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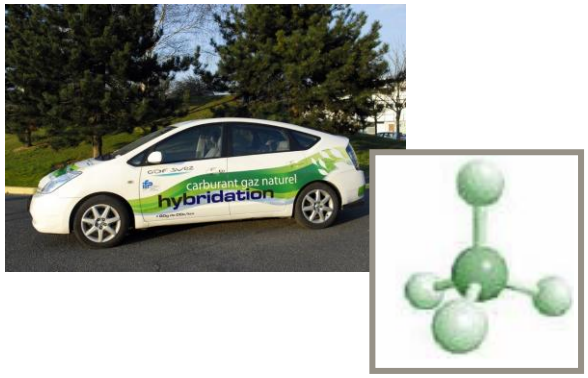

Biomethane + CNG hybrid: a reduction by more than 80% of greenhouse gases emissions compared to gasoline

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What do we mean by sustainable mobility?

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Answer #2?

Sustainable mobility… one possible definition

Mobility could be defined as a transport policy which tries to combine:

- **Accessibility**
- **Economic progress**
- **Environmental objectives**
- **Sustainable aspects**

In order to develop sustainable mobility/greener transport, the chosen action plan focuses on:

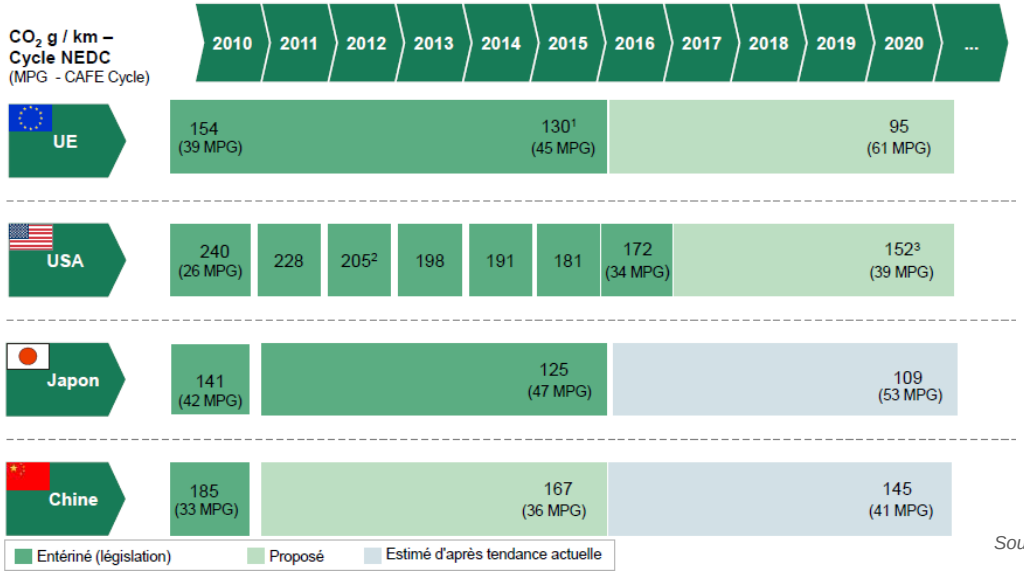
- **Technological innovation**
- **Organizational innovation**
- **Services & usages innovation**

At a country/territory scale, the idea is to bring a real mix of solutions in order to optimize and to adapt , at each time, the combination fuel/vehicle/infrastructures to the mobility needs.

Why do we need sustainable mobility/greener transport?

Road transport sector – 4 key challenges (1/2)

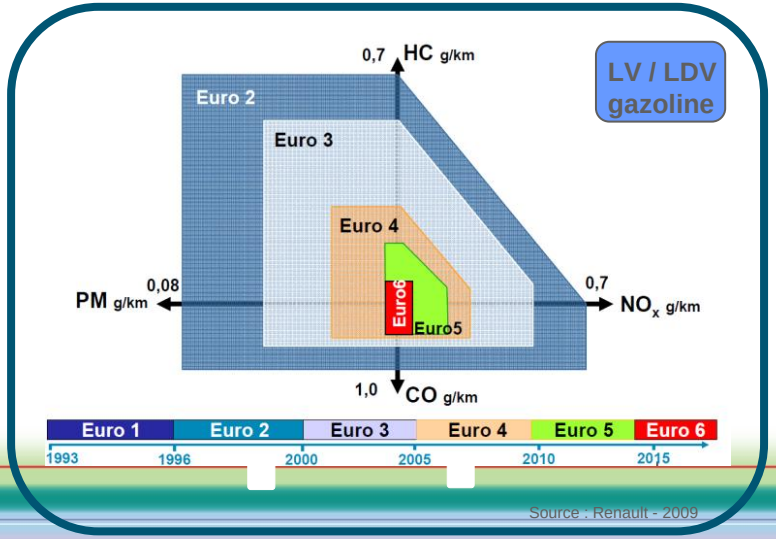
1st Challenge: CO_2 emissions reduction → Strong constrains by 2020 all around the world



Source: BCG (2011)

2nd Challenge: Pollutants emissions reduction → ex. EU: 4 regulated pollutants (Euro norms)

- Nitrogen oxides (**NOx**),
- Hydrocarbons (**HC**),
- Carbon monoxide (**CO**),
- Particulates (**PM**)



Source : Renault - 2009

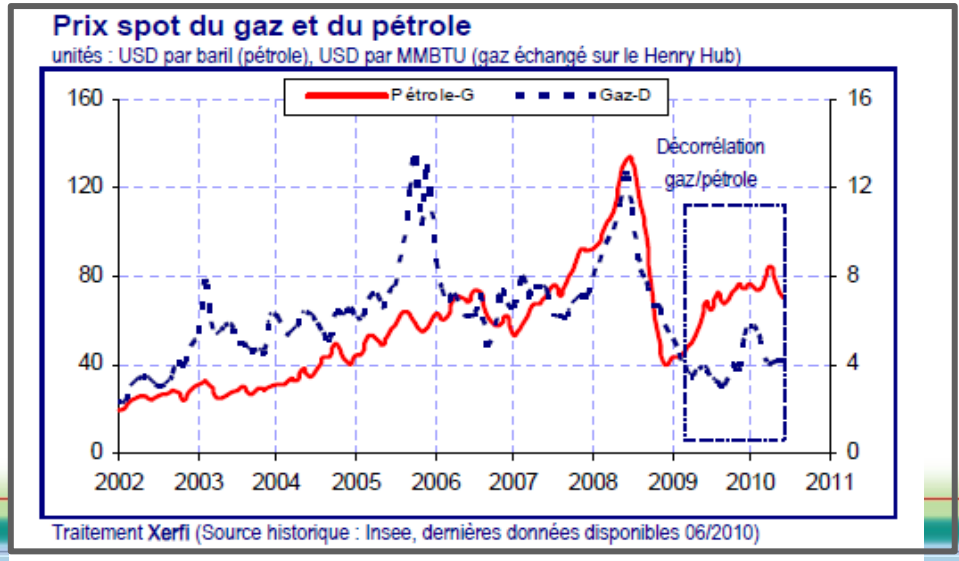
Road transport sector – 4 key challenges (2/2)

3rd Challenge: Necessary energetic diversification

- Road transports represent **51% of the worldwide oil-products consumption** *(Source: IEA-2009)*.
- Energy consumption from transport sector should **increase by +30%** between 2010 and 2030 *(Source: IEA-2009)*.
- Road transport sector relies at 98% to oil-derived fuels.
- Worldwide automotive park could increase by a factor 3 by 2050 *(Source: IEA-2009)*.

4th Challenge: High instability on oil market →Direct impact on fuels costs

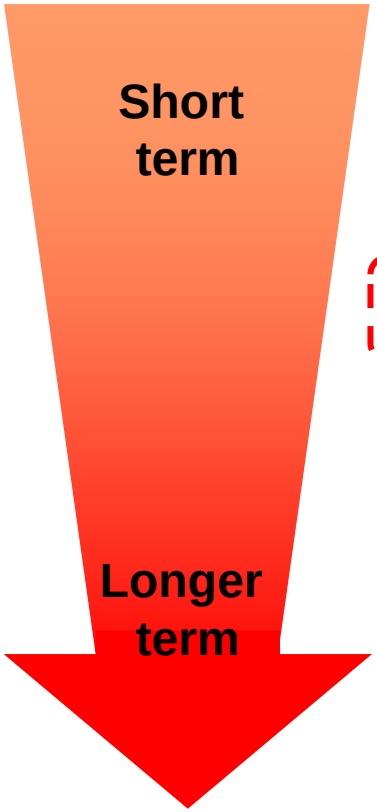
- Fuels costs between 2000-2010 in France:
  - Gasoline: +22,2%
  - Gasoil: +31,8%
  - LPG: +40,4%



Possible solutions to reduce CO_2 and local pollutants emissions

Engines & Technologies

- Diesel engines
- Gasoline Direct injection
- "Downsizing"
- Continuous Variation Transmission (CVT)
- Stop & Start
- Hybrid vehicles
  - Hybridization of gasoline/diesel engines
  - Hybridization of alternative fuels engines
- Electrical Vehicles (EVs)
- Fuel Cell Vehicles (FCVs)



Fuels

- Diesel and gasoline
- 1st generation of biofuels (ethanol, bio-diesel, etc.)
- **Gas (CNG, biomethane…)**
- **Electricity**
- 2nd generation of biofuels
- Hydrogen

Source: CCFA- Dossier émissions de CO_2 (2008)

CNG/Biomethane – A greener transport solution

CNG/Biomethane a greener transport solution …part of the "City of Tomorrow"

Waste treatment/valorisation

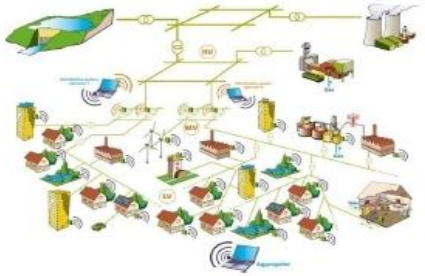
(water, organic waste, biogas, etc.)

Clean Vehicles

(CNG, biomethane, hybrids, EVs etc.)

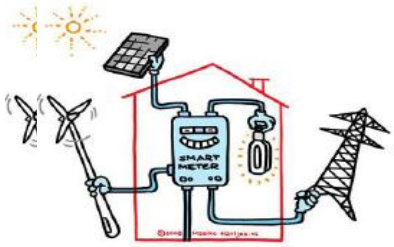
Buildings of tomorrow

(positive energy buildings, Ren. E, etc.)



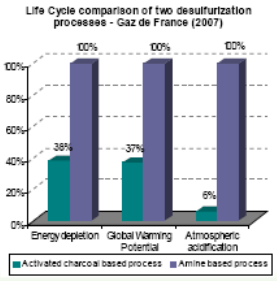
Local and decentralised electricity production & "Smart grids"

City of Tomorrow



Energetic efficiency

(smart metering, ZenBox, etc.)

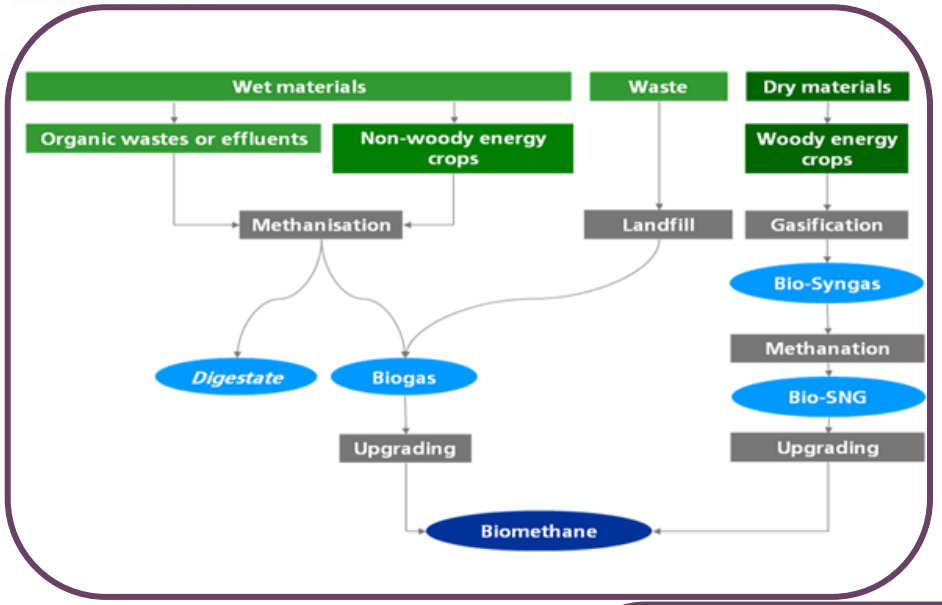


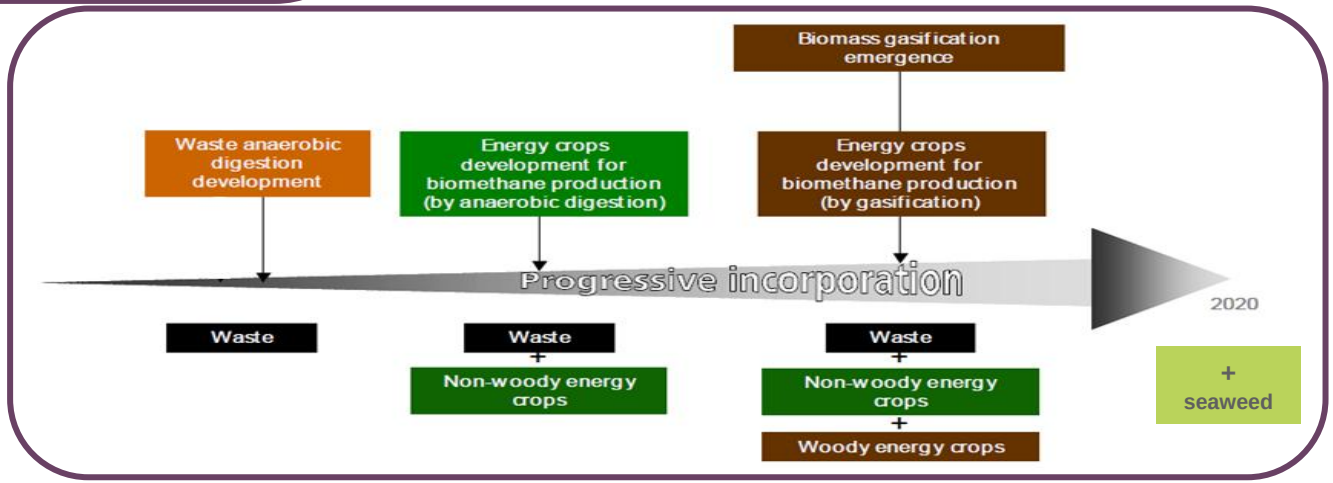
Environmental footprint & urban architecture

(LCA, environmental evaluations, etc.)

Energy production from biomass

Methanisation/gasification: different maturities

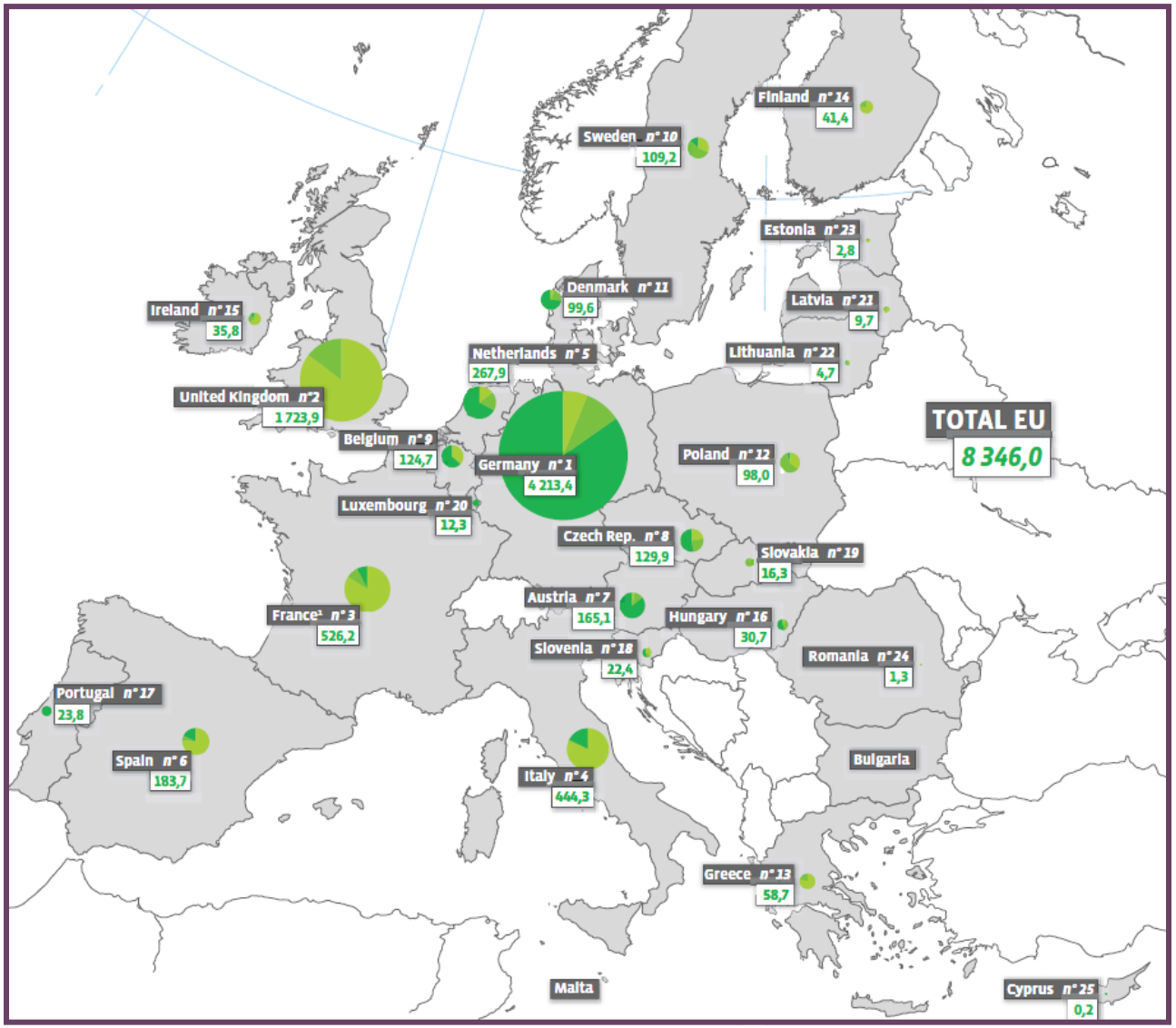




Anaerobic digestion and gasification are complementary processes for the production of green gas/biomethane (different resources and maturity).

Biogas - The European case in 2009 (Eurobserv'er 2010)

- **~97 TWh/yr** of biogas produced in Europe
- Mainly converted into **heat** and **power**
- Fast development of production of **biomethane** for vehicle **fuel and injection** into natural gas grids
- About 60 biomethane injection operations in Europe
- Mainly in Germany, Switzerland, Sweden, the Netherlands and Austria



Impact of biogas composition on the engine behaviour

Impact of biogas composition on the engine behaviour (1/3)

Objectives of the tests

➔Determine the **impact of the biogas composition (upgrading level)** on the operation, performances and emissions of a 4-stroke, 6 cylinders, 9.36L HD natural gas engine;

➔**CO_2, CH_4 and N_2** compositions have been modified

Testing conditions

➔ H_2O, particles, siloxanes and VOCs are **supposed to be eliminated**;

➔ Two kinds of biogas have been tested:

- **Biogas from methanisation;**
- **Landfill biogas.**

➔ Biogas has been tested **“pure” (100%) or “blended” with natural gas.**

Impact of biogas composition on the engine behaviour (2/3)

Biogas compositions tested

	Volumic composition (%)					PCI kWh/m^3(n)
	CH_4	C_2H_6	C_3H_8	N_2	CO_2	
Reference gases						
G_{REF}	91.5	5.5	2	1	91.5	10.62
G_{REF} + biogas from methanisation						
70%G_{REF} + 30% biogas	80.55	3.85	1.4	1.3	12.9	9.08
50%G_{REF} + 50% biogas	73.25	2.75	1	1.5	21.5	8.05
30%G_{REF} + 70% biogas	65.95	1.65	0.6	1.7	30.1	7.03
G_{REF} + landfill biogas						
70%G_{REF} + 30% biogas	76.05	3.85	1.4	9.7	9	8.63
50%G_{REF} + 50% biogas	65.75	2.75	1	15.5	15	7.31
30%G_{REF} + 70% biogas	55.45	1.65	0.6	21.3	21	5.98
Biogas (100%)						
Methanisation	55	0	0	2	43	5.48
Landfill	40			30	30	3.99

gas blending not burning in the engine, gas mixtures burning with instable combustion, gases mixtures burning in the engine

G_{REF} : Natural Gas reference

Impact of biogas composition on the engine behaviour (3/3)

Main results

- The engine **does not operate** when fuelled with a gas (CNG + biogas) containing **more than 61% (% weight) of inert compounds (CO_2 + N_2)**;
- Gases have to contain a **minimum level of hydrocarbons (CxHy): > 45% (% weight)**;
- Raw biogases (non purified) are excluded.
- **Slightly purified biogases have to be used in mixture with CNG in order to get engines running properly**;
- The mixture (biogas + CNG) does not bring to **any significant increase of the pollutants emissions**.

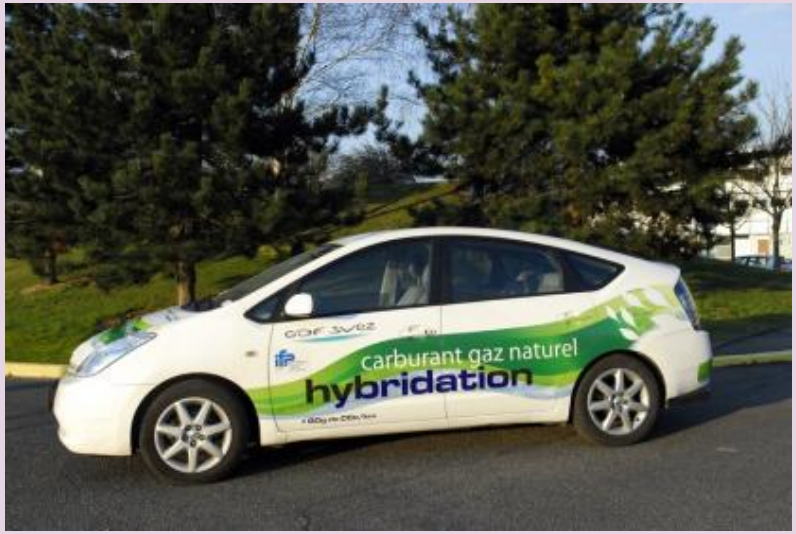
Only dedicated engines running under « lean » conditions could accept partially upgraded biogas:

- **With such engines, CNG blended with 70% (% vol.) of not upgraded biogas could be used;**
- **Lower levels of hydrocarbons in the mixtures (i.e. less than 45% weight) could be used.**

Biomethane - Well to wheels performances in terms of GHG emissions

Biomethane - Well to wheels performances in terms of GHG emissions (1/4)

Toyota Prius II full-hybrid CNG



Partnership between GDF SUEZ, I FP EN

System Description

- Adaptation of the original gasoline engine to CNG
- No modification of the energy management strategy system
- Gas cylinders integrated underneath the chassis
- Autonomy : 250km

Performances

- 78 g CO_2/km* (-25% vs. gasoline version) (* on NEDC cycle)
- Comply with EURO 4 standards
- Gold medal to Bibendum Challenge

Biomethane - Well to wheels performances in terms of GHG emissions (2/4)

Objectives of the study

➔ To assess the potential of CNG and biomethane in terms of GHG emissions reduction;

➔ Comparison, on a well to wheels basis, between gasoline, CNG, biomethane.

Study assessments

- **Gasoline engines**
  Conventional ICE: data based on the Fiat BRAVO.
  Hybrid powertrain: data based on the Toyota PRIUS II.

- **Dedicated CNG engines/vehicles**
  Conventional ICE: data based on the Fiat BRAVO CNG.
  Hybrid powertrain: data based on the CNG Toyota PRIUS II prototype.

- **The fuels considered:**
  - Conventional gasoline (representative of a European average),
  - Compressed Natural Gas,
  - Biomethane from municipal waste & from dedicated crops (wheat, barley and maize).

Biomethane - Well to wheels performances in terms of GHG emissions (3/4)

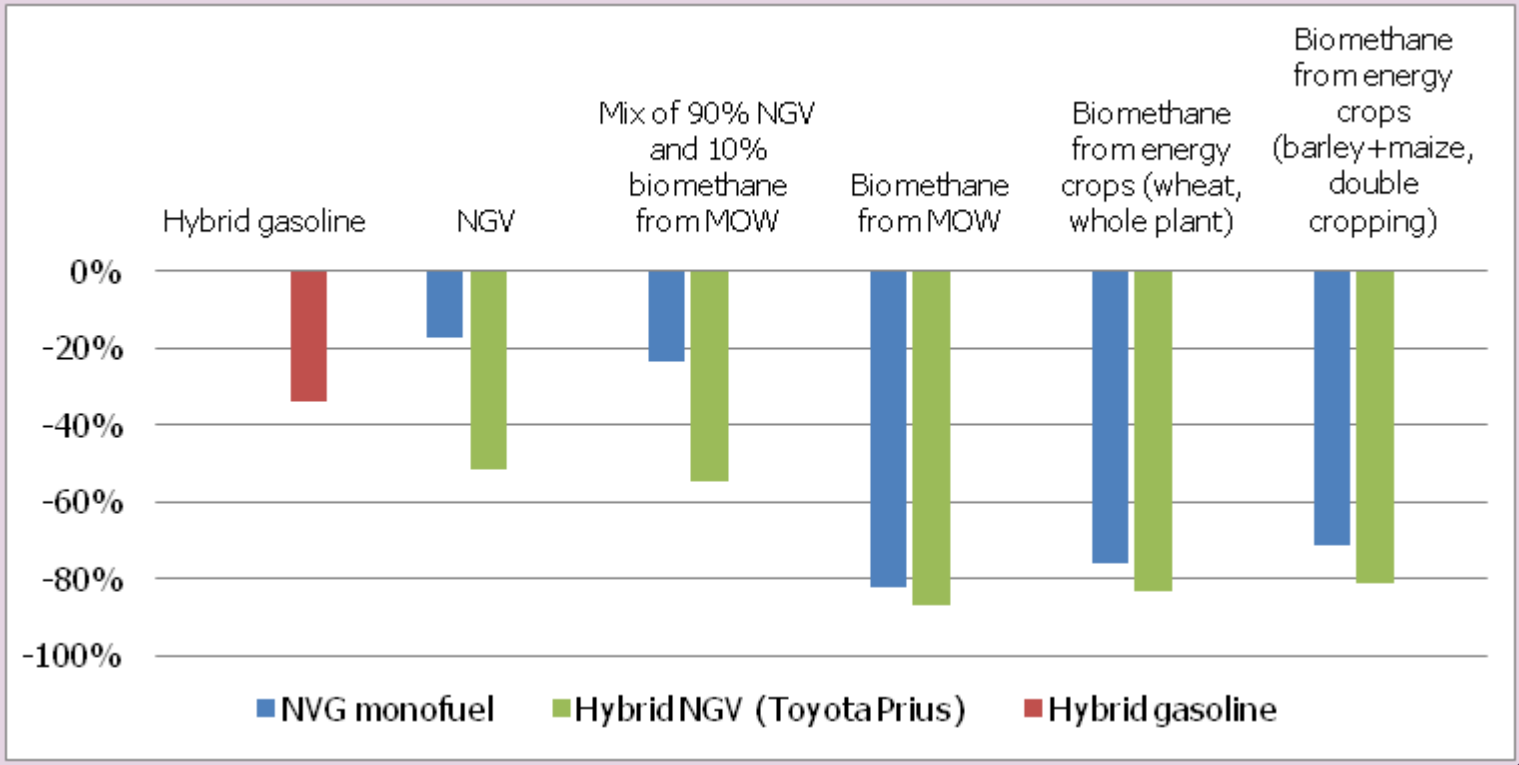
Study assessments

- The **fuel / biofuel production** (incl. raw materials extraction or production), **intermediary transport steps** and **conversion into the final fuel**,
- The **transport and distribution of the fuel** from production site to the end users,
- The **use of fuels** in vehicles.
- The following **GHG emissions associated to each fuel production chain**:

Fuel pathway	WTT GHG emissions (g $CO_{2\ eq.}$/MJ)
Conventional gasoline	12.5
CNG vehicle	
Current EU-mix (1000 km)	8.7
Piped (4000 km)	14.5
Biomethane	
From municipal organic waste (MOW)	-39.5
From dedicated crops	
Wheat (whole plant)	-34.8
Barley+Maize (double cropping)	-31.5

Biomethane - Well to wheels performances in terms of GHG emissions (4/4)

GHG emissions



Source: GDF SUEZ - 2011

When a CNG hybrid vehicle is fuelled by 100% of biomethane the greenhouse gases emissions are reduced by -86%*

(*in comparison to a gasoline vehicle)

Conclusions & perspectives

Conclusions & perspectives

From a technical point of view:

- Tests have shown that **slightly upgraded biogas** can be directly used as a fuel, if **blended with natural gas**.

- With dedicated CNG engines, **the development of new engine technologies** (lean CNG combustion) may authorize the use of **natural gas blended with 70% volume of not upgraded biogas**.

From an environmental point of view:

- A simplified environmental assessment confirms the **relevance of using CNG and biomethane as fuels**, in terms of GHG emissions reduction;

- GHG emissions from CNG vehicles may be significantly lower than the emissions of gasoline vehicles: around **17% lower in the case of dedicated CNG vehicles** and up to **51% lower in the case of hybrid CNG vehicles**;

- GHG emission levels are **lowered by 86% in the case of the Toyota Prius CNG Hybrid prototype fuelled by biomethane produced from waste**.

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Thank you for your attention !

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