



FEDERCHIMICA
AISPEC **GAIL**
GRUPPO AZIENDE INDUSTRIALI
DELLA LUBRIFICAZIONE

LUBE DAY 2024

Transizione energetica, carbon footprint e lubrificazione:
calcolo, gestione ed esperienze di filiera



POLITECNICO
MILANO 1863

DIPARTIMENTO DI ENERGIA

TRANSIZIONE 2035: quali combustibili per motori termici?

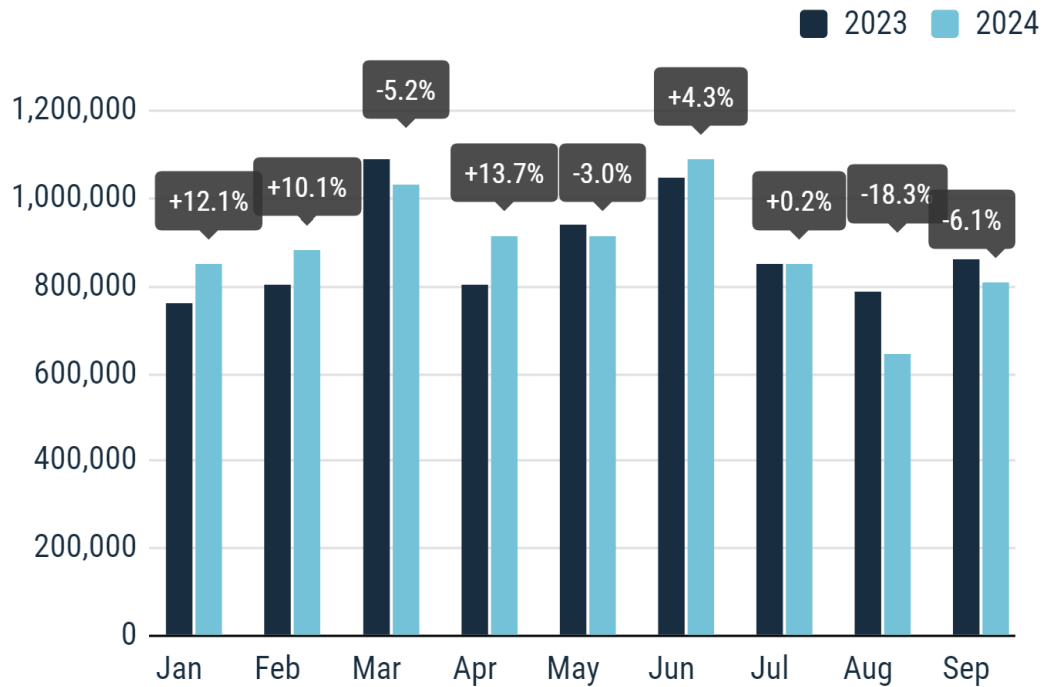
Prof. Carlo Giorgio Visconti

Milano, 29.10.2024

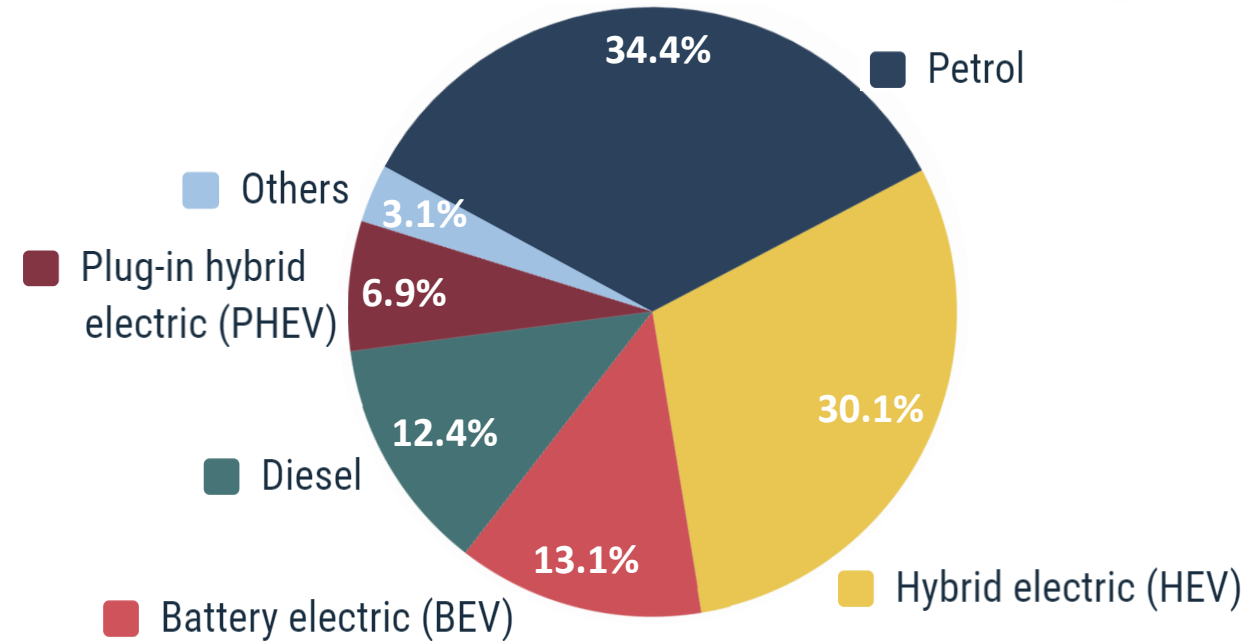
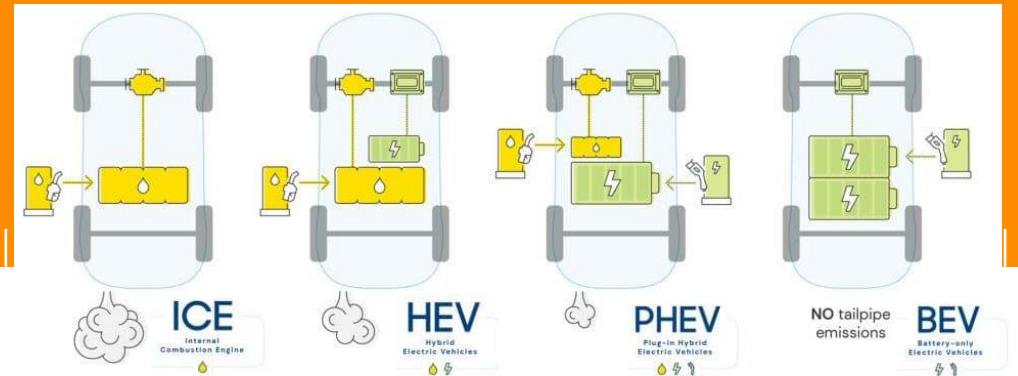


why are ICEs still very important?

EU car market trends in 2024



With respect to 2023, **new EU car registrations remained stable** (+0.6%, almost reaching 8 million units), even if, in the last 2 months, a downward trajectory is characterizing the EU market

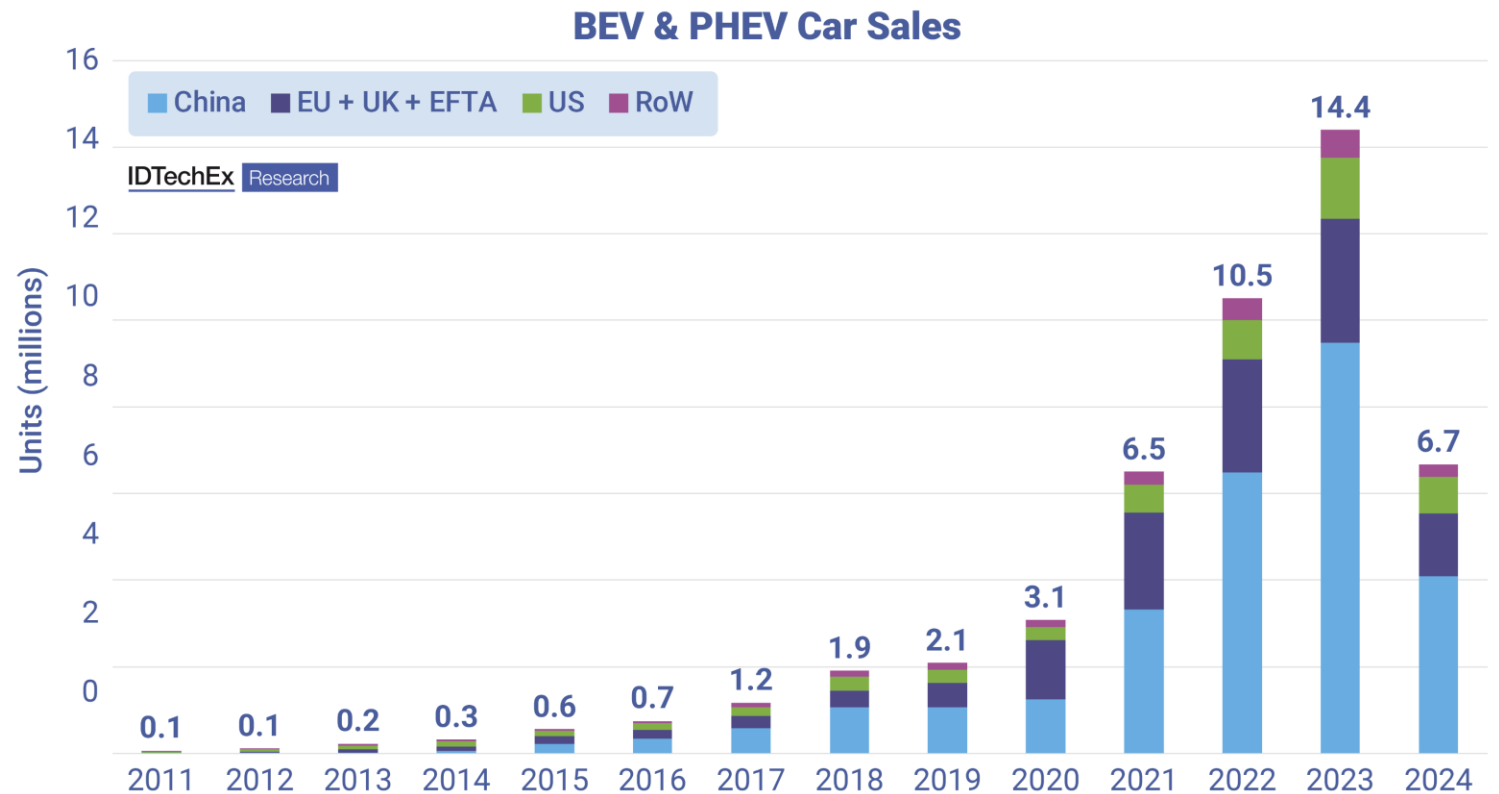


The market is still dominated by vehicles with ICEs onboard.
BEVs only account for 13.1%

why are ICEs still very important?

some numbers on the world

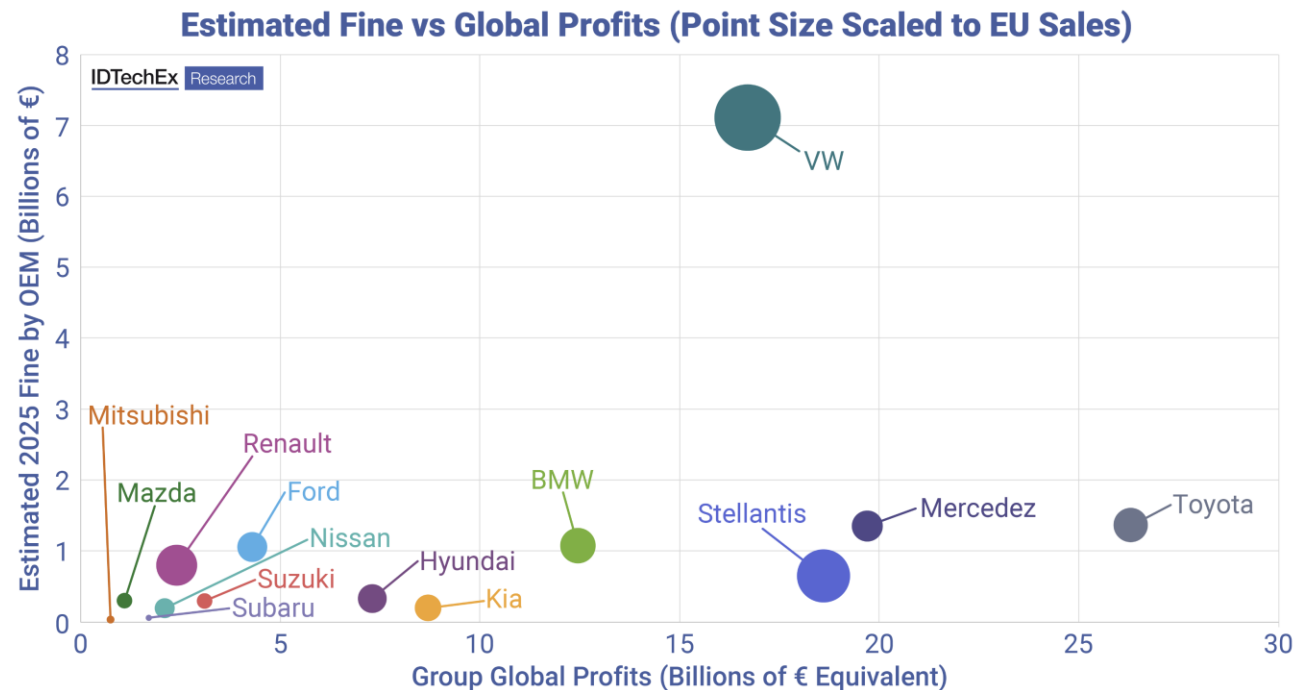
- In the world, there are more **about 1'500 million circulating road vehicles based on ICEs**
- even today, **BEVs or PHEVs sold every year are less than 15 million.** The remaining 65 million vehicles sold every year are based on ICEs



what about the future?

uncertainty is the keyword in EU (and USA)

- Up until now, BEVs market has primarily been driven by consumer preference and generous government incentives.
- Now the landscape is shifting, particularly in EU, where governments are withdrawing subsidies (the 'carrot'), and replacing them with tougher CO₂ regulations (the 'stick'): **from now on, increasingly large shares of a manufacturer's sales must be zero emission to avoid astronomical fines.**
- For the EU, the next tightening will be in 2025, with a further hike in 2030 before a full ICE ban in 2035: **in the absence of a major change in regulations, BEV sales must be drastically improved next year to avoid billions in fines.**
- Although EU has the strictest CO₂ policies, the USA also has two sets of regulations from the Environmental Protection Agency and California Air Resources Board, which also will drive **increased BEVs sales in the USA**, the world's second-largest car market.



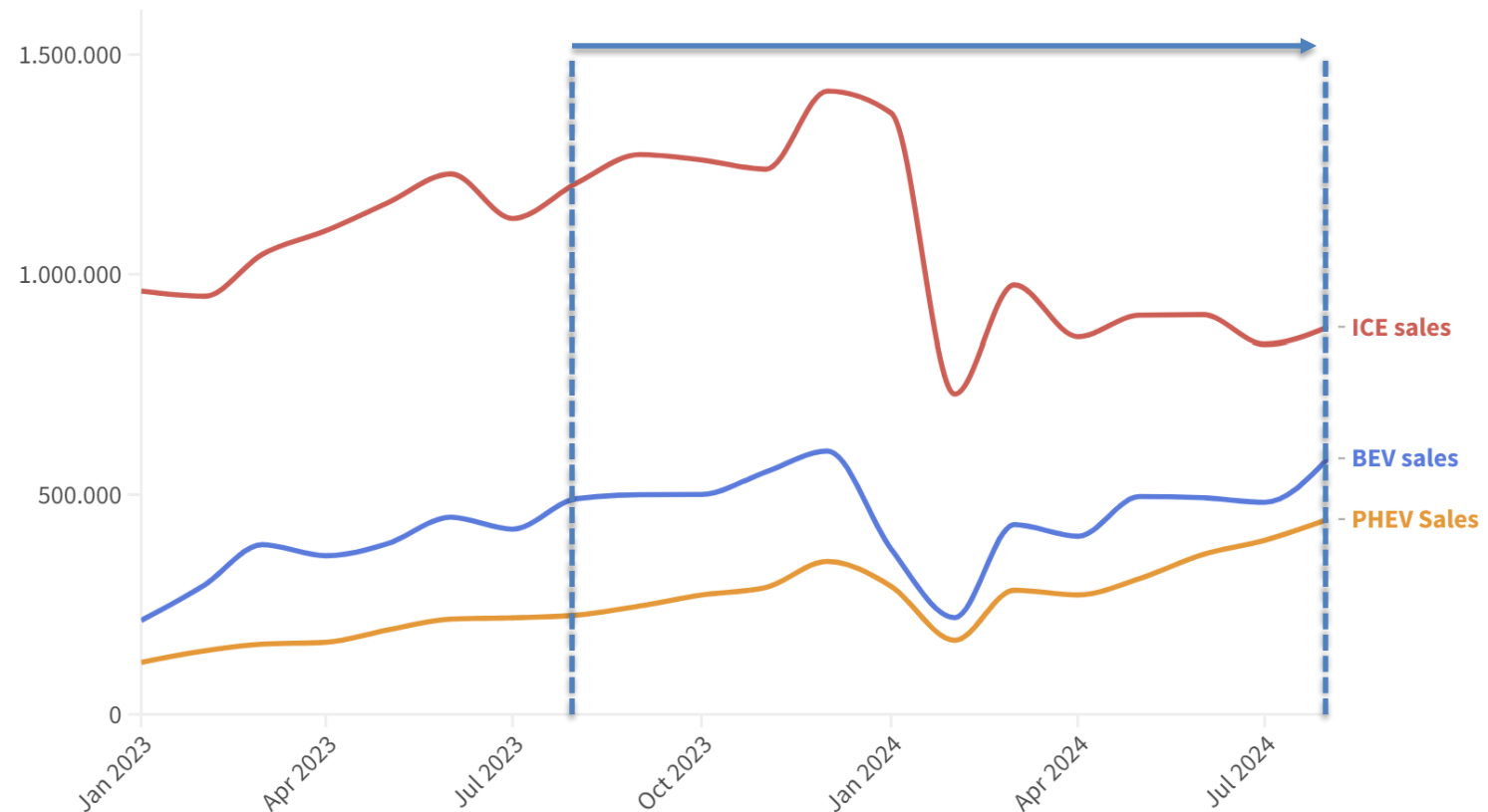
what about the future?

CN, is also demonstrating to appreciate PHEVs...

- China, the world's biggest car market by volume, could reach the extraordinary milestone in 2024 of 50% of new car sales being 'New Energy Vehicles' (NEVs, incl. BEV and PHEV)
- Important notice: **plug-in hybrids are proving especially popular in China (growing share, now at 43% of NEVs), as unlike other regions they are treated no differently from a subsidy perspective than BEVs despite essentially being ICE cars with an electric motor...**
- Trends within the year (max sales peak in Dec and min sales peak in Jan) are driven by year-end incentives and tax advantages.

Monthly passenger car vehicle sales per fuel type in China

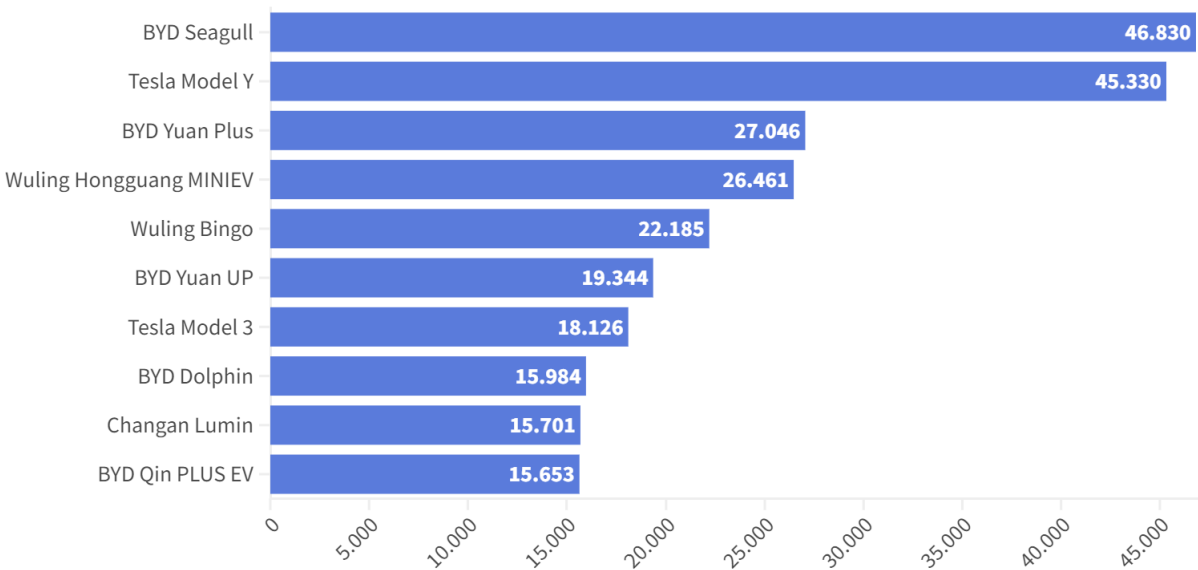
Jan 2023 - Aug 2024



what about the future?

CN preferences: small BEVs and medium/large PHEVs

Top 10 best selling passenger car BEV models in China
August 2024

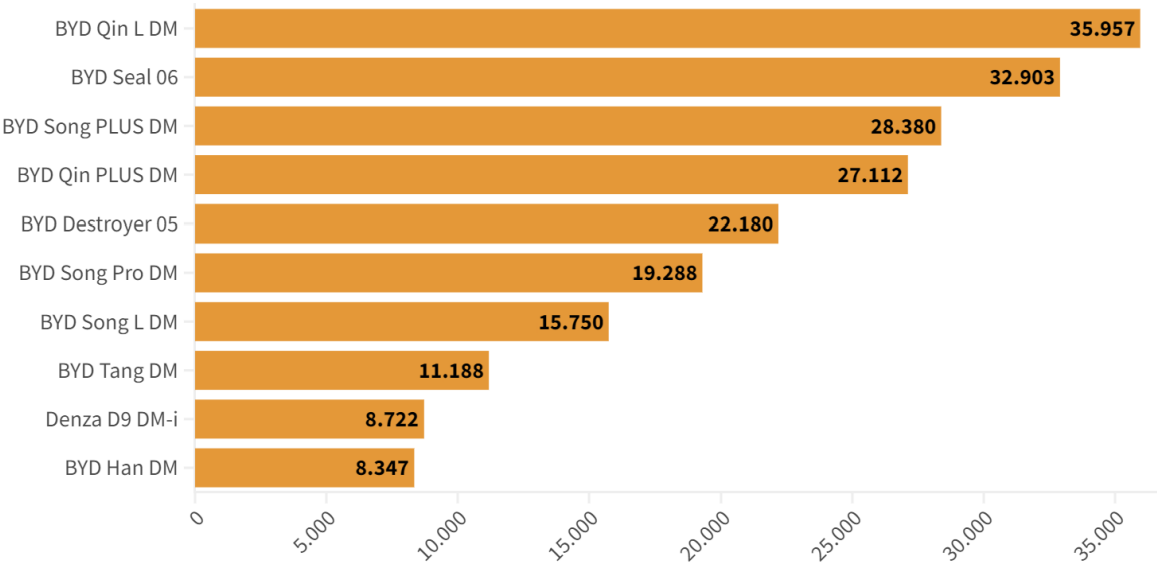


QUATTORRUOTE

BYD Seagull
L'elettrica low cost arriverà in Europa

di Mirco Magni | Pubblicato il 26/04/2024 | 72 commenti

Top 10 best selling passenger car PHEV models in China
August 2024



alVolante.it
La BYD che fa 2.100 km con un pieno

di byd qin l
di Andrea Spitti
Pubblicato 06 giugno 2024

How to decarbonise the old and new vehicles based on ICEs?

My take-home-messages at Lube Day 2023

**LUBE
DAY
2023**



1. The future of mobility will be characterized by many complementary technologies:

- a) electric vehicles
- b) H₂ fuel-cells vehicles
- c) internal combustion engines fed with bio-fuels and e-fuels
- d) hybrid solutions

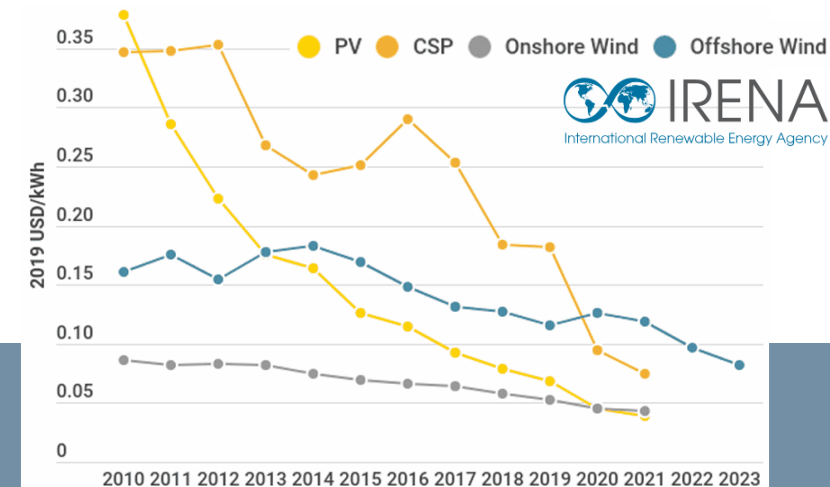


2. Technologies exploiting the existing infrastructure and vehicles will lead the transition in the next decades. Only later, more advanced solutions will come.

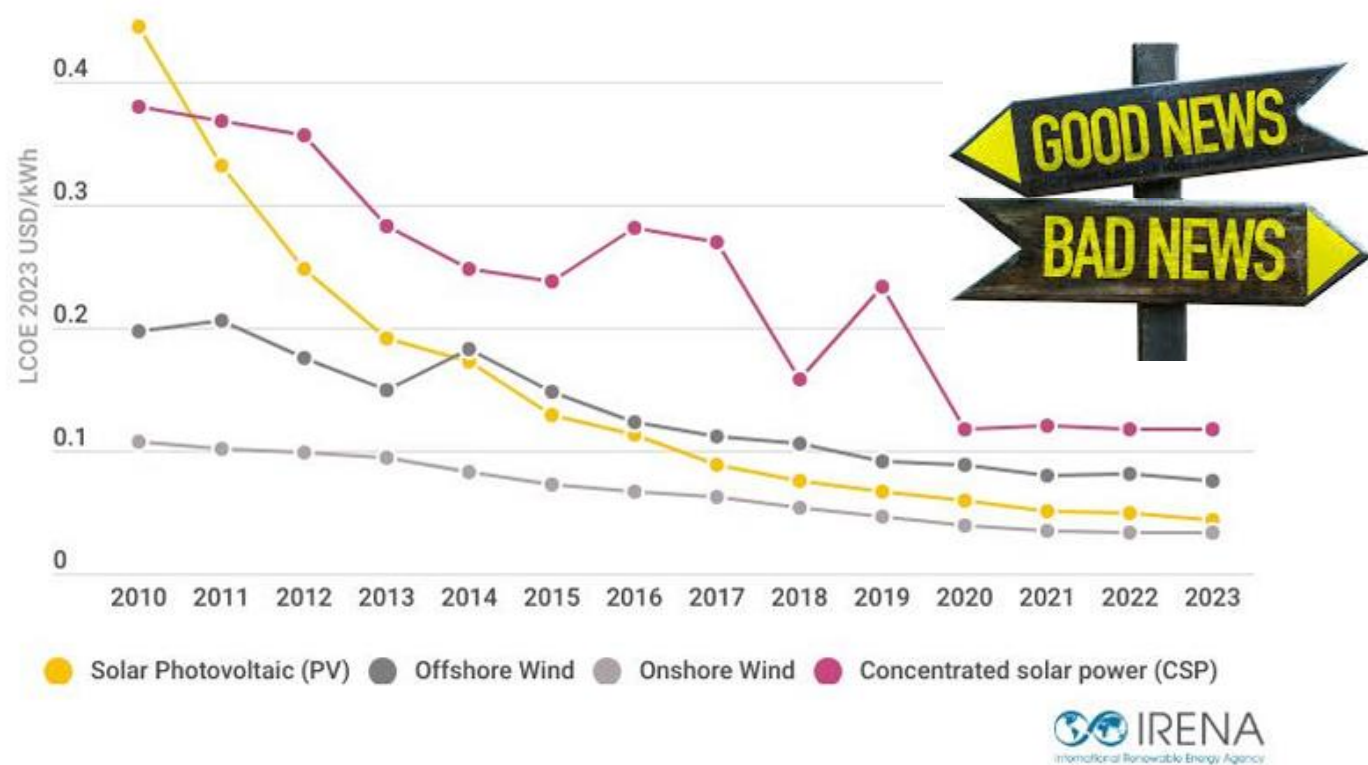
3. Industrialization is in the pipeline: new synthesis plants are expected in the next 10 years

4. To make competitive the new technologies based on renewable electricity:

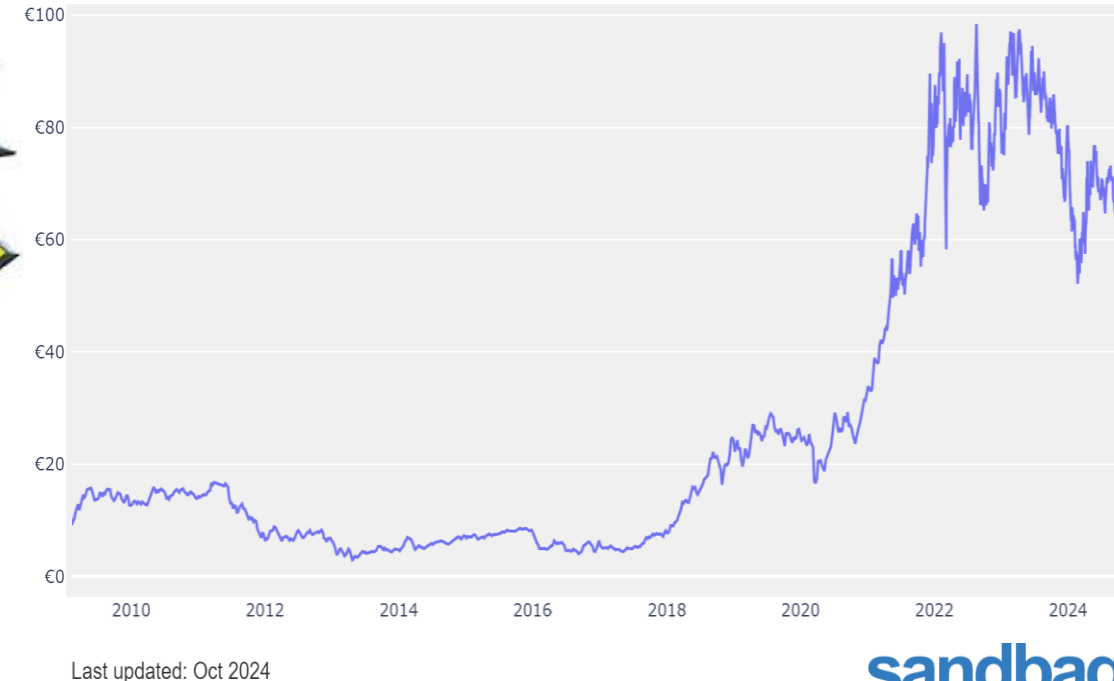
- a) the cost of renewable electricity (i.e. of green-H₂) must decrease
- b) the negative cost of CO₂ must increase (now 90 €/t)
- c) the efficiency of the synthesis processes and of ICEs must increase



cost of green-H₂ and CO₂



- LCOE trends for PV and wind power are **steadily decreasing**;
- off the record 473 GW added in 2023, 81% of newly commissioned, utility-scale renewable projects had **lower costs than their fossil fuel-fired alternatives**.



sandbag
smarter climate policy

Carbon price trend, controlled by EU Emissions Trading System, shows that, in the last 12 months, **the cost of emitting one tonne of carbon dioxide in Europe has decreased from about 90 to about 65 €**.

bio-fuels

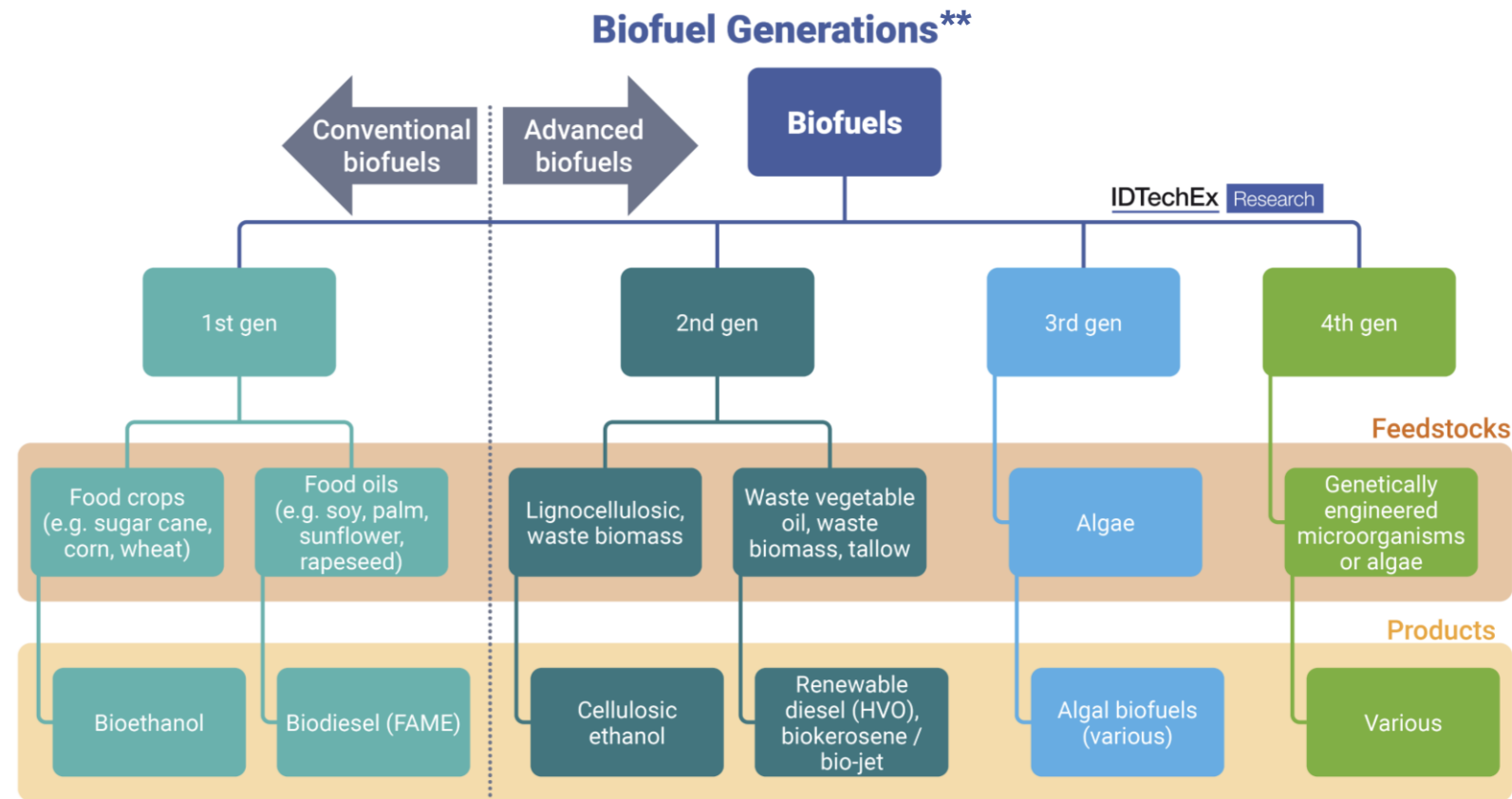
Biofuels are fuels derived from biomass, used as an alternative to fossil fuel-based transportation fuels. Biofuels are liquid fuels, apart from biomethane (obtained from biogas cleaning) and bioLPG (byproduct of HVO synthesis).

1st generation biofuels – **bioethanol and biodiesel** – are derived from edible food crops and oils

2nd generation biofuels – **cellulosic ethanol and HVO** – are produced using inedible organic parts of plants such as lignocellulosic biomass and waste vegetable oil. Ethanol can be converted to bio-jetfuel (ATJ – alcohol to jet)

3rd generation biofuels are produced from microalgae

4th generation biofuels are produced from genetically engineered microorganism and algae

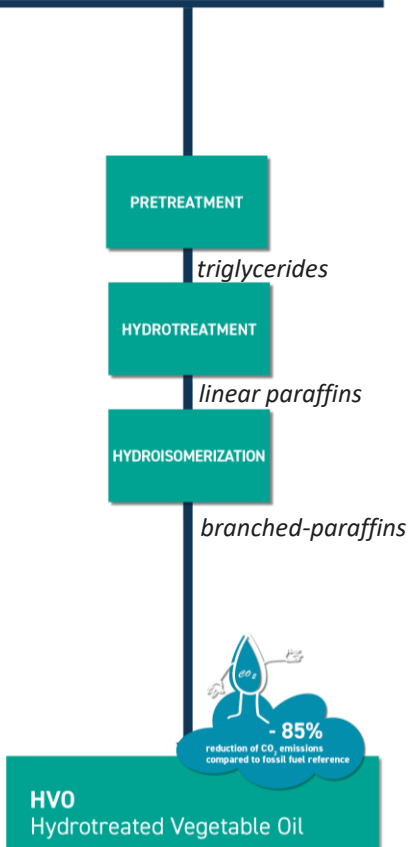


1st and 2nd generation bio-fuels are used today for ICEs



Vegetable oils,
used cooking oils

Animal fats

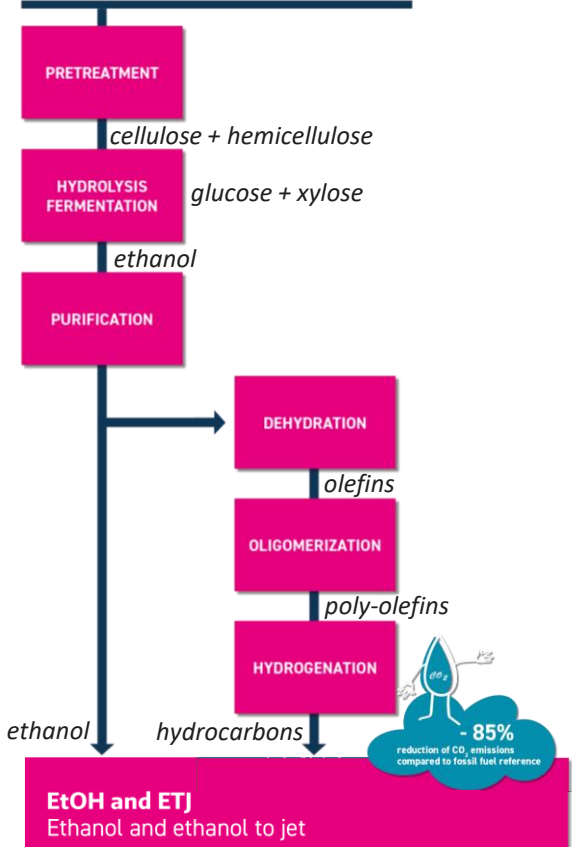


HVOlution (XTL)	super (E5)	diesel (B7)	diesel+ (B7)
100% HVO	5 vol.% ethanol	7 vol.% FAME	15 vol.% HVO



Forestry waste
and residues

Agricultural waste
and residues



bio-SAF is also available in some airports worldwide (Italy included)

The aim of SEA in this initiative is to accelerate the transition to a more sustainable aviation industry, strongly supporting the policies and initiatives for the decarbonisation of the aviation sector, in line with the global Net Zero 2050 objective and with the specific sector programs at international and national level, including the Italian National Airport Plan (“PNA”) assessment (October 2022 version) and EU Fit for 55 (Regulation EU 2023/2045 “ReFuelEU”).

That’s why SEA, in order to lower the cost of SAF at its Airports and to sustain the development of its use at Milan Airports, deployed these initiatives during the last years:

- SEA actively participate to national and European working groups aimed at defining future rules and policies to foster the use of SAF;
- In **December 2022** SEA signed an agreement with ENI to ensure the availability of SAF at Milan Airports.
- In **2023** SEA implemented a SAF Support program providing 500 € for each ton of pure SAF refueled at Milan Airports. Propose this Remuneration Scheme to partially offset the higher cost of SAF than traditional jet fuel and encourage airlines to increase their use of sustainable fuels operating in its Airports.



SEA to make the use of sustainable fuels more attractive is confirming for **2024** the remuneration plan for the use of SAF for Airlines that fill up their planes with it in both Milan Airports.

In line with the rare experiences already existing in other European airports, SEA acknowledges to recognize for the obligation deriving from the participation to SAF Support Program a remuneration equal to € 800/t of “neat SAF” purchased by the companies and effectively supplied at Linate and Malpensa airports during 2024.

Milano, 15/04/2024

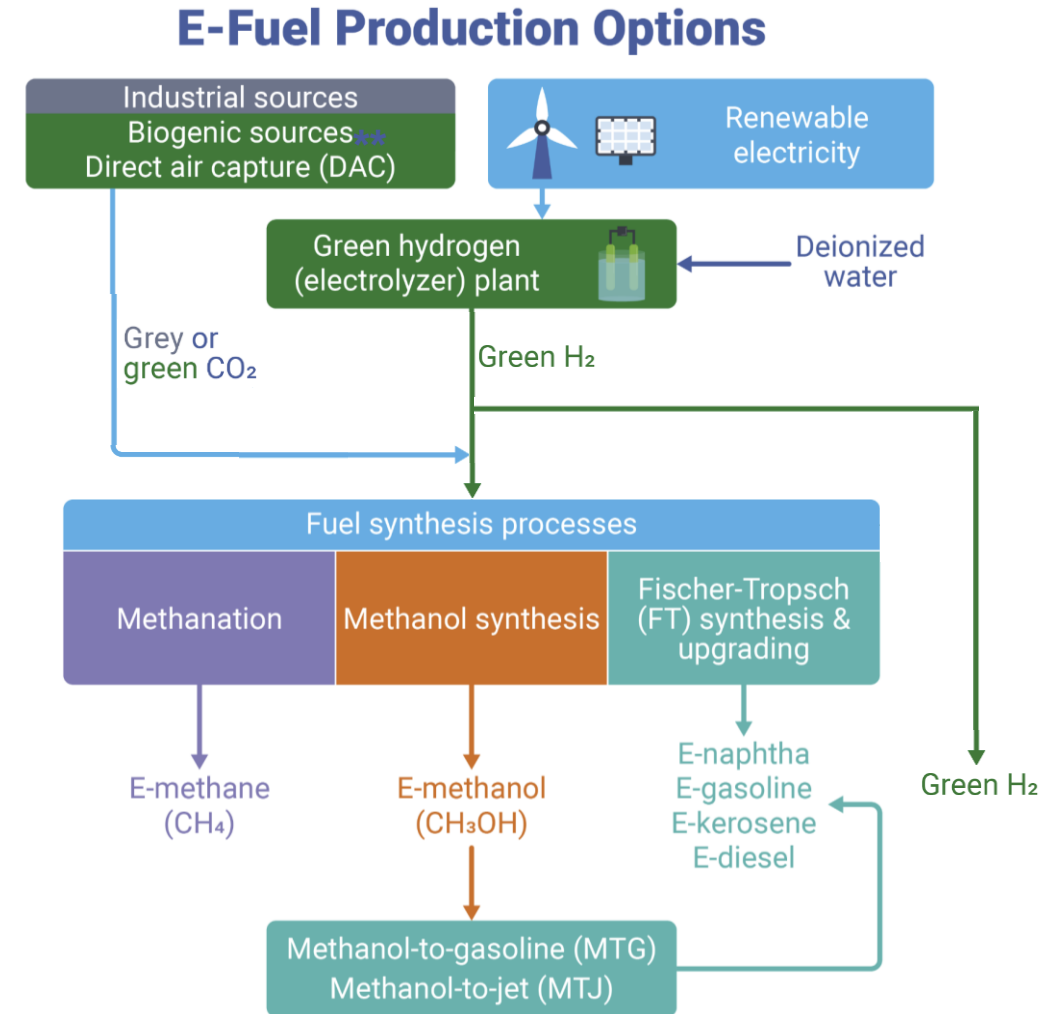
S.E.A. Società per Azioni Esercizio Aeroportuali
Ing. *Giorgio Medici*
DIRETTORE ENVIRONMENT AND FUNDED INITIATIVES

e-fuels (aka PtL fuels)

efuels are synthetic fuels produced by combining green hydrogen (from water electrolysis using renewable electricity) with captured (from industrial sources, biogenic sources or from the air) CO₂.

Gaseous and liquid efuels are available.

- **Hydrogen** is the simplest e-fuel
- **Methane (or RNG – Renewable Natural Gas)** is obtained in a once-through process from CO₂ and H₂ over Ni or Ru-based catalysts.
- **Methanol** is obtained in a recycle process from CO₂ and H₂, mostly over CZA catalysts.
It can be used as e-fuel (marine sector), as hydrogen-carrier or as feedstock for MTX processes (MTG – Methanol to Gasoline, MTJ – Methanol to Jet-fuel).
- **Fischer-Tropsch products (or e-crude)** are obtained from CO₂ and H₂ through a two-step process going through the conversion of CO₂ into CO (Co-based FT-catalysts), or through the direct conversion of CO₂ (Fe-based FT-catalysts). The “crude” is then upgraded to any liquid hydrocarbon e-fuels for transportation.

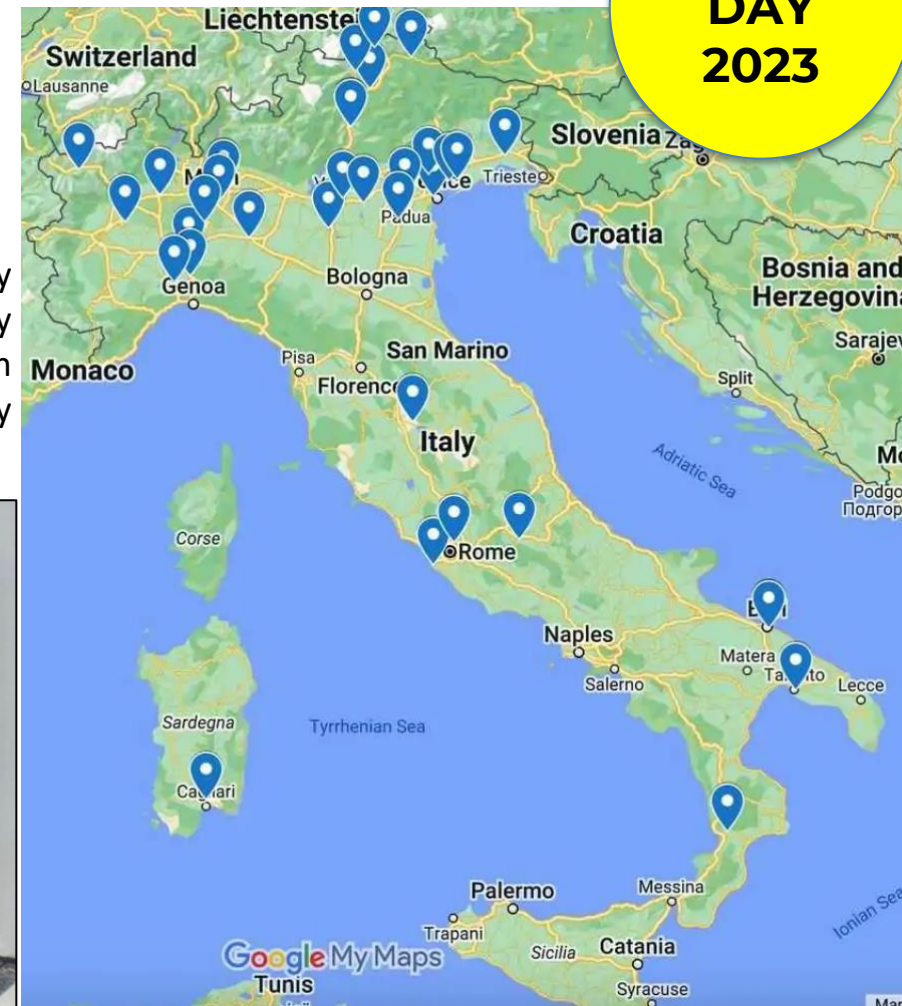


Green H₂: one refuelling station open to the public in Italy today and only other 36 are expected with PNRR funds

LUBE
DAY
2023

Only one H₂ refuelling station in Italy open to the public...

... and even if funded by PNRR with 100 M€, only 36 new refuelling stations will be built in Italy



Jun. 10, 2022

Eni inaugurates the first hydrogen refuelling station in Venice Mestre

Venice Mestre (VE), 10 June 2022 – Today Eni inaugurated the new San Giuliano Enistation in Mestre, Venice, in the presence of Venice Mayor Luigi Brugnaro, Eni Energy Evolution Chief Operating Officer Giuseppe Ricci and Toyota Motor Italia CEO Luigi Ksawery Luca. This is the first road mobility station to open to the public in an urban area in Italy where it is also possible to refuel using hydrogen.

The system is equipped with two dispensing points with a capacity of over 100 kg/day, which can refuel vehicles in about 5 minutes and buses too. The station was fitted with innovative safety and fire-fighting equipment. It was completely rebuilt in recent months and has reopened to the public in February.



HYDROGEN – What has happened one year later?

Production and distribution

PRODUCTION VOLUMES

The **REPowerEU** Strategy of 2022 set out the aim of producing 10 Mt/y H₂ and importing 10 Mt/y by 2030. Actual forecasts* say that by 2030 **not even 50% of the expected domestic EU production target will be reached.**

DISTRIBUTION INFRASTRUCTURE

Autobrennero will build 5 H₂ production plants and 9 H₂ storage and distribution plants (H₂ at 350 and 700 bar) along the motorway section managed by the company (the A22 Brennero-Modena). The company has in fact published a **call for tenders** aimed at awarding the contract "for the executive design and construction of a hydrogen refueling station at the C.S.A. (Motorway Safety Centre) in **Verona**". The overall value of the contract is 14.7 M€.

Within the *SerraHydrogenValle* project, **Milano Serravalle Milano Tangenziali SpA** will install 5 H₂ Refueling Stations (HRS) along the A7 Milan-Genoa motorway. Each of the refueling stations will consist of 2 dispensers with delivery pressures of 350 and 700 bar and 2 storage units of 475 kg each, which will be refueled with H₂ from third-party sources and delivered by truck. Total investment of approximately 45.8 M€.



HYDROGEN – What has happened one year later?

Utilization

UTILIZATION IN ICEs

Compared to a FCEV, H₂ICE offer some advantages:

- lower purity requirements of H₂;
- greater durability;
- longer lifespan;
- much simpler operation;
- lower cost.

H₂ICE is the next logical step in the evolution of a conventional ICE and is similar to it in terms of structure, operation and operating conditions.

MAN Truck & Bus will be the 1st EU manufacturer to launch trucks (MAN hTGX) with **ICEs powered by H₂**. Initially, around 200 vehicles will be built and delivered to customers in Germany, the Netherlands, Norway, Iceland and some non-EU countries during the first months of 2025.

The H45 hydrogen ICE is derived from the proven D38 diesel engine and is produced at Nuremberg, DE.



Stępień Z.
Combustion Engines
197(2), 2024, 32-41.

range: 600 km,
power: 520 hp,
2 variants:
- 6×2 axle
- 6×4 axle,
56 kg_{H₂} at 700 bar,
fully refueled in 15min

Manufacturer	Status of work
JCB	Start of production announced
MAN	
PUNCH - Torino	
Toyota	
Deutz	
DAF	Ongoing development
Kawasaki	
Yamaha	
Daimler	
Cummins	
Liebherr	
MTU	
Hongqi	Research announced
Ford	
Volvo	
Scania	
Great Wall	
Caterpillar	

HYDROGEN – What has happened one year later?

Utilization

UTILIZATION IN ICEs

20.07.24
Suzuka Circuit, JP



Kawasaki Ninja H2 HySE
ICE V4 998 cc, 740 hp
2 liquid H₂ tanks at -253°C



sconti



11.05.24
Model HY4
Spa-Francorchamps
Endurance Race
(FIA WEC)

ALPINE Alpenglow – Competition Car
- Model HY4: ICE V4 turbo 2000 cc, 340 hp
3 H₂ tanks x 2.1 kg_{H2} each
- Model HY6: ICE V6 biturbo 3500 cc, 740 hp



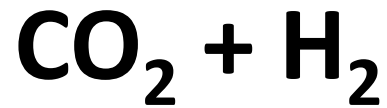
HYDROGEN – What has happened one year later?

TOYOTA swappable H₂ cartridge (160 g_{H2}, vs 5.65 kg_{H2} Toyota Mirai)



Japan Mobility Show Bizweek 2024, Tokyo, 15-18.10.24





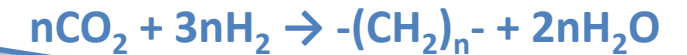
CH₄ (e-methane)

CNG/LNG trucks



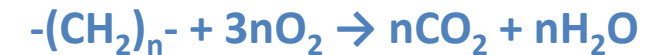
CH₃OH (e-methanol)

passenger cars and maritime



-(CH₂)_n- (e-hydrocarbons)

aviation and heavy duty



C-based e-fuels

Policy framework

 Official Journal
of the European Union

EN
Series L

2023/241331.10.2023

DIRECTIVE (EU) 2023/2413 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 18 October 2023
amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652

Renewable Energy Directive III - RED III
Amending Directive EU/2023/2413, approved on Oct., 2023

by 2030, minimum 29% share of renewables in the transportation sector. In particular:

- min. 5.5% of Advanced biofuels + e-fuels (RFNBO, Renewable Fuels of Non Biological Origin)
- min. 1.0% of e-fuels (RFNBO, Renewable Fuels of Non Biological Origin)

 Official Journal
of the European Union

EN
Series L

2023/240531.10.2023

REGULATION (EU) 2023/2405 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 18 October 2023
on ensuring a level playing field for sustainable air transport (ReFuelEU Aviation)
(Text with EEA relevance)

ReFuelEU Aviation
Regulation EU/2023/2405, approved on Oct., 2023

*all fuel made available to aircraft operators at EU airports must contain a **minimum share of SAF from 2025** and, from 2030, a **minimum share of synthetic fuels**, with both shares increasing progressively until 2050.*

	2025	2030	2035	2040	2045	2050
SAF tot	2%	6%	20%	34%	42%	70%
e-kerosene	--	1.2%	5%	10%	15%	35%

C-based e-fuels Policy framework

Von der Leyen, Political Guidelines for the next EU commission '24-'29
Strasbourg 18 July 2024

*“Reaching climate neutrality by 2050 will require a wide range of innovative technologies, in areas from mobility to energy. For instance, the 2035 climate neutrality target for cars creates predictability for investors and manufacturers. Getting there will require a technology-neutral approach, **in which e-fuels have a role to play** through a targeted amendment of the regulation as part of the foreseen review.”*

Questionnaires to the Commissioners-designate

EN

QUESTIONNAIRE TO THE COMMISSIONER-DESIGNATE

Wopke HOEKSTRA (European Commissioner
for Climate Action)

Climate, Net-Zero and Clean Growth



EUROPE'S CHOICE

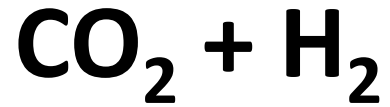
POLITICAL GUIDELINES
FOR THE NEXT EUROPEAN COMMISSION
2024–2029

Ursula von der Leyen
Candidate for the European Commission President

Declaration by Wopke Hoekstra – Oct 2024

*“The Commission will therefore work on this targeted amendment [amendment of the regulation setting CO₂ emissions performance standards for cars and vans] as part of the review foreseen in 2026. This work will also consider the **need for e-fuels in other sectors, where no other technological alternatives exist, such as aviation and maritime transport**, taking into account their projected scarcity, their energy intensive production process, and their projected costs.”*

e-methanol – CH₃OH



CH₄ (methane)

CNG/LNG trucks



CH₃OH (methanol)

passenger cars and maritime



-(CH₂)_n- (long chain hydr.)

aviation and heavy duty



e-methanol – CH₃OH

one demo plant operating in Iceland

George Olah renewable methanol plant



**CARBON
RECYCLING
INTERNATIONAL**

**LUBE
DAY
2023**

- the world's only e-methanol plant (since 2012), near Iceland's Blue Lagoon (Svartsengi)

INPUT:

- 5'500 t/y CO₂ from a nearby geothermal power station
- H₂ from 6 MW_{el} alkaline electrolyzers
- renewable energy from the Icelandic grid

OUTPUT:

- **4'000 t/y of renewable methanol** (commercialized as Vulcanol® by CRI) made at 250°C and 100 bar
- FID for a 100'000 t/y of renewable methanol in Finnfjord (northern Norway) expected in 2024.
- Same technology used in China for low-carbon CH₃OH



e-methanol – CH₃OH

the first industrial plant expected to be operational soon in Denmark



**Kassø e-methanol plant
(Aabenraa, Denmark)**



danske
commodities



EUROPEAN
ENERGY



MITSUI & CO.

- the world's largest e-methanol plant (start-up expected in late 2024), in southern Denmark

INPUT:

- 150'000 t/y CO₂ from a biogas plant
- H₂ from 51 MW_{el} PEM electrolyzers (3 units x 17 MW each) by Siemens Energy fed with renewable-energy by a nearby 300 MW solar park

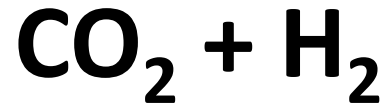
OUTPUT:

- **32'000 t/y of e-methanol** (produced in 2 parallel trains) delivered to 4 long-term off-takers: Maersk, Novo Nordisk, the LEGO group, and Circle K.

CATALYST:

- Clariant's MegaMax®

e-hydrocarbons / e-crude



CH₄ (e-methane)

CNG/LNG trucks



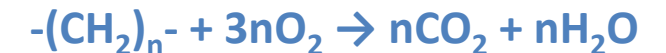
CH₃OH (e-methanol)

passenger cars and maritime



-(CH₂)_n- (e-hydrocarbons)

aviation and heavy duty



Development of technology for e-hydrocarbons synthesis, $-(CH_2)_n$

First commercial plant under construction, to make e-kerosene

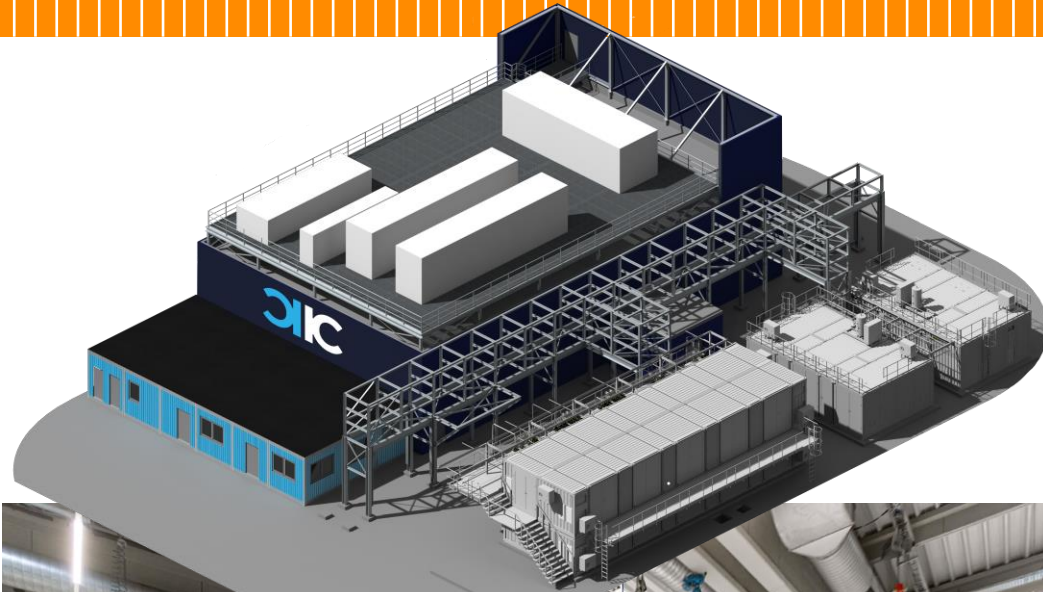
LUBE
DAY
2023

- When: announced in 2022, under construction from April 2023, scheduled for completion in 2024
- Who: INERATEC
- Where: Industriepark Höchst site (Frankfurt, Germany)
- Investment > 30 M€
- **INPUT:** 8000 t_{CO2}/y
- **OUTPUT:** 2500 t_{syncrude}/y (equivalent to 4.35 ML_{syncrude}/y)



Development of technology for e-hydrocarbons synthesis, $-(CH_2)_n$

First commercial plant under construction, to make e-kerosene



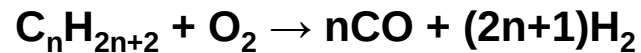
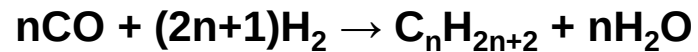
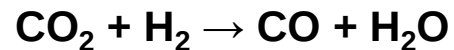
- When: announced in 2022, under construction from April 2023, start-up late 2024
- Who: INERATEC (exploiting SASOL low-temperature Co-catalysts for the FTS)
- Where: Industriepark Höchst site (Frankfurt, Germany)
- Investment > 30 M€
- **INPUT:** 8000 t_{CO2}/y
- **OUTPUT:** 2500 t_{syncrude}/y (equivalent to 4.35 ML_{syncrude}/y)



e-SAF initiatives in Italy

SARAS S.p.A. and Politecnico di Milano are working on the construction, at the Sarlux refinery in Sarroch (Sardinia), of a demonstration plant for the production of e-kerosene from CO₂ and green H₂, with a capacity of 300 t/y.

The reactions involved are:



rWGS

FTS, n: 1->50

CPOX, n: 1-4

The catalytic process under development leads mainly to the synthesis of long-chain hydrocarbons (e-crude), from which aviation fuels (e-kero) can be obtained through conventional refinery processes.

The plant will be operational in about one year from now. NextChem (MAIRE) has been selected for EPC.



**SARAS S.p.A.: RICONOSCIUTO DAL MASE A SARAS E POLITECNICO DI MILANO
UN FINANZIAMENTO PNRR PER LA REALIZZAZIONE DEL PRIMO
DIMOSTRATORE DI PRODUZIONE DI COMBUSTIBILE SINTETICO VERDE IN
ITALIA.**

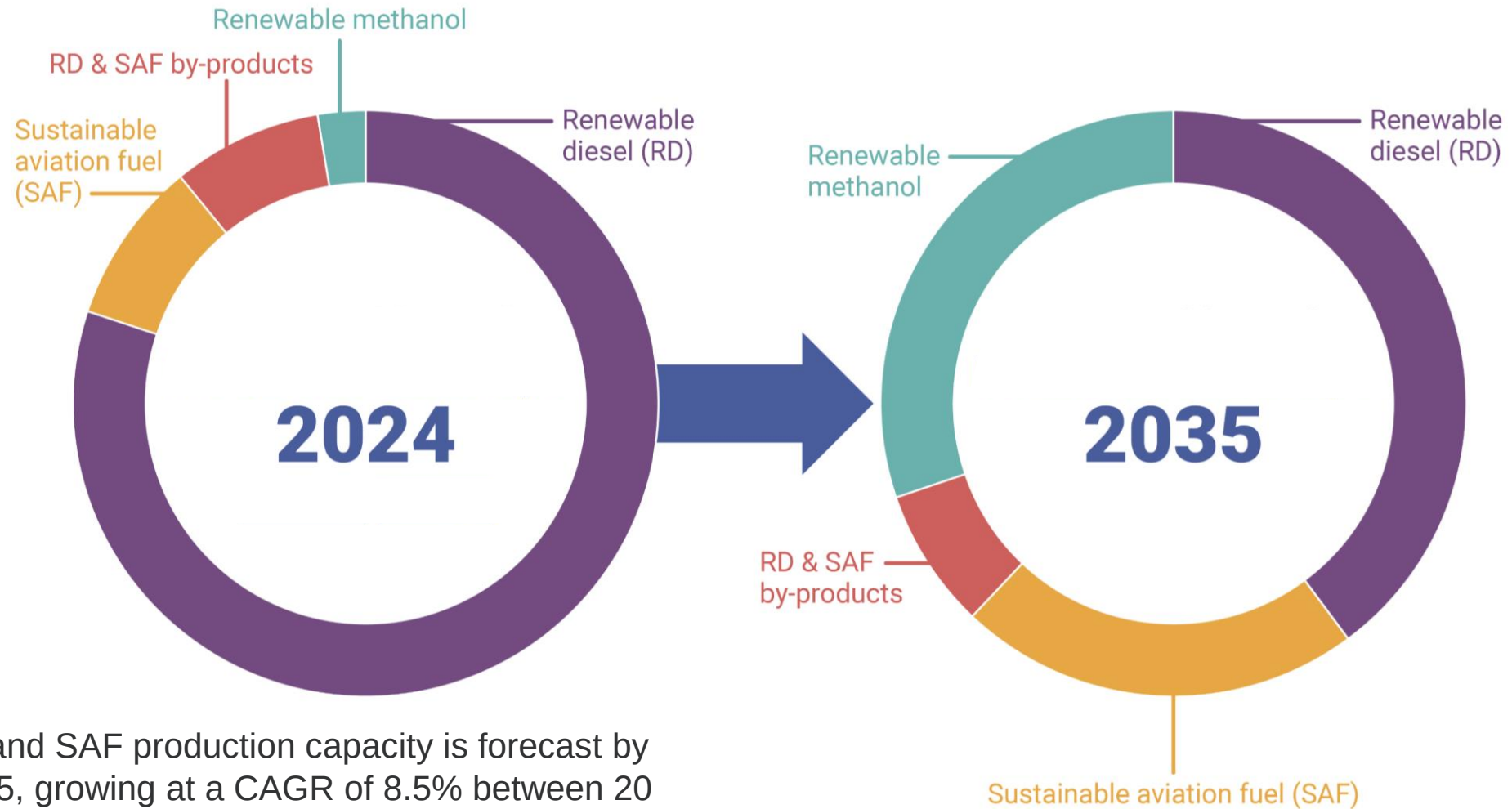
Milano 13 dicembre 2023 - Nell'ambito del percorso di evoluzione da "pure refiner" a "sustainable energy player", il Gruppo Saras guarda anche alle opportunità offerte dalle nuove tecnologie in ambito di transizione energetica.



COMUNICATO STAMPA – N. 47
02/08/24

**NEXTCHEM (MAIRE) SI AGGIUDICA DA SARLUX LICENSING,
SERVIZI DI INGEGNERIA, FORNITURA DI EQUIPMENT
PROPRIETARIO E DI CATALIZZATORI PER INTEGRARE LA
PROPRIA TECNOLOGIA NX CPO™ IN UN IMPIANTO PILOTA DI
SAF**

Sustainable fuel production landscape: advanced biofuels & e-fuels market in 2024 and 2035



The global RD and SAF production capacity is forecast by 57 Mtpa by 2035, growing at a CAGR of 8.5% between 20

Major drivers and challenges for the growth

DRIVERS

- policy developments
- push from vehicle fleet operators and airlines to reduce carbon emissions
- success of EU projects funded with the recovery fund
- low EU refinery margins (switch from fossil to bio-refineries)
- emergence of a wide range of production technologies and their commercial uptake in sustainable fuel production projects

CHALLENGES

- 2nd, 3rd, 4th feedstock availability (*bio-fuels*)
- direct electrification as steady-state solution (*e-fuels*)
- overall energy efficiency (especially when comparing e-fuels to EVs for road transport)
- long development timelines and significant funding needed (e-fuels in particular)
- achieving cost parity with conventional fossil fuels

Take-home-message: let's save ICEs, EU and climate by investing in renewable fuels

1. Mobility based on ICEs does not have its days numbered, not only in EU
2. Biofuels and e-fuels are effective solution to decarbonize ICEs
3. EU industry will not be able to meet the CO₂ emission reduction targets set (in 2019) by CAFÉ (Regulation EU/2019/631) for 2025: to meet the limits, the BEV market share in passenger cars and in vans should be at least 20%.
To be compliant with the regulation, EU OEMs will have either:
 - a) to stop the production and sale of more than 2 million ICE passenger cars and more than 700 000 ICE vans (so that the BEVs represent 20% market share), which is the equivalent of more than 8 EU factories;
 - b) to be exposed to penalties that could be reaching 13 B€ for passenger cars and 3 B€ for vans;
 - c) to drastically cut prices of BEVs to reach the 20% market share.**Those options are not sustainable for EU OEMs.** Reduction targets must be temporarily delayed, and further **efforts have been done to increase the production of renewable fuels.**

CONTATTI

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