathways from the Network for Greening the Financial System (NGFS) or the One Earth Climate Model (OECM), we see that the climate ambition lags behind the required emission reductions for staying within a 1.5°C global warming range (see Figure 2). The necessary pipeline for infrastructure investments and implementation of mitigation measures shows a gap of three years compared to the projections by the NGFS. Comparing the pipeline to the pathway of OECM, which relies only on low levels of Carbon Capture (Utilization) and Storage (CC(U)S), the EU faces an even larger implementation gap of 14 years in its aspirations.

It should be noted that this implies a front-loading of investments, not an increase of the total transition costs: Road transport would need an additional EUR4bn per year of front-loading investments until 2030, while shipping would need EUR8.6bn per year and aviation EUR4.5bn per year.

This proportion is almost twice as high as the corresponding average for the four European countries.

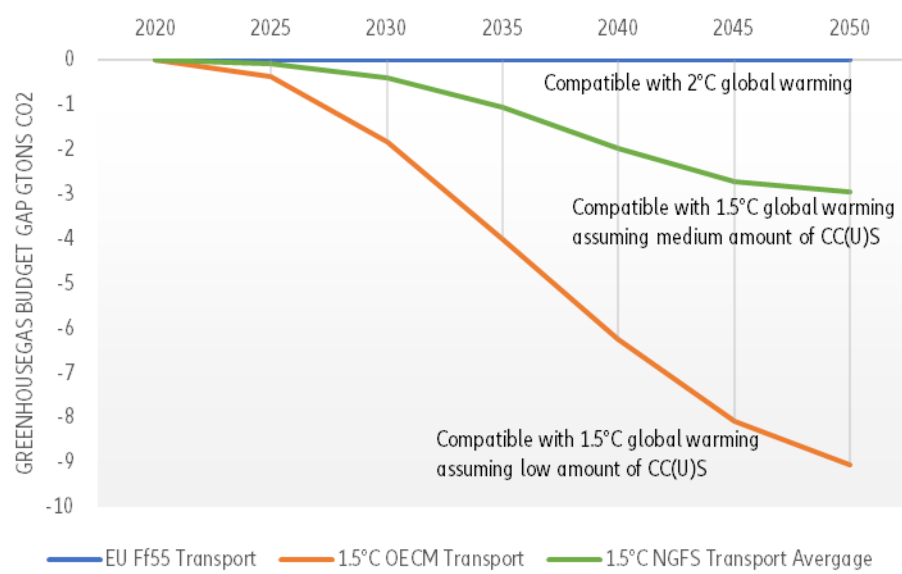
Figure 2: Transport implementation gap %



Source: Allianz Research

Figure 3 aggregates the emission path differences into the accumulation of total emissions from the transport sector. We observe that under Ff55 the transport sector will have already emitted an additional 400 Mt of CO2 by 2030[1] compared to the NGFS scenarios. This has to be put into perspective against the total 310 Mt CO2 of negative emisisons or carbon capture that the EU plans by 2030. The carbon capture would thus have to more than double to offset the additional emissions. However, as the EU generally plans with relatively low carbon-capture activity, it makes sense to compare its transport emissions path to other low carbon-capture paths like the one from the OECM model. After all, you don't have to capture what you don't emit in the first place. This comparision reveals that the EU would lag behind by a total of 1,800 Mt of CO2 by 2030.

Figure 3: Cumulative emission budget savings in 1.5°C transport scenarios compared to EU Fit for 55

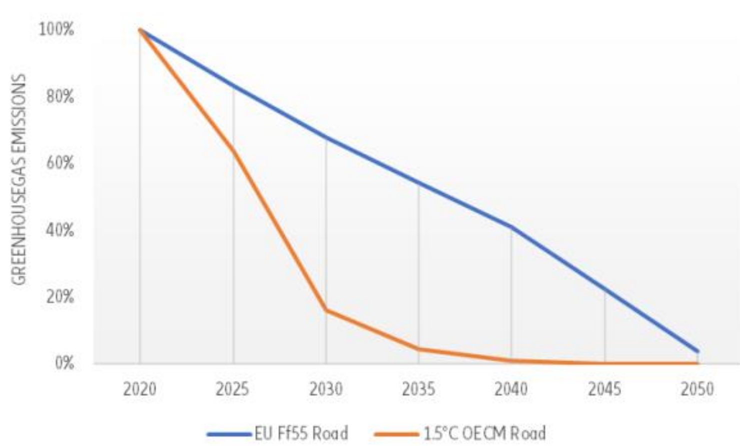


Source: Allianz Research.

ROAD TRANSPORTATION
HIGHWAY TO (ELECTRIC) HEAVEN

Road transportation is a sector that has high potential for decarbonization in the short and medium-term, accounting for 71% of overall EU transportation emissions in 2018. Zero-emission technology, such as battery electric vehicles, will play a key role in the decarbonization transition. With an eye on 2030 targets, the Ff55 legislation proposes that the average emissions of new cars should decrease by 55% from 2030, and 100% from 2035. (The UK has proposed a similar timeline.) Essentially, all new passenger cars and vans on the market would be zero-emission starting in 2035. Ambitious as it sounds, the comparison with the OECM pathway makes clear that the EU will still miss the 1.5°C target by a wide margin (see Figure 4). Staying below 1.5°C can only be achieved through a massive increase of negative emissions in the form of CC(U)S or, if that is not on the agenda, a much quicker reduction of emissions as displayed in the OECM path or some combination of increased CC(U)S and quicker emission reduction. However, achieving an ambitious OECM-like path would de facto imply the dispossession of combustion engine vehicles as those have to be decommissioned long before their usual life cycle ends (their typical operating life within the EU is 10-15 years).

Figure 4: Road transport sector pathways[2]

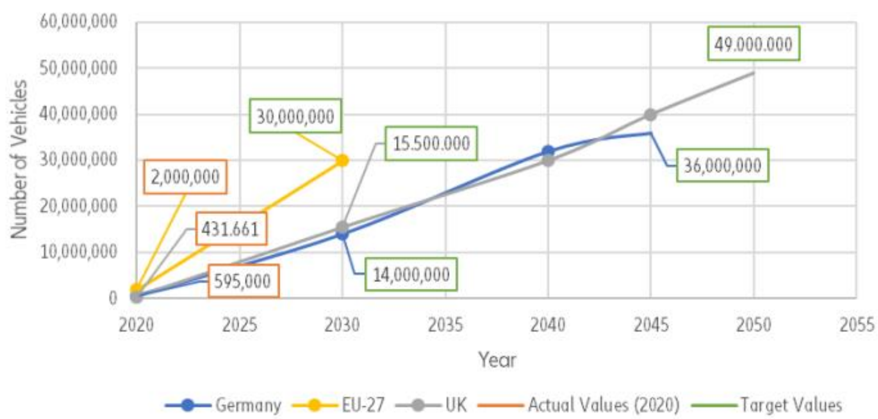


Source: Allianz Research.

[2] Negative emissions refer to measures that extract CO2 from the air and store them permanently. A prominent example for this is afforestation.

Over the past few years, alternative fuels such as electric, hydrogen fuel cell, natural gas and LPG have developed at vastly different rates and acceptance levels. Since 2014, the electric vehicle market has strongly matured and by now it is the dominant market of alternative fuel. Although electric vehicles accounted for 10.5% of new passenger car registrations in 2020, they still hold a small share of total registered vehicles on EU roadways (<1%)[3]. With just over 1.25mn electric passenger cars on European roads in 2020[4], and the average age of a vehicle in the EU being 11.5 years, there are still large gaps to overcome. For example, the German market had approximately 595,000 electric passenger vehicles on the roads in 2020 (13% share of total new car registrations)[5], but around 1.5mn cars will need to be added to the roads each year to meet the target of 14mn passenger cars by 2030 and 36mn cars by 2045 (Figure 5). This would imply that 59% of all passenger and light commercial vehicle cars on German roads are BEV/PHEV by 2045. By 2050, it is anticipated that 88-99% of all vehicles in the EU will need to use zero or low-emission technology in order to meet climate neutrality targets. This anticipated influx of car demand will approximately triple the electricity demand of the transport sector by 2030 (vs 2015) in the EU (an additional 105 TWh by 2030 and 488 TWh by 2050).

Figure 5: Development of electric vehicles in the EU-27, Germany & the UK[8]



Source: Allianz Research.

[3]Source: European Alternative Fuels Observatory (EAFO)

[4]Includes hybrid (plug in electric vehicles)

[5]Source: European Alternative Fuels Observatory (EAFO)

[6]Source: Towards a Climate-Neutral Germany by 2045, AGORA (2021)

[7]The implications for the energy sector will be analyzed in a forthcoming report: title

To avoid infrastructure being a bottleneck, a large expansion of alternative refueling infrastructure must start now and correspond across EU countries to ensure trans-EU travel. The Ff55 legislation proposes clear targets for infrastructure development for electric and hydrogen refueling stations, which indicate that the electric charging infrastructure must increase four-fold by 2025 to meet the expected growth of electric fleets. The EU's end goal would be to have approximately 16mn charging points by 2050 (Figure 6).

Although electric charging infrastructure grew significantly between 2018 and 2019 alone (40%), this overall growth is unevenly concentrated in member states such as Germany, France and the Netherlands, where 70% of all recharging infrastructure is located today. Development varies depending on the type of charging available as well. While high power charging (>22kW) is preferred, development is uneven across countries, with Germany having the highest share of fast-charging infrastructure among EU countries (15.1% vs. the EU average of 11%). Meanwhile, the UK is leading the European continent, with around 18.6% of all public charging stations being rapid chargers, and has shaped its infrastructure roll-out around increasing access to rapid chargers across its strategic road network. The UK expects to have 2,500 rapid charge points by 2030 and 6,000 in total by 2035. At the end of 2020, the EU had over 224,000 publicly accessible charging points, but trans-EU connectivity is still lagging as only 7% of the entire TEN-T comprehensive network was equipped with at least one 150 kW charger at every 60km. The varying charging infrastructure by country will pose a large challenge for trans-EU travel in the next decade as the electric market continues to grow (Figure 7).

Figure 6: Development of electric charging stations across the EU-27

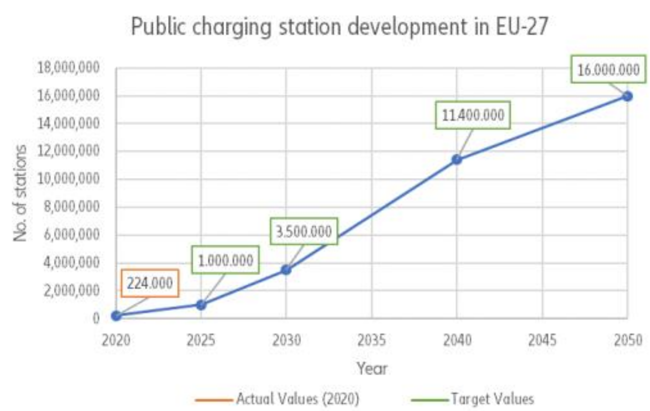


Figure 7: Forecast of electric charging stations by country

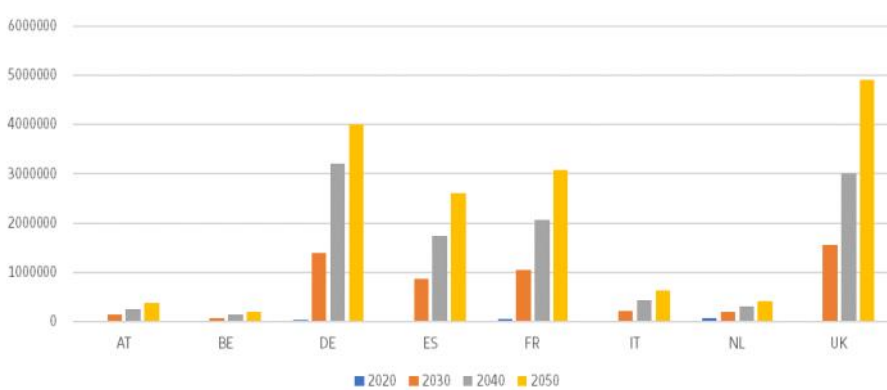
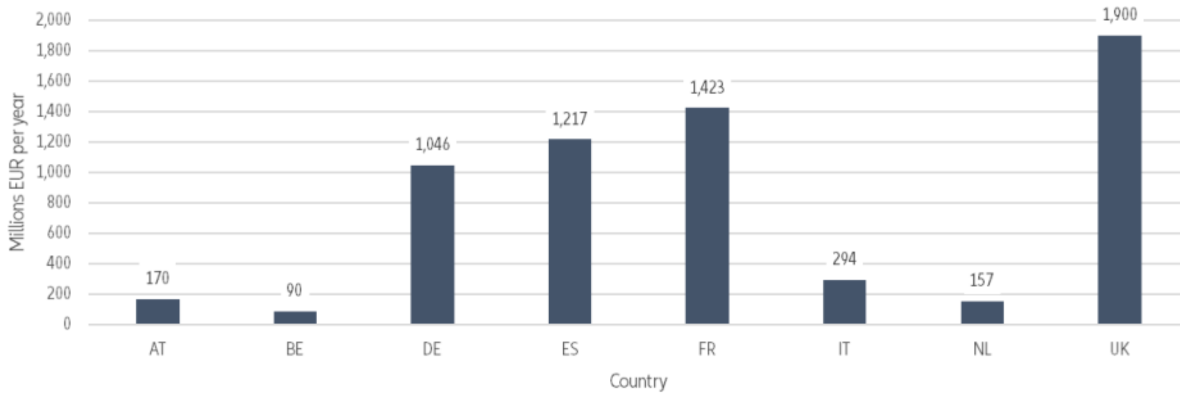


Figure 8: Estimated electricity recharging infrastructure investment needed until 2050, in EUR mn EUR per year[12]



Source: Allianz Research

But with a growing EV market, new business opportunities will emerge for (much-needed) investment. From 2014 to 2020, Connecting Europe Facility, which is a funding instrument managed by the EU Commission, awarded an estimated EUR698mn for alternative fuel development in road transport, with about EUR343mn going towards electric charging projects[11]. If the proposed Ff55 legislation is implemented, an estimated EUR430bn is needed from 2021-2050 — about EUR13.4bn per year — for recharging infrastructure across the EU-27. Broken down by country, German, France and Spain would need to expend the most investment for charging stations to reach 2050 forecasts (Figure 8).

In addition, the expansion of the EV market will provide numerous climate-tech opportunities. In Germany alone, an estimated EUR730mn per year of start-up financing is needed until 2030 to address gaps in the development and standardization of charging infrastructure and services[13], which will accelerate deployment. With 90% of chargers in Germany already being private, growing demand and market pressure will lead to a stable market for charging deployment, especially for residential buildings where approximately two-thirds of households have a garage or parking space, making installation attractive to consumers. For Germany especially, with EUR300mn in public funding available in 2021 for SMEs to deploy public recharging stations at their locations, consumer confidence in EVs will continue to build, especially as purchase grants (up to EUR9,000 per car) and vehicle tax exemptions continue for EV purchases. On the other hand, for heavy-duty vehicles, a market for battery technology in truck transport is emerging, with an estimated start-up financing of EUR635mn per year needed[14]. Although the heavy-duty vehicle market has moved slower in comparison to passenger cars, it is critical that until 2030 emission-free technology reaches maturity for commercial scale fleet deployment. Expansions of public-private investment initiatives, such as Germany's "Electric Mobility Showcase" program, which provided nearly EUR300mn to 90 projects, should continue to provide the market with the boost it needs to meet 2030 targets and demand.

[11]Source: Source: Special Report on infrastructure for charging electric vehicles, EU Court of Auditors (2021)
[12]Source: Allianz Research
[13]Source: DENA, Investing in Net Zero (2021)
[14]Source: DENA, Investing in Net Zero (2021)
[15]Source: Energy Transition Outlook (2020)

SHIPPING INDUSTRY: UNCHARTED WATERS

While maritime transport is a critical component of EU external and internal trade volumes, as well as passenger travel, the sector needs significant CO2 reduction through increasing energy efficiency and the use of cleaner energy sources. Maritime transport accounted for 3-4% of total EU emissions in 2019 so the FuelEU Maritime initiative was specifically proposed to support its decarbonization across the EU-27 via the use of sustainable fuels, which less than 1% of the world fleet runs on today[15]. Based on the 2030 Climate Target Plan modelling, renewable and low-carbon fuel should provide 6-9% of the maritime fuel mix by 2030 and 86-88% by 2050. To achieve this, the new regulation proposes to limit the greenhouse gas emission-intensity of energy used onboard a ship, increasing limits over time. Starting in 2025, the yearly average greenhouse gas emission intensity of the energy used onboard a ship is proposed to be limited to -2% vs 2020 levels. This would incrementally increase from -6% in 2030 to -75% in 2050 (Table 1). On the other hand, the UK is still developing policy frameworks and instruments for how to best accelerate the decarbonization of the maritime sector. In 2022, after public consultation, a Course to Zero plan should be established, setting targets from 2030 onwards.

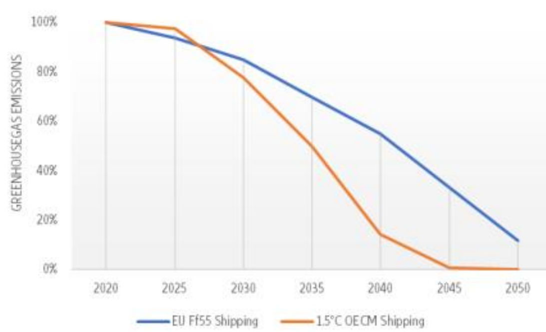
Again, these targets fall short of what is needed to achieve the low CC(U)S 1.5° C path (see Figure 9). However, compared to road transportation, the gap is smaller, particularly up to 2030. After 2030, a more ambitious policy towards sustainable fuels and the retrofitting of existing ships would be required.

Table 1: Proposed reduction targets for GHG emission intensity of energy for shipping

Target Year	Proposed GHG emission intensity reduction target for a ship's onboard energy
2025	2%
2030	6%
2035	13%
2040	26%
2045	59%
2050	75%

Source: European Commission.

Figure 9: Maritime transport sector pathway



Source: Allianz Research.

[15]Source: Energy Transition Outlook (2020)

In comparison to the aviation industry's propsed fuel mixing mandates, the greenhouse gas intensity limits for shipping allows the industry to decarbonize in a more flexible manner since technologies are still evolving. The development of suitable alternative fuels for shipping is challenging due to energy density, technological maturity and commercial readiness, flammability on board and emissions such as methane and nitrous oxide. There are very mixed reviews on fuel options today: Currently, the cleanest readily available alternative option is switching to LNG from heavy fuel oil, which could contribute to a 20% reduction of carbon emissions. However, methane slippage must be controlled. While the EU Commission supports LNG investment, other environmental groups[16] disagree and believe its benefits are not long-term. Promising fuel options in the future include (limited) biofuels (19-88% emission reduction depending on the feedstock used), which could be blended with fossil fuels, and more promisingly (green) hydrogen and ammonia, either of which could be used in fuel cells or as a replacement combustion fuel. When produced cleanly from renewable electricity, there is a large potential for emission reduction but unfortunately the trade-off is the lack of technological maturity, commercial readiness and refueling (bunkering) availability at ports. Since there is not an absolute winner in alternative fuels for shipping, uncertainty lingers as investors shy away from what they perceive as high-risk investments.

Action is needed now: Ships ordered in the next five years will impact sector emissions for decades to come. On average, shipping vessels have an average lifetime of around 30 years in operation, with smaller ships (e.g. general cargo) having even higher lifetimes of 40 years. Approximately half of all global vessels are more than 15 years old and a third of ships are more than 25 years old[17]. With new fleet renewals scheduled soon, it will be critical that zero-emission technology (e.g. hydrogen or synthetic fuel) be ready for operation in at least smaller vessels by 2030.

Ammonia (using clean hydrogen) appears to be the most promising alternative fuel for the shipping industry but high investment is needed for research, development and the infrastructure ramp-up. The University Maritime Advisory Services (UMAS) and Energy Transitions Commission estimate at least USD1trn in global investments is needed to decarbonize the industry between 2030-2050 and reduce emissions by 50% by 2050[18]. For a complete decarbonization in 2050, which is in line with a 1.5° Celsius warming scenario, at least USD1.5-1.9trn could be required, with most funding (87%) going towards land-based supply infrastructure such as fuel production, storage and refueling infrastructure. Of the 87% of funding, half of the share should fund hydrogen production, while the other half contributes to ammonia synthesis, storage and distribution. On a more granular level, the sixth carbon budget analysis estimates that for the UK approximately EUR188mn per year is needed until 2035, increased to EUR412 million per year until 2050, to support the efficiency, electrification and infrastructure adjustments required for zero-carbon ammonia usage.

Decreasing renewable electricity costs will help make alternative fuels more price-competitive against their fossil fuel counterparts. By 2030, hydrogen is projected to be cost competitive with

fossil fuel and ammonia will be competitive by 2050[19] (Figure 10). Although hydrogen production is more competitive in the medium-term to ammonia, the overall capital cost of ammonia is likely to be more attractive considering that it has less storage challenges (hydrogen requires cryogenic temperatures and high pressure) and is commonly used around the world as a fertilizer. As a result, many countries are familiar with handling and transporting it. In addition, the cost competitiveness of green hydrogen from low-cost renewables can help continue to drive down ammonia cost production.

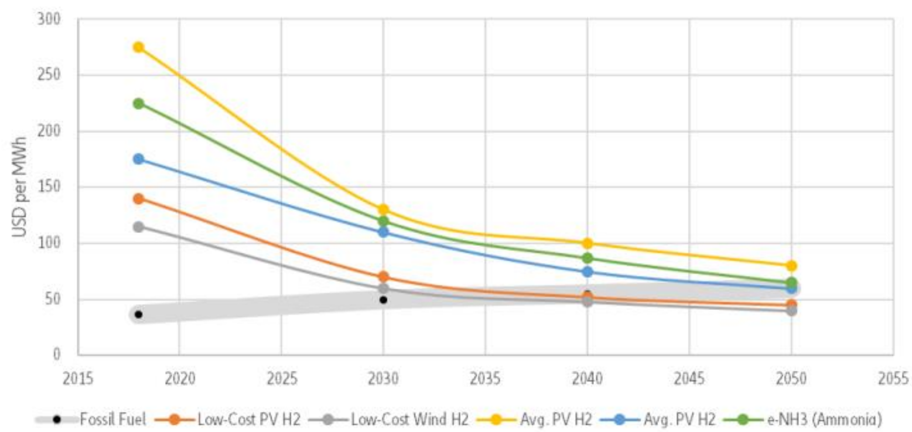
[16] E.g. International Council on Clean Transportation and Transport & Environment

[17] Source: How hydrogen can help decarbonize the maritime sector, Hydrogen Europe (2021)

[18] Source: Aggregate investment for the decarbonization of the shipping industry, UMAS & ETC (2020)

[19] Source: Navigating the Way to a Renewable Future, IRENA (2019).

Figure 10: Maritime fuel cost projections[20]



Source: Allianz Research, based on IRENA .

For the first time, it is proposed that the shipping sector would now also be included in the EU ETS gradually from 2023, phased in over a three-year period. The in-scope emissions from large vessels (at least 5,000 tonnes) would include all emissions for voyages within the EU and 50% of emissions from voyages that start or end outside of the EU, as well as all emissions while at berth in EU ports. This proposal would cover around 66% of all EU shipping emissions. The inclusion in the EU ETS and FuelEU Maritime proposal would help incentivize the sector to take steps towards decarbonization and energy-efficiency measures on board vessels, but uncertainty in fuel development could erode investment potential, which would fund the critical progress that needs to be made in research and development before 2030.

[20] Source: Navigating the Way to a Renewable Future, IRENA (2019).

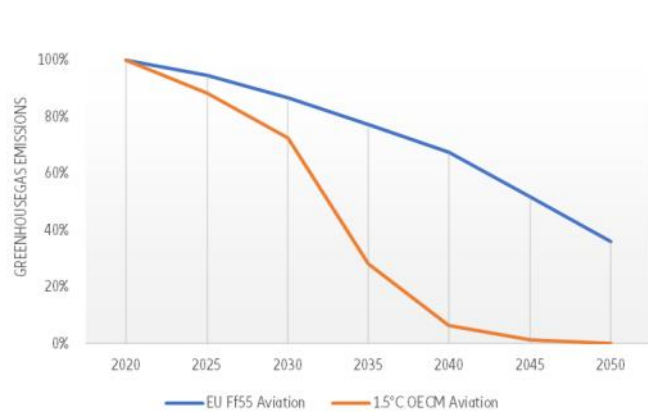
AVIATION SECTOR: FLIGHT OF FANCY

In 2018, the aviation industry connected 1.2bn passengers but also contributed to 3.6% of the EU's total greenhouse gas emissions, with emission growth likely to continue if left uninterrupted. From a policy perspective, there are several frameworks that are proposed to direct the aviation industry to address its carbon emissions, such as introducing fuel-mixing mandates for sustainable air fuels, as well as the inclusion of aviation into the various Emissions Trading Schemes (e.g., EU ETS, UK ETS).

However, comparing the EU Ff55 aviation transport emissions pathway with the low CC(U)S sector pathway from OECM, we observe that the climate ambition lags behind the required emission reductions for staying within a 1.5°C global warming range, particularly after 2030 (see Figure 11). From a technological perspective, a more ambitious path is achievable. However it not only requires a much quicker ramp-up of sustainable air fuels, but also an increase of the fuel efficiency of the air fleet, both of which will result in higher air fares.

A promising pathway is the use of sustainable air fuel (SAF), which could help reduce emissions by 75%[21]. SAF is a biofuel produced from sustainable feedstocks with biological origins, such as cooking oil, animal waste fat or forestry/agriculture residues. On the other hand, synthetic fuels, also known as power-to-liquid or e-fuels, are renewable fuels from non-biological origins, made from renewable electricity. Both SAF and synthetic fuels can replace fossil jet fuel as they can be directly blended and power existing aircrafts without any additional technical modifications, unlike electric and hydrogen-powered aircrafts that are promising but not viable alternatives in the short- to medium-term. To create a competitive market for SAF, the ReFuelEU Aviation initiative was proposed in July 2021, which would set fuel-mixing targets that start in 2025 for the EU-27 (Table 2). It would apply to all commercial air transport flights and set gradually increasing minimum shares of synthetic aviation fuels over time, all in line with the EU's climate objectives. In addition, the UK is also planning to consult on a potential UK SAF blending mandate as part of their larger "Jet Zero 2050" plan.

Figure 11: Aviation transport sector pathway



Source: Allianz Research

Table 2: Proposal for SAF mixing mandates for aviation

Target Year	Minimum volume shares of sustainable air fuel (SAF)
2025	2% of SAF
2030	5% of SAF of which at least 0.7% are synthetic aviation fuels[22]
2035	20% of SAF of which at least 5% are synthetic aviation fuels
2040	32% of SAF of which at least 8% are synthetic aviation fuels
2045	38% of SAF of which at least 11% are synthetic aviation fuels
2050	63% of SAF of which at least 28% are synthetic aviation fuels

Source: European Commission .

[21]Sources: ReFuelEU Sustainable Aviation Fuel by EU Commission (2021)

[22]Fuels that are renewable fuels of non-biological origin, made from (renewable) electricity

Currently there are seven certified production pathways for advanced SAF biofuels with varying levels of technological maturity. Perhaps the most readily available and technologically mature fuel is using the Hydroprocessed Esters and Fatty Acids (HEFA) process, which is the only SAF currently being used and can be blended with kerosene up to 50%, contributing to a CO2 emission savings of 20-69%. Meanwhile, alcohols to jet (AtJ) and biomass gasification with Fischer-Tropsch synthesis (Gas+FT) are less mature, but also provide promising CO2 emissions savings (37-70% and 85-95%, respectively). Because of their mature technology, HEFA-pathway biofuels currently have the lowest production costs in comparison to other options, but there may be constraints in the future due to feedstock availability since they are in high demand to produce other transportation biofuels (e.g. for road transportation). It is important to note that feed and food crop-based fuels are generally discarded by airlines and not eligible for SAF because of indirect land-use change and sustainability concerns. Meanwhile, synthetic fuels (or synfuels) that are not sourced from biological origins but rather from renewable electricity have not yet reached commercial availability. Only two processes have been certified for fuel mixing and are not yet available on an industrial scale.

Starting from scratch, EU countries must ramp up research and production now to meet the proposed 2030 targets. In 2020, sustainable air fuel was less than 0.05% of total jet fuel use, mostly due to a lack of price-competitive, mature fuel options, which have been slow to develop. One of the main problems with SAF is limited production and costs. Currently the EU has no plants dedicated to producing sustainable air fuel on a regular basis at commercial scale, which is one of the reasons why production costs are 1.5-6 times higher than fossil jet fuel[23] (Table 3). For synthetic fuel, the largest commercial plant recently opened in Germany and will produce approximately eight barrels (1 ton) of synthetic kerosene per day in early 2022.

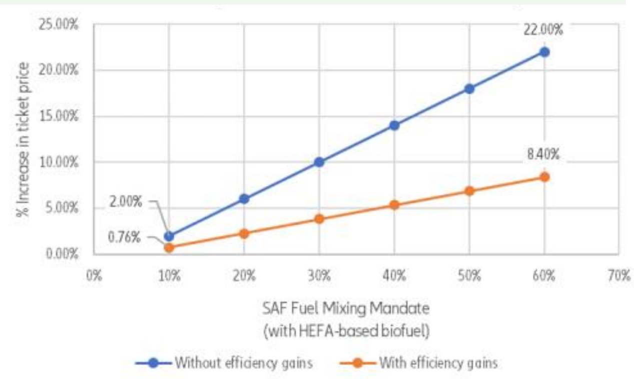
Although SAF is more expensive, consumers would experience only limited increases in the cost of plane tickets. Fuel costs are approximately 20% of airlines' total costs. Therefore, assuming that SAF is twice as expensive as fossil jet fuel, a 20% fuel-mixing mandate[24] (proposed by 2035) would result in a +6% increase in ticket prices (Figure 12). If accounting for fuel efficiency gains that have been improved with newer aircrafts, ticket prices could increase by +2% with a 20% fuel mandate. By 2050, the proposed fuel-mixing mandate (assuming fuel efficiency gains) would result in an estimated +8% ticket price increase, which is also supported by EU ticket-price estimations in the Ff55 legislation.

Table 3: Estimated production costs in 2020 for various sustainable air fuels and synthetic fuel

Production Route	Fossil Jet Fuel	HEFA	Gas+FT	AtJ	Synthetic Fuel
Estimated production cost[1] in 2020 (k€/tonne)	0.6	0.95 – 1.14	1.7 – 2.5	1.9 – 3.9	1.8 – 3.5

Source: European Commission .

Figure 12: Estimated plane ticket price increase with SAF fuel mixing[25]



[23]Source: European Commission, ReFuelEU Sustainable Aviation Fuel (2021)

[24]Source: Allianz Research; Efficiency gains were calculated from the current average fleet consumption of 3.5 liter per passenger per 100km, while modern efficient aircrafts, such as A320neo, have an average fuel consumption of 2.3 liter per passenger per 100km (using data from Klimaschutzreport 2018)

[25]Source: Allianz Research

Until 2030, HEFA-based SAF is expected to be the main fuel source for mixing but in the long-term it is expected that the largest share of SAF will come from synthetic fuels[26]. To support the ramp-up of SAF production, it is estimated that 30 plants by 2030 and 250 plants by 2050 are required to be developed, each ranging in output from 0.15 – 0.5 Mt per year, with HEFA and PtL technology having the highest output. In Europe, 15 plants are already being planned, largely for HEFA-based fuel production, but large-scale development to produce synthetic fuels needs to start before 2030. Once technology is ready for commercial up-scaling, it takes approximately three to four years in project lead times until plant operational readiness. Therefore high investment in technology development is needed upfront to realize the expected share of synthetic fuels after 2030.

From 2020-2050, the Energy Transition Comission estimates that approximately EUR15bn per year in total capital expenditure (CAPEX) investment is needed to ramp up SAF in the EU[27]. The minor share of investment (approximately EUR7bn total) will be required to ramp up HEFA plant output before 2030, while the majority (approximately EUR250bn) will be needed to build infrastructure for synthetic fuels, which will play a critical role starting in 2030. Of the synthetic fuel infrastructure, a majority (two-thirds) of this investment is needed to build up green hydrogen production. Public financial support needs to concentrate on research and development of the less mature pathways (e.g. synthetic fuels), where approximately EUR30bn over the next 15 years is needed to realize the fuel transition. For example, Germany announced its own EUR1bn investment in May 2021[28] to take steps toward a national Power-to-Liquid (PtL) roadmap to produce one-third of its current fuel consumption for domestic flights by 2030. Furthermore, it is estimated that the UK SAF Industry could generate between EUR824mn-EUR1.8bn in gross value added per year. To build on this potential market, around EUR17mn has been provided in 2021-2022 to support the development of a first-of-a-kind commercial SAF plant in the UK via the Green Fuels Green Skies competition, as well as another EUR3.5mn invested to identify airport infrastructure needs to handle new forms of zero-emission aircraft. Still, an estimated EUR460mn per yer of additional investment is needed in the UK until 2035, followed by EUR672mn per year until 2050.

There is potential for cost-reduction by 2050 through economies of scale, research and development and lower renewable electricity prices. For example, the production process for electrolyzers, which produce synthetic fuels, is not currently automated, yet the technology is ready to be scaled up for commercial production. The costs of green hydrogen can also be decreased. In favorable locations, the Energy Transition Comission estimates that green hydrogen can be produced at USD0.5/kg by 2050, while in France it would reach USD1/kg by 2050, which would cost 65% more than fossil jet fuel. On the other hand, decreasing the cost to USD0.5/kg will make it only 30% more expensive than fossil fuel jet fuel (vs. 130% more expensive at USD2/kg, which could result in an +18% price increase on long-haul flight tickets)[29].

In addition to the proposed new fuel-mixing regulation, there are two proposed market-based measures, the EU Emissions Trading Scheme (ETS) and Carbon Offsetting and Reduction Scheme (CORSIA) that will also support the industry in additional emission-reduction efforts through carbon pricing and offsetting. For intra-EAA flights, it is proposed that starting in 2024, 25% of the free allocation of emission allowances under the EU ETS would end and instead be auctioned. The share of freely allocated allowances would then decrease linearly and, by 2027, free emission allowances would be completely phased out. For extra-EAA flights, CORSIA would apply. CORSIA's goal is to ensure that carbon emissions from international aviation do not go above 2019 levels. When actual emissions are above 2020 levels, each unit of carbon dioxide that is emitted must be offset through the purchase of an approved carbon credit. In other words, they must be sequestered or removed from the atmosphere. Taking into consideration the impact of the Covid-19 pandemic on international air travel, it is expected that the airline industry will become the largest source of carbon-credit demand in the future. The SAF could also be used to decrease airline emissions but the bigger debate here is whether these two mechanisms are strong enough to incentivize the industry towards a much-needed fuel transition.

[26]Source: Guidelines for a Sustainable Aviation Fuel Blending Mandate in EU (Clean Skies for Tomorrow, ETC, WEF (2021)

[27]Source: Guidelines for a Sustainable Aviation Fuel Blending Mandate in EU (Clean Skies for Tomorrow, ETC, WEF (2021), which is more ambitious than the investment figures outlined by Fit for 55 (ReFuelEU Sustainable Aviation Fuel)

[28]Source: PtL Roadmap, BMVI (2021)

[29]Source: Making the Hydrogen Economy Possible, Energy Transition Commission (2021)

Conclusion

The road to net-zero is rocky, paved with high costs and high uncertainty. But these difficulties notwithstanding, large-scale investments must be made in the next 10 years to build the necessary infrastructure, including research as well as commercial-scale production and distribution networks for alternative fuel technologies. What is happening (or not happening) in the 2020s will largely determine how close we come in achieving a net-zero scenario by 2050. This requires the willingness to take (high) risks as a majority of zero-emission solutions and technologies are not yet market ready; most of these technologies require substantial research and investment funding and will not be ready for market deployment until 2030, which means that they will not actively contribute to the emissions reductions needed in the next 10 years. Therefore, short-term solutions that already exist and can help reduce emissions over the next decade must be used in parallel – but with a clear understanding of their "bridge" character to avoid lock-ins into unsustainable pathways that are only partially-decarbonized: The trade-offs between short-term emission reductions and a zero-emission future has to be actively managed. This is very likely the most difficult balancing act of the green transition, which requires a clear compass in the form of scientific-based net-zero pathways.

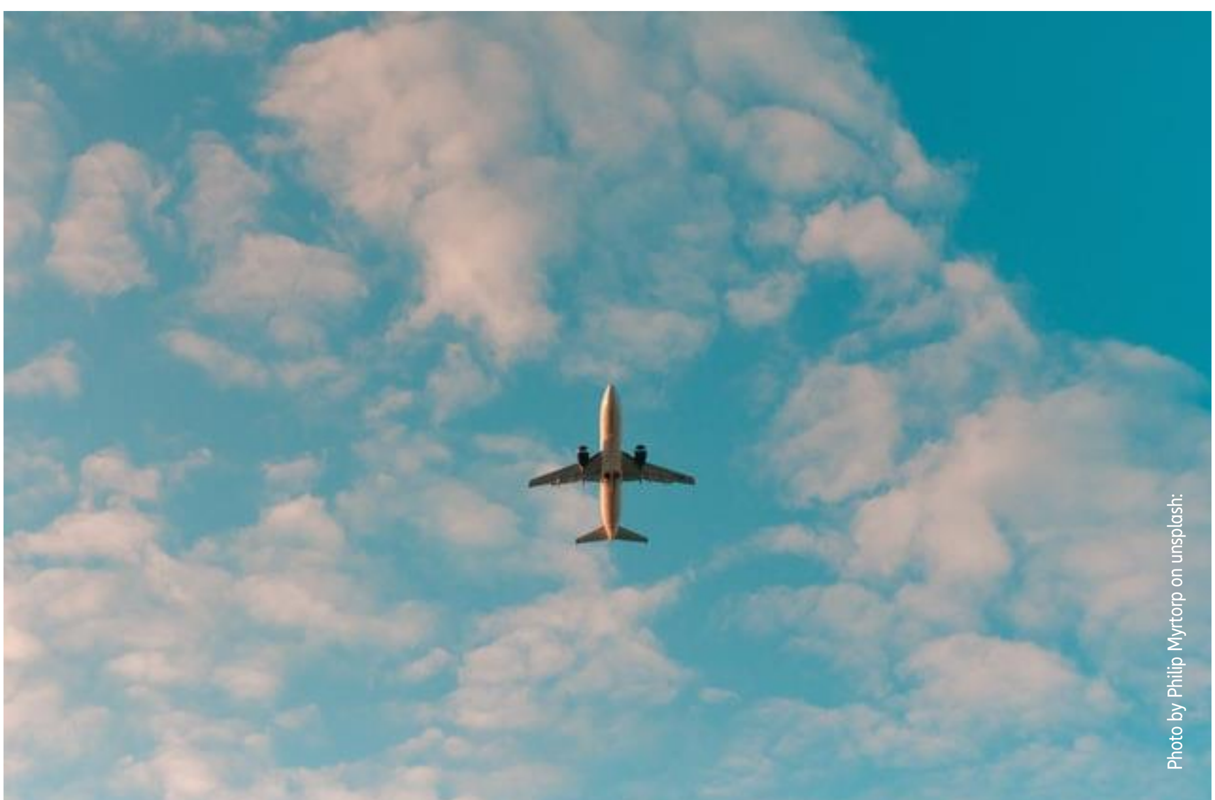
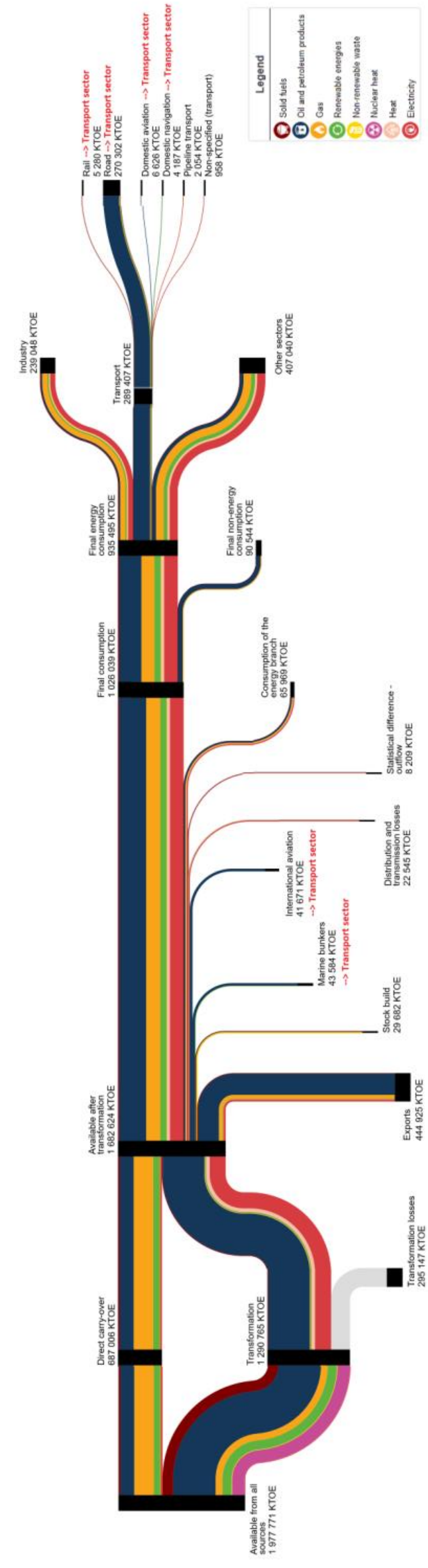


Photo by Philip Myrtorp on unsplash:

Appendix


Legend
Solid fuels
Oil and petroleum products
Gas
Renewable energies
Non-renewable waste
Nuclear heat
Heat
Electricity
Rail --> Transport sector
5 280 KTOE
Road --> Transport sector
270 302 KTOE
Domestic aviation --> Transport sector
6 626 KTOE
Domestic navigation --> Transport sector
4 187 KTOE
Pipeline transport
2 054 KTOE
Non-specified (transport)
958 KTOE
Industry
239 048 KTOE
Transport
289 407 KTOE
Other sectors
407 040 KTOE
Final energy consumption
935 495 KTOE
Final non-energy consumption
90 544 KTOE
Final consumption
1 026 039 KTOE
Consumption of the energy branch
65 969 KTOE
Statistical difference - outflow
8 209 KTOE
Distribution and transmission losses
22 545 KTOE
International aviation
41 671 KTOE
--> Transport sector
Marine bunkers
43 584 KTOE
--> Transport sector
Stock build
29 682 KTOE
Available after transformation
1 682 624 KTOE
Exports
444 925 KTOE
Transformation losses
295 147 KTOE
Direct carry-over
687 006 KTOE
Transformation
1 290 765 KTOE
Available from all sources
1 977 771 KTOE

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