Eni contribution to Energy Transition

New fuels for transportation and sustainable mobility

Roma, 19 Aprile 2018

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Summary

- *Effect of vehicles exhaust emissions on urban air quality*
  - *Urban air quality*
  - *Regulated exhaust emissions and exhaust gas post treatment systems*
  - *New cycles for emissions assessment*

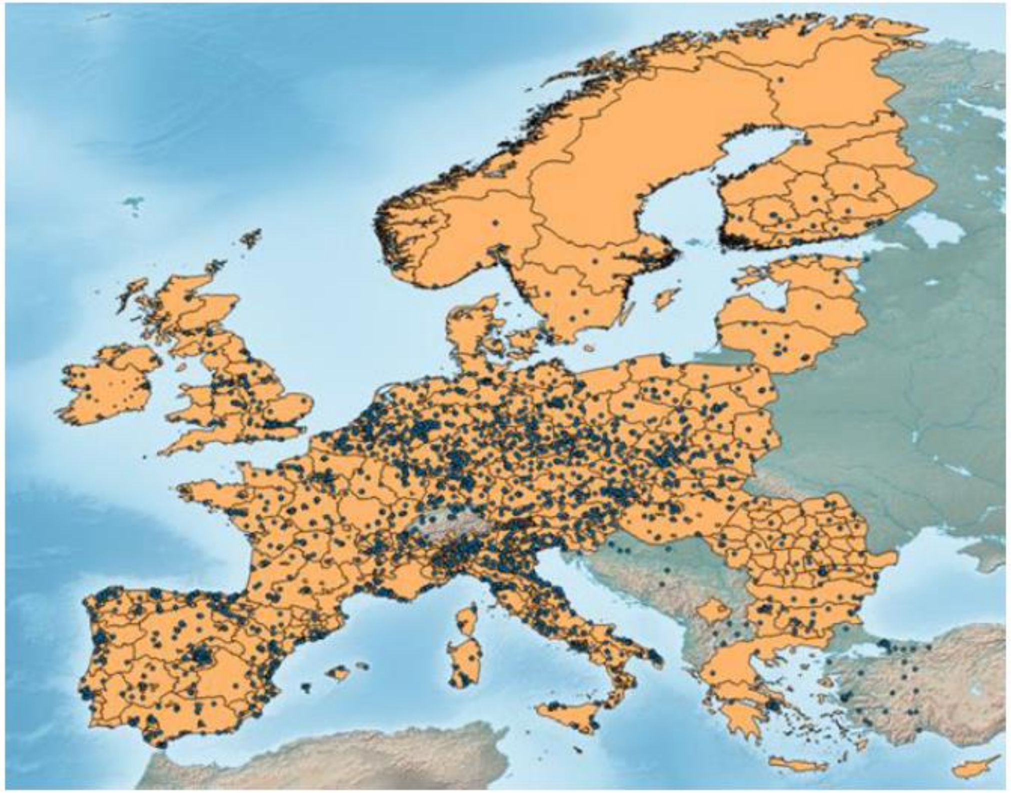
- *Decarbonization of transports*
  - *Evaluation of CO_2 emissions with "well to wheel" approach (production-transportation-combustion)*
  - *Development of "low-carbon fuels" to lower GHG emissions from road transportation:*
    - *High quality biofuels produced by green refineries;*
    - *The natural gas as a bridge for the decarbonization of transports;*
    - *Methanol as energy carrier and the methanol circular economy;*

Urban air quality:
Effect of vehicles exhaust emissions

Urban Air Quality EU countries (CONCAWE Study)

- European cities are facing increased pressure to take action to ensure compliance with nitrogen dioxide (NO_2) and particulate matter (PM) air quality standards.
- Despite considerable improvements in European air quality resulting from the progressive implementation of emission reduction measures over the past decade, non-compliance area persists.
- For both atmospheric particulates and nitrogen oxides (NO_X), the primary focus for emission reductions at both national and local levels is road transport.

European AQMZ and measuring stations



- Air quality management zones are designated under the ambient air quality directive (2008/50/EC) and oblige Member States to divide their entire territory into zones.
- The compliance of individual stations within each zone is used to determine overall zone compliance, specifically the single least compliant station is chosen for PM2.5 and NO_2. This means that zone compliance is reflective of the "worst" compliance situation within that zone.
  - The position of monitoring stations should have a huge influence on the measured value because of the different conformation of land and also weather conditions.
  - Within short distances, the measured concentration should vary widely mainly because of the complex path of air flows that drag exhausted particles.

Likely compliant (the modelled concentrations are less than the AQLV by at least 5µg/m^3)

Uncertain compliance (the modelled concentrations are within 5µg/m^3 of the AQLV)

Likely non-compliant (the modelled concentrations are greater than the AQLV by at least 5µg/m^3)

Particulates ($PM_{2.5}$, PM_{10})

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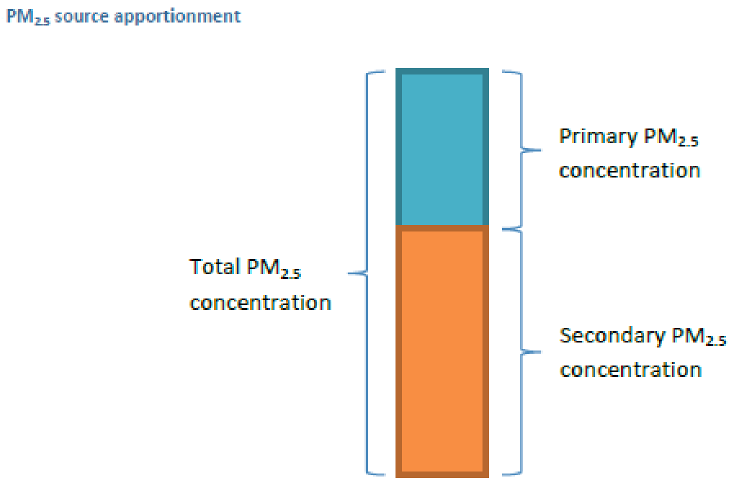
ENVIRONMENTAL SCIENCE FOR THE EUROPEAN REFINING INDUSTRY

- Common sources of particulate matter inside urban areas include wood and diesel for domestic heating, carbon for combustion, vehicles exhausted emissions, tires and brake wear.
- The relationship between emissions and particulate matter (PM) concentration is complex because significant, but varying portion of the total PM concentration derives from secondary sources.
- PM is made up of a primary and a secondary component; primary PM (PPM) is emitted at source while secondary PM (SPM) is formed from SO_2, NO_X, NH_3 & VOC emissions by chemical & physical processes in the atmosphere: this means that much of the PM measured at an air quality measuring station may have been emitted as a totally different chemical elsewhere, including trans boundary sources.



- In the case of PM10 there are two limit values, an annual mean and a daily exceedance limit. The daily limit of 50 µg/m³ must not be exceeded more than 35 times in a year and that the annual limit can still be fulfilled

Pollutant	Limit Value	Uncertainty Bounds
$PM_{2.5}$	25 µg/m³	±5 µg/m³
PM_{10}	30* µg/m³	±5 µg/m³
NO_2	40 µg/m³	±5 µg/m³

$PM_{2.5}$ UNCERTAINTY BOUNDS

Likely Compliant	< 20 µg/m³
Uncertain Compliance	20-30 µg/m³
Likely Non-Compliant	> 30 µg/m³

PM_{10} UNCERTAINTY BOUNDS

Likely Compliant	< 25 µg/m³
Uncertain Compliance	25-35 µg/m³
Likely Non-Compliant	> 35 µg/m³

Particulate (PM): The particles are classified according to their dimension:

- Total suspended particulate matter
- PM10 (particles diameter <10 µm di diametro)
- PM2,5 (particles diameter <2,5 µm)
- Ultrafine particles (particles diameter <0,1 µm).

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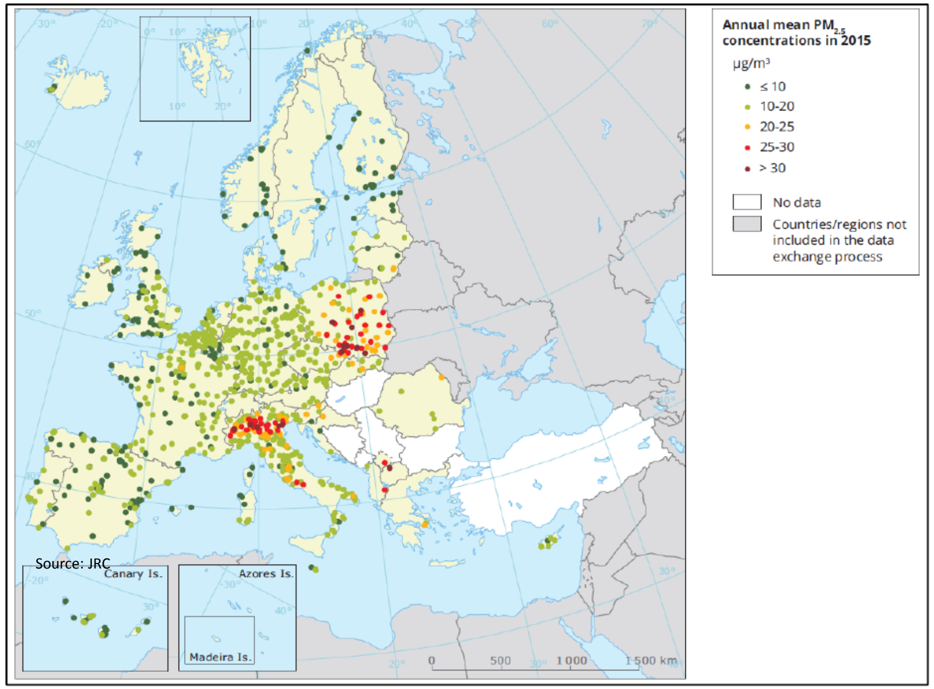
Urban Air Quality EU countries - Particulates ($PM_{2.5}$)

- The Concawe "Urban Air Quality study" analyses the effect of PM and NO_2 emissions on urban air quality in EU 27 countries:

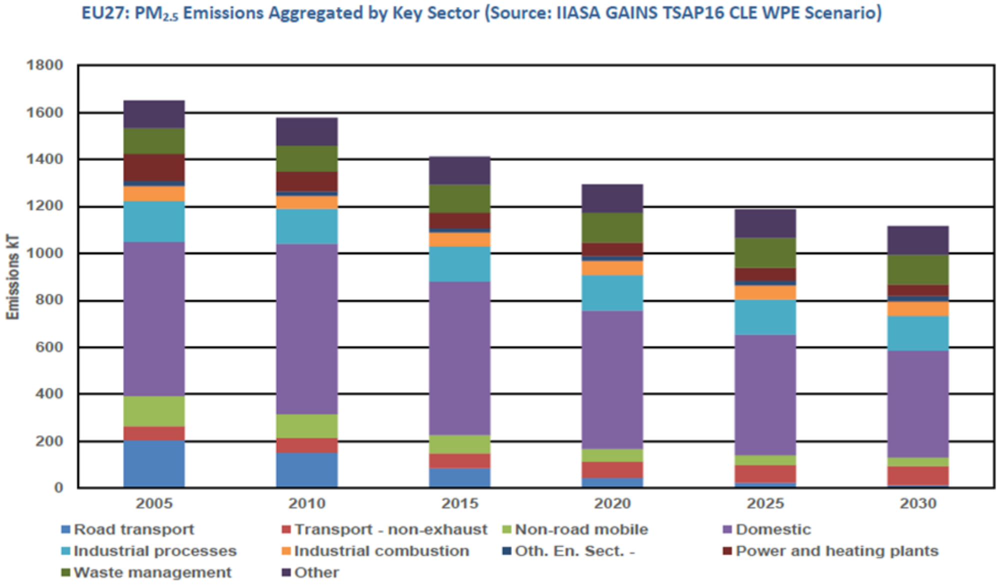
<u>**Annual average concentration PM 2.5 in 2015 (µg/m³)**</u>

EU target annual PM2.5 (25 µg/m³).



$PM_{2.5}$ AQLV Compliance: In 2015 the percentage of the EU population living in “likely non-compliant” zones is only 4%; with 68% of the population in “likely compliant” zones and 28% of the population living in zones that are close to the AQLV (within zones of “uncertain compliance”).

PM 2.5 Road Transportation: This study clearly highlights the diminishingly small contribution from the exhaust of road transport to overall PM concentrations between now and 2030. By 2020 non-exhaust emissions (related to brake, road and tyre wear: these sources are present in all road transport including 100% battery powered vehicles) emerge as the dominant emission from road transport (albeit small as a contribution to the total concentration) and by 2030 primary $PM_{2.5}$ emissions from road transport are essentially independent of the powertrain, meaning that all vehicles, regardless of motive force, would produce equivalent PPM emissions. <u>However these emissions represents just a lower percentage and the major contribution comes from other sectors (e.g. industrial plan still strongly dependent on the use of coal for power generation).</u> **By 2030, thanks to the renewal of the current car fleet with vehicles Euro 6 and seq., primary $PM_{2.5}$ emissions from road transport are essentially independent of the powertrain, meaning that all vehicles, regardless of motive force, would produce equivalent PM emissions.**



Urban Air Quality EU countries - Particulates ($PM_{2.5}$)

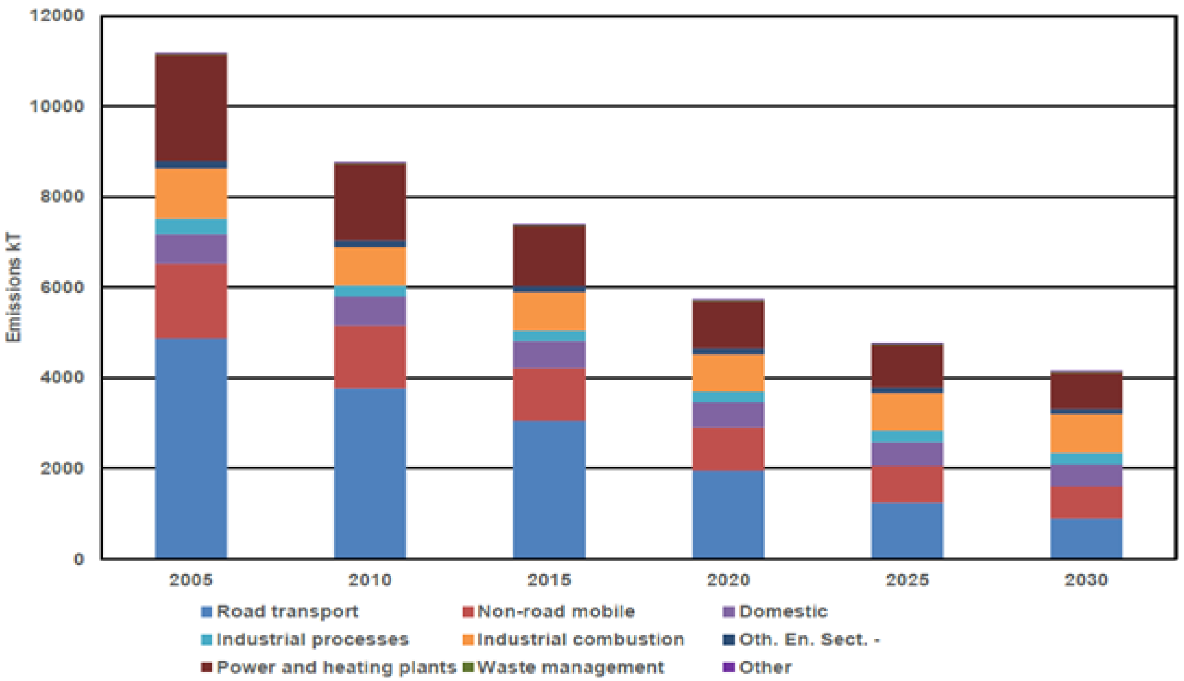
Urban Air Quality Study

In 2015 the percentage of the EU population living in “likely non-compliant” zones (max concentrations above 30µg/m3) is only 4%; with 68% of the population in “likely compliant” (modelled concentrations below 20µg/m3) zones and 28% of the population living in zones that are close to the AQLV (within zones of “uncertain compliance” between 20 and 30µg/m3). The EU population living in these zones of “uncertain compliance” continues to decline between 2015 and 2030 as already legislated measures take effect so that the population living in likely compliant zones increases to 77% by 2020 and to 81% by 2030. At the same time, the population living in zones of uncertain compliance reduces to 19% by 2020 and to 15% by 2030. The percentage of population living in likely non-compliant zones remains unchanged at 4% from 2015.

Urban Air Quality EU countries – NOx

- NOx is the generic term for mixture of nitric oxide (NO) and nitrogen dioxide (NO_2) deriving from the combustion process.
- NO is produced during combustion and, due to the reaction with ozone, forms NO_2 which is released in the atmosphere.
- NO_2 should decompose at sunlight so that the mixture (NO/NO2) should vary widely.
- Sources of NOx in the urban environment are road transportation, domestic combustion, generation for industrial processes,
- For NO_X emissions the proportion produced by road transport, which is today the major contribution, is reducing over time and this is consistent across all EU27 countries.
- By 2030 road transport is still a relatively large source of NOX emissions however, by this time, it only accounts for 21% of the total emissions.

EU27 NO_x Emissions by Key Sector (IIASA GAINS TSAP16 CLE WPE Scenario)

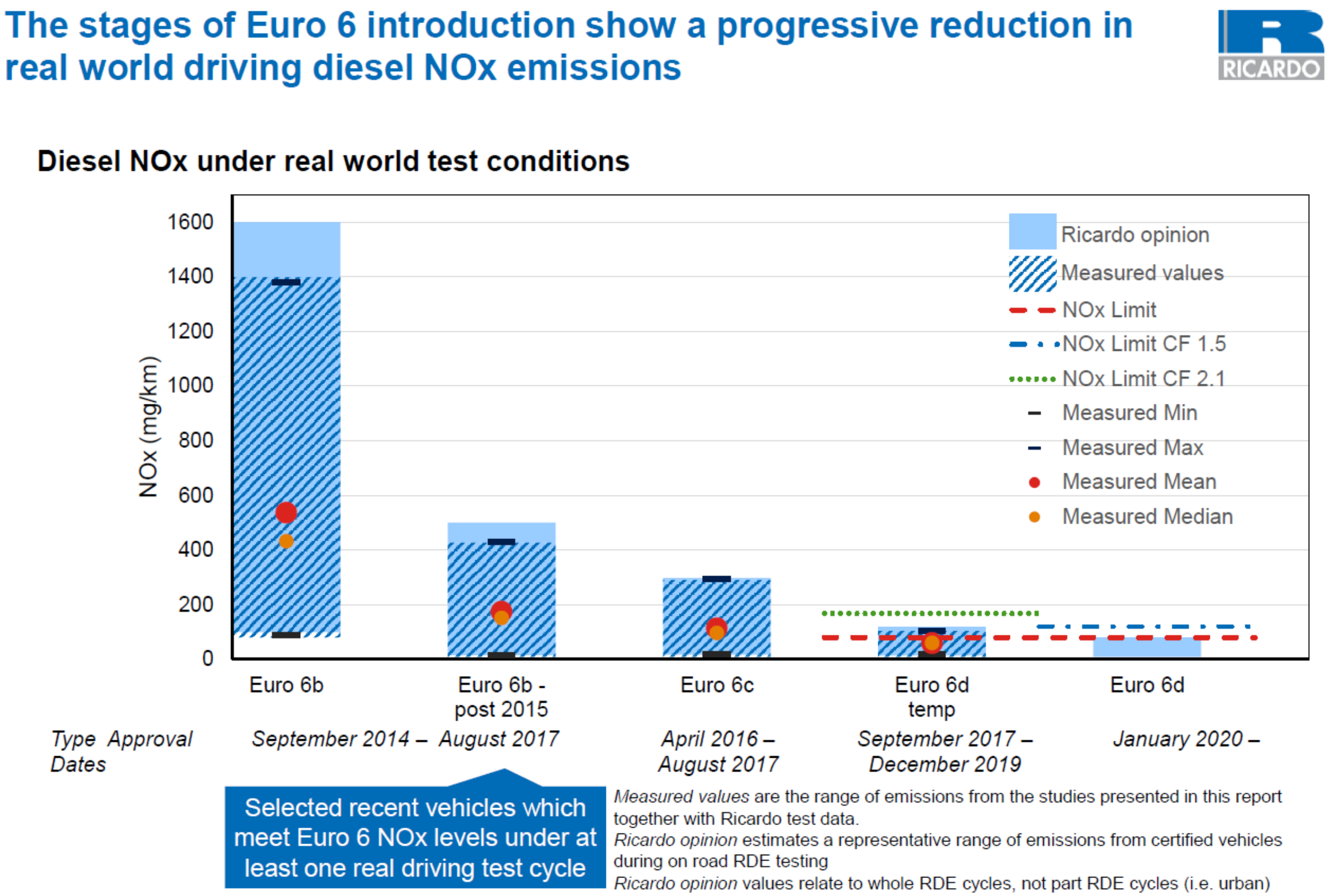


FOCUS ON NOx MEASUREMENT

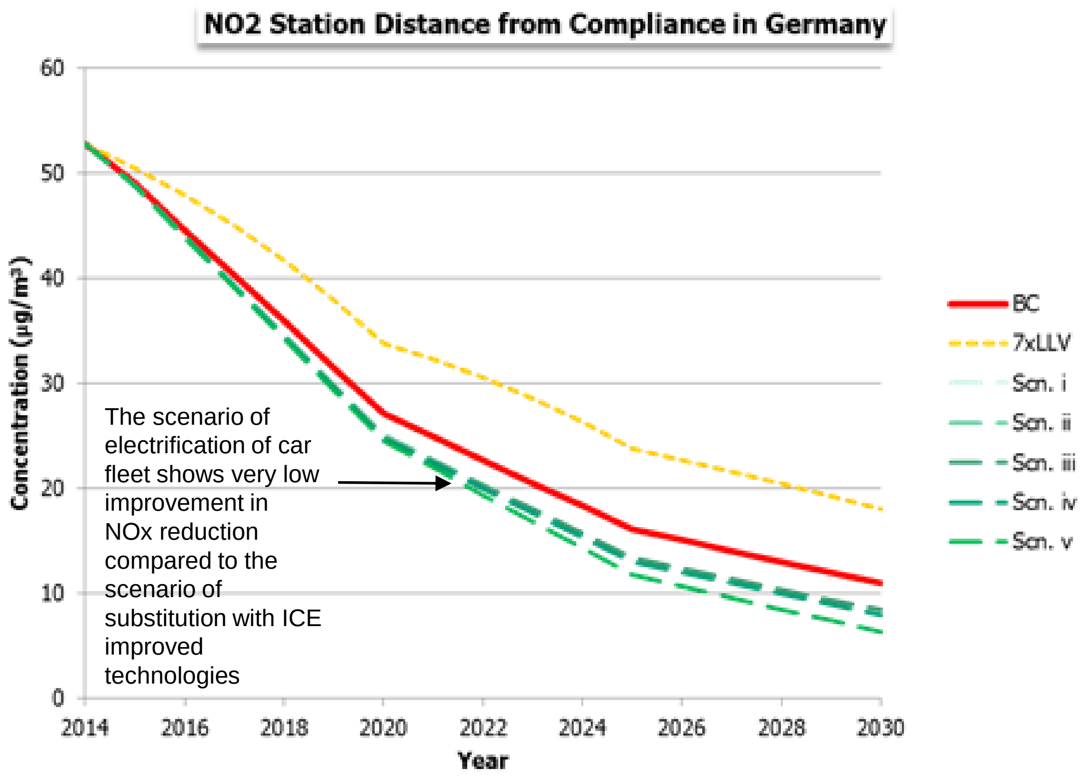
- As a result of the so called "Dieselgate", significant mismatches between laboratory tests and real driving behavior have been registered;
- The pollutants whose real evaluation has resulted highly further the measured value, have been exactly NOx, with emissions factor 2-4 times higher on average than regulated limits. Individual tests (JRC, ICCT, TNO, ADAC), have shown higher discrepancies with NOx values 14 times higher;
- The development of new Real Driving Emissions homologation cycles, is actually producing a realignment of emissions values between homologation and real driving conditions;
- This realignment should certainly contribute to reduce the contribution of road transportation to overall NOx emissions.

Ricardo study on diesel vehicles emissions – NOx (1)

- The study carried out by the consultancy company Ricardo on behalf of Concawe, shows a significant reduction of NOx exhausted emissions with the new diesel technologies (from euro 6d onwards).
- In this study, emissions have been evaluated with the new vehicle homologation procedure, the so called "Real Driving Emissions", developed after the dieslgate to have a higher accuracy of these tests compared to normal driving conditions on the road.
- The new legislation for emission regulation, for NOx exhausted emissions, has introduced a conformity factor CF 2,1 from 2017 and CF 1,5 from 2020.



Ricardo study on diesel vehicles emissions – NOx (2)



- Regarding NOx emissions future trends, Ricardo study realizes an analysis based on different scenarios which represent the substitution of the current car fleet with vehicle characterized by progressively better CF for NOx compliance.
- Euro 6d vehicles, homologated with the new WLTC cycle, completely fulfill NOx limits and no CF are needed.
- The scenario V considers the complete electrification assuming that after 2020 no diesel vehicles will be registered but just electric vehicles.
- Starting from 2025-30 only 1% of the stations inside the Air quality management zone is going to show non compliance in terms of NOx emissions (regardless of diesel/EV substituted). The contribution of Road transportation, indeed, will be irrelevant while mitigation measures will be still needed in other sectors like domestic heating.

In 2030 NOx from road transportation will be limited, measures will be required in other sectors like to industrial combustion and power and heating plants.

Urban Air Quality EU countries - NOx

Figure 6.16 - Base Case - NO_2 - Air Quality Management Zone Compliance - 2010

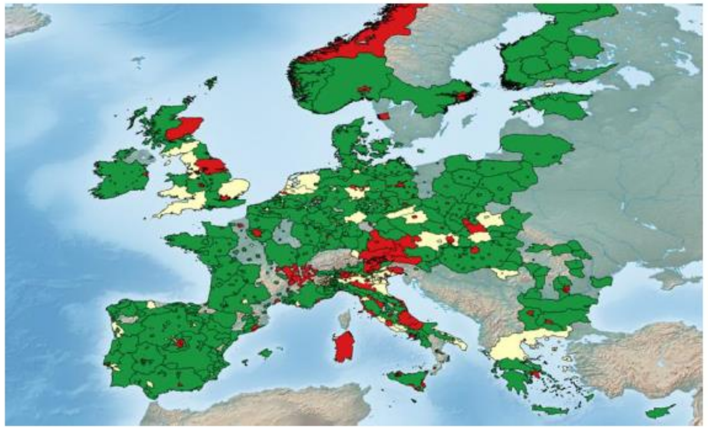


Figure 6.17 - Base Case - NO_2 - Air Quality Management Zone Compliance - 2020

Figure 6.18 - Base Case - NO_2 - Air Quality Management Zone Compliance - 2025

Figure 6.19 - Base Case - NO_2 - Air Quality Management Zone Compliance - 2030

In 2015 the percentage of EU population living in “non-compliant” zones (modelled concentrations above 45µg/m3) is approximately 18%; while 69% of the population live in “likely compliant” zones (modelled concentrations below 35µg/m3) and 13% of the population live in zones that are close to the AQLV and so within zones of “uncertain-compliance” (modelled concentrations between 35 and 45µg/m3).

The population living in zones of “uncertain compliance” continues to decline between 2015 and 2030 as those already legislated measures that are included in the emissions inventories take effect and by 2030 the population living in “likely compliant” zones increases to almost 93%. Importantly, in the period from 2015 to 2030, the pattern of residual non-compliance moves from large contiguous areas to discrete, small islands of non-compliance.

EU Emissions Standards for passenger car

- **Total Particulate**:

Particulate emissions are more relevant for diesel vehicle because, before the introduction of DPF (Diesel Particulate Filter), diesel vehicles exhaust emissions had a higher content of particles compared to gasoline vehicles. DPF is an efficient filter able to remove more than 99% of particulate matter in exhaust gases. In the next future, thanks to these abatement technologies, the particulate matter will be for a very low percentage caused by the combustion phase while, non-exhaust emissions related to tire, brake and road wear will be the higher contribution to the whole particulate emissions from road transportation.

- **Number of Particles (PN)**:

In addition to Total Particulate, in the European Emissions Standards, there is also a requirement for the Number of Particles (PN), for both diesel and gasoline vehicles. The limit on PN emitted per kilometer is now still evaluated with NEDC cycle and this requirement is set for Compression Ignition Engine (diesel) and gasoline direct ignition engine (GDI) which are more likely to emit a higher number of particles compared to indirect injection gasoline engine. The PN from gasoline vehicles can be reduced through the use of particulate filters (GPF, Gasoline Particulate Filters) which are however not still really widespread. Starting from September 2017, the limit for PN on gasoline vehicle will be reduced by ten times (from $6x10^{12}$ to $6x10^{11}$) reaching the same value fixed for diesel vehicles.

Table 1EU Emission Standards for Passenger Cars (Category M1*)

Stage	Date	CO	HC	HC+NOx	NOx	PM	PN
		g/km					#/km
Compression Ignition (Diesel)							
Euro 1†	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	0.14 (0.18)	-
Euro 2, IDI	1996.01	1.0	-	0.7	-	0.08	-
Euro 2, DI	1996.01[a]	1.0	-	0.9	-	0.10	-
Euro 3	2000.01	0.64	-	0.56	0.50	0.05	-
Euro 4	2005.01	0.50	-	0.30	0.25	0.025	-
Euro 5a	2009.09[b]	0.50	-	0.23	0.18	0.005[f]	-
Euro 5b	2011.09[c]	0.50	-	0.23	0.18	0.005[f]	6.0×10^{11}
Euro 6	2014.09	0.50	-	0.17	0.08	0.005[f]	6.0×10^{11}
Positive Ignition (Gasoline)							
Euro 1†	1992.07	2.72 (3.16)	-	0.97 (1.13)	-	-	-
Euro 2	1996.01	2.2	-	0.5	-	-	-
Euro 3	2000.01	2.30	0.20	-	0.15	-	-
Euro 4	2005.01	1.0	0.10	-	0.08	-	-
Euro 5	2009.09[b]	1.0	0.10[d]	-	0.06	0.005[e,f]	-
Euro 6	2014.09	1.0	0.10[d]	-	0.06	0.005[e,f]	6.0×10^{12}[e,g]
Euro 6C	2017.09	1.0	0.10[d]	-	0.06	0.005[e,f]	6.0×10^{11}[e,g]

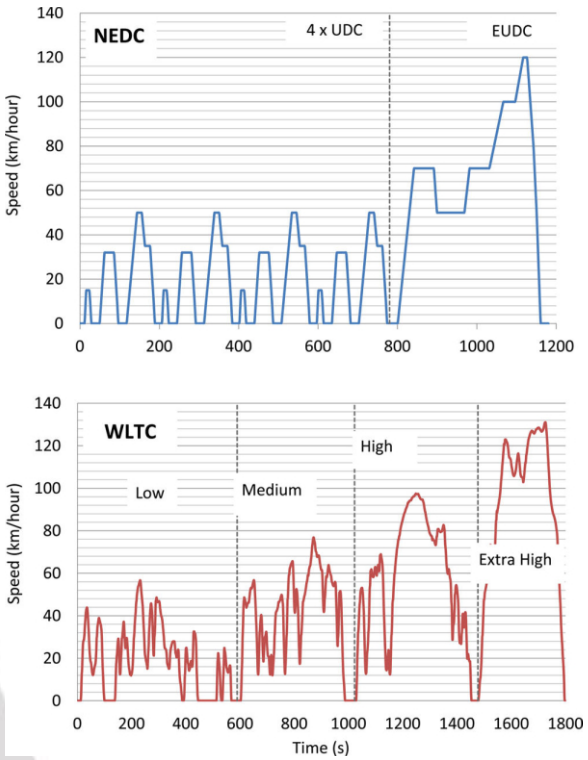
EU Emissions Standards for passenger car & Euro 6 Phase Out

- **Nitrogen oxides**

NOx emissions from gasoline vehicles are much lower than those from diesel vehicles. That is because gasoline engine works with stoichiometric conditions (ratio air/fuel=1) while diesel engine is operated with air excess (ratio air/fuel>1); for this reason in gasoline engines it is possible to effectively use a three-way-catalyst able to simultaneously reduce all emissions, including NOx.

There are also methods to reduce NOx emissions in diesel vehicles using technologies like exhaust gas recirculation (EGR), selective catalytic reduction (SCR) and NOx trap (LNT).

EGR should be used together with one of the other available abatement system (SCR and LNT) as well as a diesel oxidation catalyst (DOC) or a particulate filter (DPF). SCR catalysts are commonly used in heavy duty vehicles and are becoming increasingly common also for light duty vehicles, they work with AdBlue, a reducing agent based on urea which transform NOx in N_2, that can be released in the atmosphere. LNT is generally used in smaller vehicles and does not use any separate reducing agent.

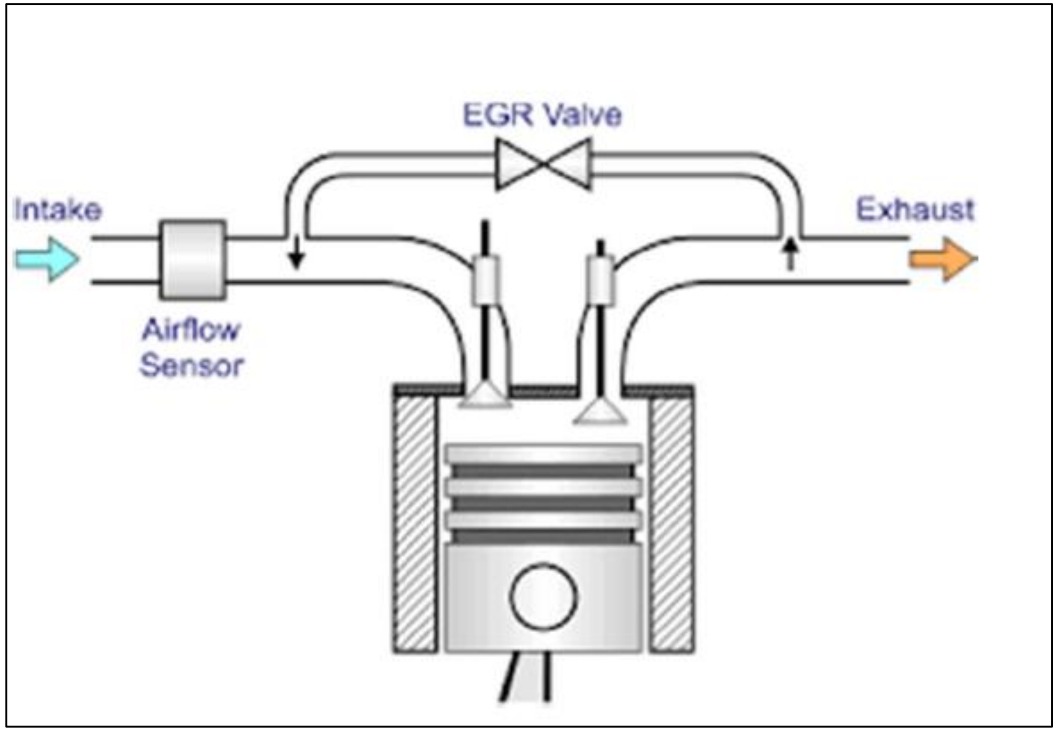


Key parameters	NEDC	WLTP
Duration (s)	1800	1800
Distance (km)	11.03	23.27
Average speed (km/h)	33.6	46.5
Max speed (km/h)	120.0	131.3
Stop duration (%)	23.7	12.6
Constant driving (%)	40.3	3.7
Acceleration (%)	20.9	43.8
Deceleration (%)	15.1	39.9
Average positive acceleration (m/s^2)	0.59	0.41
Maximum positive acceleration (m/s^2)	1.04	1.67
Average positive "speed·acceleration" (m^2/s^3)	1.04	1.99
Maximum positive "speed·acceleration" (m^2/s^3)	9.22	21.01
Average deceleration (m/s^2)	−0.82	−0.45
Minimum deceleration (m/s^2)	−1.39	−1.50

WLTC is far more representative of real-world driving conditions and emissions that NEDC for vehicle testing and certification.

Emission Abatement Systems - EGR: Exhaust Gas Recirculation

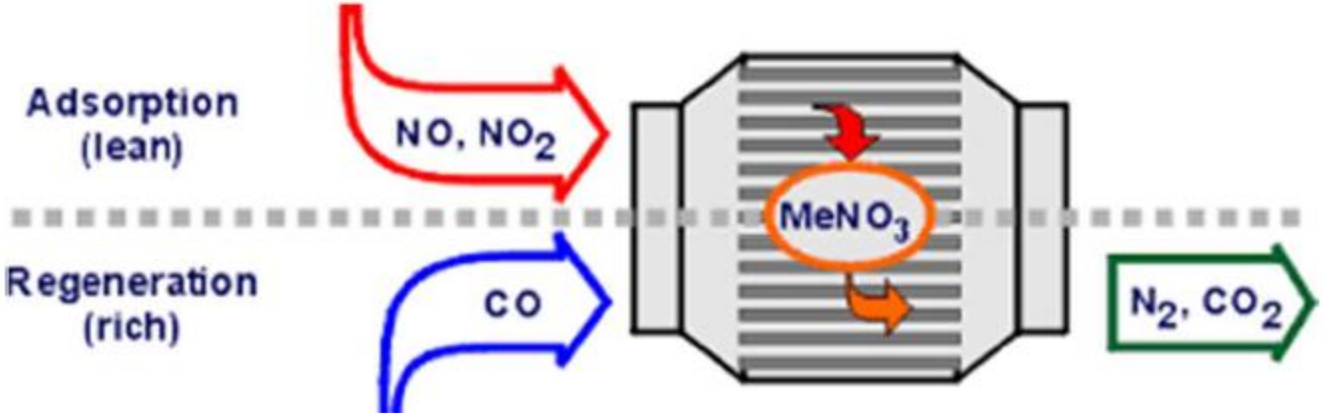
- A fraction of the exhaust gas is recirculated in the combustion chamber to reduce the temperature and the formation of NOx emissions engine out.
- The high pressure EGR is based on the recirculation of the exhaust gas before the turbine while the low pressure EGR recirculates the exhaust stream that has already gone through the particulate filter DPF.
- The main advantages of EGR are that:
  - An additional onboard hardware is not required
  - No reducing additive are needed



Source: Innovhub SSC

Emission Abatement Systems – LNT: Lean NOx trap

- The NOx are adsorbed on the catalyst during the operation of the engine in lean conditions. When the catalyst is completely saturated by NOx, it is regenerated in short time with rich mixture and NOx trapped inside are catalytically reduced

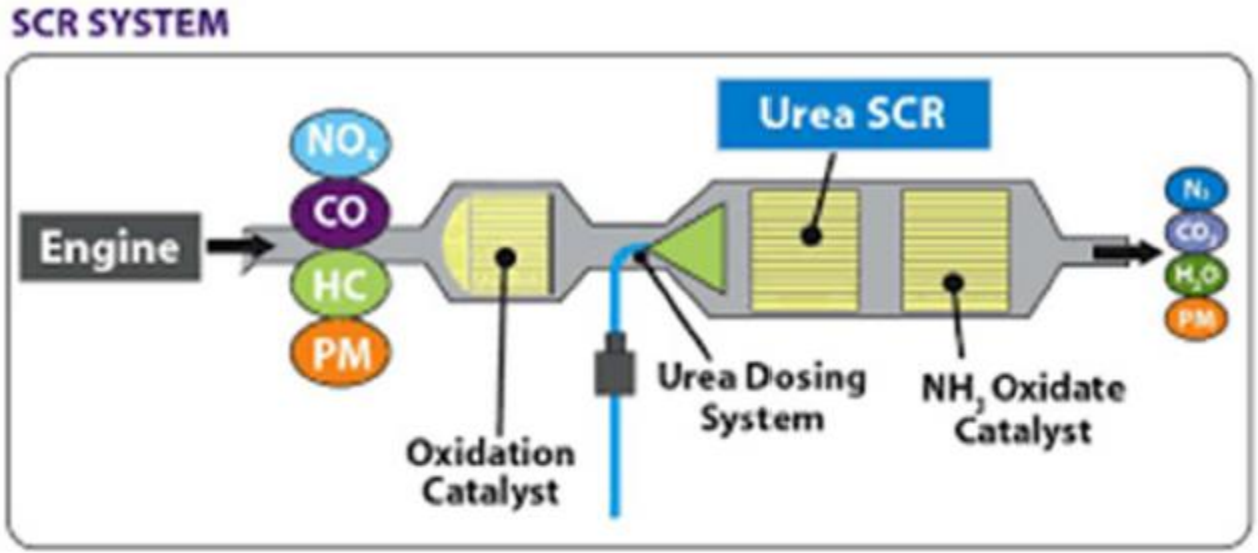


- Efficiency 70-90% at low engine load
- Good performances in terms of durability and NOx reduction
- Economically convenient for engine < 2.0 L
- An additional tank for reducing agent is not required
- A reducing additive in not required (no refill needed)

Source: Innovhub SSC

Emission Abatement Systems – SCR: Selective Catalytic Reduction

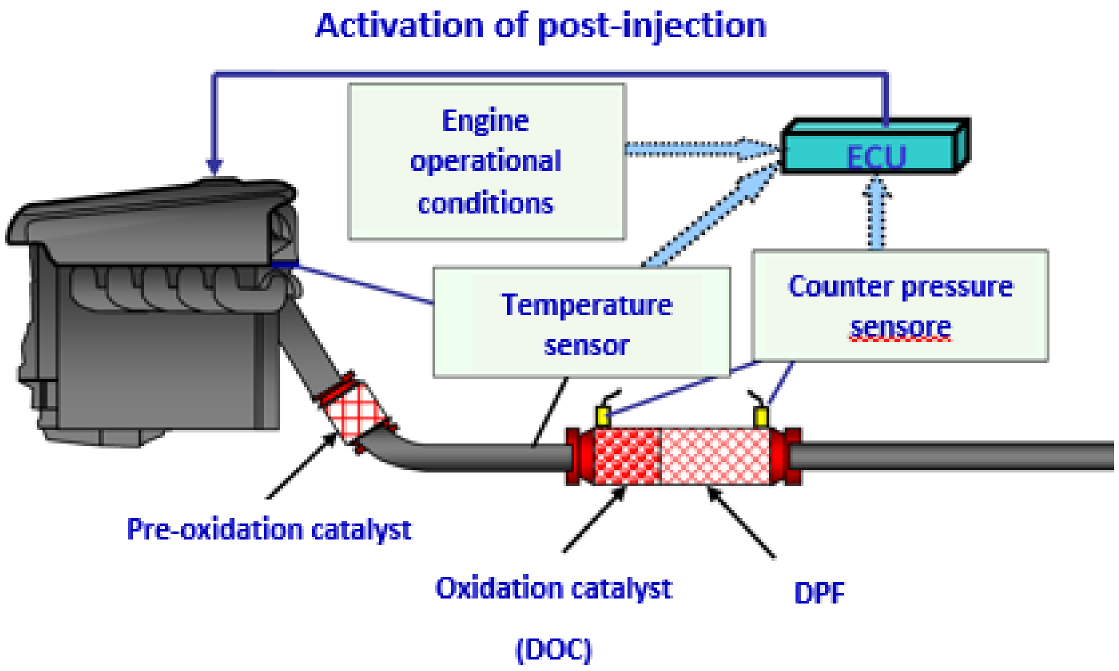
- A catalyst reduces NOx to gaseous nitrogen and water in the presence of ammonia.
- In most cases a solution of urea and water (an additive for diesel emissions, eg. AdBlue®) as a precursor of ammonia.



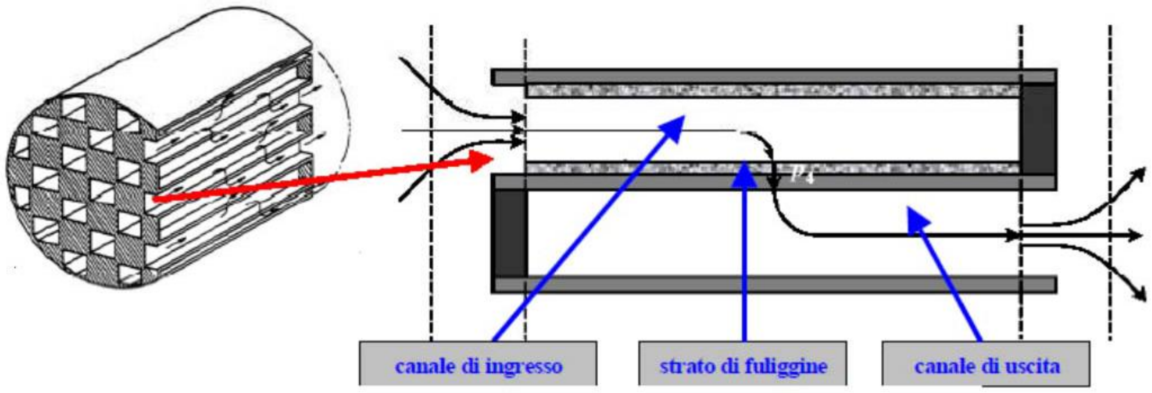
Source: Innovhub SSC

- Conversion efficiency NOx > 95%.
- More economically convenient for engine> 2.0 L.
- SCR also determine a higher fuel economy and a reduction of CO_2 emissions.

Emission Abatement Systems – DPF: Diesel Particulate Filter



Source: Innovhub SSC



T_{comb} PM ~ 650°C

T_{comb} PM ~ 450°C

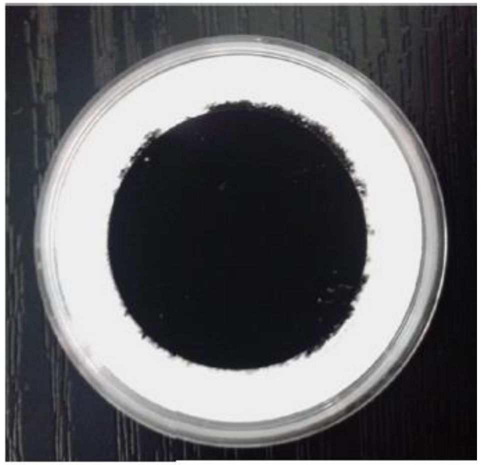
With a catalyst added to the fuel

- The DPF has become an essential component for diesel vehicles for the compliance to the **particulate emissions limits (6*1011 #/km)** defined by **Euro 5** and **Euro 6** standard.
- The operating principle of DPF is based on the separation of particulate from gaseous flow for deposition on a collecting surface.

Measurement of total particulate – diesel vehicles

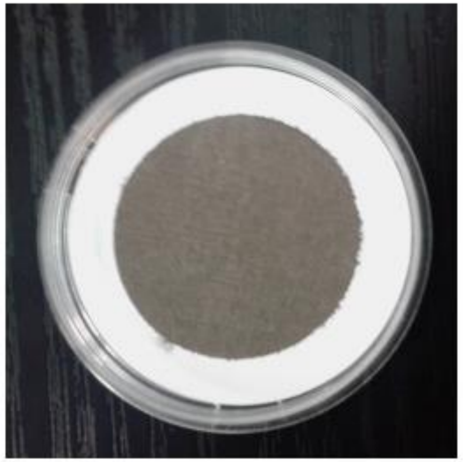
Cold start Urban Driving Cycle (UDC)

EURO 3



> 1 mg !

EURO 4 without DPF



~ 1 mg

EURO 4 with DPF

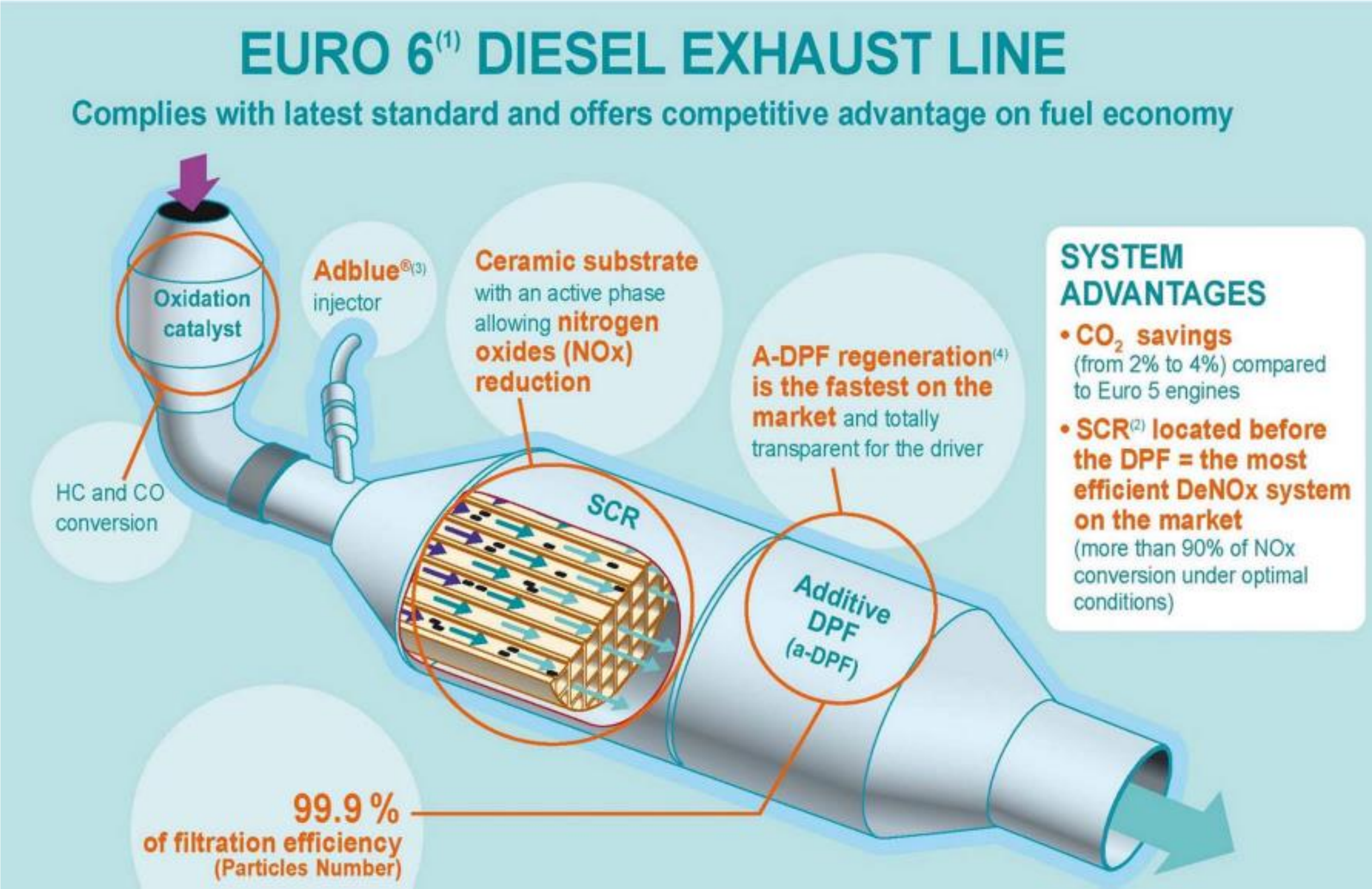
<< 1 mg

EURO 5

~ 0 mg !

DPF ensures the maximum efficiency for particulate abatement

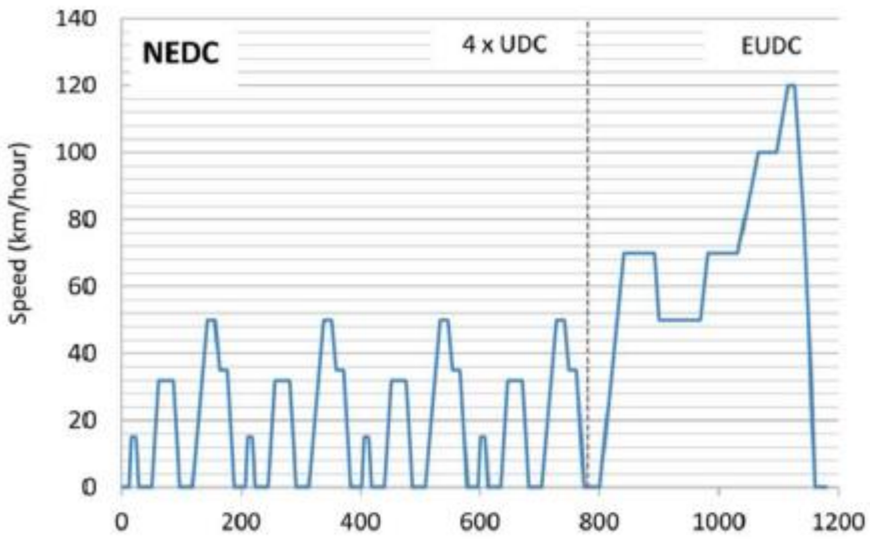
Reduction of NOx e $PM_{2.5}$ from diesel exhaust emissions

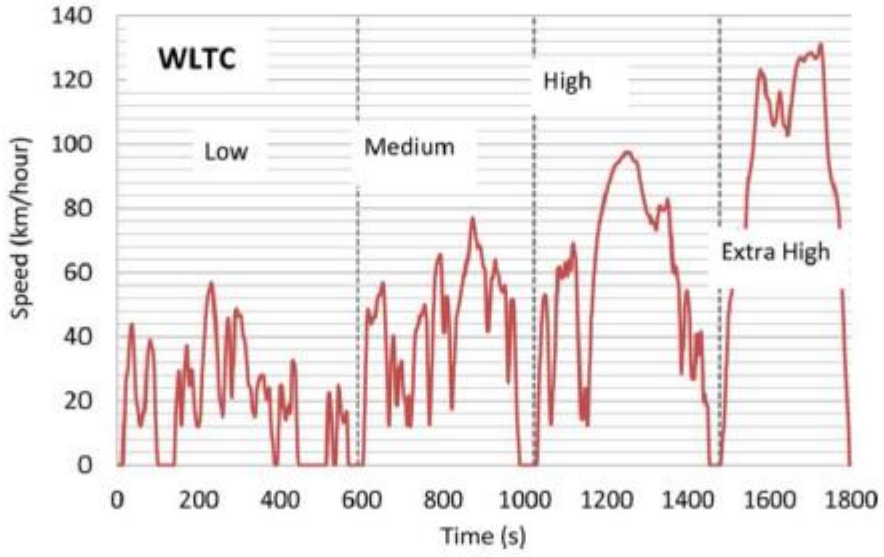


Low carbon fuel for CO_2 emissions reduction

CO_2 Emissions Regulation for New Vehicles Homologation

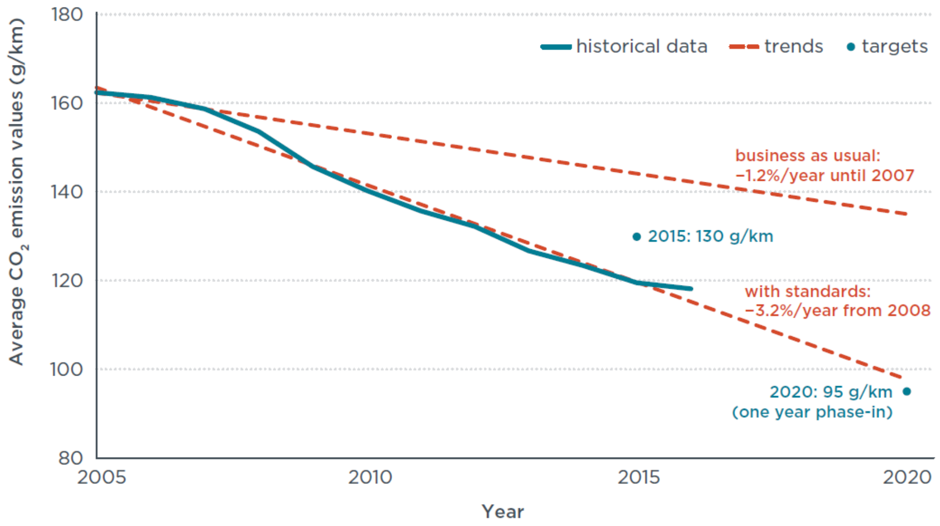
- The emissions regulation of vehicles in the road transportation, gives a key contribution to the strategy for the reduction of CO_2 emissions.
- From 2020 new rules on emissions level for vehicles homologation will come into force: the new vehicles shall not emit more than 95 gCO_2/km while, before 2020, this limit was set at 130 gCO_2/km.
- Currently CO_2 emissions from new vehicles are measured with the "New European Driving Cycle" – NEDC which, starting from 2017, will be replaced by the "Worldwide Harmonized Light Vehicles Test Procedure" – WLTP that gives a better representation of real driving cycle. The two methodologies WLTP and NEDC need to be mathematically related to fix the same emission level as homologation limit.





CO_2 Emissions from Passenger Car: EU 2015 figures (Reference ICCT – July 2017)

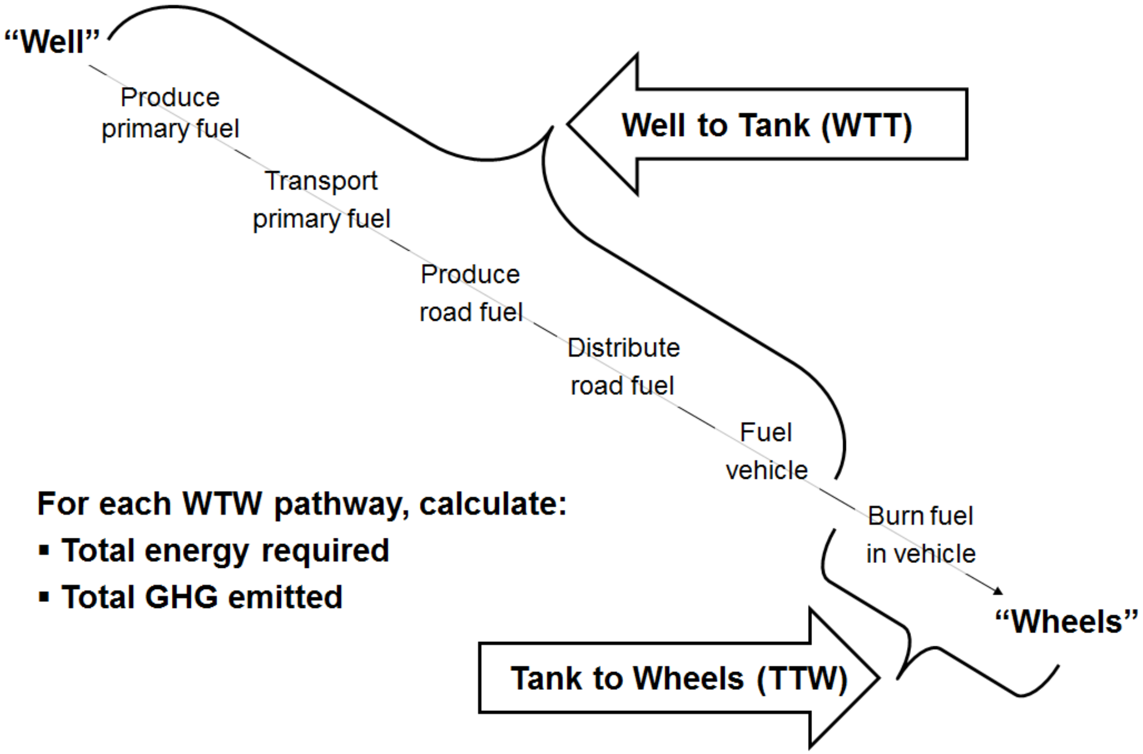
- In 2015 the CO_2 performances of passenger cars, averaged at 119,6 gCO_2/km, was about 8% less than the EU target of 130 gCO_2/km.
- Since 2008, when the CO_2 target for vehicles manufacturers was first set, CO_2 emissions have been reduced of about 3,2% per year.
- To meet the 95 gCO_2/km target by 2020, the % of CO_2 reduction should be maintained at the same level of last years (3-3,5%).
- The achievement of this challenging target, should require new proposal for the development of the engine/fuel pair in order to reduce the overall CO_2 emissions *(well to wheel approach)*.

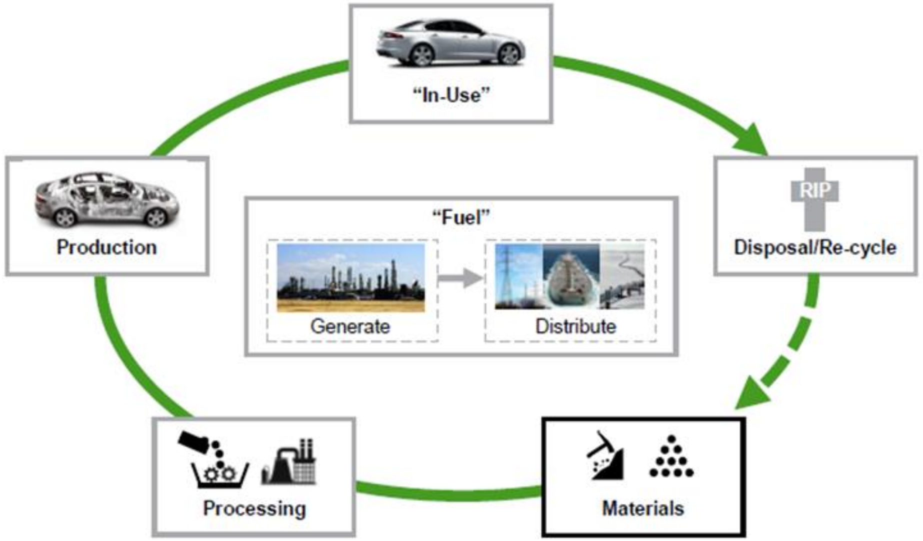


Well to wheel and LCA approach for CO_2 assessment

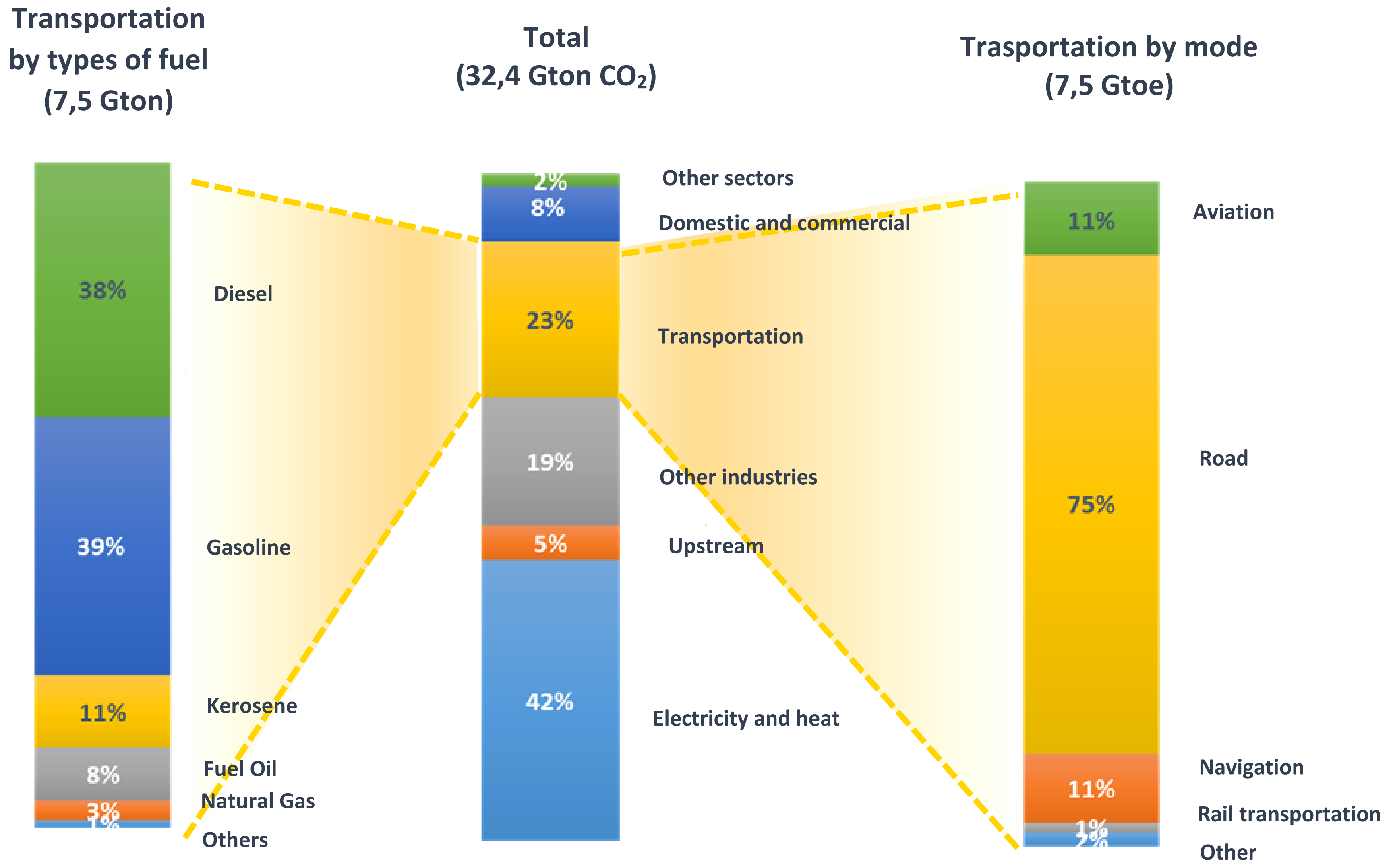
- When comparing different technologies for the reduction of CO_2 emissions it is important to consider the energy consumption and consequent CO_2 emissions in every step of the process from the production of crude oil, or other feedstocks materials, through transportation, refining, formulation and distribution of the finished fuels (the "Well-to-Tank"), to the consumption of the fuel in the vehicle (the "Tank-to-Wheels"). The "**Well-To-Wheels**" (WtW) approach breaks down the CO_2 emissions associated with mobility into different stages.

- **Life Cycle Assessment (LCA)** is a broader methodology that can be used to account for all the environmental impacts of an industrial process. This could include not only energy and GHG (as in the WTW) but also the consumption of all the materials needed for the production process, water requirements, emission of many kinds of pollutants (liquid, gaseous etc). In other words, the LCA methodology considers in detail the footprint of any given process.



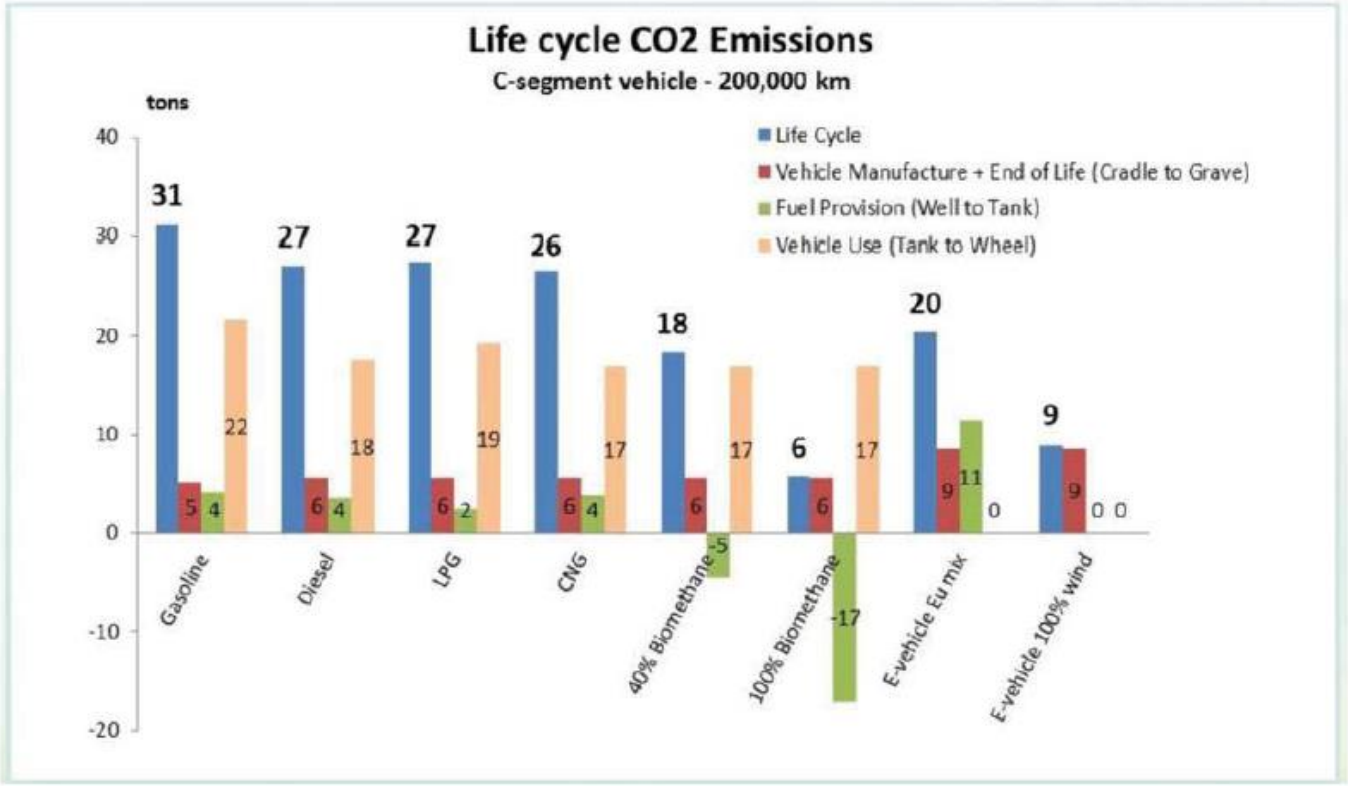


CO_2 emissions from combustion , 2014[1]



(1)Source: IEA, CO_2 emissions from fuel combustion

Post 2020 light vehicle CO_2



Source: ArtFuels study financed by European Commission

- The energy transition in the short-mid-term should be based on:
  - a continuation of the growing trend for vehicle efficiency, with realistic and achievable targets by different technologies.
  - the recognition of the fact that blending sustainable biofuels/renewable fuels results in a substantial reduction of CO_2 emissions.
- Regarding electro mobility:
  - advantages of electric vehicles (“EVs") rely on their high efficiency, simplicity, low maintenance, zero tailpipe emissions.
  - however, from a GHG perspective, EVs are not always more sustainable than ICE vehicles, as it is shown in Figure 1 below. In this case the improvement of the CO_2 emission must strictly be of competence of the electric energy producers.

The Eni Strategy for Sustainable Mobility

green 15% eni diesel+

- Promotion of renewable component produced by Eni green refineries (Green Diesel).
- New fuels with CO_2 reduction benefit for the existent vehicle fleet.

enjoy

- Smart Mobility: reducing CO_2 emissions in urban driving.
- Promoting the share economy

metano / metano liquido

- Promotion of CNG, Compressed Natural Gas.
- Promotion of LNG, Liquefied Natural Gas.

R&D ACTIVITIES

- A "memorandum of understanding" has been signed between Eni and FCA for joint activities on Sustainable Mobility
- Several activities have been kicked of:
  - Development of an alternative fuel with high alcohol content,
  - CCS-CCU project, for Carbon Capture and Storage
  - ANG, Adsorbed Natural Gas project
  - Pure HVO, benefit evaluation

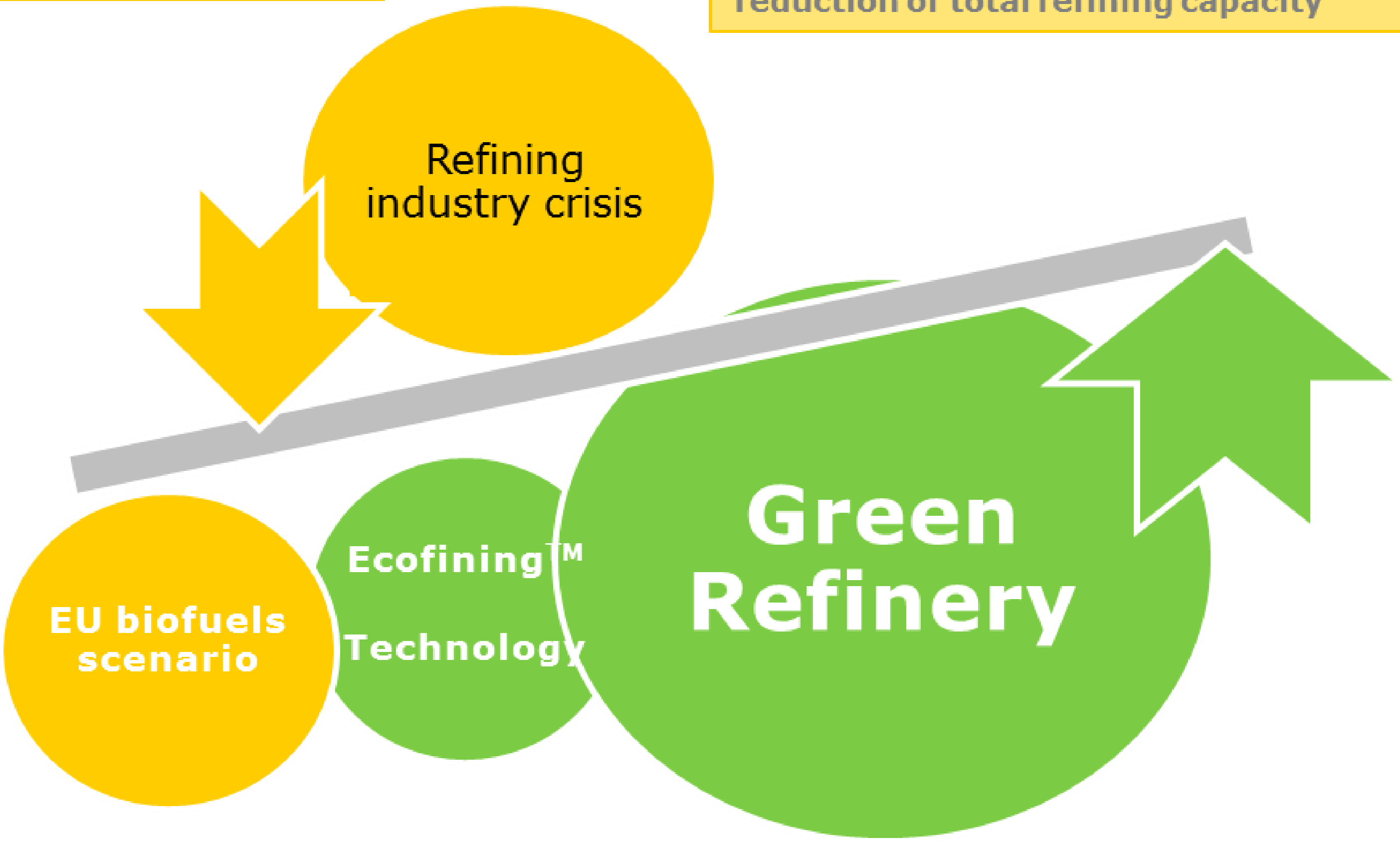
eni

Eni Green Refineries

Innovation for a Sustainable Future

Structural issues and reduced competitiveness of European refineries

In 2009, 15 European petroleum refineries were closed leading to a 1,6 Mbbl/g reduction of total refining capacity



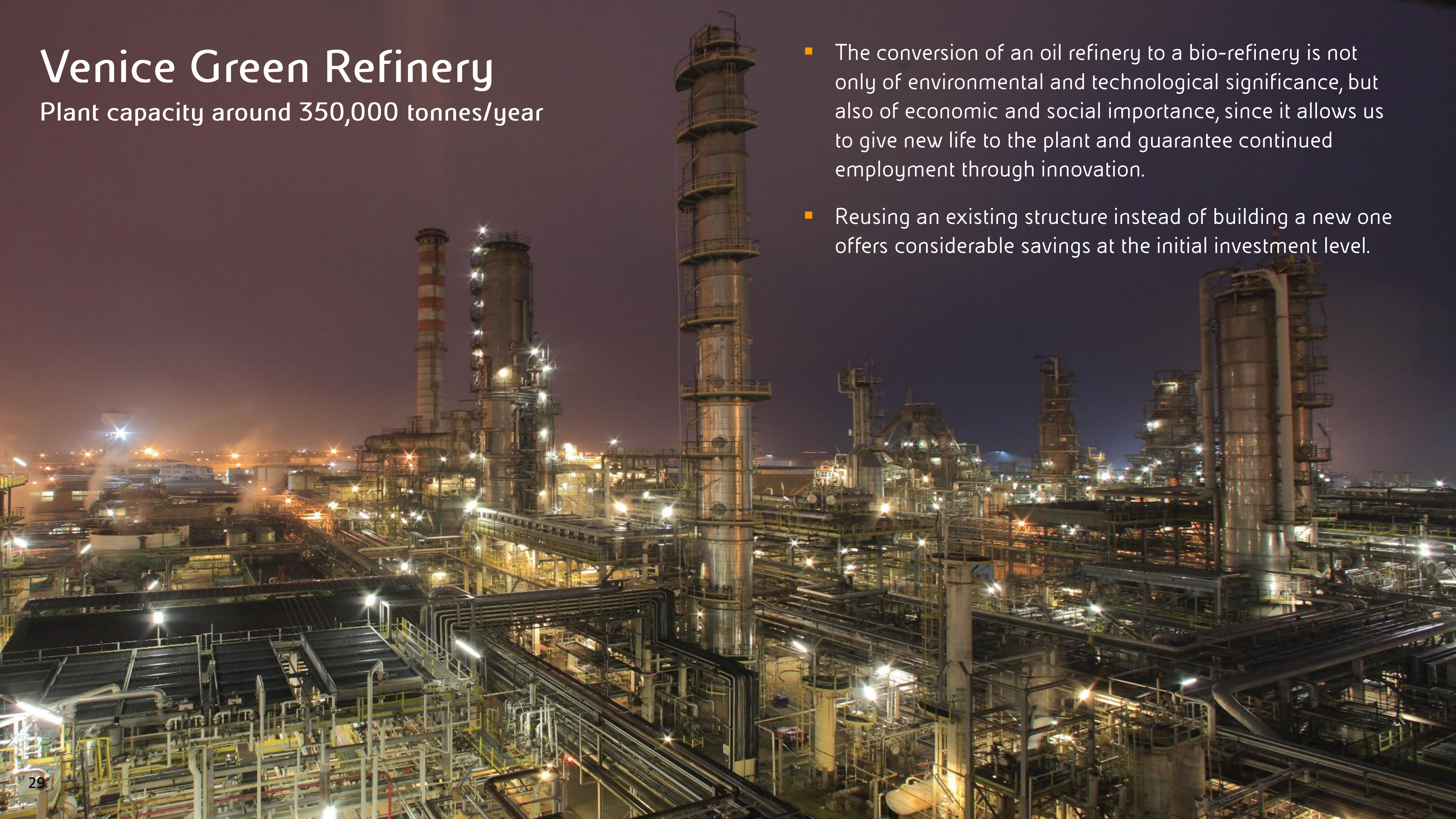
Innovation for a Sustainable Future

In this context, in 2014 Eni realized in Venice the first convertion of a traditional petroleum refinery into a biorefinery, implementing the proprietary technology Ecofining™

Venice Green Refinery

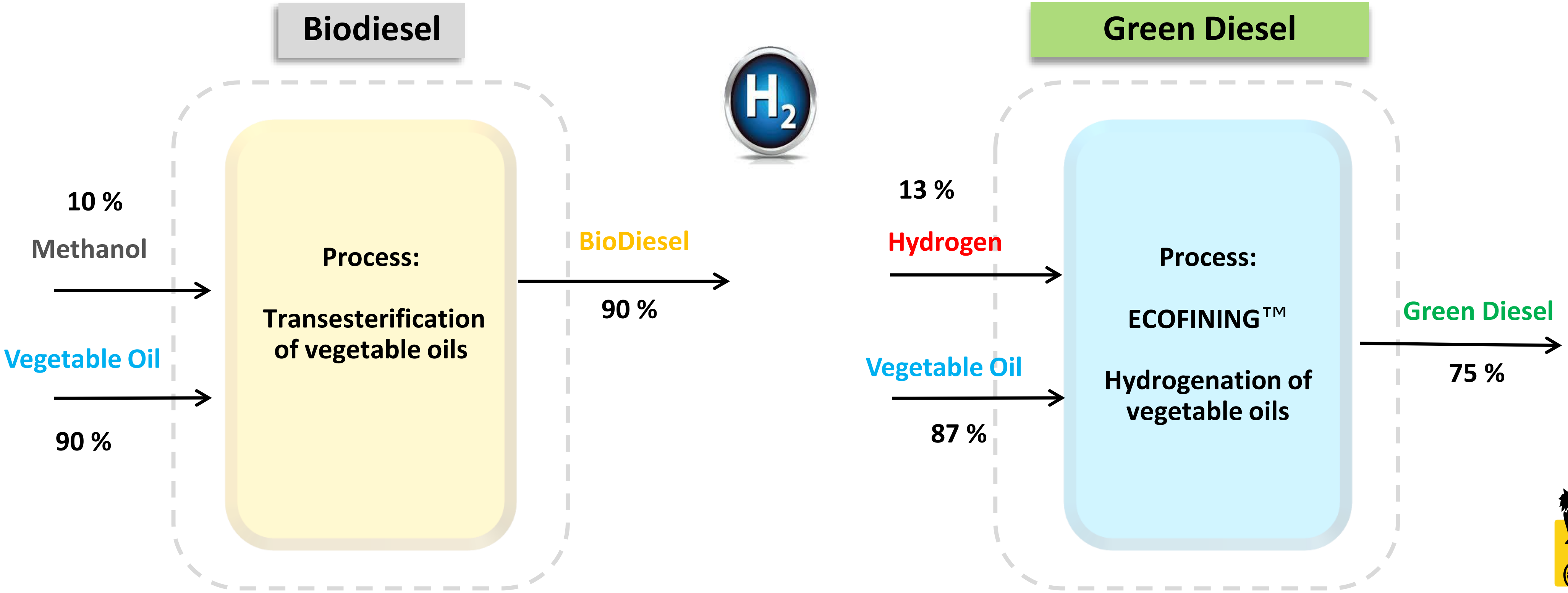
Plant capacity around 350,000 tonnes/year

- The conversion of an oil refinery to a bio-refinery is not only of environmental and technological significance, but also of economic and social importance, since it allows us to give new life to the plant and guarantee continued employment through innovation.
- Reusing an existing structure instead of building a new one offers considerable savings at the initial investment level.

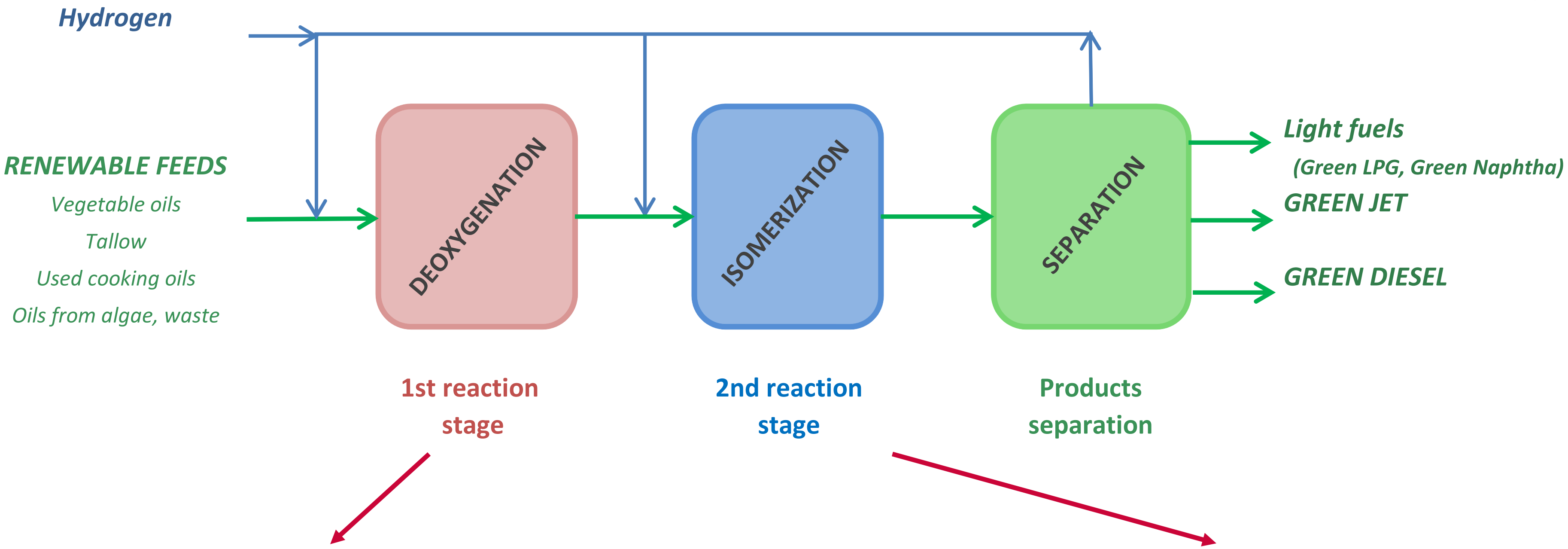


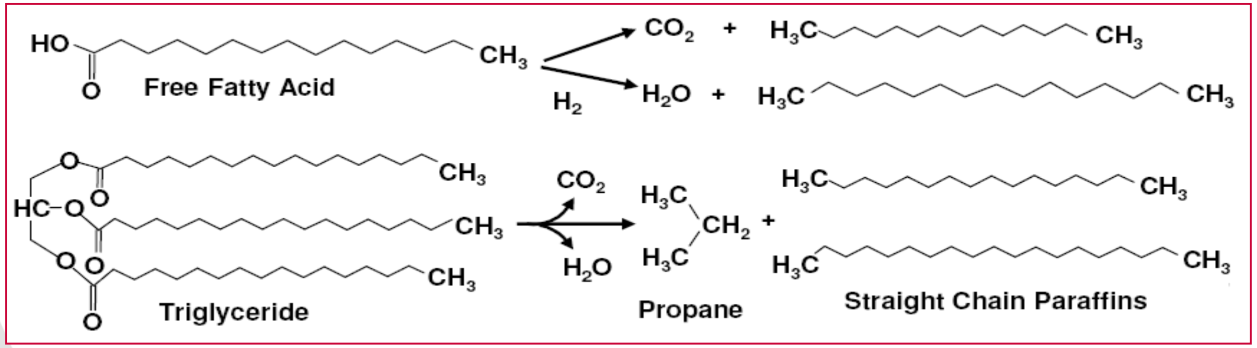
Biodiesel vs Green Diesel

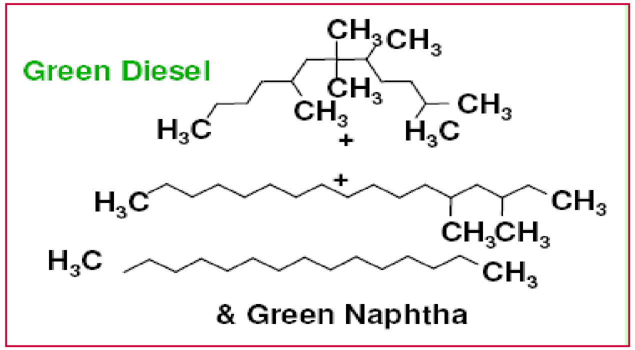
- Eni, in partnership Honeywell-UOP, has developed a proprietary technology, EcofiningTM, to overcome qualitative issues related to traditional biodiesel through an innovative hydrogenation process.
- The convertion of vegetable oils for the production of traditional biodiesel is realized using methanol as feedstock.
- Ecofining™ process instead, thanks to the use of pure hydrogen, is able to completely remove oxygen from the organic feedstock, obtaining a final product, called Green Diesel, which has a totally hydrocarburic composition. This chemical structure determines a full compatibility with fossil diesel and allows the blending of high percentages without any qualitative issue. Moreover, Green Diesel quality does not depend on feedstock type.



Ecofining™ technology







Renewable Component Characteristics

Biodiesel

Green Diesel

Triglyceride + Methanol → Biodiesel + Glycerol

- **Low chemical stability**
- **Quality variability**
- **Microbiological contamination and filter blocking issues**
- **Low energy content**
- **Tendency to dilute engine lubricant**
- **Additivation limit at 7%**

Triglyceride + Hydrogen → Green Diesel + Water

- **Higher chemical stability and full compatibility with fossil diesel**
  - Obtained through a hydrogenation process that completely eliminates oxygen
- **Very low water solubility**
  - Prevent microbiological contamination and filter blocking phenomena
- **Very high Cetane number**
  - Improve vehicle driveability and cold startability
- **High hydrogen content and heating value**
  - Beneficial impact on fuel consumption
- **Possible additivation up to 100%**
  - No compatibility issues

EN 15940: Main Properties

Property	Unit	Limits Class A		Limits Class B		Test method [a]
		minimum	maximum	minimum	maximum	(See Clause 2)
Cetane number [b]		70,0	–	51,0	-	EN ISO 5165 DIN 51773 EN 15195 [c]
Density at 15 °C	kg/m³	765,0	800,0	780,0	810,0	EN ISO 3675 [d] EN ISO 12185
Flash point	°C	Above 55	–	Above 55	–	EN ISO 2719
Viscosity at 40 °C	mm²/s	2,000	4,500	2,000	4,500	EN ISO 3104
Distillation % (*V*/*V*) recovered at 250 °C % (*V*/*V*) recovered at 350 °C 95 % (*V*/*V*) recovered at	% (*V*/*V*) % (*V*/*V*) °C	85 –	– < 65 360	85 –	– < 65 360	EN ISO 3405 [e] EN ISO 3924
Lubricity, corrected wear scar diameter (wsd 1,4) at 60 °C [f]	µm	–	460	–	460	prEN ISO 12156-1
FAME content [g]	% (*V*/*V*)	–	7,0	–	7,0	EN 14078
Manganese content [h]	mg/l	--	2,0		2,0	EN 16136
Total aromatics content [i]	% (*m*/*m*)	–	1,1	–	1,1	Annex C
Sulfur content	mg/kg	–	5,0	–	5,0	EN ISO 20846 [j] EN ISO 20884
Carbon residue (on 10 % distillation residue) [k]	% (*m*/*m*)	–	0,30	–	0,30	EN ISO 10370
Ash content	% (*m*/*m*)	–	0,010	–	0,010	EN ISO 6245
Water content	mg/kg	–	200	–	200	EN ISO 12937
Total contamination	mg/kg	–	24	–	24	EN 12662 [l]

- Green Diesel produced by Eni is free of sulphur, aromatics and poly-aromatics.
- It has a Cetane number higher than 70 and very good combustion characteristics.
- It can be classified, according EN15940, as Class A.

Green Diesel quality

- Green Diesel is composed almost completely by paraffinic molecules and represents a perfect component for the blending with fossil diesel: it can be added at very high percentages, also at 30-35%, depending on density of fossil fuels.

Proprietà	Fossil Diesel ULSD	FAME	Green Diesel
BIO	**0**	**100**	**100**
Oxygen, %	**0**	**11**	**0**
Density	0.840	0.880	0.780
Sulphur, ppm	<10	<1	<1
Heating Value, MJ/kg	**43**	**38**	**44**
Cloud Point, °C	**-5**	**From -5 to +15**	**Down to -20**
Polyaromatics, %w	**8**	**0**	**0**
Cetane Number	**51**	**50-65**	**70-90**
Oxydation Stability	Standard	Poor	Excellent

Biofuel regulatory requirement & Transition to Second Generation Bio-Fuel

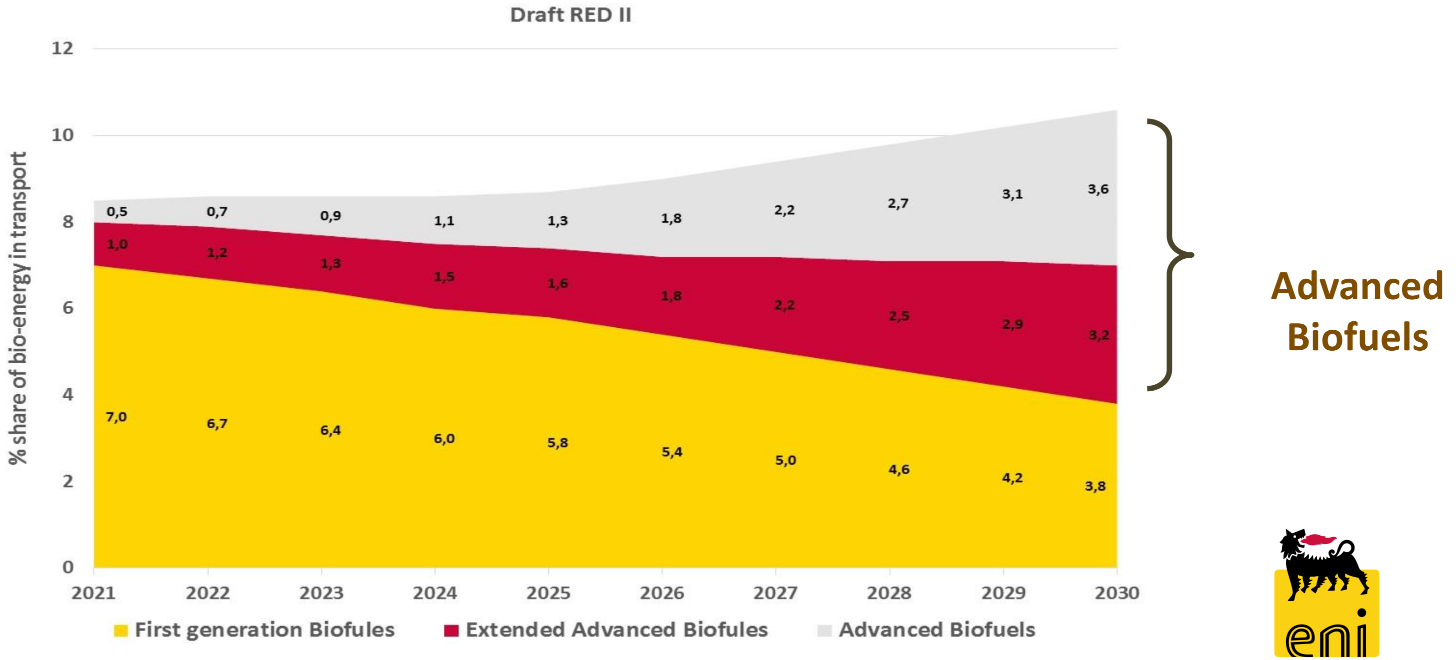
Italian Legislation: obligation on biofuel blending (%)

With a Decree aimed to correct the DM 10/10/2014 the Italian ministry MISE has defined the mandatory percentages for the blending of biofuels in the fuels released on the Italian market up to 2020.

	MISE Corrective decree of DM 10th October 2014		
	Biofuels, total	of which biomethane	of which advanced biofuels
2018	7,0%	0,45%	0,15%
2019	8,0%	0,6%	0,2%
2020	9,0%	0,675%	0,225%

Biofuels produced starting from UCO, Tallow oils and molasess [cap at 1.7%]; the overall renewable energy mandate should be achieved through renewable liquid and gaseous transport fuels of non-biological origin, waste-based fossil fuels, renewable electricity or Advanced Biofuels

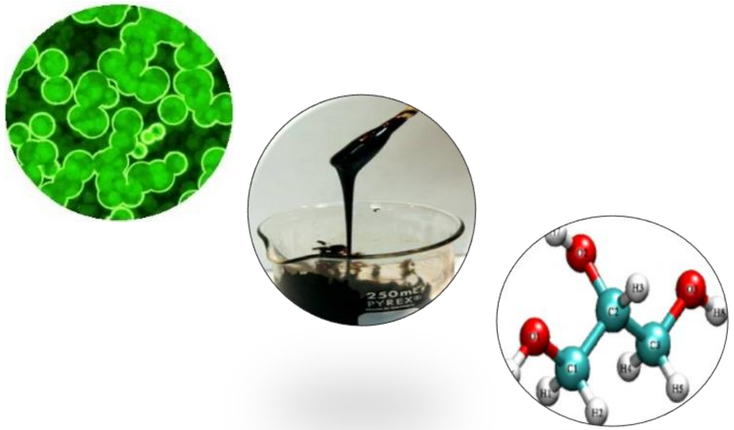
European evolution biofuels [Draft RED II]



Eni R&D Activities on Advanced Biofuels Production

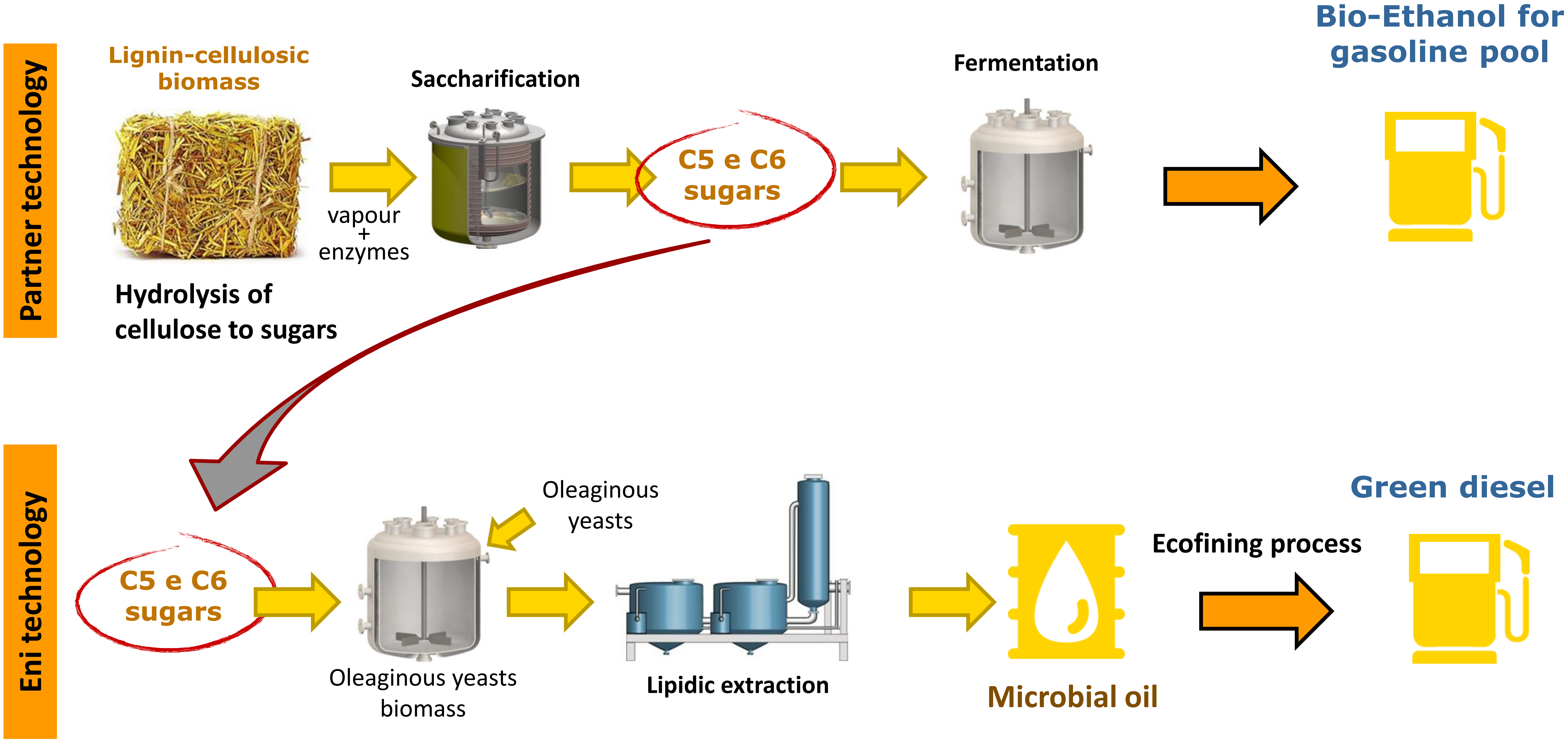
*Feedstocks for **Advanced Biofuels** production:*

- Algae
- Organic waste
- Raw glycerine
- Biogas
- **Cellulosic material, lignocellulosic biomass and residual of forestry activities**
- Straw, compost, pitch
- Low-starch-content crops
- Industrial waste including material from trade and food industry



→ **Microbial Oil production**

Microbial Oil Production from Biomass

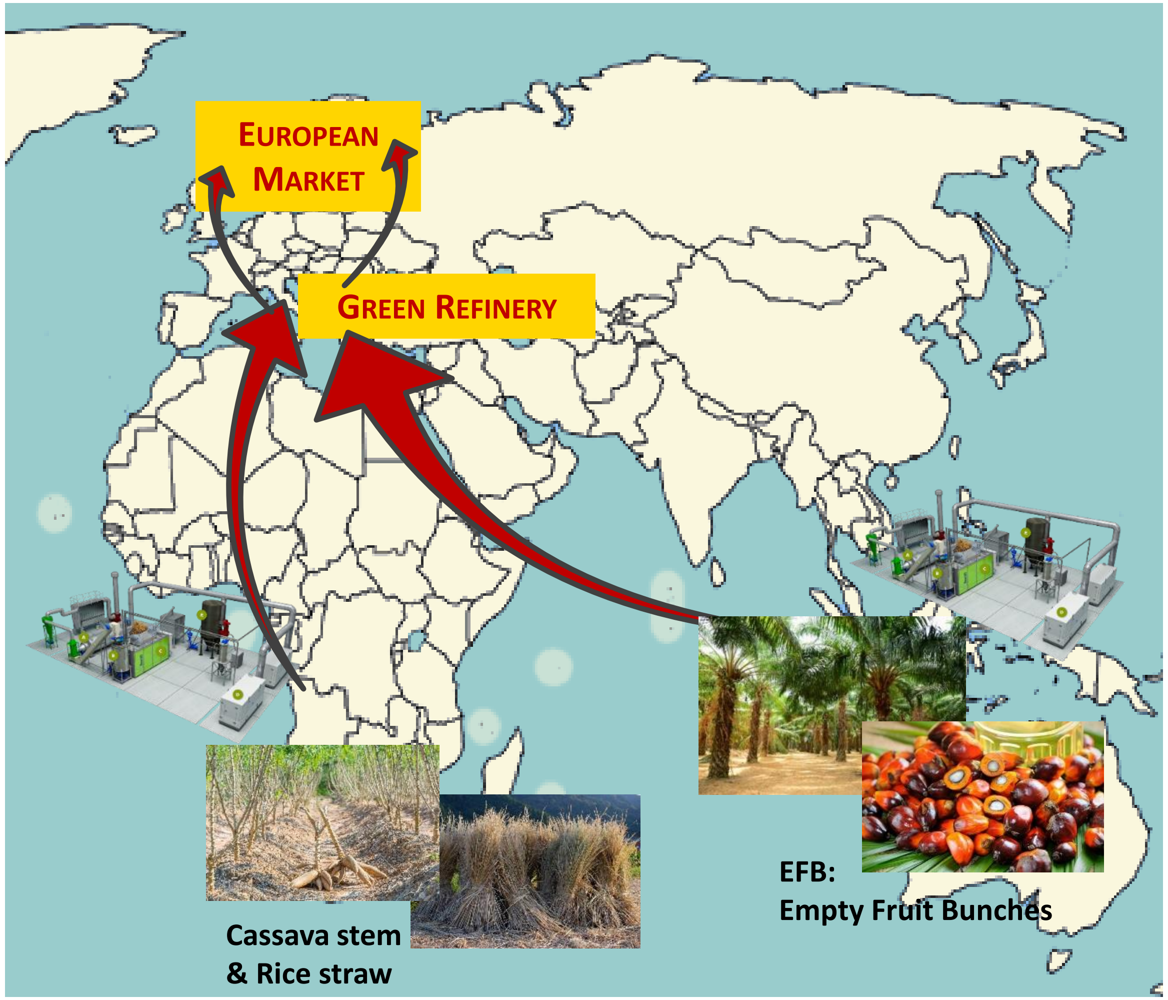


Transition to advanced biofuels necessary:
How to feed the Eni Bio-refineries

Eni is planning to gradually utilize feedstock non in competition with food production and market

From Palm Oil to Advanced feedstock:

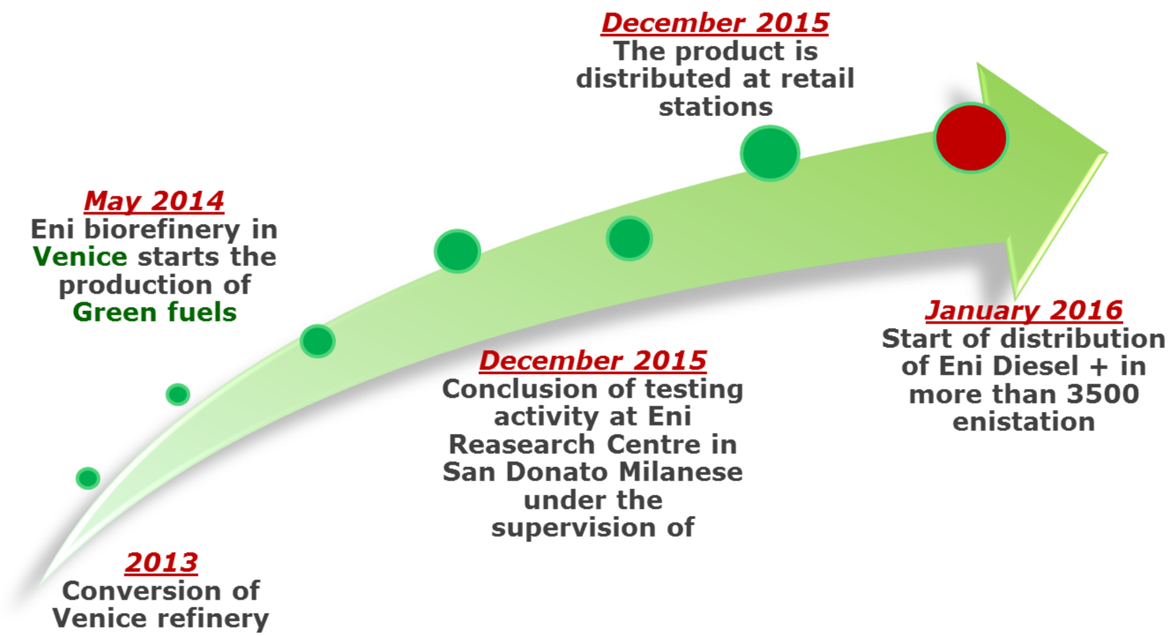
1. **Widen feed selection options, thanks to advanced/alternative feedstock improved KH**
2. **Development of new technologies to favor integrated "Upstream/Downstream" sustainable business**
   - ✓ Local production of crude bio-oil
   - ✓ Export of crude bio-oil to be refined in Italian bio-refineries for domestic and UE market



From the Venice biorefinery…

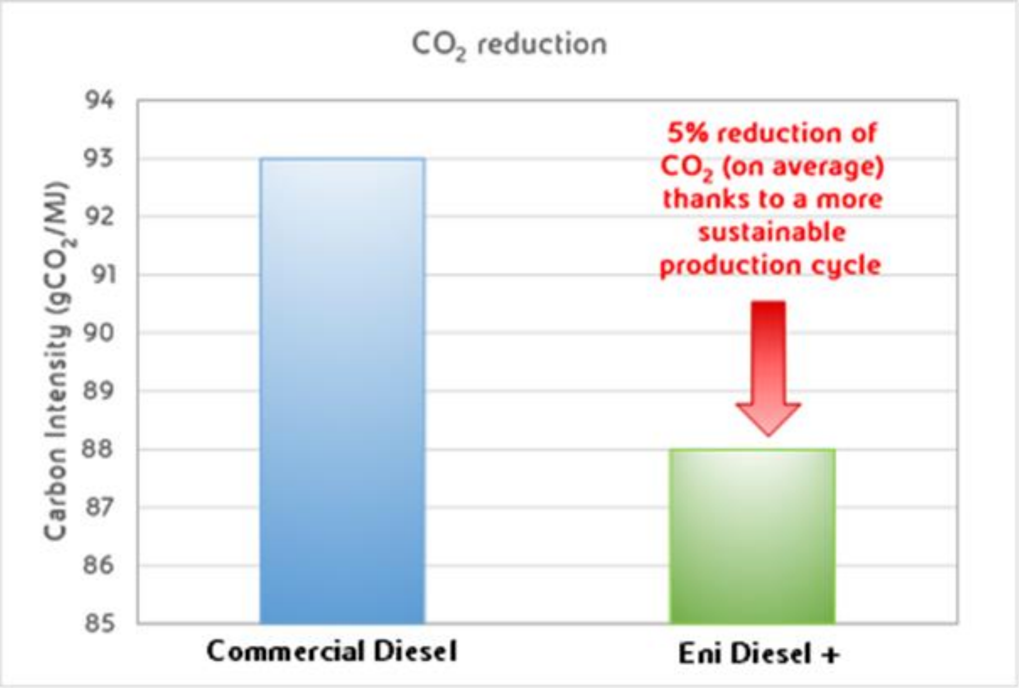
Eni Venice biorefinery is the first plant worldwide which was converted from a traditional petroleum refinery to a biorefinery in 2014 using the proprietary technology Ecofining™ developed by Eni R&D together with the American firm Honeywell-UOP. **Instead of processing crude oil the biorefinery uses vegetable oils as feedstock:** after a hydrogenation process, they are transformed in **Green Diesel**, a high quality renewable component which **outcomes the problem caused by traditional biodiesel**.

Eni Green Diesel **is useful to comply with regulatory requirements for the addition to the products released into the European market, of a progressively higher percentage of biofuel up to 2020**. Traditional biodiesel can't be added to fossil diesel beyond 7% (blending wall).



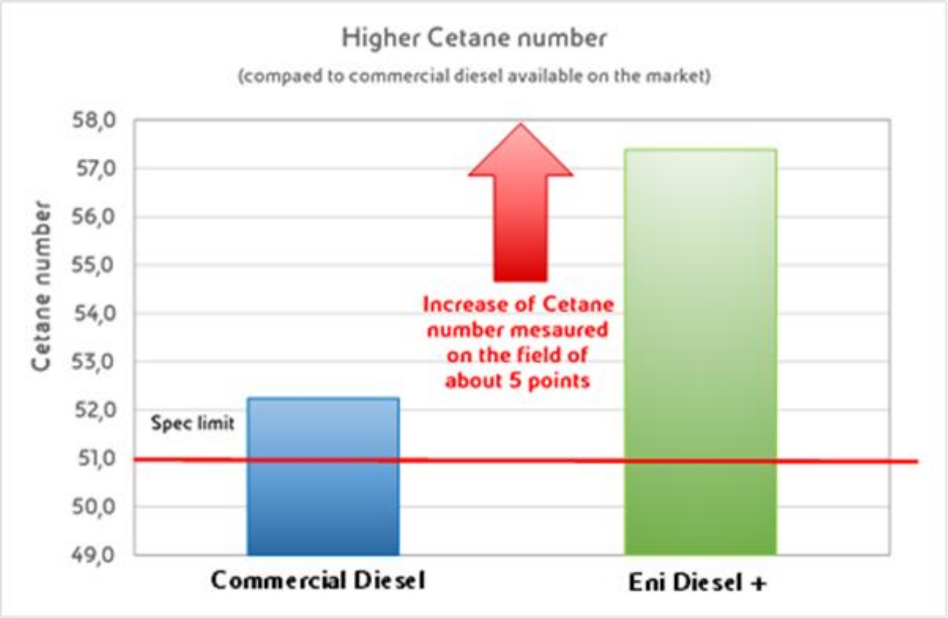
…to the new product Eni Diesel +

- **Eni Diesel +** is the new Eni premium diesel formulated with 15% of **Green Diesel,** the innovative renewable component produced by **Eni Green refinery of Venice** using the **proprietary technology Ecofining™**.
- **Eni Diesel+** complies with the European specification for automotive diesel **EN 590.**
- Thanks to the presence of the renewable component **Green Diesel,** produced through a more sustainable production cycle, Eni Diesel + shows a "Carbon Intensity " lower than other commercial diesel formulated with biodiesel and **contributes to reduce CO_2 emissions of 5% on average.**
  - Emissions tests performed during the experimental phase, showed a significant reduction of exhausted gas emissions (CO and HC) up to 40%.



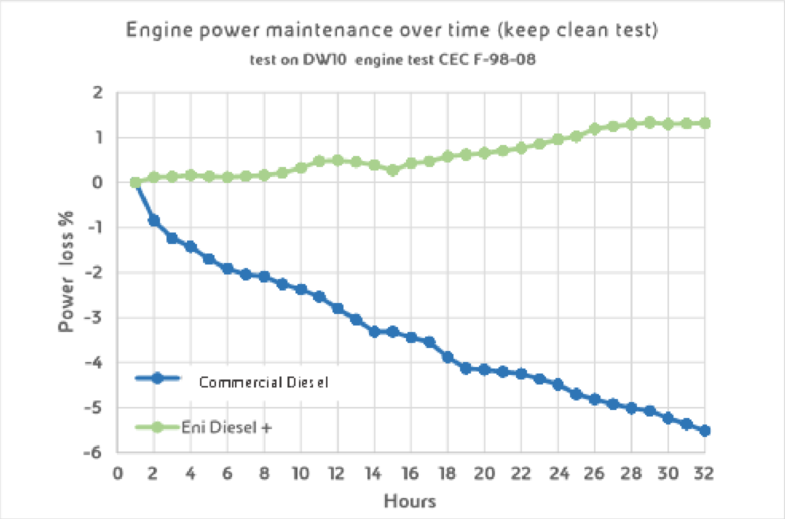
Higher Cetane number

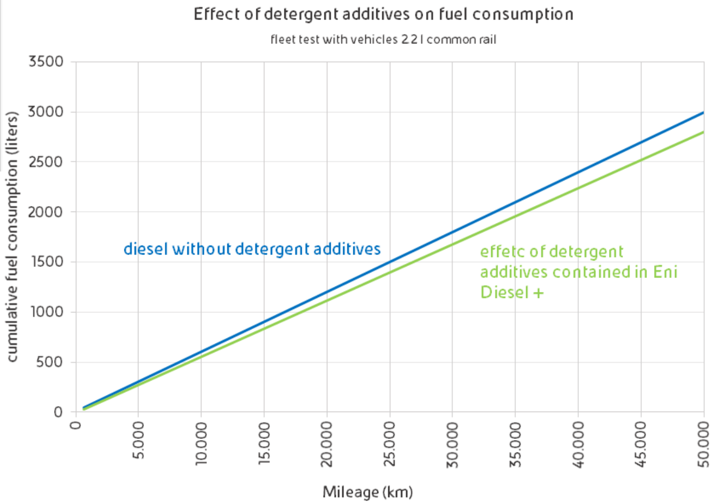
- **Eni Diesel +** has a minimum Cetane number of 55 while the EN 590 specification set a minimum value of 51.
- Thanks to higher Cetane number, **Eni Diesel +** improves cold startability, reduces engine noise and vibrations, and results in a better driving experience.
- The Cetane number increase, contributes to both combustion efficiency and acoustic comfort (-1/2 db).

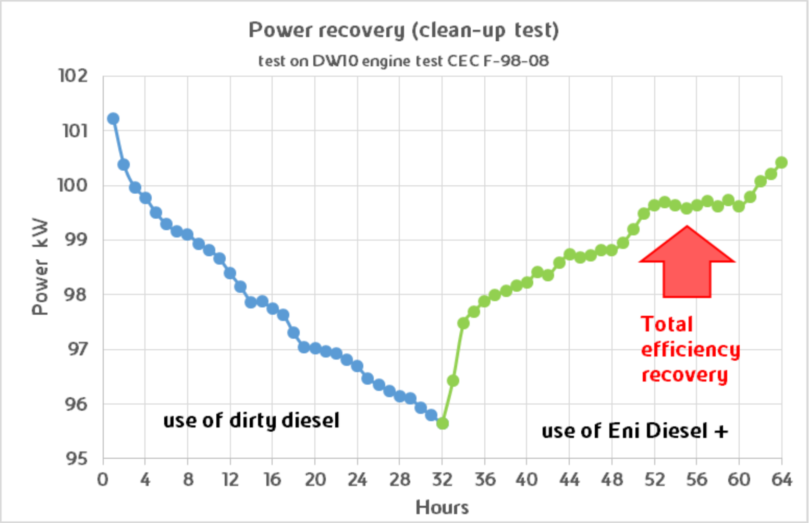


Detergency and fuel economy benefits

- **Eni Diesel +** thanks to the presence in its formulation of special detergent additives, is able to guarantee a high detergency of the injection system.
- Indeed, due to the high temperatures in the combustion chamber, some deposits should form into injector holes, reducing the engine efficiency and, therefore, increasing fuel consumption and emissions.



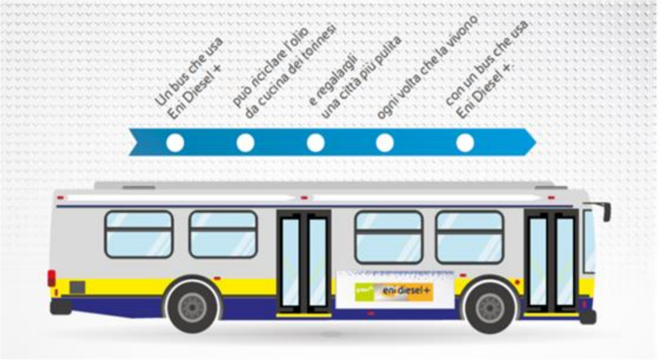




Potentials risks associated to Biodiesel

- The presence of oxygen in the chemical structure of Biodiesel facilitates microbiological contamination which should lead, in some case, to filter blocking phenomena.
- In the pictures below some examples of filter blocking are represented : all these examples are referred to fuels containing biodiesel as renewable component.

Eni Diesel + for the city of Turin



On 4th July Eni, City of Turin and Amiat signed an agreement for the use of Eni Diesel + for public transportation

GTT buses fuelled with Eni Diesel+

GTT has used Eni Diesel+ in its buses giving Eni continous feedback on their operating conditions

Test on GTT bus at Eni Reasearch Centre

Eni Research Centre, in collaboration with CNR, has assessed the environmental impact of Eni Diesel + on a GTT bus (exhaust emissions reduction)

Initiative to encourage the collection of Used Cooking Oil

The city of Turin is encouraging the collection of Used Cooking Oil from household utilities to convert them to biofuels in the Venice biorefinery

Eni Diesel + for Venice lagoon ferries

- Venice is conducting an experiment in circular economy: instead of being thrown away, the oil used by the public to fry food is being converted into biofuel for the city's waterborne transport system. From 1 April to 31 October 2018, the iconic vaporetti in the city's AVM/Actv fleet, normally powered by traditional diesel, will use Eni Diesel +.

LNG: a low carbon fuel for transportation

LNG in Italy

- LNG supply chain, already developed in other European countries, is growing also in Italy
- The application for road transportation, among possible uses, is one of the most promising
- This is because there is a big expectation between stakeholders of an increase of this market
- Also European Institution considers LNG as a key product for the decarbonization of transportation and has provided EUR 400 million to several project related to supply chain development
- The European policy on LNG, has also been applied at national level with Legislative Decree 16th December 2016, n. 257 implementing the directive 2014/94/UE on alternative fuels infrastructure

LNG retail station Italy

Impianti di distribuzione di GNL per autotrazione (30/04/2017)

Tipo di impianto	*Gestore*	*Regione*	*Provincia*	*Comune*	*anno*
Impianto pubblico	Concessionaria ENI	Emilia Romagna	Piacenza	Piacenza	2014
Impianto pubblico	F.lli Ratti	Piemonte	Alessandria	Novi Ligure	2015
Impianto pubblico	VGE Carburanti	Emilia Romagna	Bologna	Castel San Pietro Terme	2016
Impianto pubblico	Concessionaria Esso	Marche	Macerata	Corridonia	2016
Impianto pubblico*	Maganetti	Lombardia	Como	Gera Lario	2016
Impianto pubblico	Concessionaria ENI	Toscana	Pisa	Pontedera	2016
Impianto pubblico	Concessionaria ENI	Piemonte	Cuneo	Villa Falletto	2017
Impianto pubblico	Liquimet	Veneto	Padova	Padova (Interporto)	2017
Impianto pubblico	Vulcangas	Emilia Romagna	Rimini-Cesena	Rimini	2017
Impianto pubblico	IPER Carburanti	Emilia Romagna	Parma	Noceto	2017

** Impianto solo GNL aperto per mezzi convenzionati*

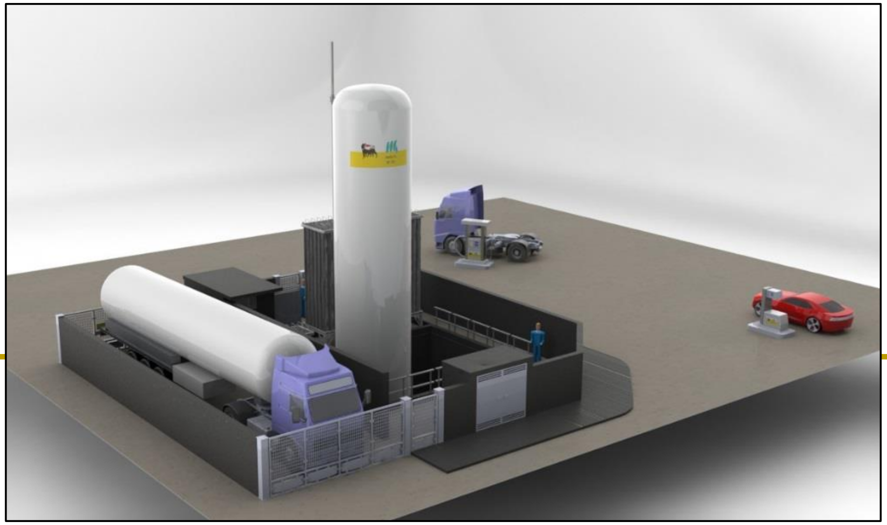
Fonte: elaborazione REF-E

- 10 retail stations already opened in Italy and 20 retail stations foreseen by next year
- Country target: 200 retail stations by 2030
- Eni opened 2 retail stations: Piacenza and Pontedera
- One LNG retail station exposing Eni brand in Cuneo

Retail station LNG and L-CNG

- The LNG retail station can deliver only LNG or both LNG for heavy truck and CNG for vehicles (L-CNG station)

Advantages of L-CNG retail station	Advantages of LNG retail station
▪ It's possible to sale CNG for vehicles also when the station is far from gas pipeline ▪ Really good handling of Boil-Off	▪ Station dedicated to heavy duty transportation ▪ More simple and economic structure compared to L-CNG station



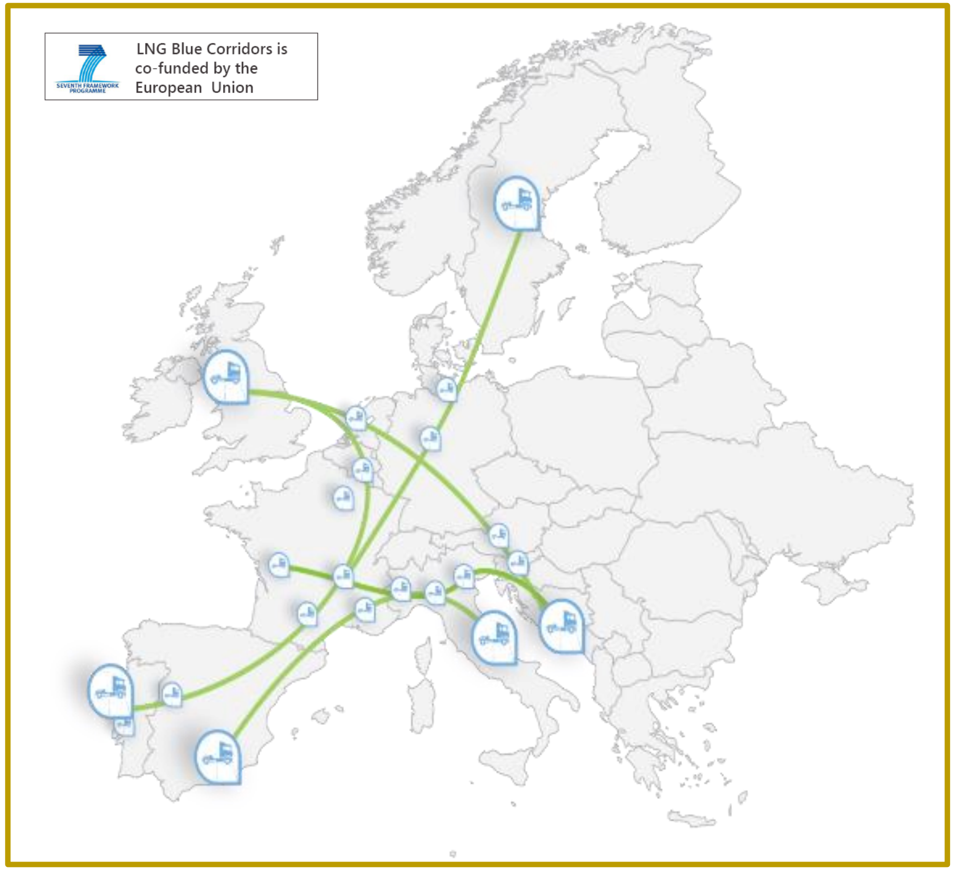
Eni L-CNG station in Piacenza

Eni in the Blue Corridor project

- Since 2013, Eni has joined the LNG Blue Corridor activities aimed to analyze the feasibility and the design of LNG plant for heavy duty transportation along 4 main corridors

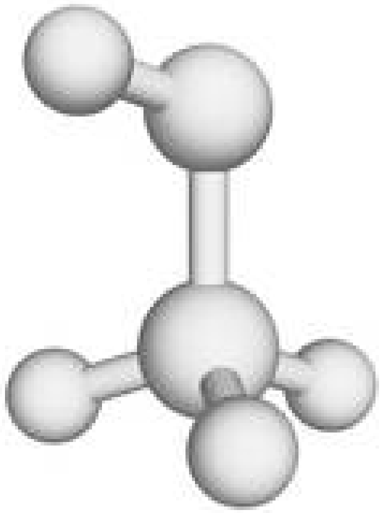
- Within this project, which involves several operators of LNG supply chain, 10 LNG retail stations have been realized in Europe for the fuelling of 150 heavy truck. These trucks were continuously monitored to evaluate performances

- The project will run until April 2018

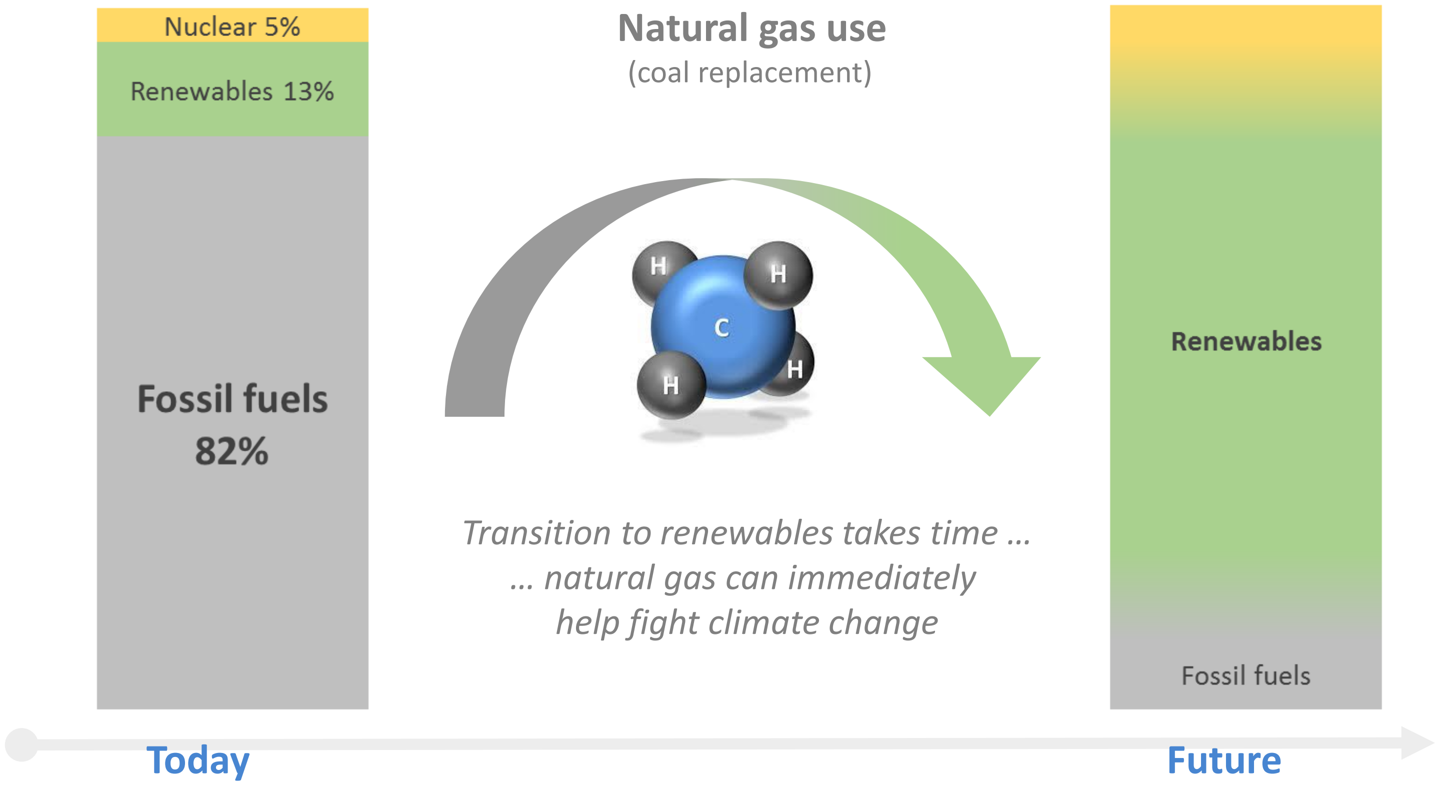


- The two Eni LNG retail station at Piacenza (opening April 2014) and Pontedera (opening September 2016) have been financed as part of Blue Corridor project

Methanol as energy carrier

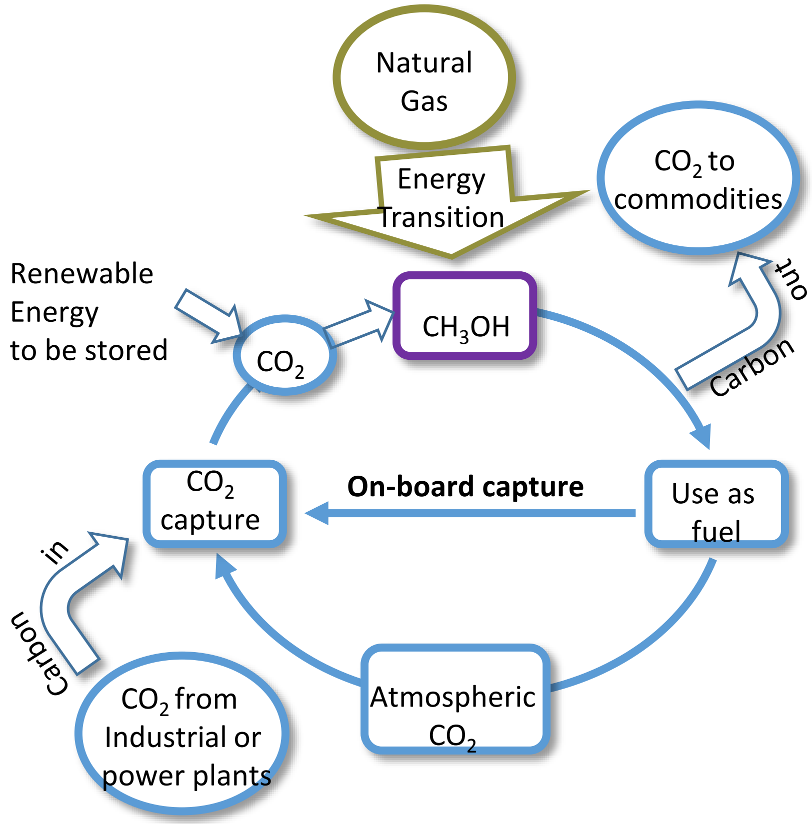


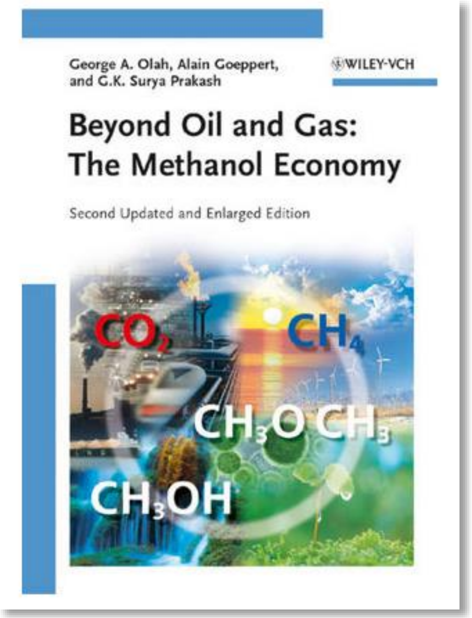
Energy Transition Program in Eni (ETP): focus on Natural Gas



- The Energy Transition vision in Eni considers, as main pillar, Natural Gas (NG) which is a reliable bridge toward transports decarbonization.
- NG is a technology mature and widely available.
- The Carbon Footprint of NG is lower compared to that of Carbon and Crude Oil.
- CCS & CCU (Carbon Capture Storage & Utilization) technologies should contribute to further reduce the overall emissions balance of the product.

The "Methanol Economy" vision





MIT Technology Review

Energy

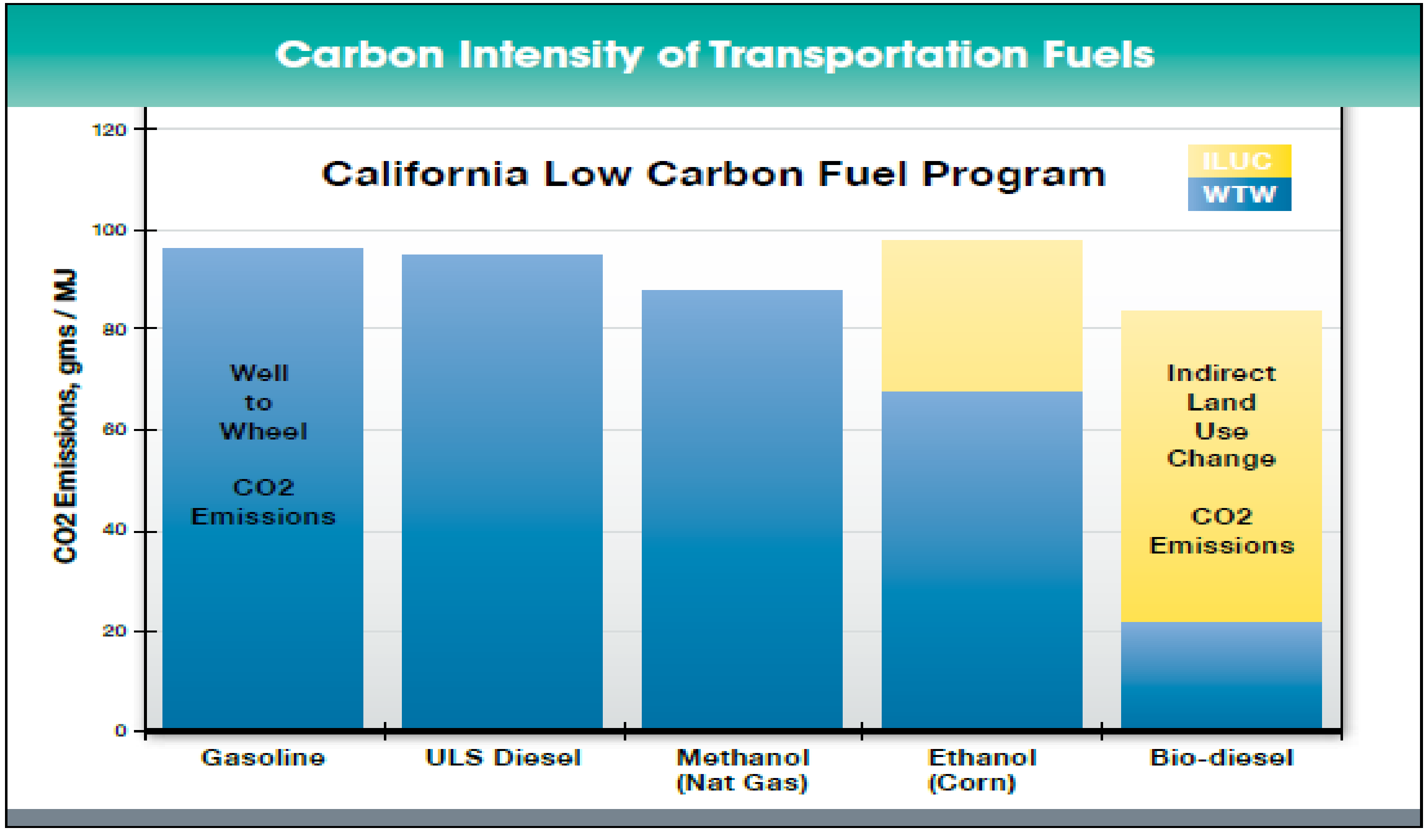
The Methanol Economy

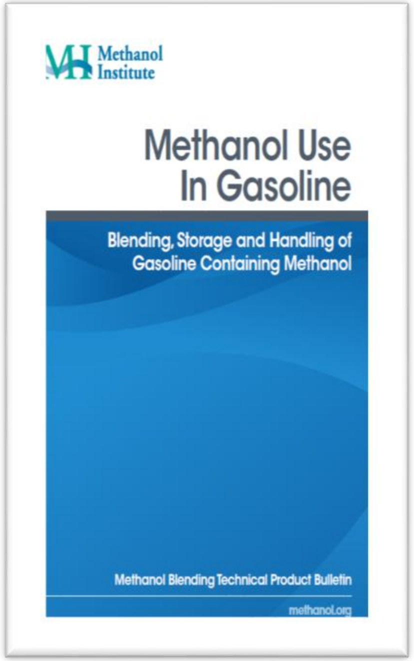
Forget about the hydrogen economy. Methanol is the key to weaning the world off oil. George Olah tells us how to do it.

by Kevin Bullis March 2, 2006

- Methanol is mainly produced from natural gas; it should also be obtained from agricultural waste and other recovery materials.
- Another possible pathway to obtain methanol in the future, should be the production from the CO_2 coming from industrial activities and tailpipe emissions captured with new adsorption technologies.
- In this vision, methanol should significantly contribute to the promotion of a circular economy aimed to the decarbonization of the energy mix.

Life Cycle Analysis: Well-to-wheels

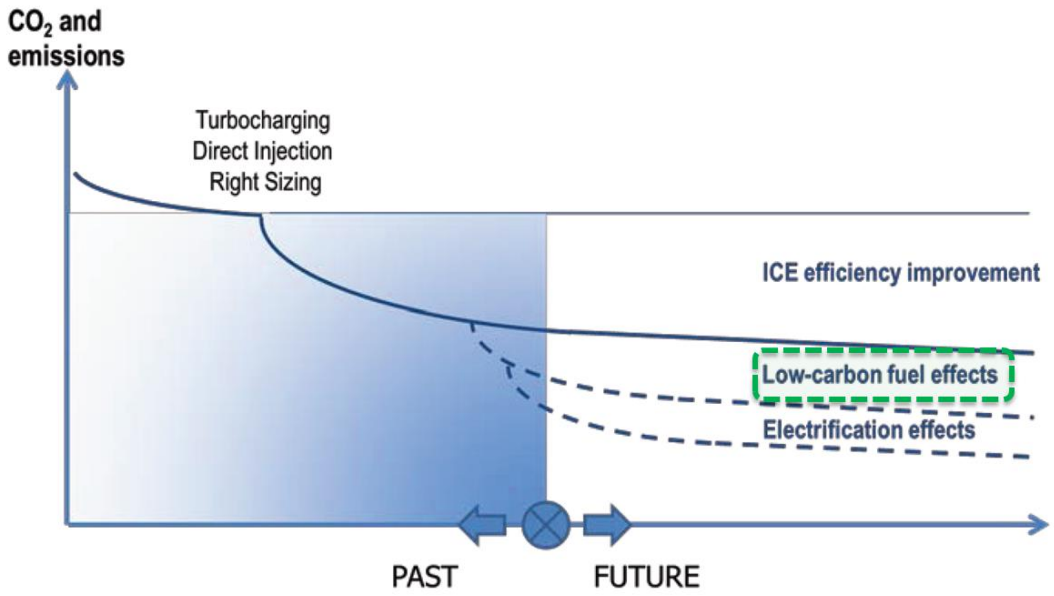




- Based on California's Low Carbon Fuel Standard (LCFS) program, the carbon emission intensity of the methanol supply chain made from natural gas is about 6% lower than that for average gasoline and about 10% lower than bio-ethanol produced from corn

Motivations for developing Low Carbon alternative fuels

- Road transport system is asked to move from the current oil derived monopoly towards a more complex system composed by different propulsion source
- Internal Combustion Engines will continue to play a role in transport sector scenario which will include also electrified vehicles.
- De-carbonization is the common goal.
- A pragmatic solution, based on ICE, is to develop a short term scenario complying with the following topic
  - **Alternative Fuel**
  - **Low Carbon Content**
  - **High Octane Number**



Source: European Road Transport Research Advisory Council

Alcohol-Based High Octane Gasoline as new alternative fuel (A20)

Property	Units	Limits MIN	Limits MAX	Test Method
Research octane number, RON		100		EN ISO 5164
Motor octane number, MON		86		EN ISO 5163
Lead content	mg/l		5.0	EN 237
Density (at 15 °C)	Kg/m^3	720.0	775.0	EN ISO 3675 EN ISO 12185
Sulfur content	mg/kg		10.0	EN ISO 13032 EN ISO 20846 EN ISO 20884
Manganese content	mg/l		2.0	EN 16135 EN 16136
Nitrogen content	ppm		100	ASTM D4629
Oxidation stability	minutes	360		EN ISO 7536
Existent gum content (solvent washed)	mg/100 ml		5	EN ISO 6242
Water content	% (m/m)		0,2	EN ISO 12937
Oxygen content	%(m/m)		10.0	EN 1601 EN 13132 EN ISO 22854
Methanol	%(V/V)	12.0	16.0	
Ethanol + other Alcohols (C3-C4)	%(V/V)	4.0	6.0	
ethers (5 or more C atoms) other oxygenates	Volume blending of these components is restricted to 10.0 % (m/m) maximum oxygen content including methanol oxygen.			EN ISO 22854

High octane number

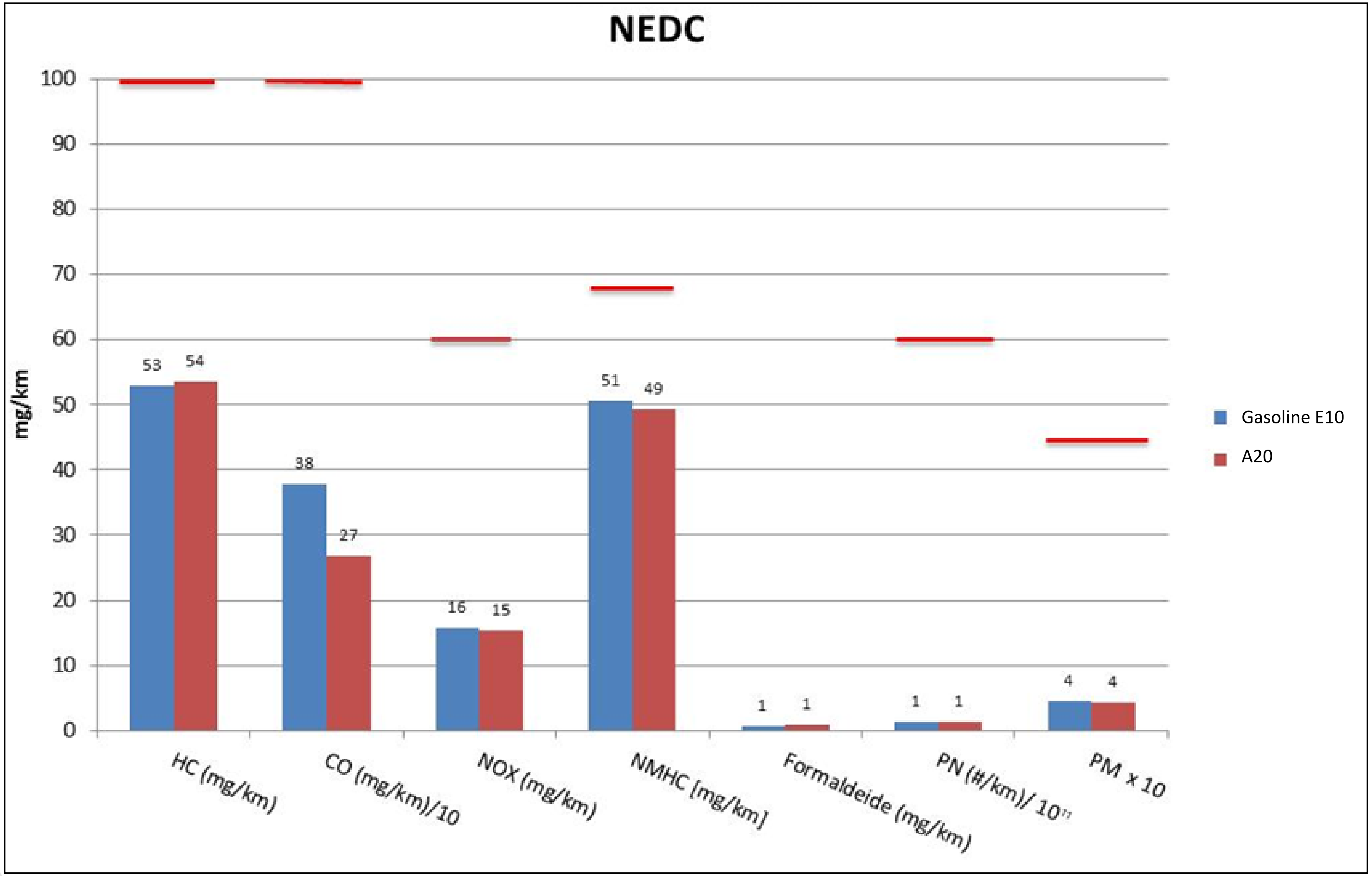
Protection against aniline octane booster

Parameters in disagreement with FQD

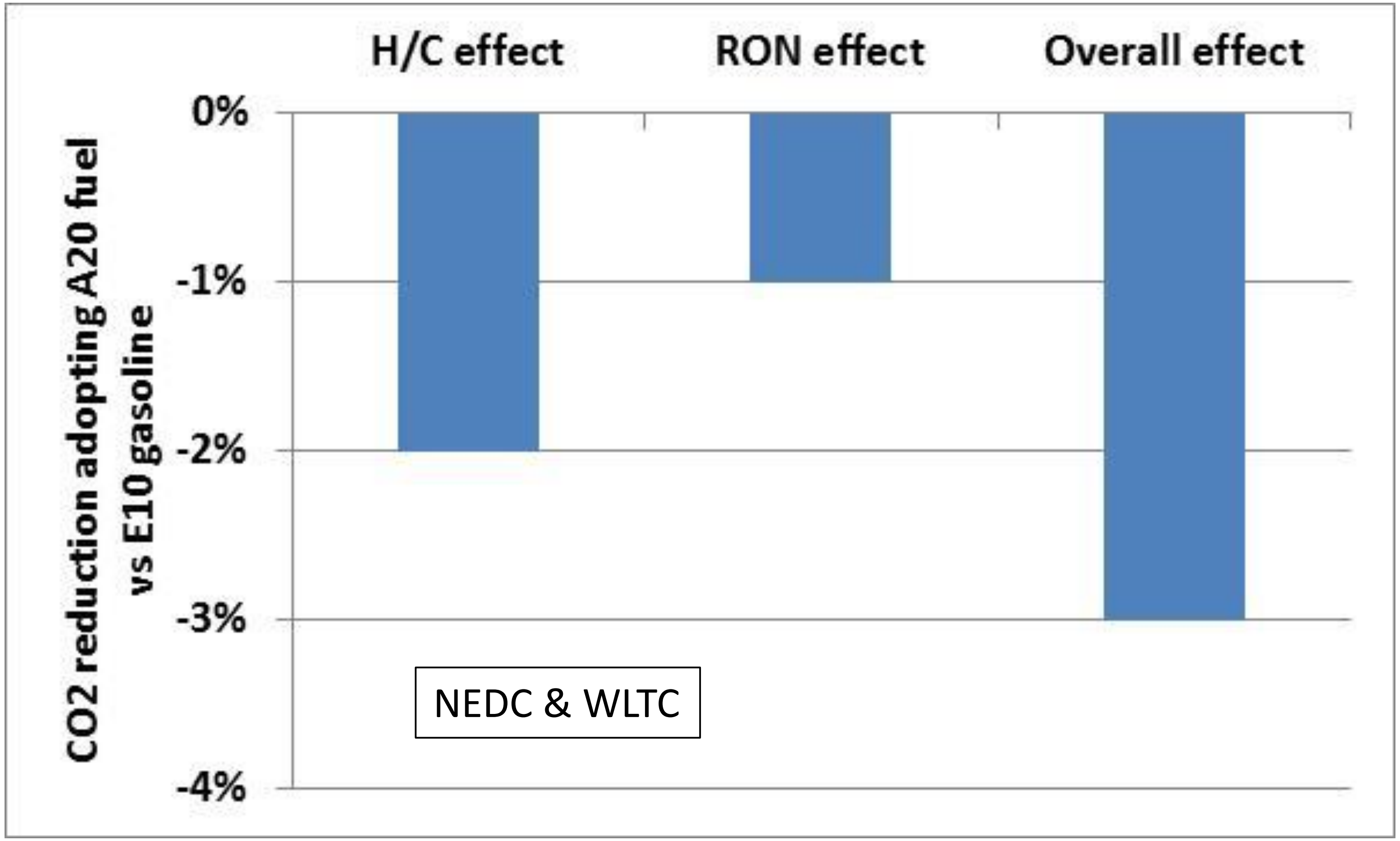
16-22 % alcohol content

A20 shall be considered as alternative fuel due to higher Alcohol, higher Octane, lower carbon content

Fiat 500 1.2 fuelled with Eni A20 fuel



Tailpipe CO_2 reduction with A20 Eni fuel



CO2 reduction with ENI A20 fuel (100 RON) vs Gasoline E10 (95 RON) is 2% due to H/C ratio and additional 1% due to higher RON (100 vs 95)

Enjoy fleet test with A20 fuel

- The fleet test with A20 fuel on Enjoy vehicles (Fiat 500), started in November, will last about 4-5 months.
- The vehicles will have a road journey of about 30000 km with an estimated fuel consumption of about 2000-3000 liters of A20 fuel.
- The fleet test is realized with 5 Enjoy vehicles, free to move in the Milan area.
- During the fleet test, the vehicle operational parameters are constantly monitored using the traditional detection system equipped on enjoy vehicles.
- The vehicle refuelling is managed by the Enjoy fleet team on a Eni retail station with a dedicated fuel dispenser not accessible to normal customers.

Conclusions

- The Eni strategy for energy transition in the Refining & Marketing and in R&D area is founded on three main pillars
  - the production of low emissions and high sustainability fuels like Eni Diesel +
  - new retail stations for the distribution of LNG to heavy duty vehicles to help the decarbonisation
  - the study of the potential use of new energy carriers in order to exploit Natural Gas reserves, like methanol.

- The outlook shown today is aimed to demonstrate the engagement of Eni on the challenges posed by energy transition, all our R&D activities for products and processes development, Commercial and Marketing initiatives, are in line with this paradigm.

- The goal is to contribute effectively to a more sustainable mobility.

Thank you for your attention!!!