



How to Make European e-SAF Production under RefuelEU Aviation Fly?

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▶ Key Takeaways

- While biogenic sustainable aviation fuels have picked up, synthetic alternatives are nowhere near to be produced in Europe.
- Airlines face the prospect of either large penalties or will trigger high imports, while customers will pay more and the market share of European airlines will shrink.
- Postponing regulation altogether risks threatening the many good projects that are being developed and that must take FID in 2026.
- Launching a limited baseload Made in EU e-fuels supply is a strategic priority. Adjustment to regulation should focus on maintaining a level playing field with non-EU competitors and using ETS allowances and payments as a facilitator.

Introduction

Three and a half years before the scheduled entry into force of the European regulation ReFuelEU Aviation (RFEUA), which requires aviation fuel suppliers at Union airports¹ to offer a sustainable synthetic alternative (e-SAF), no sizeable commercial production unit (greater than 10,000 tons per year) is active within Europe yet, nor has it even passed the Final Investment Decision (FID).

Is a major step in the European Union (EU) plans for decarbonizing air transport at risk of not happening, or at least being postponed for several years? Is Europe losing its bet to create a market for e-SAF? Under what conditions can this bet still be won? Could sovereignty and energy security preoccupations unlock necessary public support and help to overcome economic, financial, logistical or administrative obstacles?

ReFuelEU Aviation (RFEUA) in the context of air transport decarbonation

It is unanimously recognized that air transport will not be easy to decarbonize. Airplanes rely on jet fuels (kerosene of specific grades) for their propulsion and will not be able to recourse to other technologies before long (2050 or beyond, when direct use of hydrogen or batteries may become available).

Most of the jet fuels used today stem from fossil origin, being produced from oil or gas in refineries. Europe's plans have therefore been to set regulations to force the air sector to progressively replace these fossil jet fuels with fuels of the same characteristics ("drop-in") but synthesized from renewable feedstocks. RFEUA is at the core of this regulation in the EU, while the United Kingdom (UK) has set a very similar one.

Under ReFuelEU Aviation, airlines must blend Sustainable Aviation Fuel (SAF) into all fuel uplifted at Union airports, rising from 2% in 2025 to 70% in 2050, SAF being defined as "drop-in" aviation fuels that comply with the sustainability and greenhouse-gas (GHG) emissions-saving criteria of the Renewable Energy Directive (RED), and that are composed of one or more of the following:

- ▀ Synthetic aviation fuels produced from renewable hydrogen and captured carbon;
- ▀ Advanced biofuels produced from feedstocks listed in Annex IX Part A of the RED (e.g., agricultural residues, forestry residues, algae, etc.);
- ▀ Other biofuels produced from feedstocks listed in Annex IX Part B of the RED (e.g., used cooking oil, animal fats category 1 & 2);

1. Union airports are all airports with a passenger traffic of $\geq 800,000$ per year or $\geq 100,000$ tons freight throughput. Airports in "outermost regions" are excluded. Airports in scope are expected to cover roughly 95% of all EU aviation traffic.

- Recycled carbon aviation fuels (RCAFs) produced from industrial waste gases or unavoidable non-recyclable waste;
- Renewable hydrogen for direct use in aircraft (although this is not a drop-in fuel, it can count toward the SAF target);
- Synthetic low-carbon aviation fuels produced from non-fossil low-carbon hydrogen, provided they achieve greater than or equal to 70% lifecycle GHG savings.

Within this mandate, a hard sub-mandate applies for synthetic aviation fuels produced from renewable hydrogen and captured carbon *or* synthetic low-carbon aviation fuels² produced from non-fossil low-carbon hydrogen, provided they achieve $\geq 70\%$ lifecycle GHG savings. In this paper, this sub-mandate will be referred to as the “e-SAF sub-mandate”.

Eligible types of SAF under RFEUA and synthetic aviation fuel mandates³

"SAF" mandate		"Synthetic aviation fuel" sub-mandate	
Synthetic aviation fuel		Renewable fuels of non-biological origin (RFNBO)	Hydrogen or liquid fuel complying with RED II RFNBO criteria (e-fuels), the energy content of which is derived from renewable resources
Aviation biofuels	Advanced biofuels: biofuels made from feedstocks in RED-II Annex IX-A, such as municipal solid waste, agricultural or forestry residues	Synthetic low-carbon aviation fuels	Hydrogen or fuels made from low-carbon hydrogen, the energy content of which is non-fossil and non-renewable, i.e., nuclear
	Biofuels made from feedstocks in RED-II Annex IX-B, currently used cooking oils (UCO) and animal fats		
	Other RED-II eligible biofuels, with the exception of "food and feed" biofuels, e.g., cat. 3 animal fats		
Recycled carbon fuels (RCF)	Fuels whose energy content is derived from waste fossil energy, e.g., steel mill or refinery waste gases. Needs to comply with the RED-II GHG methodology for RFNBOs and RCFs.		

Source: SkyNRG.

2. The second category has been introduced to allow the use of nuclear electricity.

3. "Disentangling ReFuelEU: How Will It Shape the SAF Market?", SkyNRG, November 24, 2023, available at: <https://skynrg.com>.

It is important to note that SAF and e-SAF mandates apply to fuel suppliers that provide fuel uplift for all flights departing from the concerned airports. That means that:

- ▀ Fuel suppliers must provide the mandated SAF/e-SAF shares;
- ▀ Airport managing bodies must ensure SAF access;
- ▀ Aircraft operators must uplift fuel for the entire flight (anti-tankering rule).

Under RFEUA, e-SAF hard sub-quota should rise from 1.2% in 2030 to 5% in 2035, 10% in 2040, and 35% in 2050. Based on recent years' consumption, that would mean about 600,000 tons/year (yr) of e-SAF in 2030-2031, 2 metric tons (Mt)/yr in 2035, 4 to 5 Mt/yr in 2040 and +15 Mt/y in 2050, assuming. At the same time, the UK sub-mandate—set at 0.2% in 2028 and rising linearly to 3.5% in 2040—would add approximately 20 kiloton (kt)/yr of e-SAF in 2028, 60 kt/yr in 2030, 200 kt/yr in 2035, and 350 kt/yr in 2040, assuming a stable UK jet fuel demand of 10 Mt/yr.

Why these sub-mandates for e-SAF? The sub-mandates stem from the fact that Aviation Biofuels or Recycled Carbon Fuels are limited by the quantities of feedstocks they are made from (used cooking oils, animal fats, agricultural or forestry residues, etc.), while e-SAF could theoretically be produced without limitation (using electrolytic Hydrogen – H₂, and biogenic or atmospheric carbon dioxide – CO₂).

How are e-SAF to be produced? E-SAF production results from a complex Power-to-Liquid (PtL) operation. Two major pathways are considered today: (i) Reverse Water Gas Shift (RWGS) + Fischer-Tropsch (FT) (ii) Methanol-to-Jet (MTJ).

Until recently, RWGS + FT was considered the most mature one, used in most of the current projects/pilots or feasibility studies. It includes the following steps:

- ▀ Production of renewable or low-carbon hydrogen via electrolysis;
- ▀ Capture or supply CO₂;
- ▀ Reverse water gas shift converting CO₂ + H₂ → CO + H₂O (syngas);
- ▀ Syngas conditioning → adjust H₂/CO ratio;
- ▀ FT synthesis → produces a mix of wax, distillates and light gases;
- ▀ Upgrading/refining → hydrocracking, isomerization, distillation;
- ▀ Fractioning and blending to separate the ASTM-certified Jet Fuel fraction.

MTJ is gaining momentum as a credible rival, based on the following chain:

- ▀ Production of renewable or low-carbon hydrogen via electrolysis;
- ▀ Capture or supply CO₂;
- ▀ Methanol synthesis from 3H₂ + CO₂ → CH₃OH + H₂O;
- ▀ Methanol conversion to hydrocarbons (MTG Reactor);
- ▀ Hydrocrack and isomerize to jet fuel range;

- ▀ Fractionate and blend to ASTM D7566 jet fuel (in certification process).

In both cases, each brick of the process is reputedly well-known, but their full integration to produce e-SAF is novel and presents significant industrial challenges. Large-scale production units (over 10,000 t/yr seems a minimum to ensure a certain level of competitiveness) must be built from scratch, at high investment costs (in the range of €1 to €2 billion).

Access to abundant electricity, renewable or low-carbon, is key. E-SAF are essentially electricity-derived fuels, requiring an order of magnitude of 40 megawatt hours (MWh) of electricity per ton, i.e., 4 terawatt hours (TWh)/yr electricity for a 100,000 t/yr PtL plant. Most of this electricity is used to produce electrolytic hydrogen, which is the first critical molecule, having in mind that 1 ton of e-SAF requires approximately 0.7 t H₂.⁴

CO₂ is the second critical molecule. E-SAF require a sustainable, long-term CO₂ source. On a pure stoichiometry basis, 3.1-3.3 t CO₂ are needed per ton of e-SAF, but in industrial conditions, about 5 t CO₂ would be requested. In the first times, biogenic CO₂ should be the preferred choice on the grounds of availability, but when the quantities grow, it might be necessary to turn to atmospheric CO₂ from Direct Air Capture.

At the end of the day, adding high OPEX (operational expenditure) to large CAPEX (capital expenditure) leads to high production costs, depending on key factors such as electricity price, experience, CO₂ cost, CAPEX and financing costs, etc.

Production costs are hard to forecast. Reportedly, they could start from a high point of €6,000-€8,000/t or more (First-of-a-Kind Projects, power price around €60/MWh) to come down to €4,000/t (larger projects, Nth-of-a-Kind, cheaper power, etc.) or even below in a 2040/2050 horizon, once large, integrated PtL plants are built and cheap power contracts are secured.

In comparison, fossil jet fuel was typically priced around €750/t (€830/t with ETS) before the Iran-USA war, but prices close to €2,000/t are said to have been reached lately, and that may not be the end of the story.

At the same time, bio-SAF were offered at prices in the range of €2,000/t before the war, but they are also climbing. Incorporating e-SAF will lead to an additional cost for the airlines operating from EU airports. If this extra cost is identically reflected on the ticket prices, the resulting increase could be evaluated as follows:

- ▀ Considering an average fuel burn (all flights combined) of 3.5 l/100 passenger-km⁵ (2,8×10⁻⁵ t/passenger-km);

4 TWh/yr
electricity for a
100,000 t/yr PtL
plant

4. "Feedstocks Needs for E-Kerosene Production in 2035 and 2050", *Focus*, No. 4, IFP Énergies Nouvelles (IFPEN), 2025, available at: www.ifpenouvelles.com.

5. The International Civil Aviation Organization (ICAO) provides global averages of 3.3-3.7L/100 passenger-km, "ICAO Environmental Report: Destination Green: The Next Chapter", ICAO, 2019, available at: www.icao.int.

- ▀ Jet fuel price without ETS: €750/t;
- ▀ CO₂ emission factor: 3.16 tCO₂/t;
- ▀ EUA price: €150/tCO₂ (2030), €190/tCO₂ (2035);
- ▀ Using ~€1,200–1,350/t for intra-EEE fossil kerosene in 2030-35 ;
- ▀ e-kerosene price: €6,000/t (2030), €4,000/t (2035);
- ▀ Incorporation: 0.7% (2030), 5% (2035);
- ▀ Distances used:
 - 1,500 km = typical intra-EU flight (Paris–Rome, Frankfurt–Madrid);
 - 5,000 km = typical long-haul (Paris–Montreal, Amsterdam–Dubai).

Impact matrix on airline tickets

2030 – E-kero = €6,000/t – incorporation 0.7%

Segment	Fossil fuel price	Difference e-kero vs fossil	Extra-cost per ticket
Short-haul intra EEE (1,500 km)	€1,224/t (ETS inc.)	€4,776/t	≈ €1.4
Long-haul extra-EEE (5,000 km)	€750/t (without ETS)	€5,250/t	≈ €5.1

2035 – E-kero = €4,000/t – incorporation 5%

Segment	Fossil fuel price	Difference e-kero vs fossil	Extra-cost per ticket
Short-haul intra EEE (1500 km)	€1,350/t (ETS inc.)	€2,650/t	≈ €5.6
Long-haul extra-EEE (5 000 km)	€750/t (without ETS)	€3,250/t	≈ €22.8

Source: calculations by the author.

Thus, in 2030, the extra cost would be respectively of €1–2 for an intra-EU air ticket and +€5 on a long-haul ticket (one way). In 2035, the extra costs would be respectively of +€6 on an intra-UE ticket and +€23 on a long-haul ticket. That sounds acceptable to really make progress on the decarbonization route.

In this context, RFEUA has helped Europe to become the continent that counts the largest number of projects, followed by Asia and the United States.⁶ In Europe, France would have several competitive advantages to produce e-SAF, such as its low-carbon electricity grid, good availability of biogenic CO₂ and a large base of aviation industries.

Extra-European ultra-low-cost regions (the Middle East, parts of China, Chile, Australia) could plausibly achieve lower costs than the EU-low edge, especially after 2035.

Strong headwinds for e-SAF production in Europe

Despite RFEUA, strong headwinds have impeded e-SAF commercial production from taking off in Europe so far.

First, some incumbent aviation fuel suppliers have no interest in producing these e-fuels, as they supply jet fuel. Others have heavily invested in the adaptation of refineries to produce Bio-SAF (for example, TotalEnergies at Grandpuits or ENI at Gela). In general, oil majors are reluctant to invest in new e-SAF industries as they doubt demand for these expensive products will materialize.

One could think that the strict RFEUA penalty regime for those not incorporating e-SAF in their supplies would push them to start production, but it seems that this will not be the case and that they will purely and simply pass the penalties to air companies, if these penalties apply at all. Indeed, the financial charge of the penalties, if applied in strict accordance with RFEUA, would quickly become so huge that their implementation looks doubtful. Besides, the penalty regimes still need to be translated into the national law of each Member State, which is far from the case.

Decisively, the major oil suppliers also have control over the logistic chains that link refineries and storage to airports and airplane refueling installations.

In the general absence of the incumbents, e-SAF projects in Europe are carried by newcomers: start-ups such as the German Ineratec, the French Verso or Elyse, or businesses that are totally foreign to the aviation fuel industry (ENGIE, EDF). They all start from scratch as they do not have any established industrial basis in jet fuels. They need to build everything: technology, assets, skills, experience, finance, access to market... Suffice it to say that the task is harsh.

Consequently, none of the many projects initiated in Europe has taken FID so far. As foreseen by the incumbent fuel suppliers, they are struggling to manage to sign the long-term offtake agreements (10 years or more) requested to finance their projects.

e-SAF projects in Europe are carried by newcomers

6. See Annex 3: E-SAF projects in C. Mutrelle, F. Catte and A. Kunkel, "The E-SAF Market: Europe's Head Start and the Road Ahead", *Report*, Transport & Environment (T&E), June 2025, available at: <https://uploads.transportenvironment.org>.

This makes the transition with airlines that are the ones concerned by offtake agreements if traditional fuel suppliers do not show interest.

Airlines are very cautious about the idea of engaging into such contracts. They fear being locked in for many years, with prices becoming too high once the e-SAF market takes off and production costs fall, making them lose competitiveness in the tough air transport business. They are also concerned by additional fuel costs that could eat into their thin profit margin.

On the other hand, if penalties apply, they will quickly hurt airlines more. On March 19, 2026, Airlines For Europe (A4E), a coalition of the major European airlines, has released a declaration pointing that “e-SAF remains a very nascent technology and the e-SAF production sites that have reached FID are currently expected to produce a mere 0.71% of the volumes mandated under the 2030 EU e-SAF sub-mandate (600 kt) – that’s a whopping 99.3% of e-SAF missing”, and that “If fines were imposed due to a failing market, passengers would be forced to pay €7-9 billion of penalties, pushed onto airlines by fuel suppliers, with no environmental benefits” and asking that “the 2030 e-SAF sub-mandate must be postponed until e-SAF is sufficiently available and affordable, and the regulatory framework is redesigned to support diverse, affordable production pathways.”

It also asks that “to ensure a level playing field, costs on extra-EU routes not covered by the SAF mandate should also be addressed by a basket of measures, including a mechanism addressing carbon leakage – such as the SAF-Border Adjustment Mechanism for passenger aviation”.

In a nutshell, RFEUA’s e-SAF sub-mandate is in great danger of not being implemented on the scheduled date of January 1st, 2030, as its main retainers drag their feet. If projects do not take FID in the course of 2026, it will be for sure too late to meet the schedule.

What is needed to unblock the situation?

Project developers are hostile to any postponement of RFEUA obligations. They have quickly reacted to the A4E declaration by a letter sent on March 20, 2026, where they “encourage the European Commission to maintain the course and uphold the integrity of the ReFuelEU framework”.⁷ What is needed to unblock the situation?

Project SkyPower, a group of 75 major industry members, financial institutions, associations and non-governmental organizations (NGO) from across the European e-SAF ecosystem, has written to the European Commission in February 2026 to propose five key policy interventions to unlock FIDs for the first e-SAF projects in the EU:

- Make e-SAF a strategic priority in the EU’s Clean Industrial Deal and the Sustainable Transport Investment Plan (STIP);

7. This letter was coordinated by the following organizations: Verso Energy, Technip Energies, BpiFrance, T&E, Honeywell, EDF-Hyynamics, ENGIE, France Hydrogène, Aéro Décarbo, MGH Energy, Power 2 X, Hy24, H2V, H4Fos, Hy2gen, SkyNRG.

- ▀ Recycle EU Emissions Trading Scheme (ETS) revenues from aviation to capitalize a new government-backed market intermediary that would enter into long-term purchase contracts with e-SAF producers and short-term sales contracts with offtakers;
- ▀ Establish a bridging mechanism until the capitalized market intermediary comes online, to give early adopters priority access to the new funding instrument;
- ▀ Provide long-term certainty over the EU's mandates, production criteria and penalties;
- ▀ Mitigate project-on-project risk via government-backed safeguards and financing structures.

Proposition #2 above is particularly key. It somehow copies the public support mechanism used to develop renewable electricity projects:

- ▀ On the supply side, a government-backed market intermediary would offer e-SAF developers the long-term offtake contracts they are looking for, with prices resulting from public auctions and possibly Contract for Difference arrangements, allowing the public entity to recoup its losses should market conditions improve.
- ▀ On the demand side, the same intermediary would market the purchased quantities through short-term contracts, selling through auctions to airlines or fuel suppliers, who are thus guaranteed not to be locked in too high prices.

The crucial point is that this government-backed intermediary would bear the price difference between offer and demand, which is completely unknown for the time being and will remain so as long as production remains scarce and airline willingness to pay is uneasy to define, in a nutshell, until a real market establishes itself.

Member States such as Germany have declared their readiness to support the creation of such a mechanism. The German government has said it is ready to spend €2 billion over 10 years. Such an amount would cover a €2,000/t price difference for 100,000 tons over the 10 years. If the scheme were extended to the 600,000 tons to be produced in 2030, the cost would reach €12 billion just for one year of production, then an additional €20 billion for the 2032 production and so on. On the other hand, the revenues from the ETS allowances might be estimated around €12 billion/yr, based on +120 Mt CO₂/yr emitted by the airlines and an ETS price remaining around €80/t. In terms of figures at least, the idea to recourse to the ETS revenues makes sense.

T&E, a well-respected NGO focused on decarbonizing transport in Europe by 2050, points out additional key recommendations in its June 2025 report⁸ that deserve to be reported in extenso:

- ▀ Accelerate the deployment of Direct Air Capture (DAC), which is the only sustainable, long-term CO₂ source compatible with e-fuel production. The EU should adopt DAC-specific incentives to speed up deployment, reduce costs, and ensure future-proof CO₂ supply for aviation e-fuels”.

8. “The E-SAF Market: Europe’s Head Start and the Road Ahead”, op. cit.

- Guarantee fair and open access to jet fuel infrastructure:
 - Review competition barriers. EU and national competition authorities should investigate whether current ownership and access conditions for jet fuel infrastructure restrict competition.
 - Mandate open access across the supply chain. Reinforce ReFuelEU's airport provisions to ensure SAF producers can access critical infrastructure, such as pipelines, blending facilities, and storage terminals, on fair and non-discriminatory terms.
 - Declare airport fuel farms as centralized infrastructure (CI), as allowed under Directive 96/67/EC. Member States and airport operators should require that storage and hydrant systems be designated as CI, ensuring non-discriminatory access and fair pricing for SAF suppliers.
 - Ensure open access to strategic pipelines. EU and national competition authorities should ensure fair third-party access to key off-airport infrastructure, especially major pipelines like the Rhein-Main Pipeline (RMR) that serve strategic hubs such as Frankfurt.
- Clarify definitions and enforcement mechanisms for e-SAF
 - Exclude renewable hydrogen used in Hydroprocessed Esters and Fatty Acids (HEFA) from compliance. The Commission should refuse to endorse certification schemes that consider that green hydrogen added during bio-refining processes (e.g., HEFA upgrading) can qualify towards the e-SAF mandate. This interpretation, if allowed, would divert compliance volumes away from genuine e-fuels and weaken the investment case for new synthetic fuel plants.
 - Make financial penalties for non-compliance enforceable and clearly defined. All Member States must urgently embed ReFuelEU penalties into national legislation and, preferably, assign specific monetary values to them. For consistency, values should be benchmarked to European Union Aviation Safety Agency (EASA) price references (e.g., €14,000/t).
 - Treat non-compliance penalties as accounting liabilities. Regulatory authorities and auditors should recognize expected non-compliance costs as financial liabilities on obligated parties' balance sheets. This would ensure fuel suppliers are held accountable by their shareholders if they fail to sign long-term offtake agreements or bring e-kerosene production online”.

Could other concerns help to initiate e-SAF production?

It seems that so far, public decision-makers in the EU, whether at national or at EU level, have been hesitant to engage the financial support and measures that are required to initiate e-SAF production.

Their hesitations may seem legitimate. There are several arguments that play against too large a use of public money. Critics observe that e-SAF mandates (replacing €1,000/t ETS-included Jet Fuel with €6,000/t e-SAF) imply a very high abatement cost, in the range of €1,000/tCO₂.⁹ That is indeed:

- ▀ 5–7× higher than current EU ETS prices (€70-100/tCO₂);
- ▀ 5× higher than 2030 ETS projections (€150-200/tCO₂);
- ▀ Higher than almost any other decarbonization option in the economy.

This is why e-SAF mandates are not justified by carbon pricing alone. They are justified by:

- ▀ technology-forcing (creating early markets);
- ▀ industrial policy (building EU PtL capacity that increases electricity demand);
- ▀ energy security (domestic synthetic fuels);
- ▀ long-term decarbonization of hard-to-electrify aviation.

Technology-forcing and industrial policy call for a specific vigilance towards China in particular. One has in mind what happened in the renewable industries, where Europe has been completely overtaken by China in the production of photovoltaic panels and lithium-ion batteries, just to name a few.

The fear is that history repeats itself with the production of e-SAF, because indeed China is beginning to show a lot of initiatives in the field, as evidenced by the number of projects under development there (see list of projects in annex). This is even more to be feared since China has a great deal of experience in the field of methanol and its chemistry, which it could use to develop a Methanol to Jet route.

Energy security is emerging as another powerful consideration that may ease general public acceptance of public money spending and push politicians to bring stronger support to e-SAF projects.

9. Burning 1 ton of fossil jet fuel emits: 3.16tCO₂(combustion) +upstream emissions. Life cycle assessments (LCA) typically round this to ~5 tCO₂ avoided when switching to RFNBO e-kero, because:

- RFNBO e-kero is counted as zero-emission at combustion under EU rules;
- Fossil jet fuel has 3.16 tCO₂ from combustion;
- Upstream emissions (extraction, refining, transport) add 1.5-2 tCO₂;
- Total avoided ≈ 4.5-5.2 tCO₂ depending on the LCA boundary.

Energy security concerns are gaining ground at the military level in the EU, both nationally and within NATO,¹⁰ with a specific focus on the supply of fuels for military air or ground vehicles. Domestic production would reinforce security and sovereignty. European air forces should become involved and also commit to take volumes and options as part of the overall defense preparedness effort.

Conclusion

It is difficult to predict which of RFEUA's pros and cons will prevail, but time is running out for the start of implementation in 2030. The year 2026 will be decisive for the respect of the regulatory schedule. The solutions that have been identified to overcome headwinds do not look unfeasible when considering what is at stake. What matters decisively is now to unleash the first projects in Europe and keep options open to adjust post-2035 targets later, while ensuring that no European airlines lose market share versus competitors.

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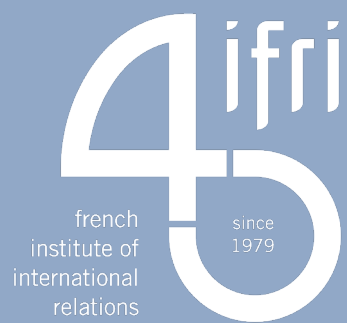
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10. NATO is a military alliance established in 1949 to ensure the collective defense and security of its member states. Its primary purpose is to guarantee the freedom and security of its members through political and military means, promoting mutual defense in response to any attack.



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