Vision 2050

A pathway for the evolution of the Refining Industry and Liquid Fuels

An Industrial Opportunity

APETRO's Conference – "Vision 2050 – Fuels and Lubes"
Alessandro Bartelloni

Conference Centre of the Museu do Oriente

Lisbon, 25th September 2018

FuelsEurope
REFINING PRODUCTS FOR OUR EVERYDAY LIFE

Aviation and energy storage

Boeing 787

230 tons at take-off

Jet fuel

100 tons[1]

Electric battery

2000 tons[1]

(1) http://www.latimes.com/business/la-fi-electric-aircraft-20160830-snap-story.html

FuelsEurope represents 41 Member Companies ≈ 100% of EU Refining

A vision ? What for ……….

Contributing to delivering the Paris Agreement

EU 2050 climate objectives

Reducing transport GHG emissions

Air Quality

Describing how the refining industry can contribute to the transition to a low carbon economy

An industrial opportunity for the EU

EU average refining production

Sources: EUROSTAT, EUROSTAT, http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Consumption_of_oil_EU-28,_2015,_percentage.png and Wood Mackenzie product markets long-term outlook H2 2017 Demand in EU 28, NOR, CH, ISL for 2015

Oil extraction

↓

Refinery

↓

Products

EU AVERAGE REFINING PRODUCTION

65% Mobility

- Diesel
- Gasoline
- Kerosene
- Heavy oil
- Liquid gas

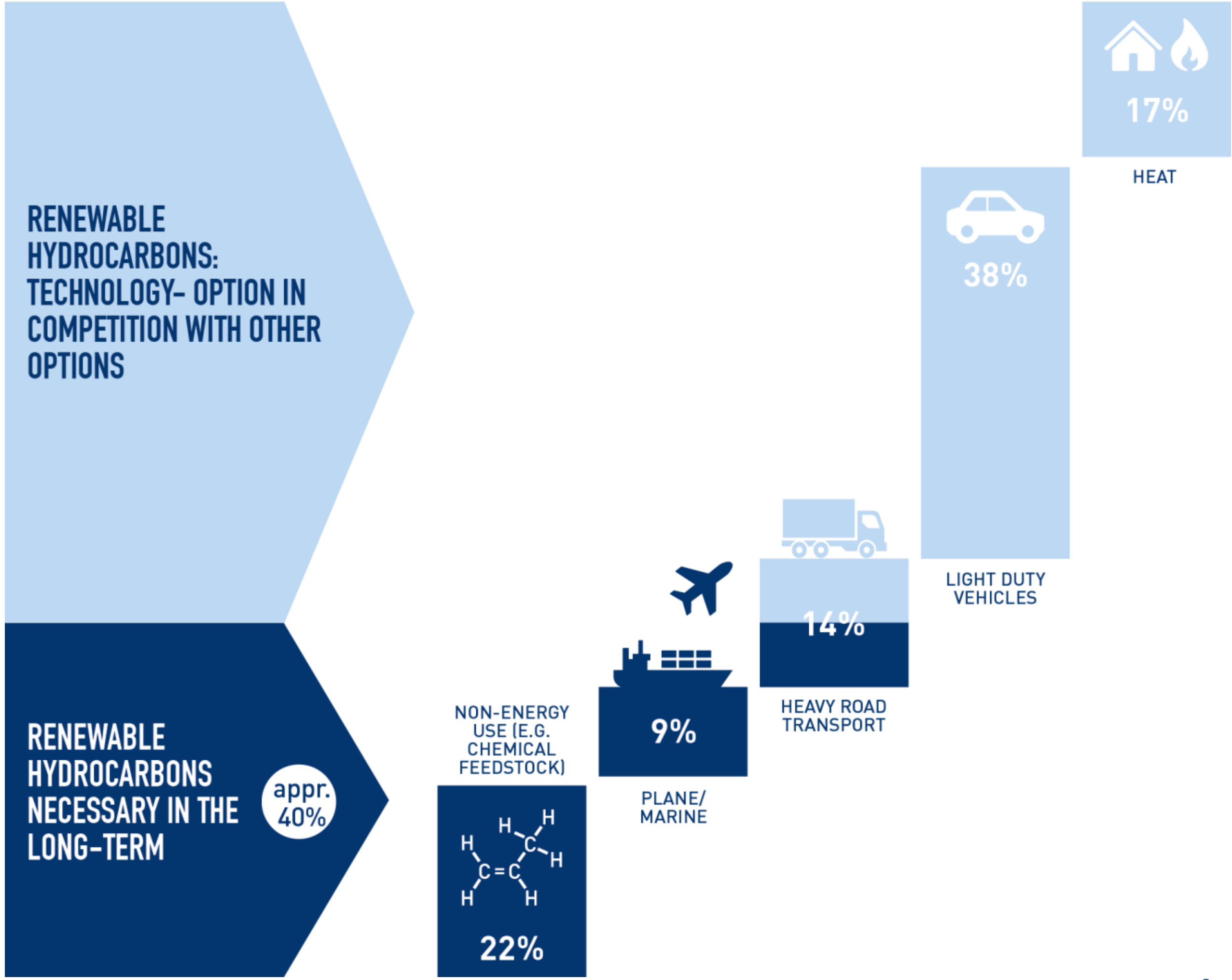
25% Other Products

- Petrol
- Heavy oil
- Liquid gas
- Bitumen
- Lubricant
- Oil coke
- Heating oil

10% Petro-chemical feedstocks

- Olefins
- Aromatics
- Other

Low-carbon liquid fuels and products

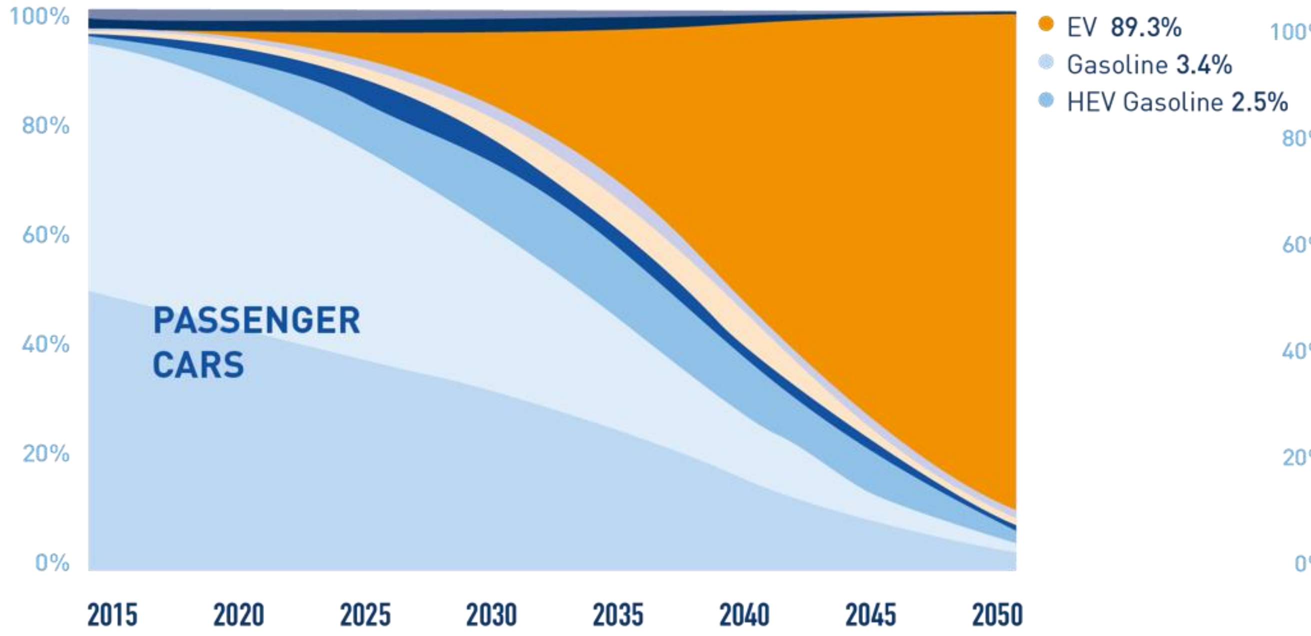


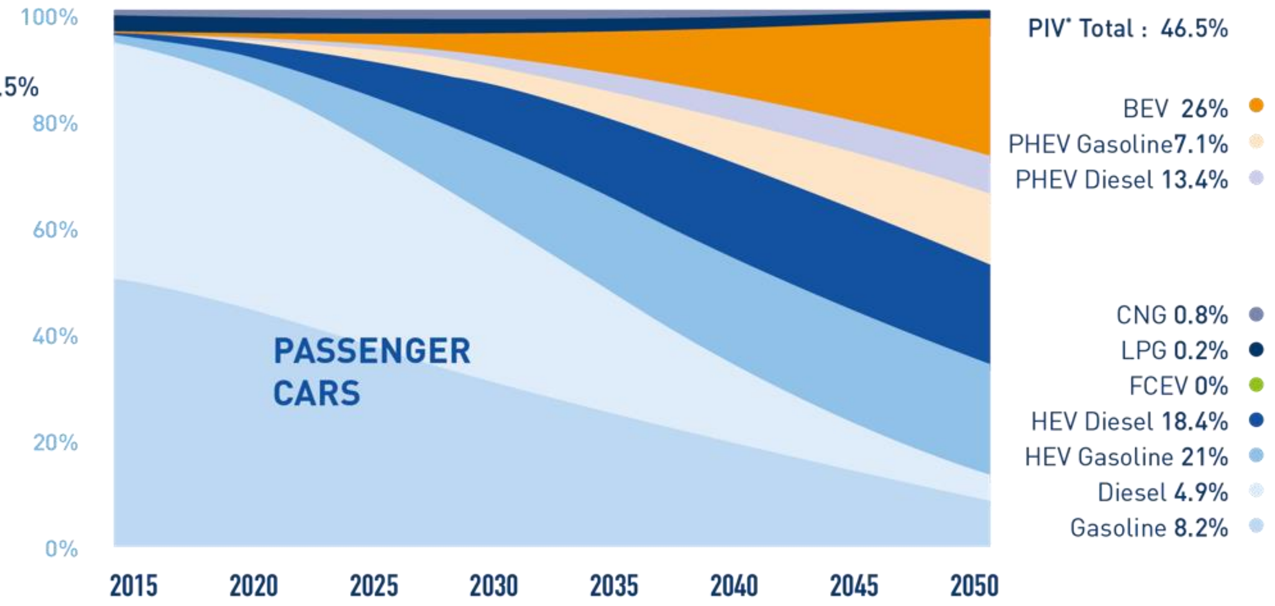
Source: Prognos AG, Berlin

GHG emissions and Climate Change

- FuelsEurope recognises that climate change is real and warrants action.
- Answering the demand for energy while limiting the GHG emissions is a critical challenge.
- What are the options for example for Light Duty Vehicles (LDV)?
    - Mass Electrification scenario or Low-Carbon Liquid Fuels scenario

Mass Electrification vs Low-Carbon Liquid fuels





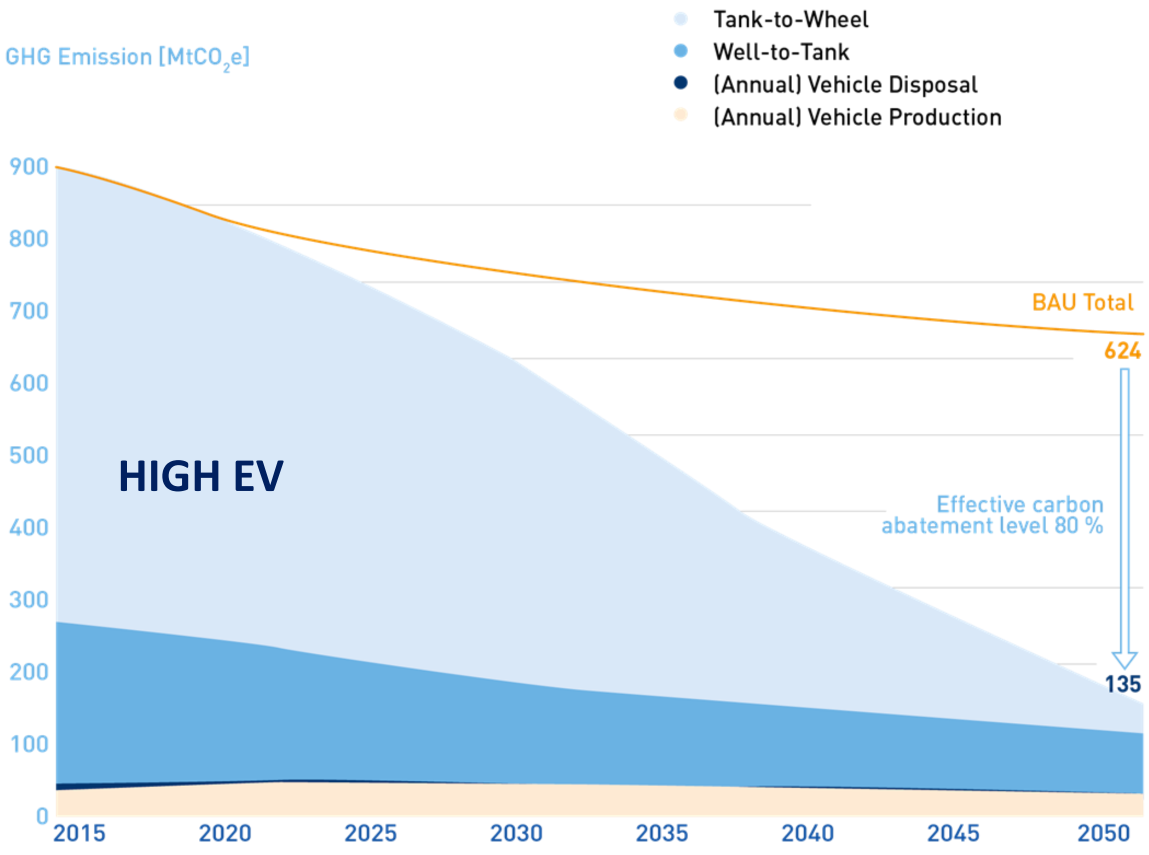
Source: Ricardo, Impact Analysis of Mass EV Adoption and Low Carbon Intensity Fuels Scenarios, August 2018

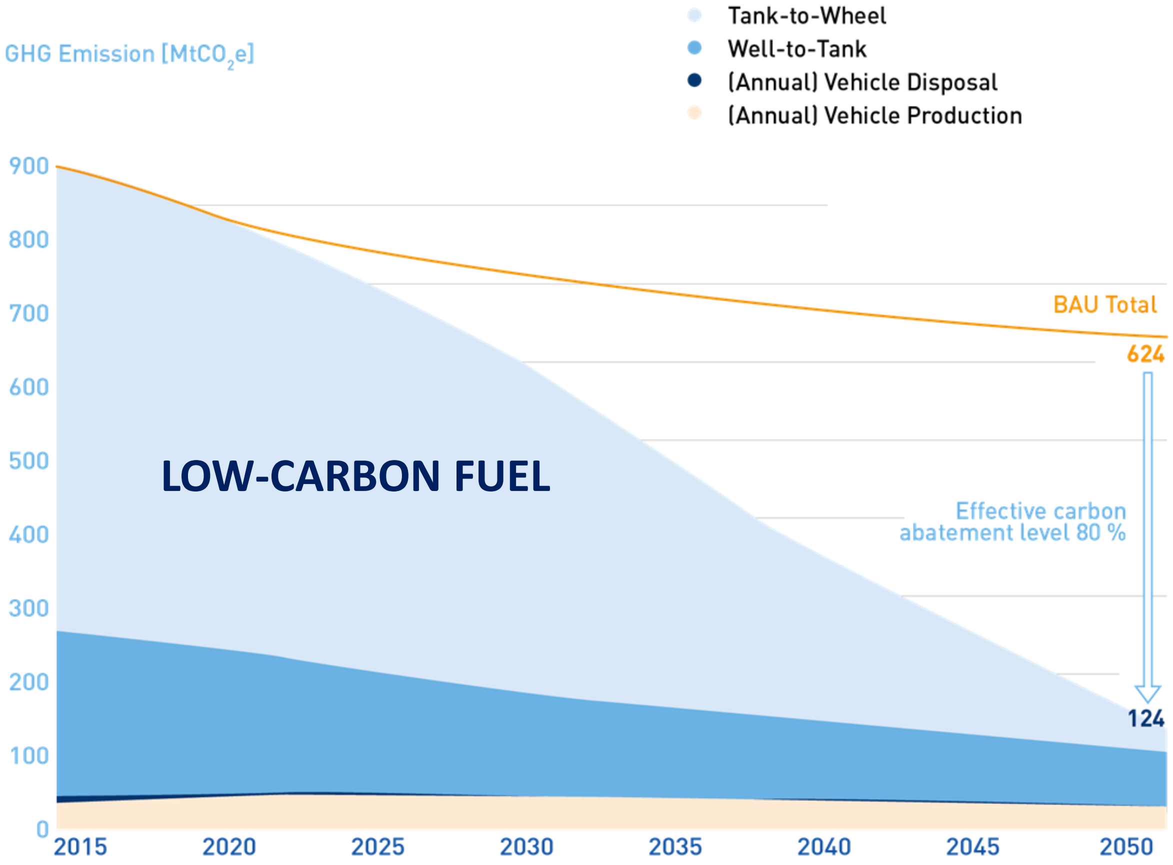
- The Mass electrification scenario shows 90% electrification of passenger cars and light duty vehicles in 2050
- It assumes that, as of 2040, 100% registrations are battery electric vehicles.

- The Low Carbon Liquid Fuel scenario show that the share of liquids will reach 68%. It will be complemented by 23% of electricity

Source: Ricardo Energy & Environment SULTAN modelling and analysis

Mass Electrification vs Low-Carbon Liquid fuels



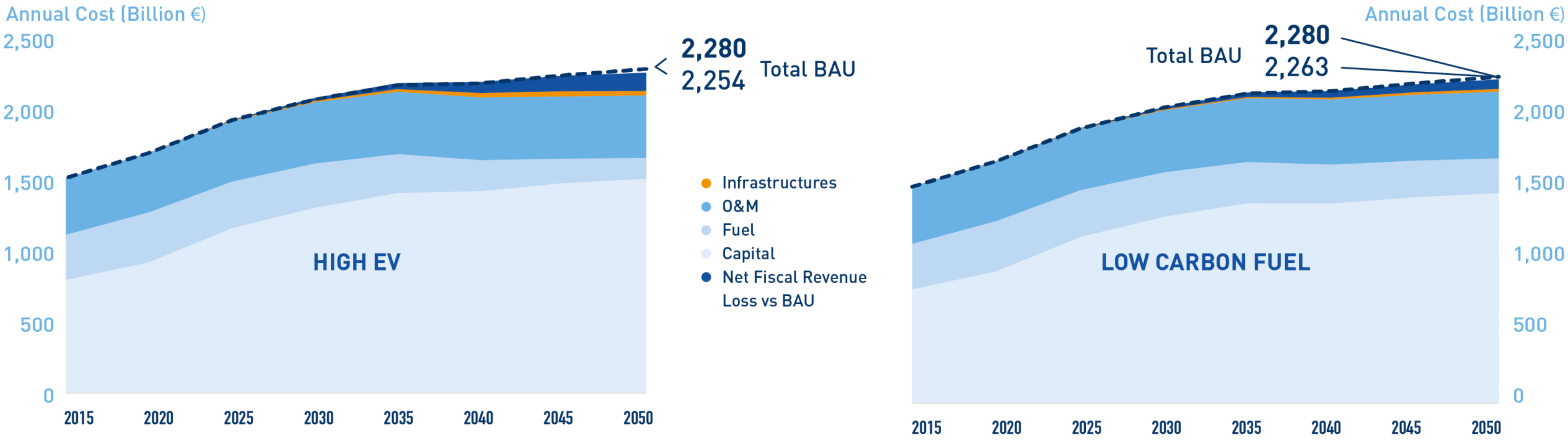


- It is expected to achieve 87% reduction of GHG emissions in 2050 vs 2015.

Source: Ricardo Energy & Environment SULTAN modeling and analysis

- It is also expected to achieve 87% reduction of GHG emissions in 2050 vs 2015.

Cost comparison between the Mass EV and the Low-Carbon Liquid Fuel scenarios



Source: Ricardo Energy & Environment SULTAN modeling and analysis

Mass EV scenario – What about raw materials and import dependency ?

Comparing costs and import dependency
Costs of fuel and batteries over a vehicle lifetime – Base Scenario

	Mini (VW Polo, Nissan Leaf*)	Small Family (VW Golf, BMW i3)	Executive (BMW 5, Tesla S)
Vehicle Lifetime and Mileage	16 years, 15,000 km/year. Battery lifetime 10 years.		
BEV Battery size	25 kWh	35 kWh	75 kWh
Cost of battery 2017	$180-270/kWh		
Cost of battery 2027	$75-115/kWh		
ICE Fuel Efficiency**	0.050 l/km	0.060 l/km	0.075 l/km
Oil prices	IEA WEO 2016 oil prices		
Imports**	Oil for ICE: 89%, Batteries for BEV: 91%		
ICE Fuel Cost (PV €) ***	2,100 – 2,600	2,500 – 3,100	3,100-3,900
BEV Battery Cost (PV €) ***	4,100 – 6,200	5,800 – 8,700	12,400 – 18,500

* Nissan Leaf 2016 on sale in 2017 had a battery size of around 25kWh, newer models available in 2018 have a larger battery size more comparable to small family car

** Includes Real Driving Effects

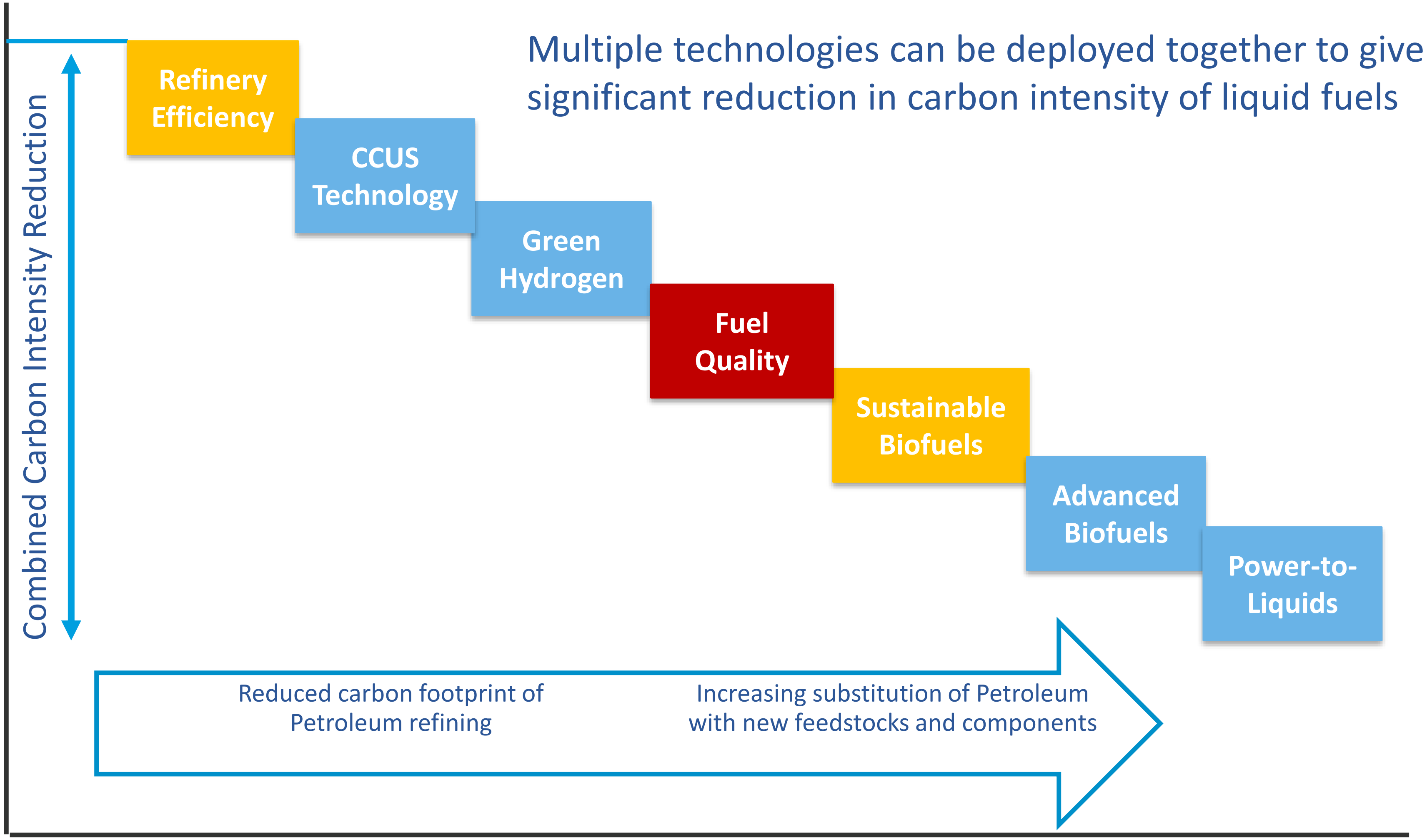
*** Base Scenario treats Norway as outside EU, for consistency with Eurostat statistics on import dependence. We also show a sensitivity case where Norwegian production is treated as within Europe for the purpose of calculating import shares.

**** PV calculated using discount rates of 10%

Source: NERA Economic Consulting

We have the technologies…

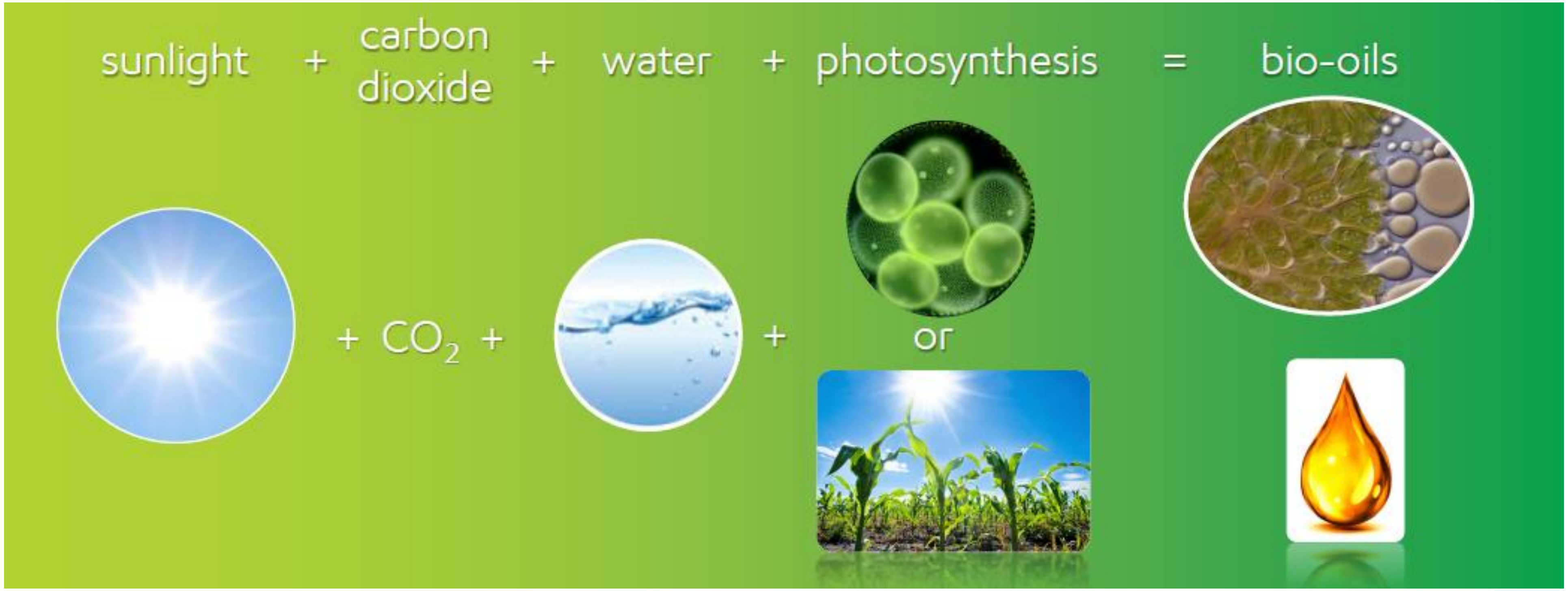
Multiple technologies can be deployed together to give significant reduction in carbon intensity of liquid fuels



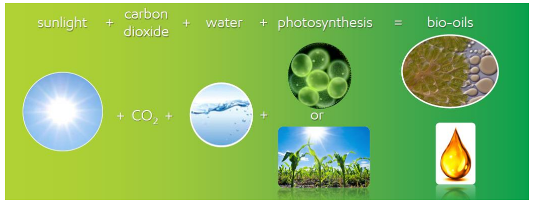
Standard | Current first examples | New proposed strategy

The technologies are being developed....

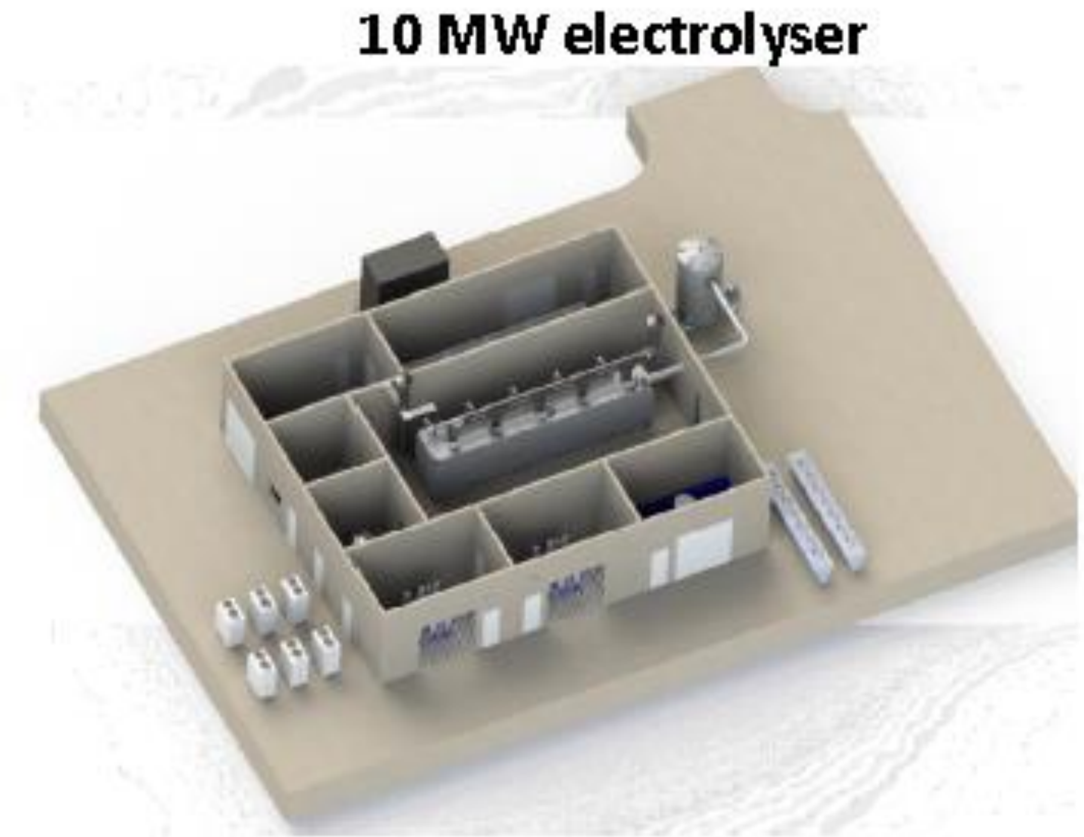
Algae, a biofuel of tomorrow



The technologies are being developed....

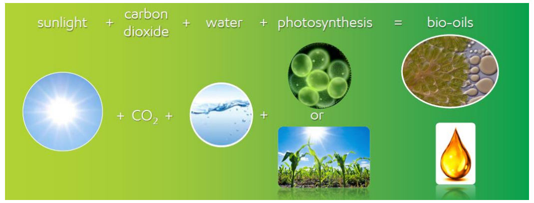


REFHYNE Project, 10 MW PEM Electrolyser



REFHYNE
CLEAN REFINERY HYDROGEN FOR EUROPE

The technologies are being developed….



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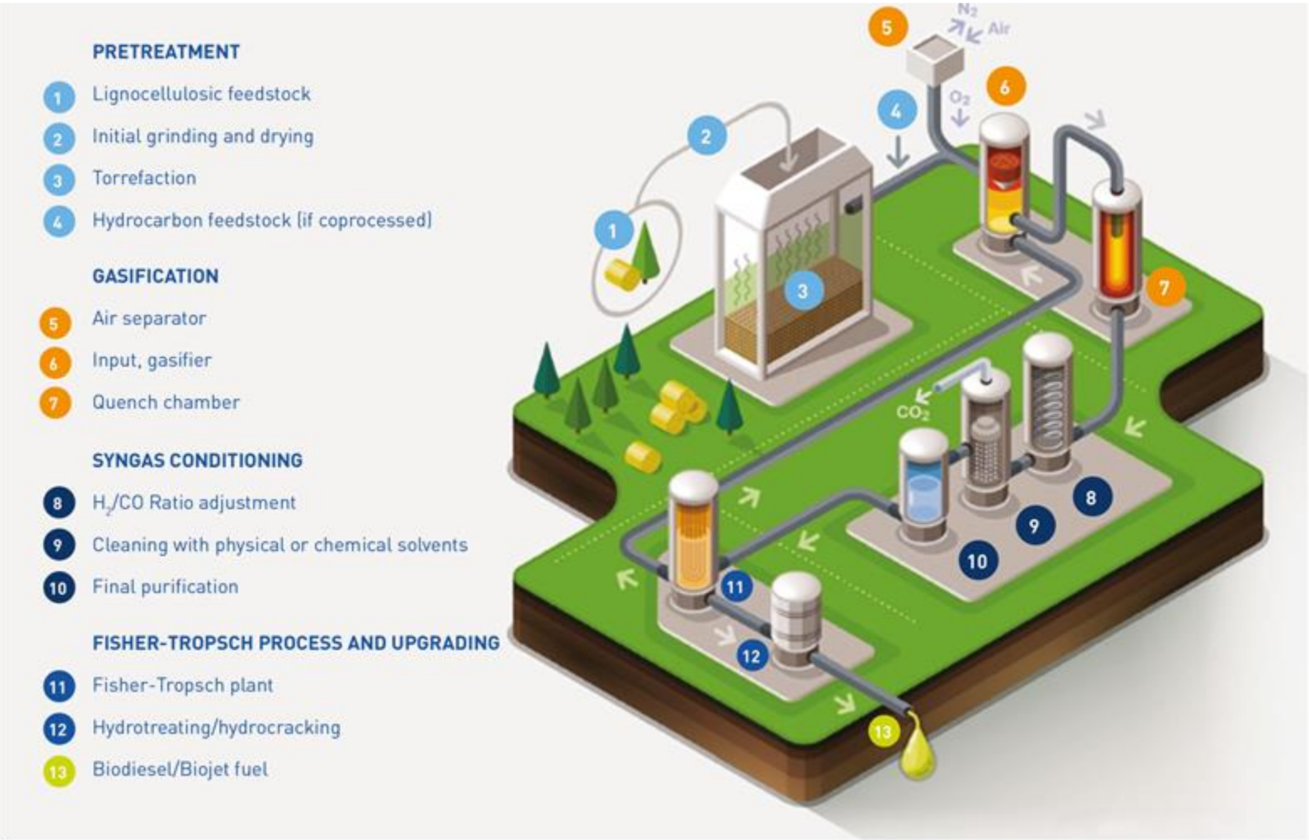
BioTfuel, producing biofuels via thermochemical conversion



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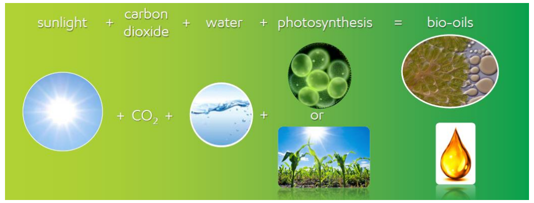

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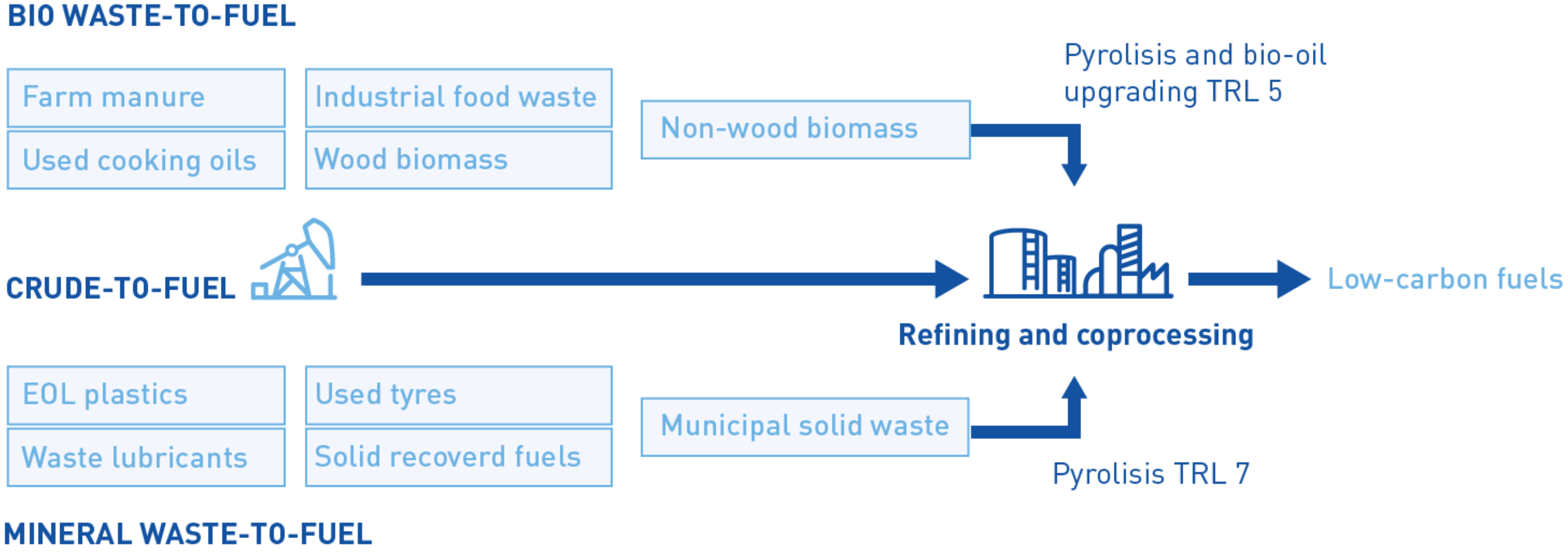
Waste-to-Fuel



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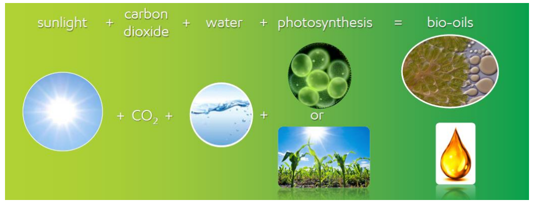

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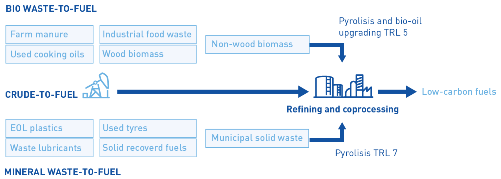
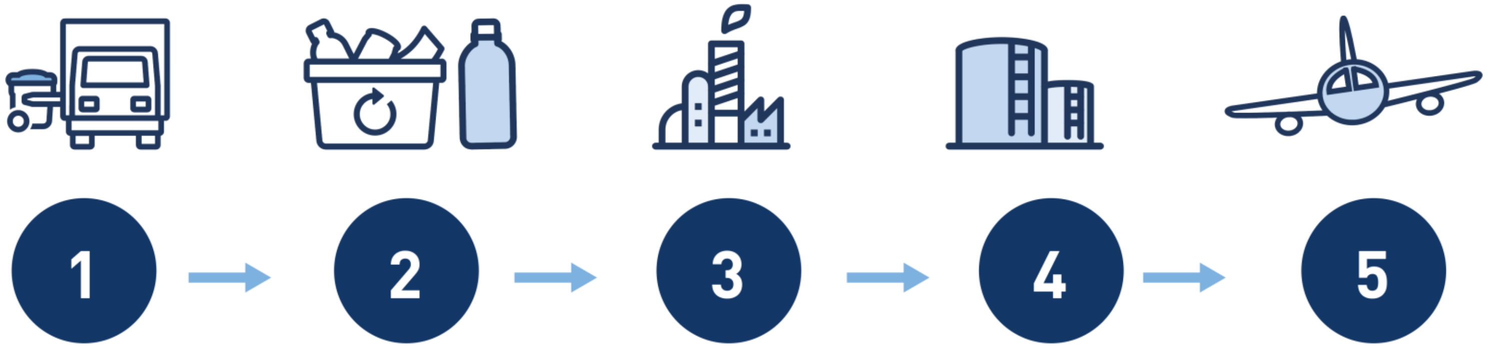
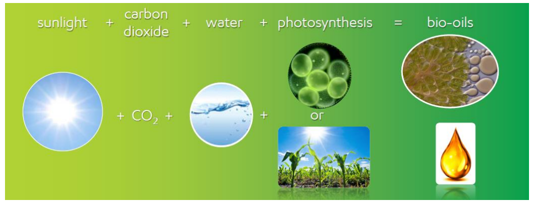


Fulcrum BioEnergy, Municipal Waste-to-Fuel



1. WASTE IS COLLECTED.
2. MATERIALS ARE RECYCLED. SUITABLE WASTE FOR JET FUEL IS COLLATED.
3. WASTE IS CONVERTED TO SYNTHETIC JET FUEL.
4. SYNTHETIC JET FUEL IS BLENDED TO MAKE IT SUITABLE FOR USE ON AIRCRAFT.
5. FUEL IS DELIVERED TO AIRPORT AND INTO WIN.

The technologies are being developed....



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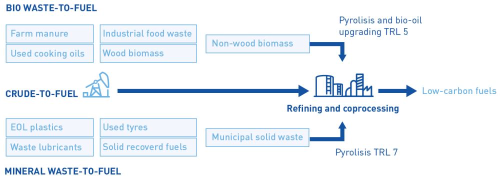
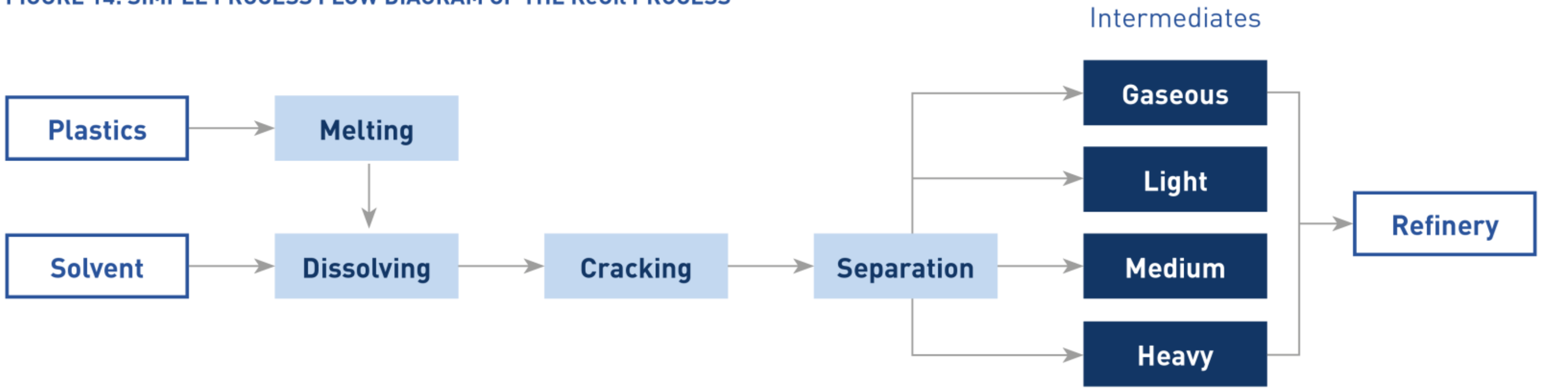
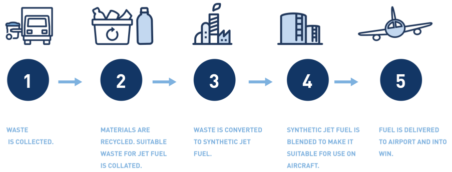


ReOil, Plastics-to-Fuels & Feedstocks

FIGURE 14: SIMPLE PROCESS FLOW DIAGRAM OF THE ReOil PROCESS





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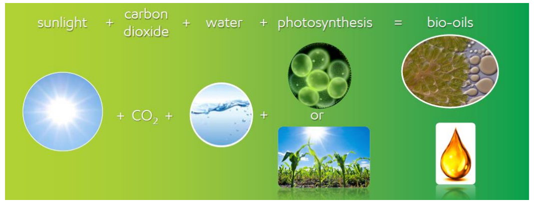

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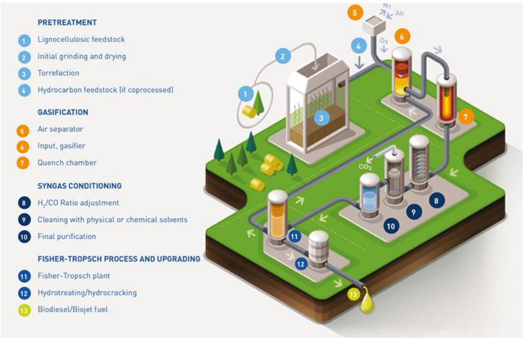
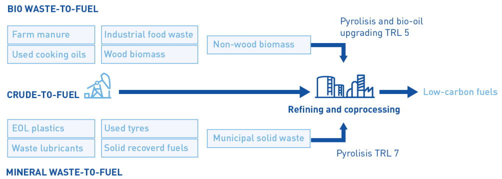
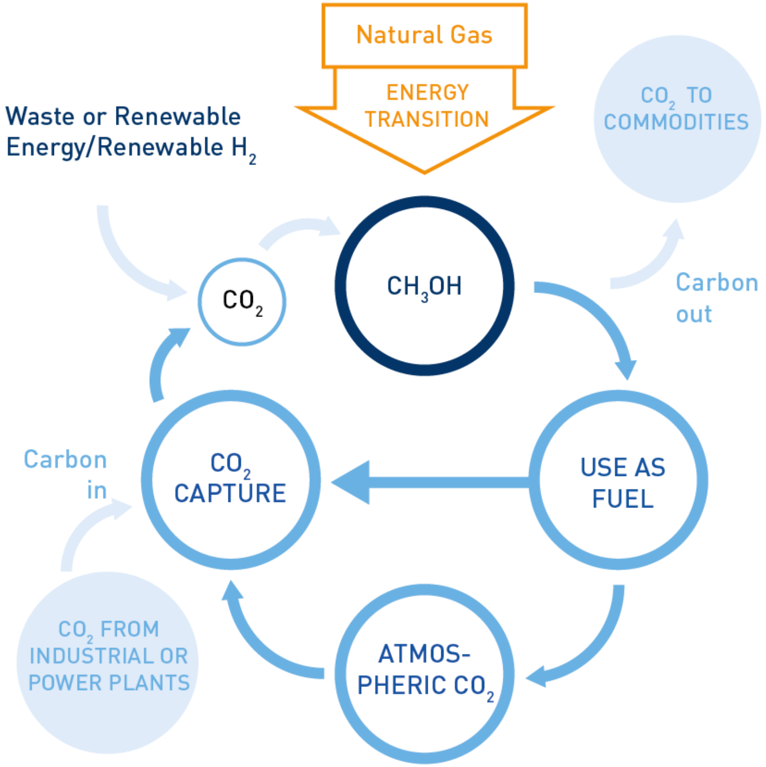




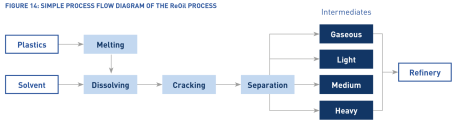
Methanol Economy

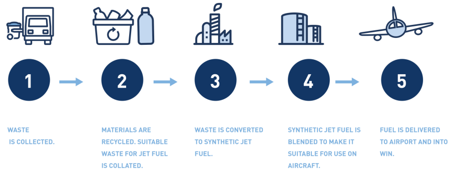


CO_2 concentration in wet flue gases

- Approx. 11% vol.
- Approx. 8-8.5% vol.
- Approx. 20% vol.
- Approx. 4% vol.

FIGURE 14: SIMPLE PROCESS FLOW DIAGRAM OF THE ReOil PROCESS





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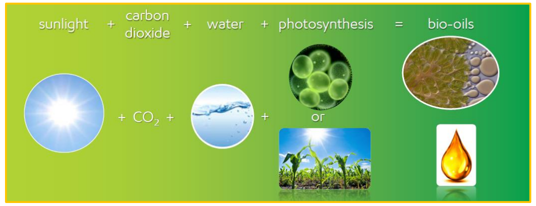

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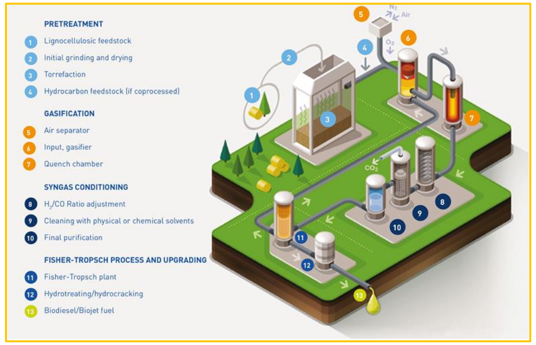
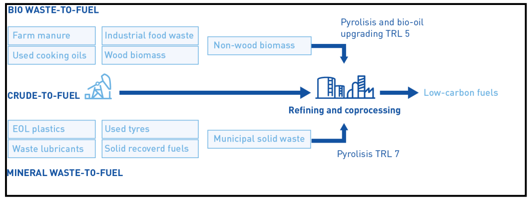
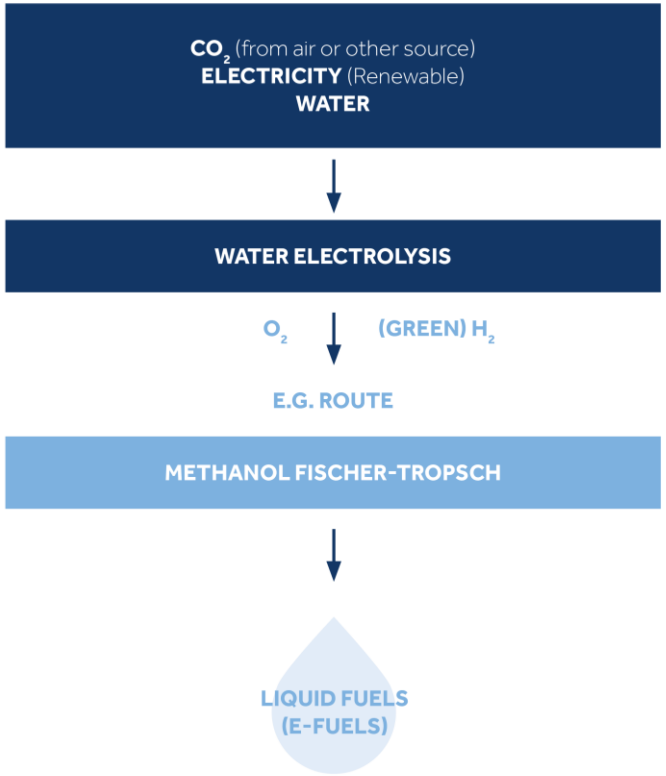
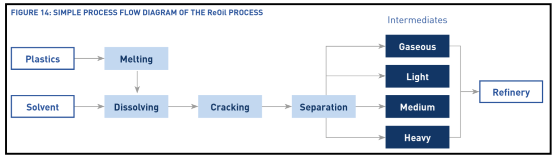
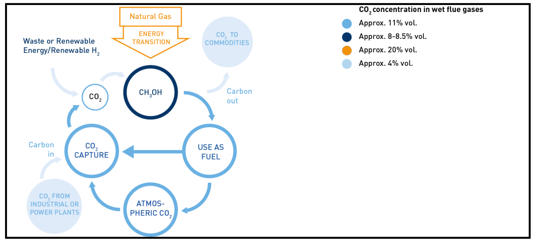


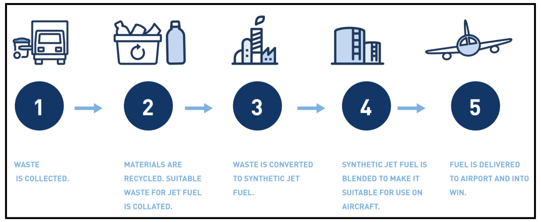


Sunfire, Power-to Liquid



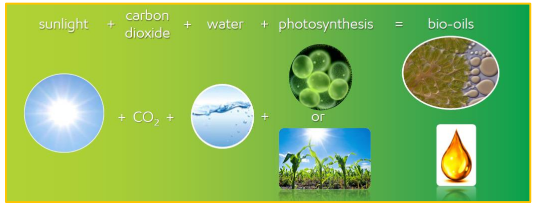






The technologies are being developed….

On-board Carbon, Capture & Storage



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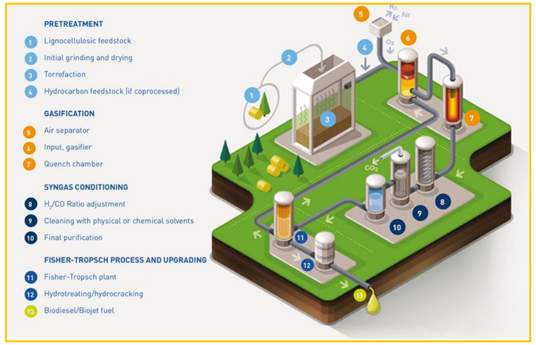

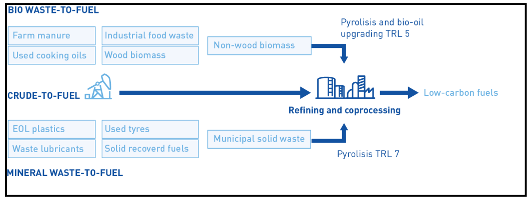

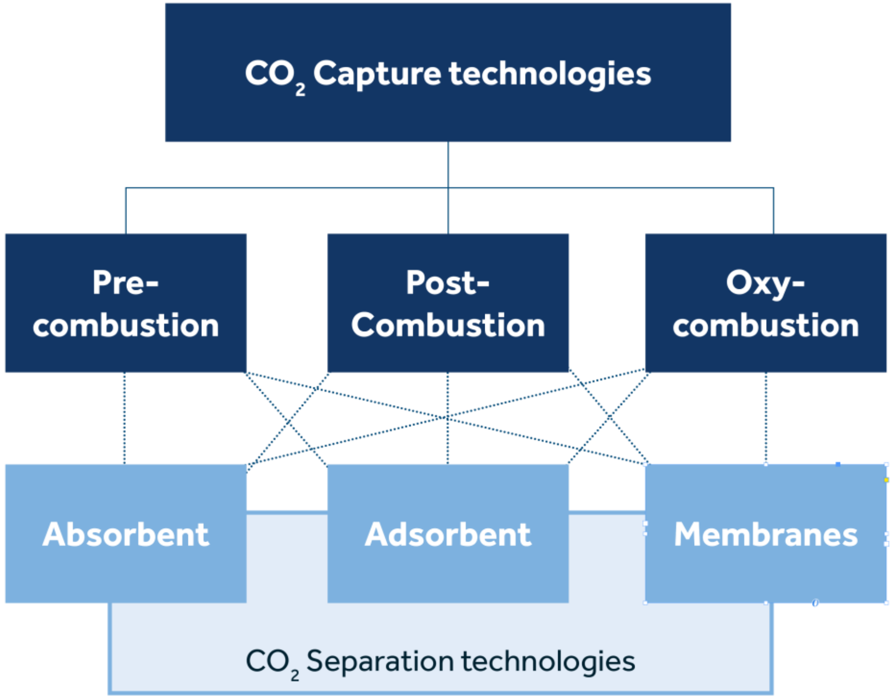

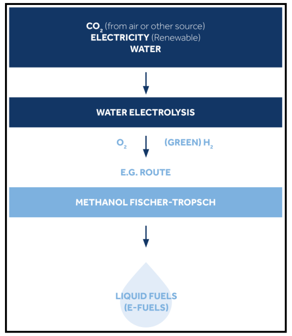

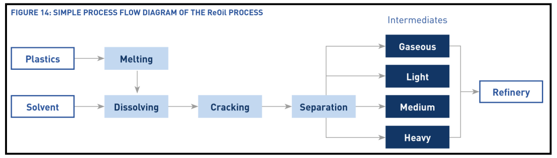

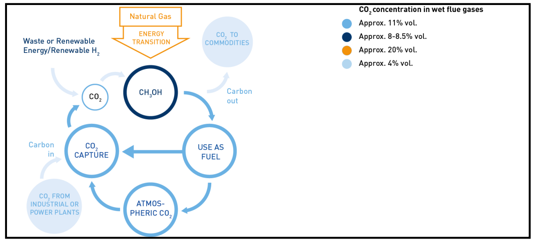

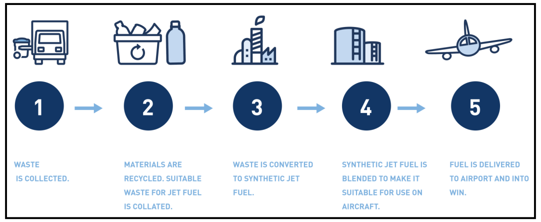

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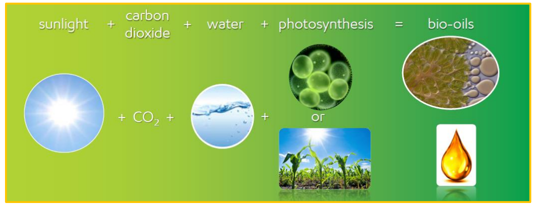

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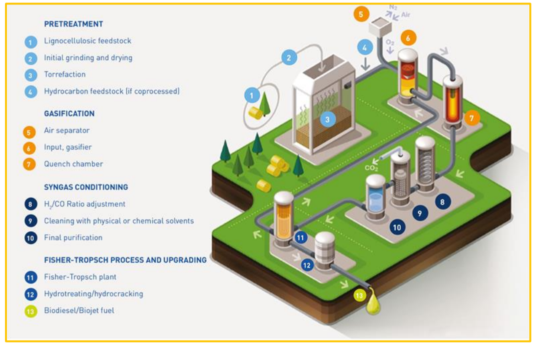
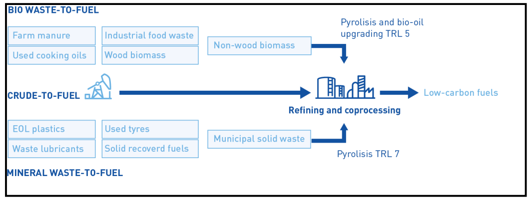
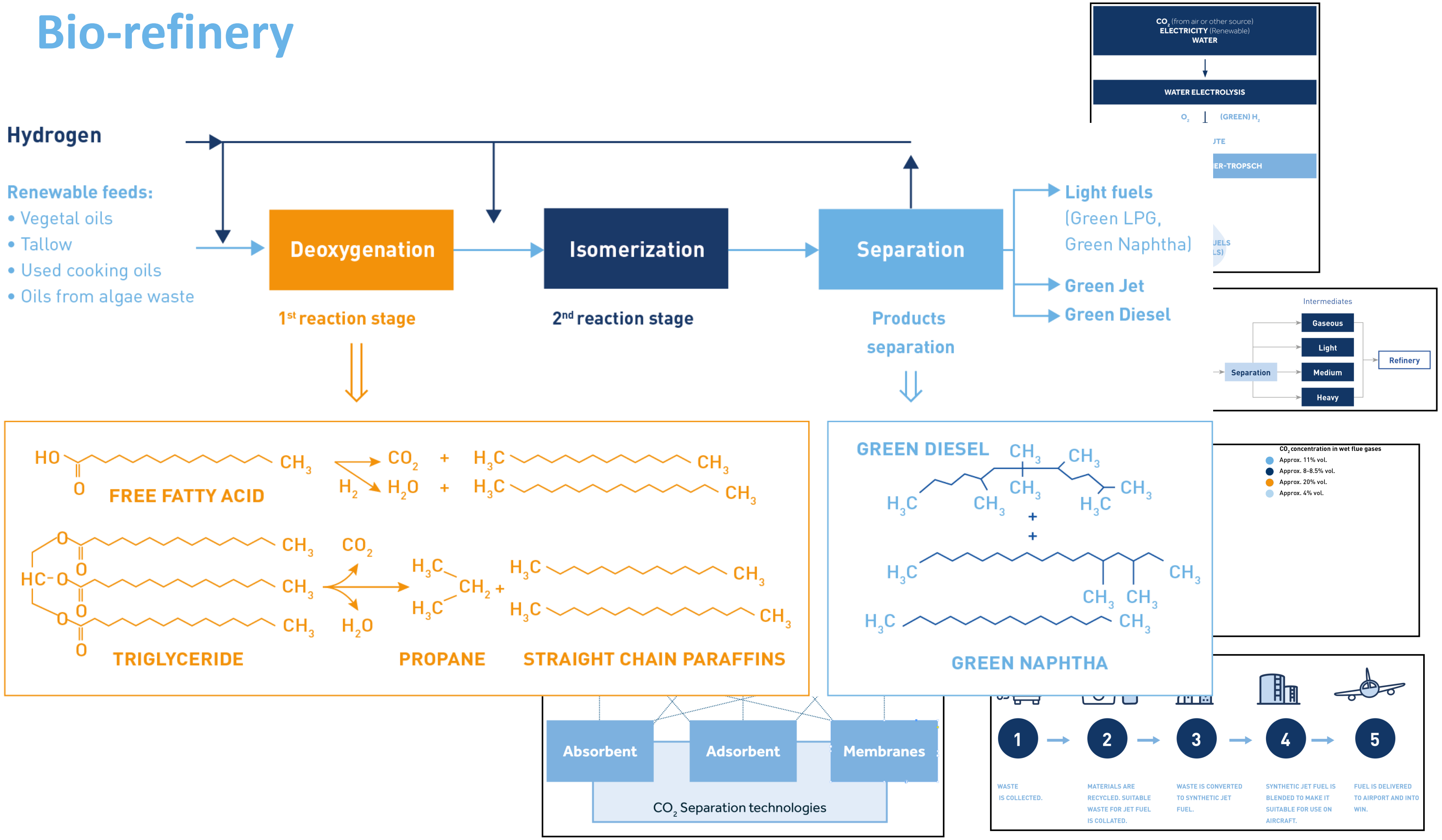




Bio-refinery



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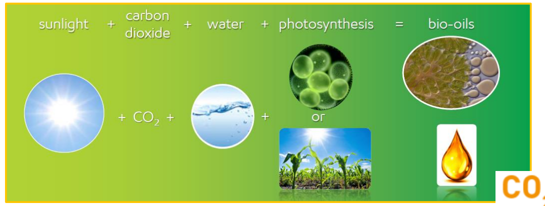
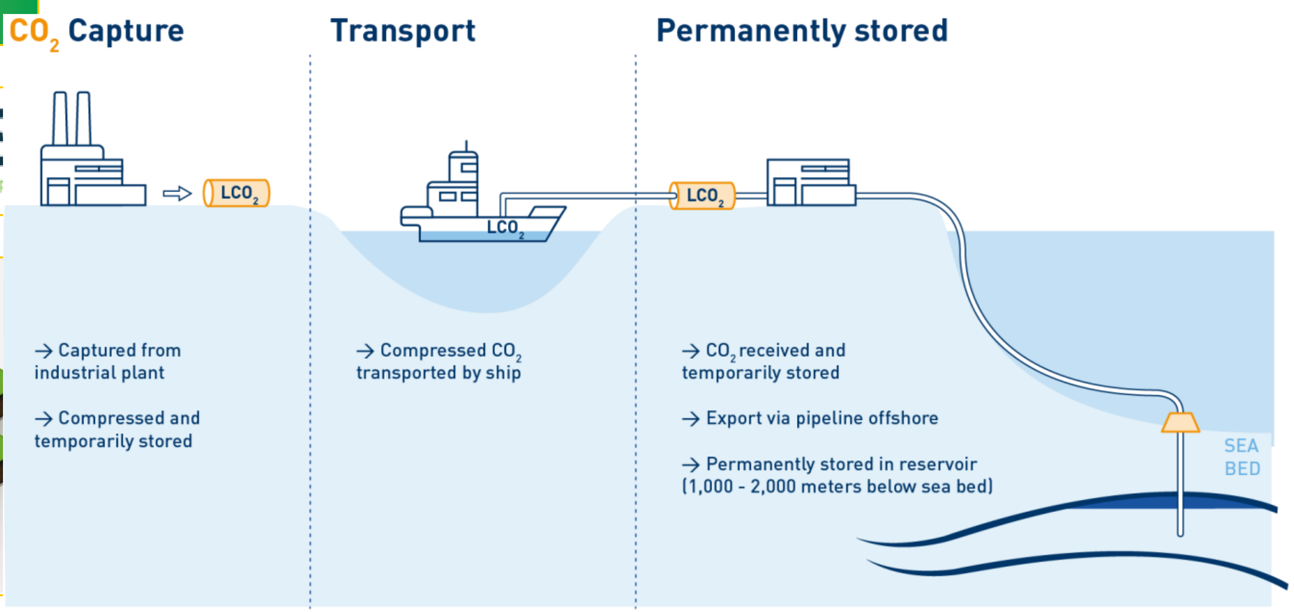
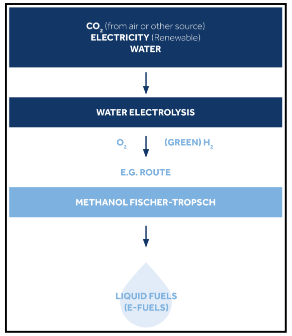


Carbon Capture & Storage value chain project





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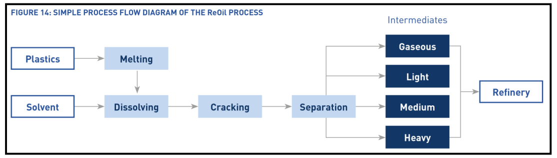
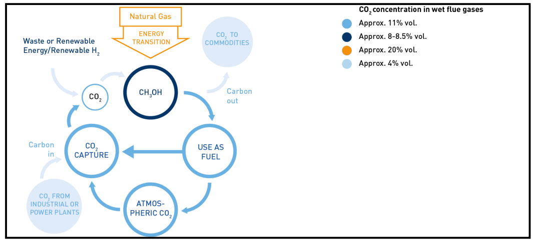
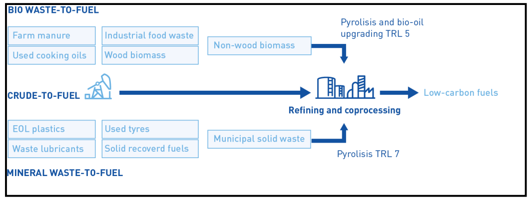
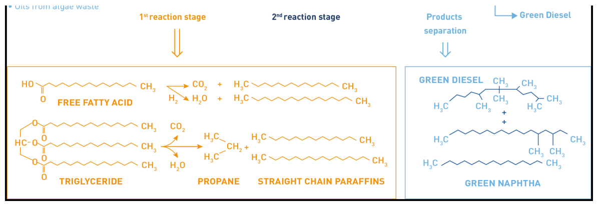
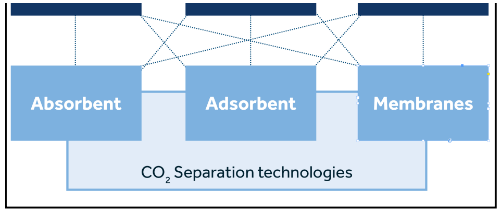
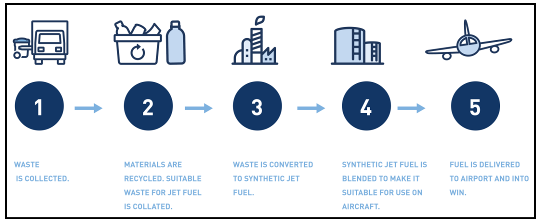




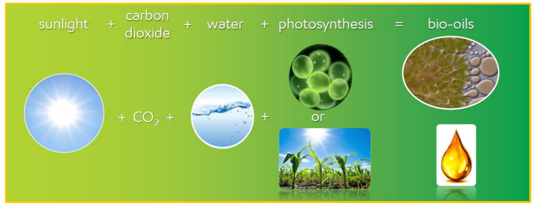








The technologies are being developed....



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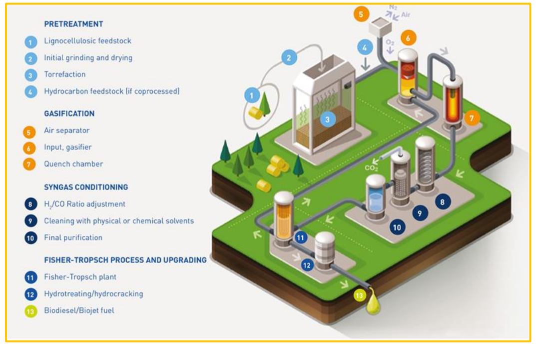
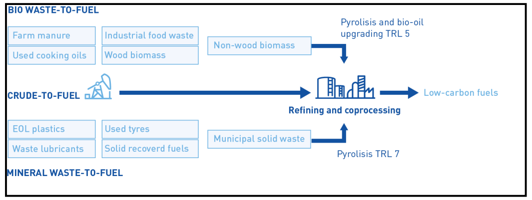
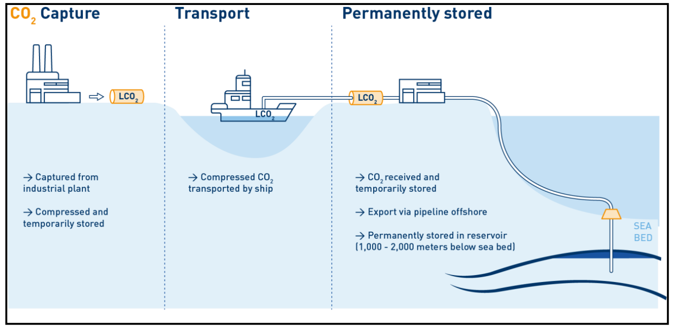
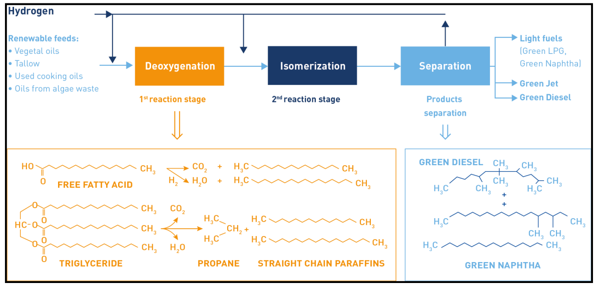
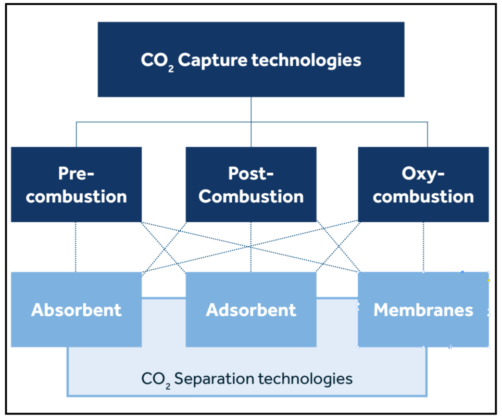


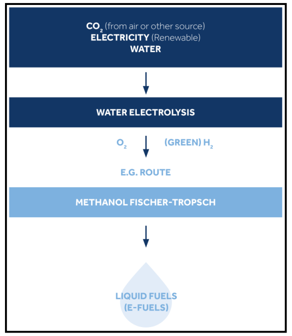


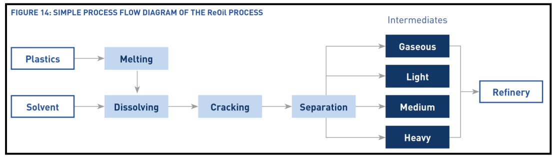
......and this is just a sample of all the R&D and Innovation projects currently underway

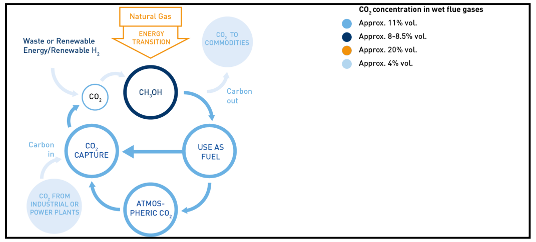


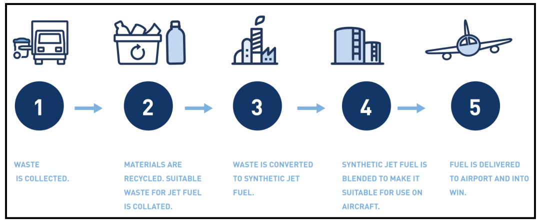




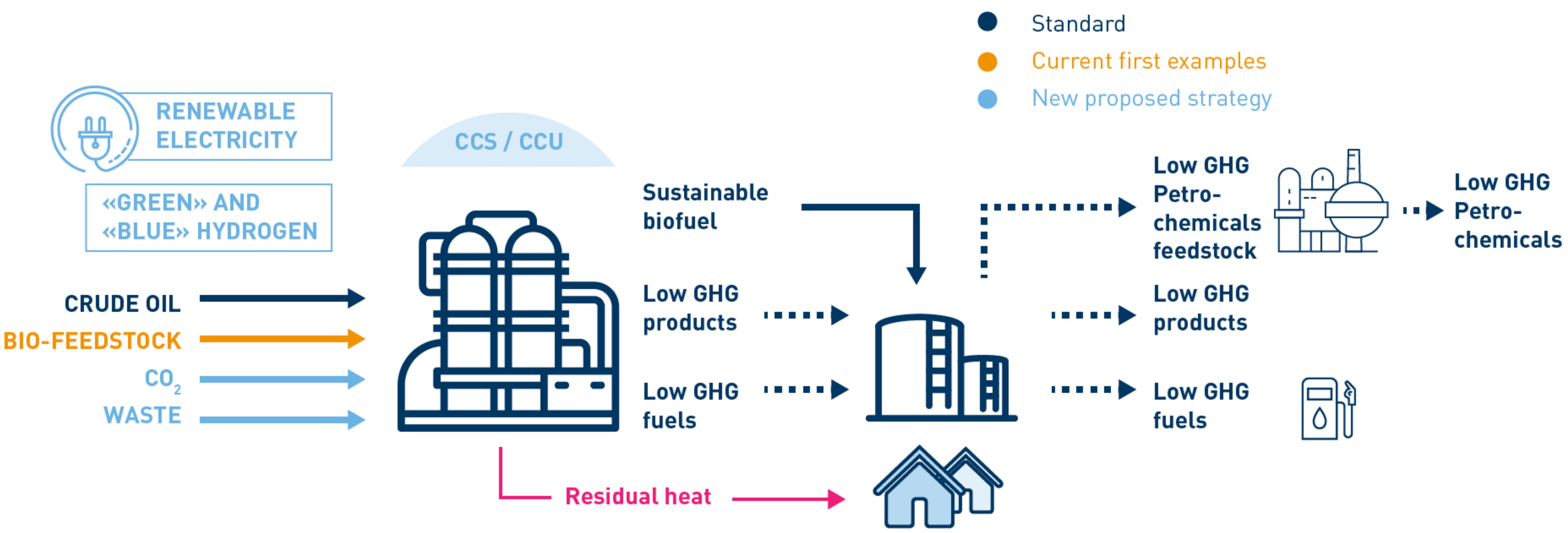








The refinery as an ENERGY HUB within an INDUSTRIAL CLUSTER



Why can refinery industry lead?

- Extensive corporate R&D capability.
- Deep experience in hydrogen and biofuels technologies.
- Growing experience in CCU & CCS.
- Close involvement in industrial clusters.
- Financial & project capability.
- Already subject to strong regulation.

Why is this an attractive solution for the EU?

- **Industrial clusters** exploit synergies and jointly develop innovative low carbon technologies.
- Low carbon liquid fuels reduce emissions of **all the vehicles in circulation immediately.**
- Complements Europe's **global lead on ICE technologies.**
- Full **utilisation of existing infrastructure** from refineries to service stations.
- **Industrial opportunity for EU** to export technologies to the rest of the world.
- **Skilled jobs, energy security, technological leadership** for EU economy.

Policy enablers and requests

- Ensure refinery and fuels low-carbon transition are included in **the EU's industrial and technology strategies.**
- Policy framework and regulatory system for **long-term investor confidence.**
- Retain refineries' **economic viability** despite aggressive **international competition.**

Policy framework: a proposal

Throughout the transition → Protection of the international competitiveness of the industry

UNTIL 2030
ALIGN CURRENT VEHICLES AND FUELS REGULATIONS

- TTW correction for RED – based on market average
- CO2 credit system for new fuel technologies
- CO2 credit system for CCS

POST 2030
"BREAK THE SILOS": A COMMON CARBON PRICE FOR VEHICLES & FUELS

- Vehicle standard becomes sole CO2 regulation in transport (no RED,…)
- CO2 credits generated from all WTW (or LCA) steps count for vehicle standards

LONGER TERM
A COMMON CARBON PRICE ACROSS THE ECONOMY

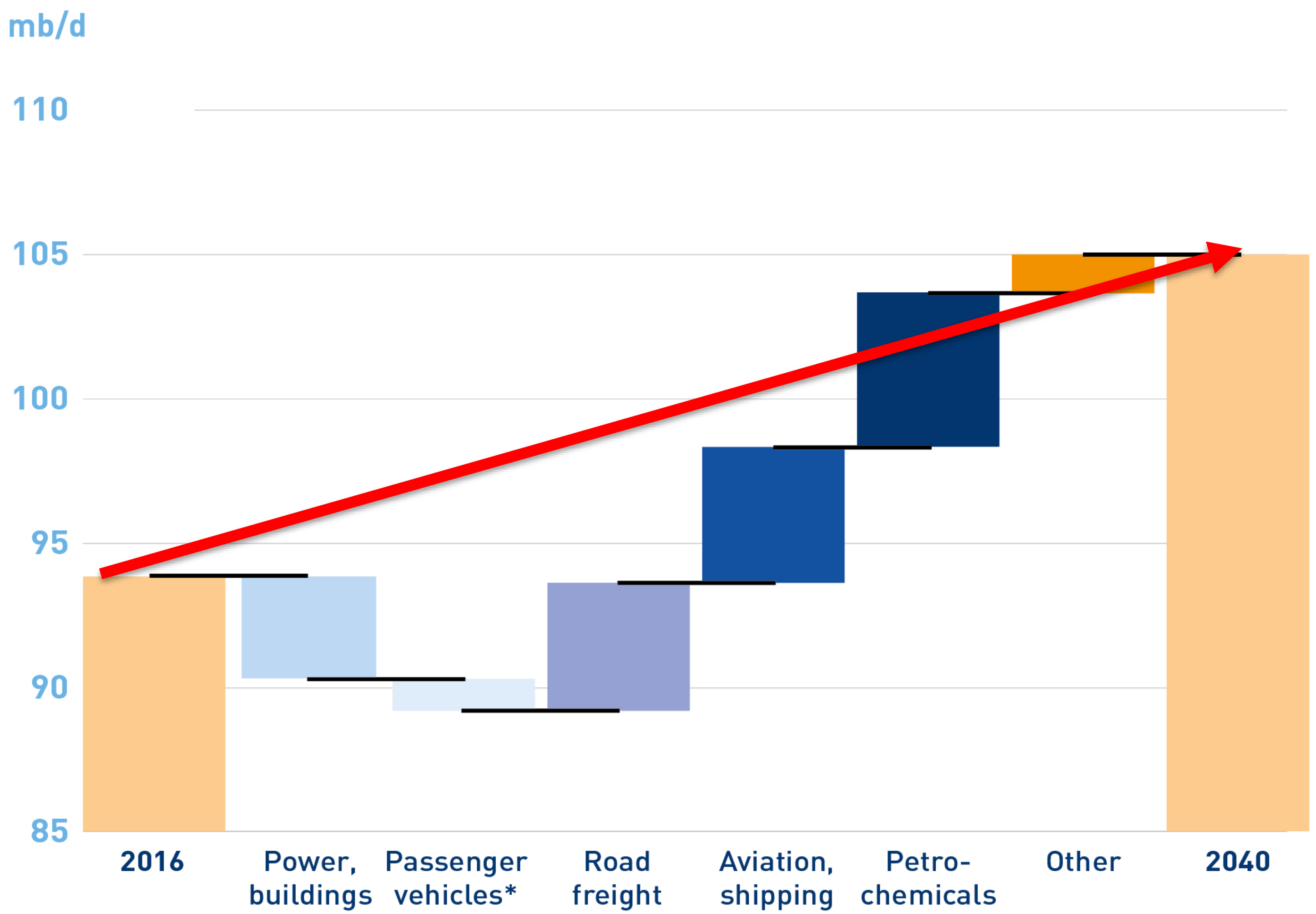
- One carbon price – based on LCA – for all sectors
- Effective carbon leakage protection for EU industry and economy

Conclusion

Reinforcing European climate leadership through technologies and industrial strategy.

BACK UP SLIDES

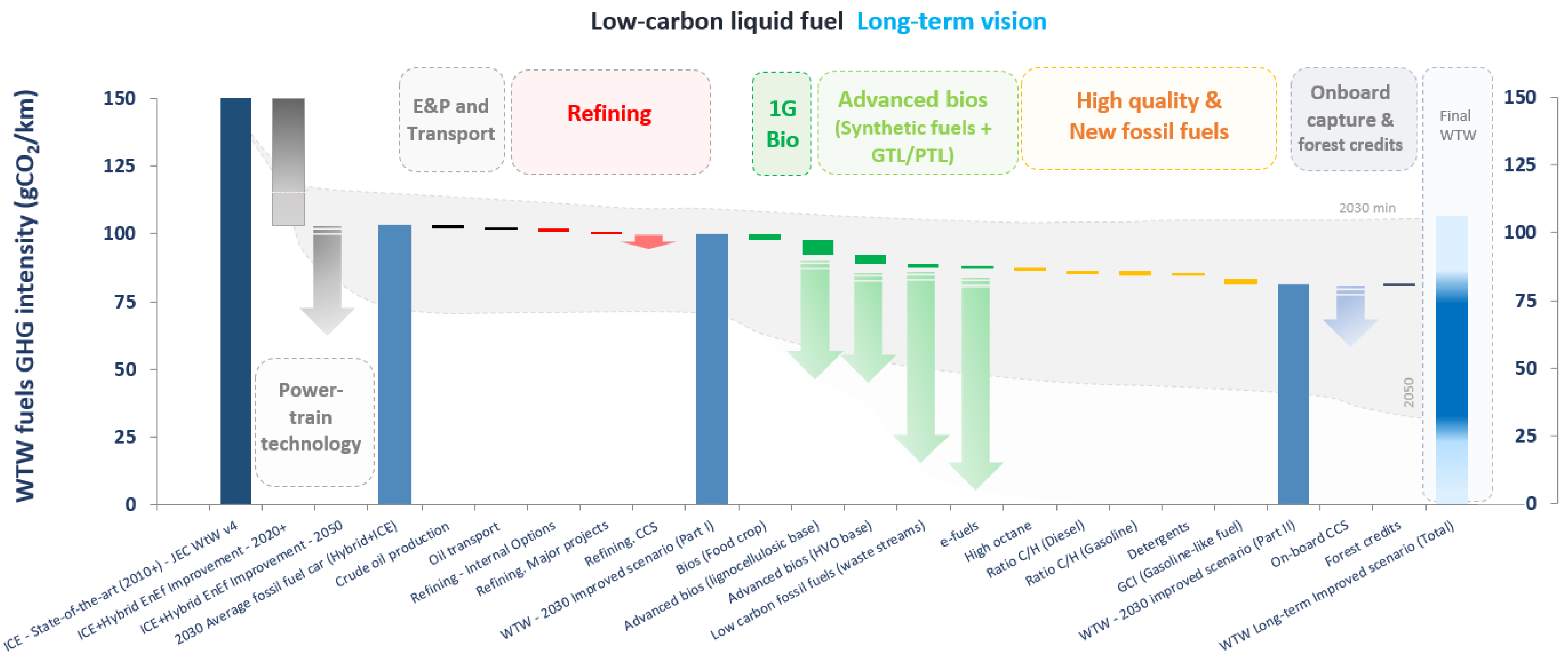
Change in world oil demand by sector in the New Policies Scenario - IEA WEO 2017



Source: IEA, WEO 2017

We have the technologies…

Multiple pathways towards low carbon transport



Comparison between the Mass EV and the Low-Carbon Liquid Fuel scenarios

Mass Electrification scenario

- An estimated investment in EV charging and network infrastructure between 630B€ to 830B€ to 2050.
- Electricity demand for charging EVs in the Light Duty Vehicle segment will represent 17,5% of EUs' 2015 electricity generation.
- Measures to address the annual loss of 66B€ in fiscal revenue from fuel sales.
- The construction of 15 Gigafactories to supply batteries to the European EV market (550TWh).
- Significantly increased Lithium extraction just for the full electrification of the European cars and vans, with a peak estimated at 6 times the 2016 Lithium global production level in the world.
- Construction of an equally large battery recycling industry will be needed, with unknown power requirements and environmental impact.

Low-Carbon Liquid Fuels scenario

- Requiring significantly lower infrastructure investments since only 50% of the recharging capacity of the High EV scenario will be needed (326 to 390B€).
- Only require 5 or 6 Gigafactories for battery production and significantly limit dependency on demand of raw materials to less than half of the High EV scenario requirements
- Offer a sustainable alternative for other transport segments such as Aviation, Marine and Heavy Duty road transport
- The opportunity to supply to the entire existing light duty fleet as these low-carbon fuels appear on the market, thereby enabling a wider GHG reduction compared to the usual fleet renewal scenario.

Cumulative societal cost comparison between the Mass EV and the Low-Carbon Liquid Fuel scenarios

- From the graph we can see that externalities related to the Low-Carbon Liquid Fuels scenario are similar to what would be the full electrification scenario, serving as the reference in this assessment
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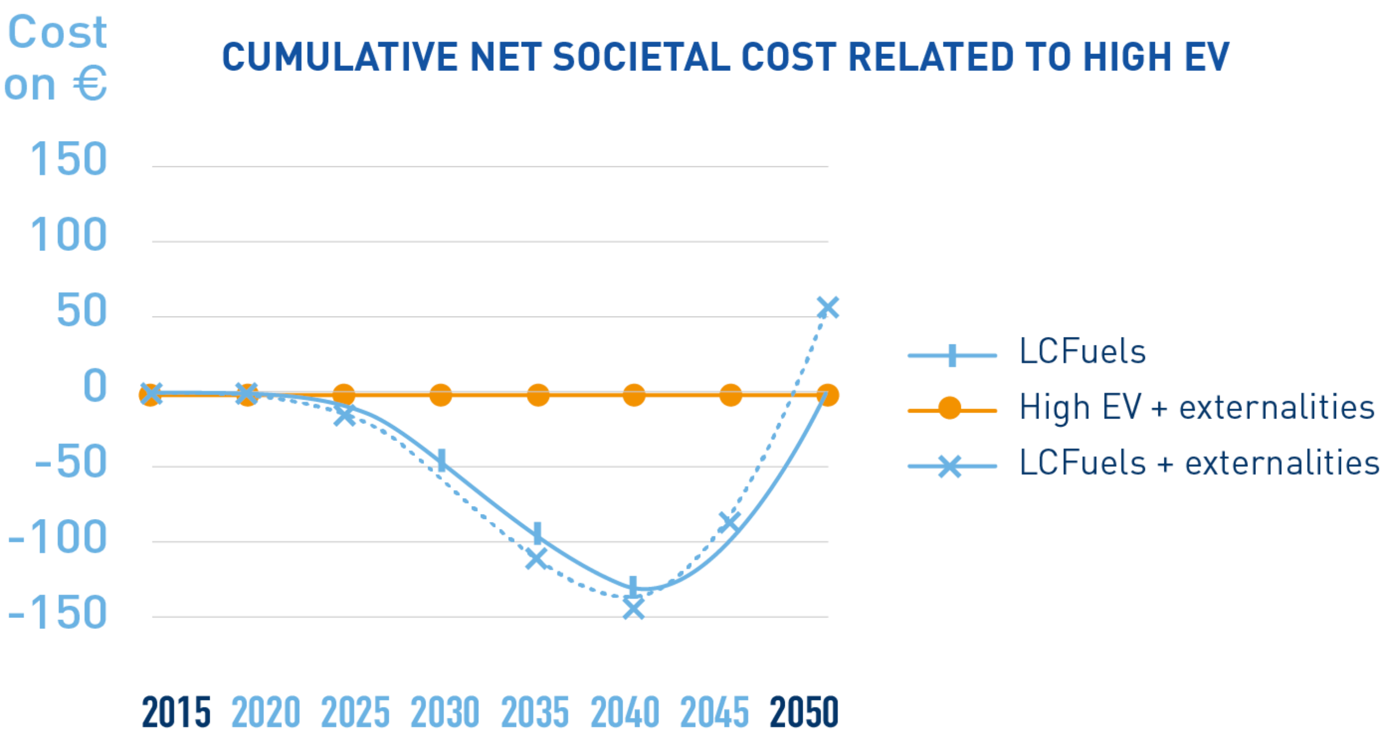


Source: Ricardo Energy & Environment SULTAN modeling and analysis

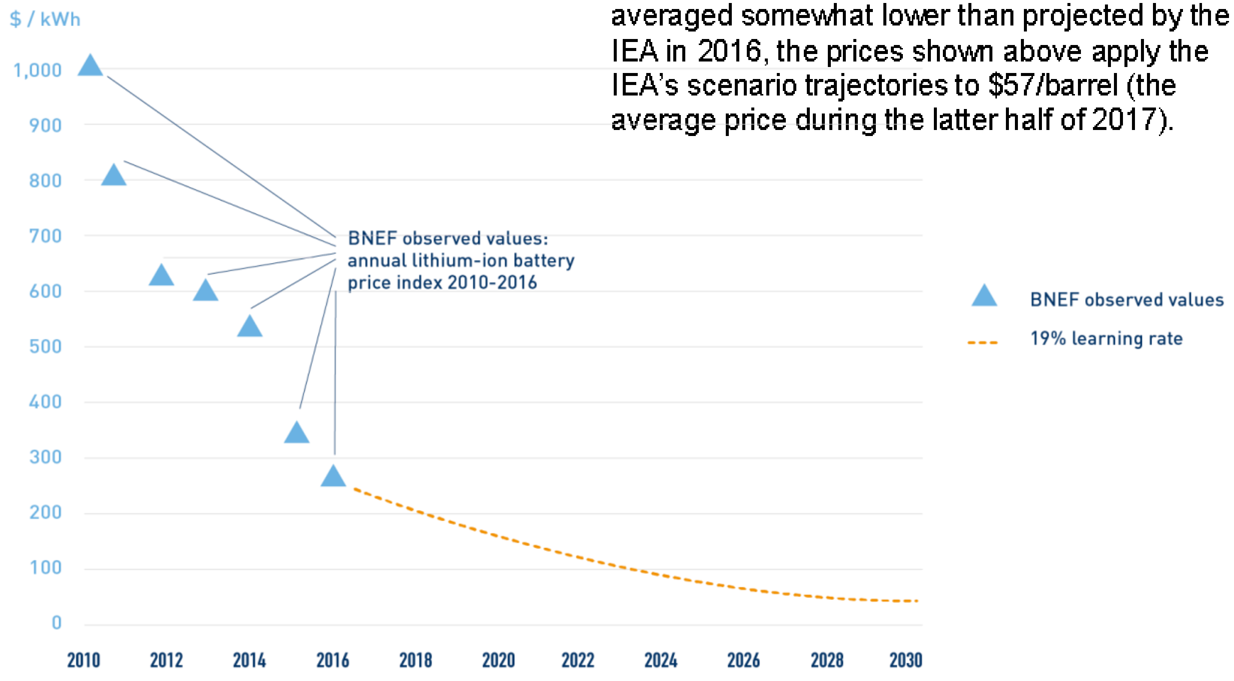
External costs (or 'externalities') are the monetary value attached to the impacts of GHG, air quality pollutant emissions and other impacts such as noise and congestion due to indirect effects, for example on public health and other elements

Mass EV scenario – What about raw materials and import dependency ?

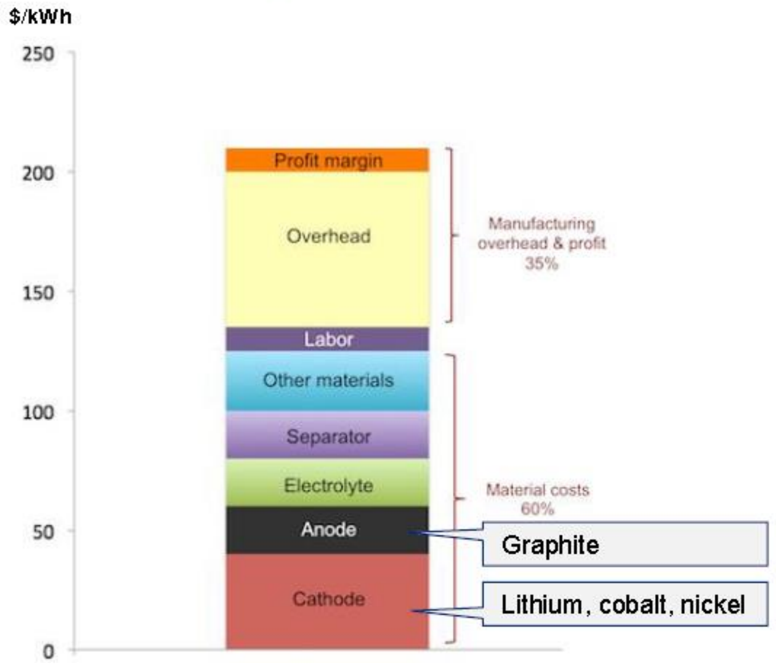
Source: NERA Economic Consulting

Oil prices used by scenario	real 2016 $/barrel			
	2017	2020	2030	2040
Current policies scenario	57.1	83.0	128.5	147.8
New policies scenario	57.1	80.0	112.3	125.5
450 Scenario	57.1	73.9	86.0	78.9

- To reflect the fact that 2017 oil prices have averaged somewhat lower than projected by the IEA in 2016, the prices shown above apply the IEA's scenario trajectories to $57/barrel (the average price during the latter half of 2017).



Lithium-ion battery cost breakdown



Mass EV scenario – What about raw materials and import dependency ?

Source: NERA Economic Consulting

Battery raw materials are likely to be imported : key metals required

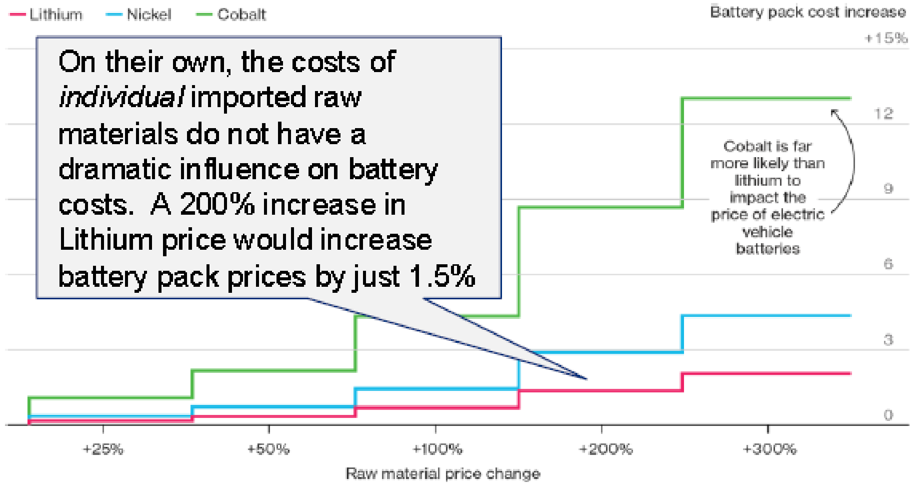
Over 50% of global lithium reserves are in

Even if 100% of European BEV battery demand were to be supplied by European battery producers (for example, if European

Metals required

- **Lithium** – Portugal produced around 200 tonnes of lithium in 2016 (around 0.5% of global production). There are some further Lithium deposits in Europe potentially being developed (e.g. Serbia, Czech Republic, Saxony in Germany and Cornwall in the UK).
- **Cobalt** – More than 50% of production in 2016 came from Democratic Republic of Congo (DRC). Other major producers are China, Canada, Australia and Russia.
- **Nickel** is more widely available – the biggest producers are the Philippines, Russia, Canada and Australia.

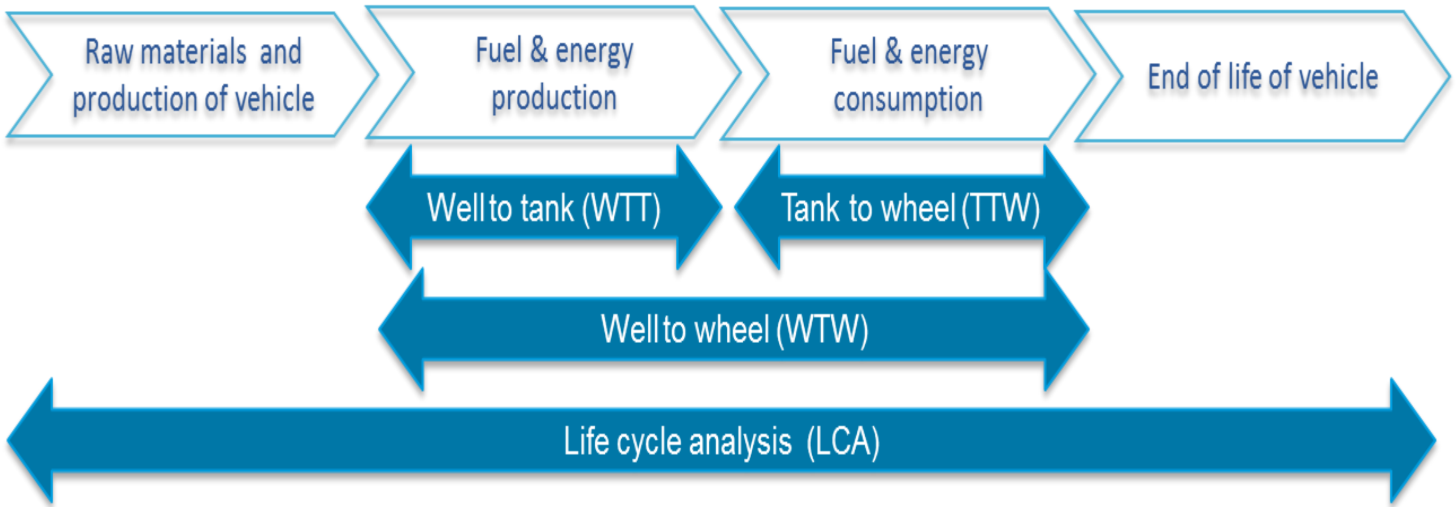
Battery price impact of higher metal prices



Cost ($)	12,000	1,000	7,000	20,000
-% EU	10%	100%	100%	54%
-% imported	90%	0%	0%	46%

Sources: NERA Analysis based on data from Qnovo.com, US Geological Survey

Background - the Life Cycle approach



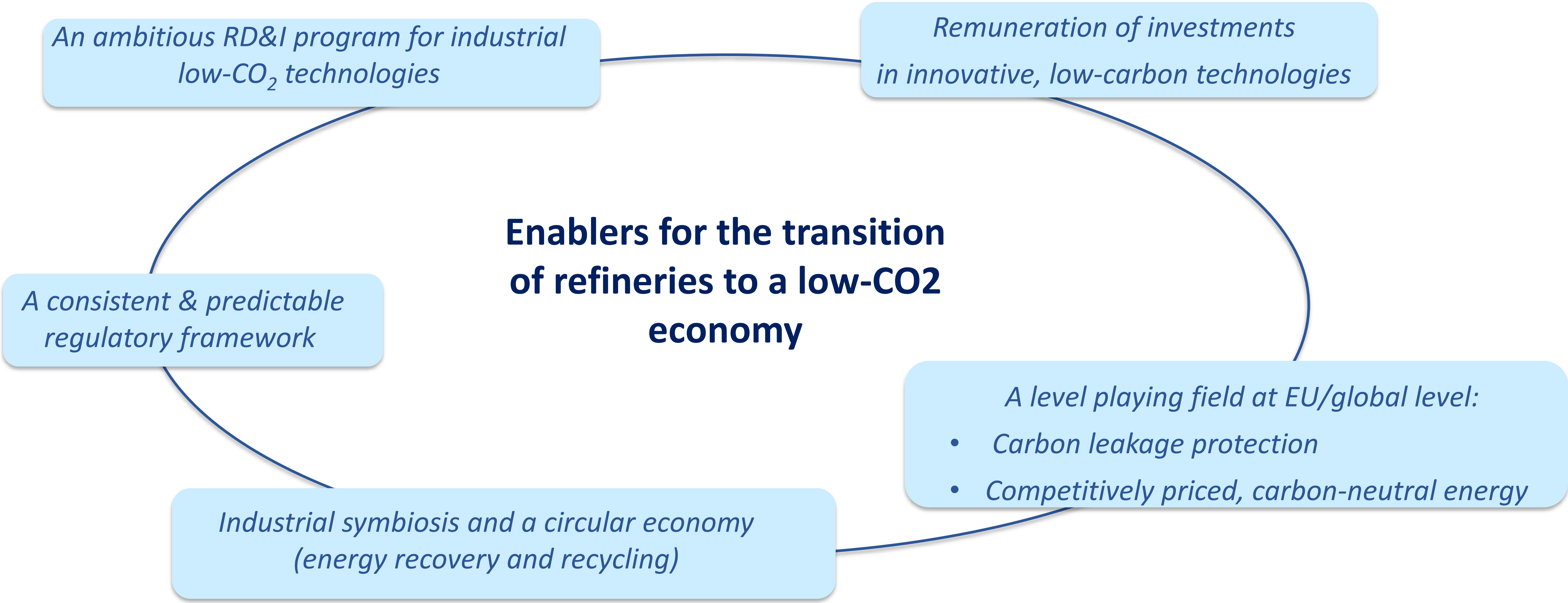
As the impact of GHG emissions on climate change is independent of the specific point of emission, a non-comprehensive approach may lead to wrong – and counter-productive – conclusions.

Other measures for the short and medium term

Other measures to stimulate R&D and unlock investment in low-carbon technologies

- **Long-term contracts with public counterparties**
- **Fiscal measures**
- **Public procurement**
- **Incentives for R&D and for early-mover investments**

Key points for the EU industrial strategy



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The regulatory framework in the short term (until 2030)

Main Goals

- **A holistic approach is needed - stop considering vehicle and fuels regulations in separate silos.**
- **A correction factor to apply when assessing a vehicle's compliance with an emissions standard (TTW)**

Tank-to-wheel correction for RED compliance based on a market average of fuels

A correction factor can be calculated by taking the **average EU percentage of all recycled carbon-based and renewable fuels** placed on the EU road transport fuel market as a result of the RED.

Alternative compliance credit system for promising fuels and technologies

An agreement between the fuel supplier and the vehicle manufacturer for more-expensive but very promising fuel technologies

Alternative credit system for capture and storage of emissions (CCS) generated by fuel producers

Credits for alternative compliance with vehicle efficiency standards could be agreed as part of a bilateral contract between an investor in CCS and a vehicle manufacturer,

The regulatory framework for the medium term (post-2030)

Main Goals

- **A cross-sectoral approach with a single cost of carbon across the economy**
- **Then, a single CO2 market for (road) transport**
- **Incentives from carbon savings for Fuels or the combination of efficient vehicles and low-carbon fuels**

A WTT/LCA regulatory approach

- A **CO_2 credit mechanism** to make the reduction in CO_2 emissions generated on a WTT basis/LCA perspective count for meeting vehicles' CO_2 targets
- The vehicle emission standard would become the **only regulatory instrument** driving the reduction of CO_2 emissions in road transport.
- The CO_2 credit certificates issued by **fuel suppliers** would consist of
  - **proven GHG emission reduction** of the production of fuels used in the EU road transport system
  - **proven GHG emissions reduction** from the use of recycled or renewable CO_2 in the formulation of the fuel, which would count towards net CO_2 emissions from the production of that fuel

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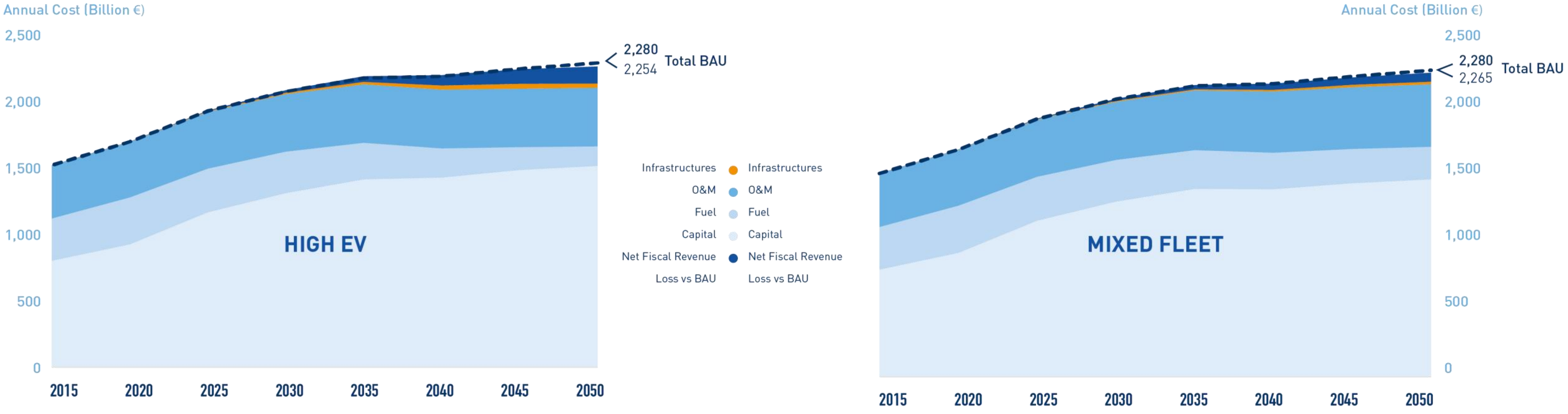
Cost comparison between the Mass EV and the Low-Carbon Liquid Fuel scenarios



Source: Ricardo Energy & Environment SULTAN modeling and analysis