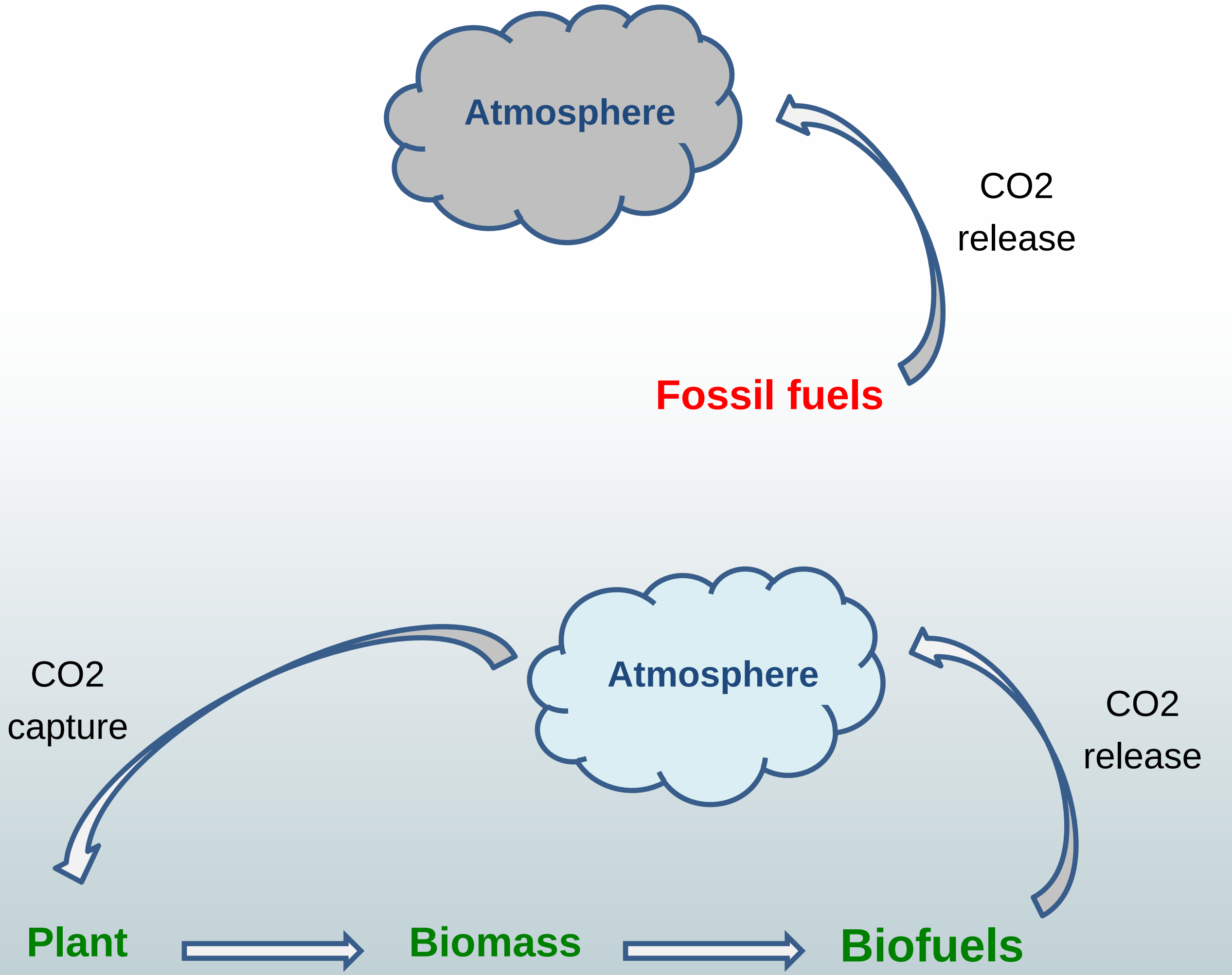
Biofuel Use On Tractors

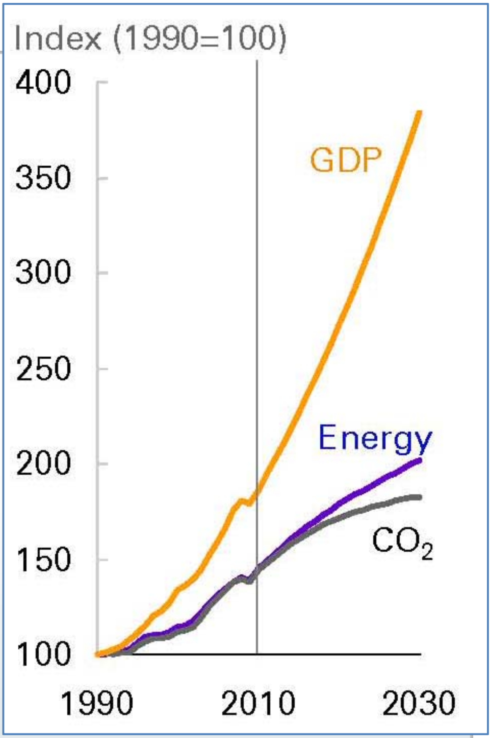
Giuseppe Gavioli, Riccardo Morselli, John Posselius
CNH Innovation

Biofuels from Biomass

- Biomass is a renewable resource of organic substance, animal or vegetal origin, that can be used in energy production (plant matter, animal waste, municipal solid waste)
- Biomass can be used to produce a variety of biofuels, liquid (e.g. biodiesel, BtL, bioethanol) and gaseous (e.g. biomethane, hydrogen)
- Biofuels can be 100% from renewable source and they have very good environmental properties:
  - Lower gaseous emissions than conventional fuels
  - More sustainable carbon footprint

Carbon Footprint





Source: BP, 2011

GHG Emission Reduction

Draft Lifecyle GHG Emission Reduction Results
For Different Time Horizon and Discount Rate Approaches
(includes land use change impact)

Fuel Pathway	100 year, 2% Discount Rate	30 year, 0% Discount Rate
Corn Ethanol (Natural Gas Dry Mill)	-16%	+5%
Corn Ethanol (Best Case Natural Gas Dry Mill)[2]	-39%	-18%
Corn Ethanol (Coal Dry Mill)	+13%	+34%
Corn Ethanol (Biomass Dry Mill)	-39%	-18%
Corn Ethanol (Biomass Dry Mill with Combined Heat and Power)	-47%	-26%
Soy-Based Biodiesel	-22%	+4%
Waste Grease Biodiesel	-80%	-80%
Sugarcane Ethanol	-44%	-26%
Switchgrass Ethanol	-128%	-124%
Corn Stover Ethanol	-115%	-116%

Source: US EPA Lifecycle analysis of GHG emissions from renewable fuels, 2009

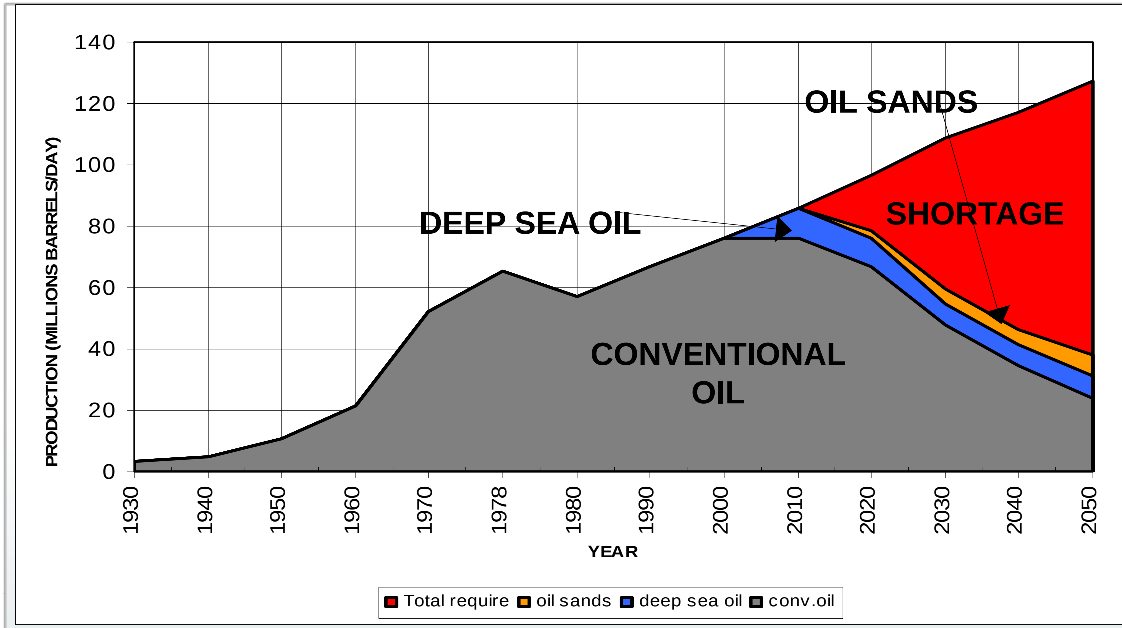
Energy Security and Economy

- Biofuels are also very important for energy security, as biomass availability is quite spread across the world and the conversion processes are mostly based on multi-scale well known and available technology.
  "*Biofuels are an important part of reducing America's dependence on foreign oil and creating jobs here at home*" (USA President speech, August 2011)

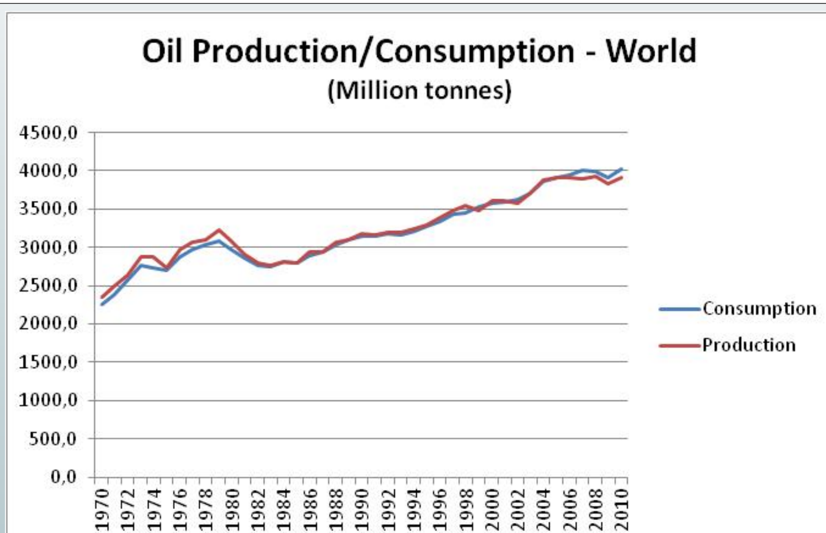
- Oil shortage and high price make biofuels more and more competitive from an economic point of view

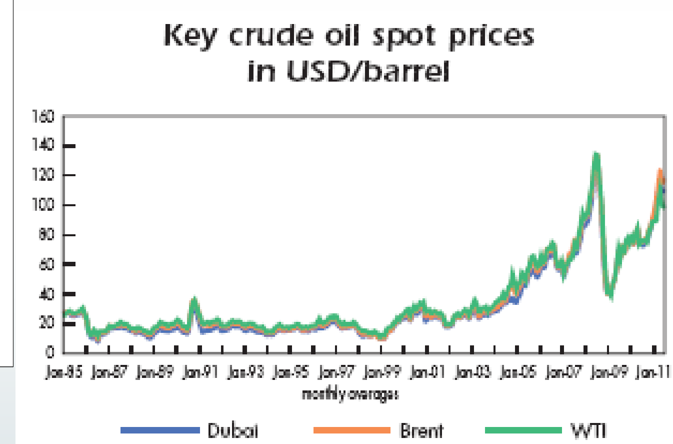
- Biofuels production in 2010 grew by 13.8%, or 35,000 t/d, one of the largest sources of liquid fuels production growth in the world. Growth was driven by the US (+20,000 t/d, or 17%) and Brazil (+7,300 t/d, or 11.5%).

Crude Oil Availability and Price Trend



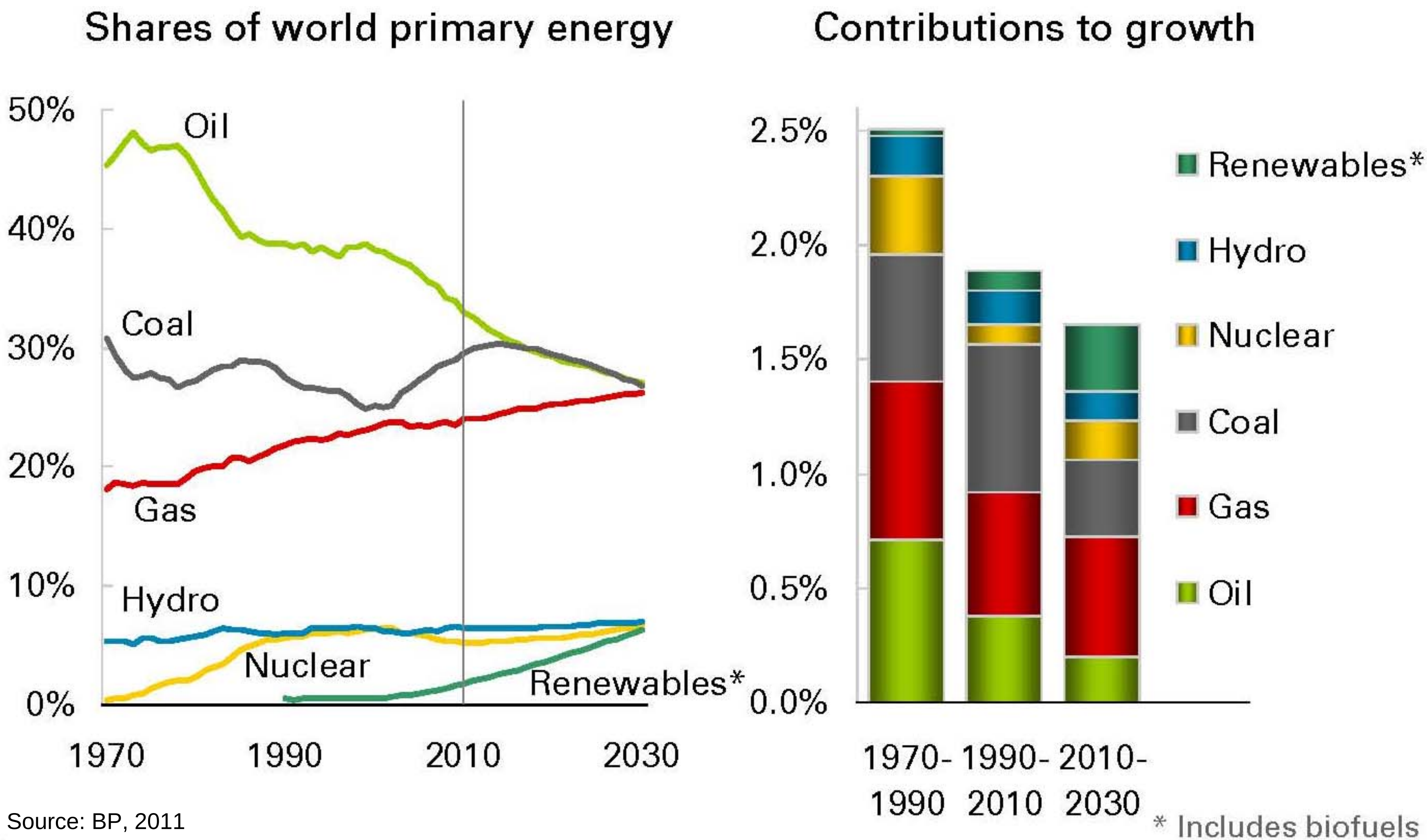
Source:
BP Statistical Review of World Energy





Source: International Energy Agency

Contribution To Total Energy Growth



Source: BP, 2011

Biofuels

Biofuel	Today main use	Perspectives
Biodiesel	Transportation and agriculture equipment	Transportation and agriculture equipment
BtL	Research	Transportation and agriculture equipment
Bioethanol	Blended with gasoline for cars	Direct use for agriculture equipment
Biomethane	Transportation, co-generation, domestic use (heating,…)	Direct use for agriculture equipment
Hydrogen	Aerospace, niche applications and research	Transportation, agriculture equipment, power plants

Biodiesel

Biodiesel is a liquid fuel manufactured from plant oil or animal fat via a transesterification process.

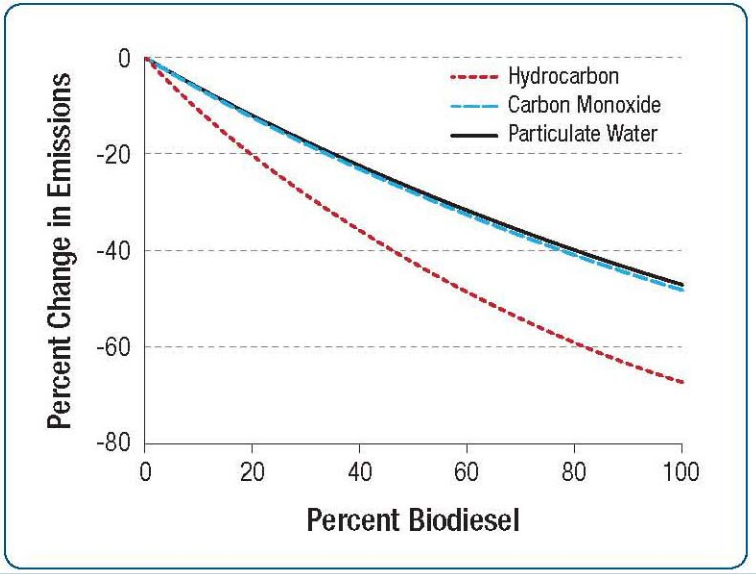
It can be used alone (100% = B100) or in blends with petroleum diesel, (B5, B20, B50, etc.). Even in low concentrations it improves fuel lubricity and raises the cetane number of the fuel.

Biodiesel contains 8% less energy per unit of volume than typical diesel fuel.

Biodiesel reduces tailpipe HC, CO and PM emissions and it doesn't increase NOx emissions.

Biodiesel must be stored at >7 C or re-heated before using it.

Average emissions impacts of biodiesel fuels on CI engines



Source: US National Renewable Energy Laboratory, 2008

Bioethanol

Bioethanol is a liquid fuel manufactured from biomass.

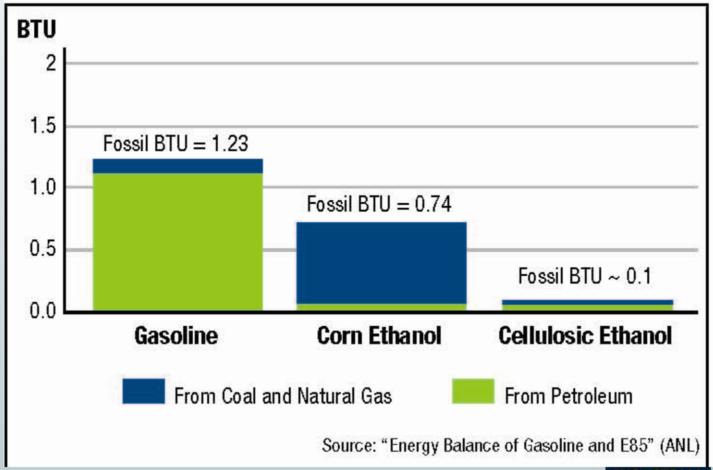
It is made by fermenting sugars derived from crops such as corn or sugar cane (1st generation bioethanol).

2nd generation bioethanol is made from cellulosic materials, such as agricultural residues (corn stover, cereal straws, and sugarcane bagasse), forestry residues (small trees and excess wood), energy crops specifically grown for fuel production (switchgrass, poplars, willows).

It is normally used in blends with gasoline (E10, E85) and it increases the octane number of the fuel.

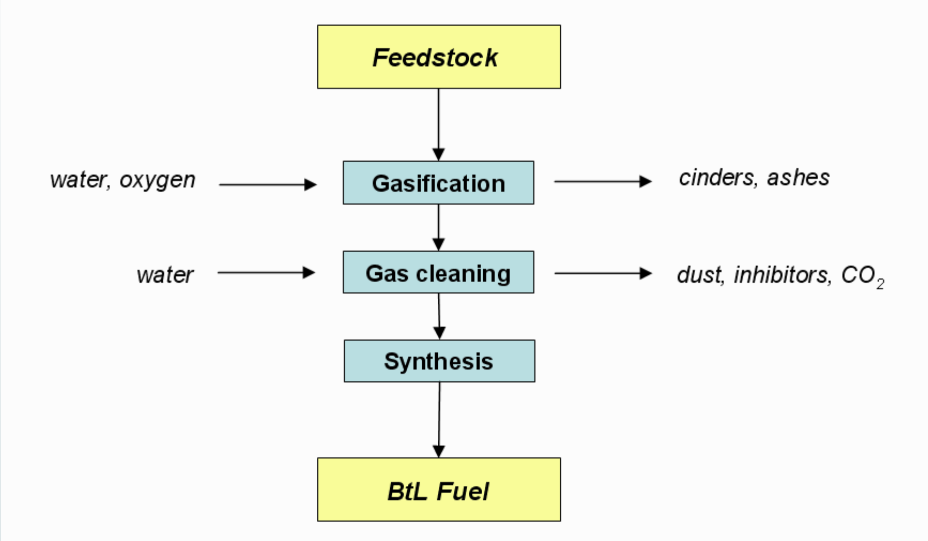
Bioethanol contains 30% less energy per unit of volume than typical gasoline fuel but it requires 10 times less fossil energy to be produced.

Fossil Energy Requirements for Gasoline and Corn and Cellulosic Ethanol (2007)



BtL (Biomass-to-Liquid)

- The development of BtL-fuels is a relatively new. BtL stands for Biomass-to-Liquid and like GTL (Gas-to-Liquid) and CTL (Coal-to-Liquid)
- BtL-fuels belong to the group of synthetic fuels (Synfuel or Sunfuel®) and are second-generation biofuels.
- Synthetic fuels can be ideally adapted to current engine concepts.
- The great advantage of BtL-fuels is that they can be made from various vegetable sources, such as agricultural remnants like straw, remainders of waste wood and energy crops which are only grown for the production of fuels.



Source: Biofuel Technology Handbook, Dominik Rutz & Rainer Janssen, 2008

Biomethane

Biomethane can be obtained by filtering the biogas obtained by anaerobic digestion of biomass. Biomethane from biogas is chemically identical with natural gas or methane.
Methane can also by obtained via biomass gasification.

With the current technology, a diesel engine is 15% more efficient than a methane engine, however toxic emissions of methane gas are much lower than diesel.

Compared to diesel, the energy density per volume of methane is low: taking into account the specific heat and the engine efficiency,
1 liter of diesel is equivalent (in terms of energy output from the engine) to 5.75 lt of methane at 200bar.

Reductions of toxic emissions (in %) from biomethane combustion in comparison with diesel	
Emission	Reduction vs diesel
NOx	80 %
CO	50 %
PM	98 %
HC	80 %
Ozone formation	85 %

Hydrogen

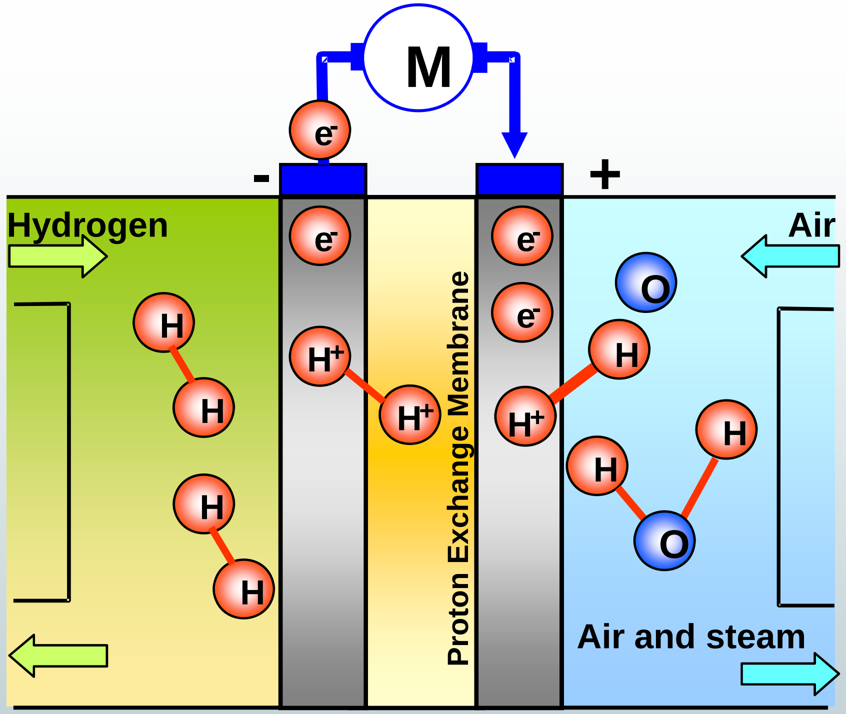
Hydrogen as a biofuel can be obtained in several ways starting either from biomass (biogas steam reforming, anaerobic digestion, gasification) or from the electric energy of solar panels and wind turbines (by electrolyses).

It can be used in combustion engines blended with methane (up to 30%-40% in volume) to reduce emissions.

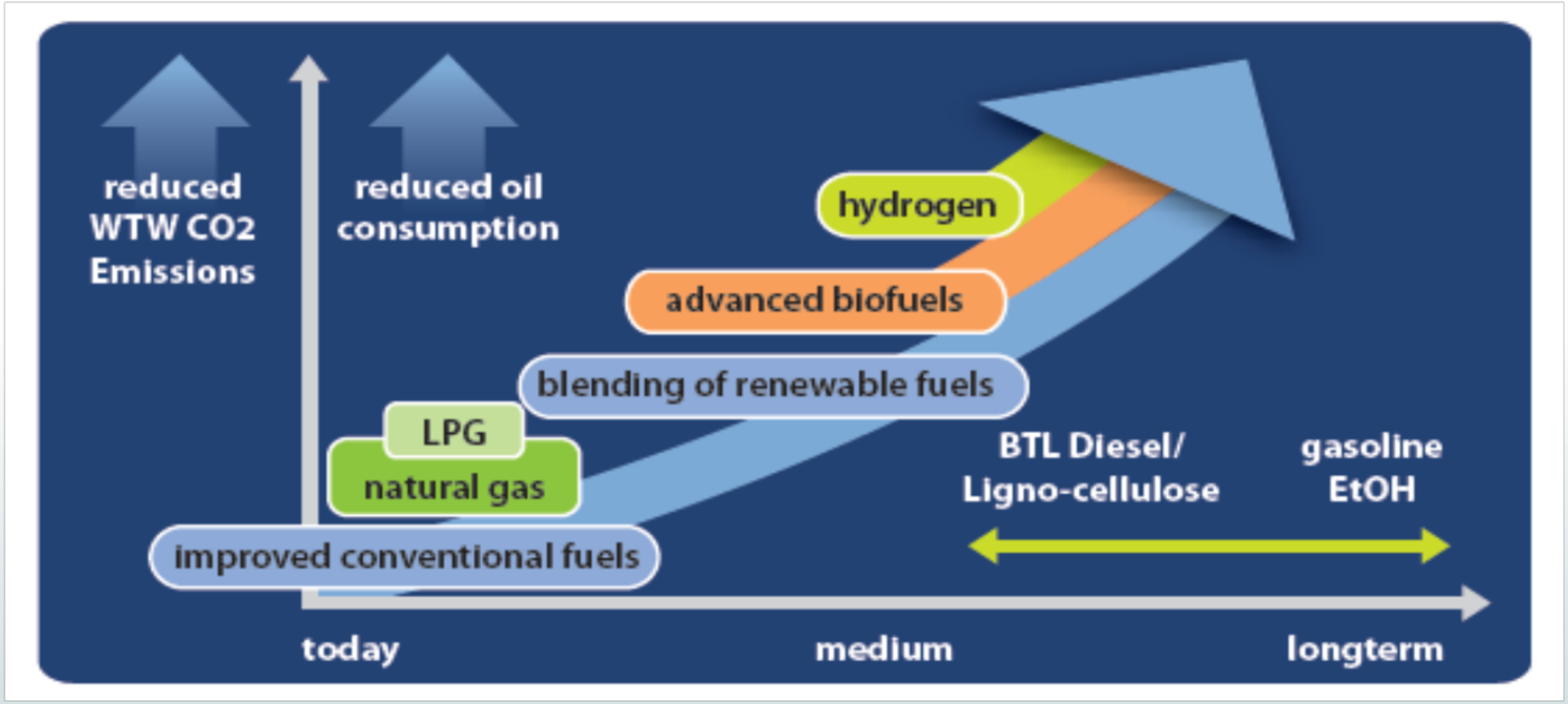
Pure hydrogen best use is in combination with fuel cells to reach **zero emissions** and the best efficiency (50-80% vs 40% of an internal combustion engine).

Hydrogen mass density is very low: 24kg/1000lt at 350bar.

With the current technology, 100kW require about 5.8kg/h of hydrogen.



Alternative Fuels Roadmap



Source: ACEA (European Automobile Manufacturers' Association)

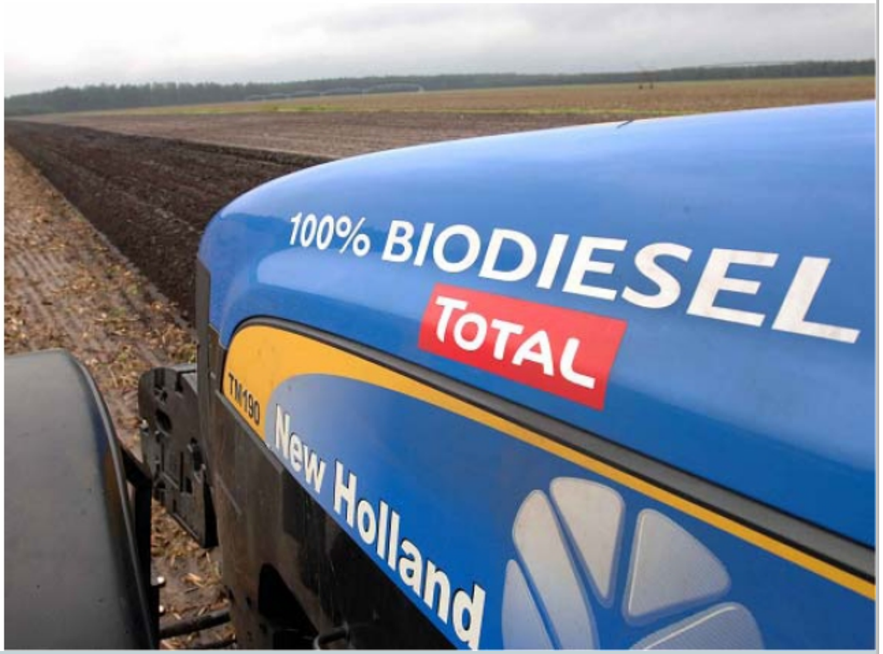
Tractors Can Use Biofuels

- Tractors and self-propelled agricultural machines can use biofuels in their internal combustion engines, as an alternative to petroleum diesel.
- All existing diesel tractors can use B5 biodiesel/diesel blend right now; most of them run well with B20. Some can run B100 with some adaptations.
- The use of bioethanol, biomethane and hydrogen on tractors is at reach: methane/diesel tractors exist, ethanol engines already run on cars, hydrogen propelled engines are being studied.

Tractors Can Use Biodiesel

- CNH has been involved in several studies validating the functionality of biodiesel
  - Penn State Universities “Tractors without Tankers”
  - Penn State Univ & ELBETT’s “SVO Technology”
  - Utah State Univ & Utah Department of Transportation’s “FreeWays 2 Fuel”
  - Directly working with customers
- Several Manufactures current have tractors that run on approved B100
- CNH is continuing work on the Tier 4 engines and various levels of biodiesel mixes to insure proper function

	Btu/lb	Btu/gal
Typical Diesel No. 2	18,300	129,050
Biodiesel (B100)	16,000	118,170



Bio-methane tractors options

Dual fuel (diesel + methane)

with low methane blend (0-50%)

- TIER 4 exhaust treatment system have to be used
- lower fuel cost reduction benefit
- simpler installation, few gas tanks
- no autonomy problems

Dual fuel (diesel + methane)

High methane blend (70-95%)

- The methane percentage to avoid the complex TIER 4 exhaust treatment system is likely high (>70%), today this is not yet proved on commercial engines
- higher fuel cost reduction benefit
- more complex installation due to a larger number of gas tanks together with the diesel tank
- autonomy problems, most of the fuel is methane.
- limp home mode with 100% diesel

100% methane

- simple exhaust treatment system to meet emissions legislation
- lower noise
- higher (optimized) efficiency with respect to dual fuel engines
- highest fuel cost reduction benefit
- Only gas tanks
- limp home mode with gasoline fuel (with an additional gasoline tank)
- autonomy and methane availability are still an issue.

Hydrogen powered tractors

- Hydrogen can easily be obtained from renewable energy sources (solar and wind energy)
- Pure hydrogen best use is in combination with fuel cells to reach zero emissions and the best efficiency (50-80% vs 40% peak of an internal combustion engine).
- Compressed hydrogen represent the highest energy density option to “store” electric energy. With the current technology, batteries are less efficient and require a long time to recharge. Agriculture would not be possible with just batteries.
- Electric motors allow to simplify the mechanical transmission and a very high efficiency powertrain can be obtained.
- Cooling of fuel cells and electric components is more demanding than in traditional tractors
- Autonomy is still a limitation: compressed hydrogen has a very low power density

- Total electric power: 50kW
- 2.4kg of Hydrogen @ 350bar
- 300V DC link
- 2x 50kW electric motors, 480Nm (cont), 93% efficiency 3000rpm max speed
- No battery pack

- Total electric power: 100kW
- 8.2kg of Hydrogen @ 350bar
- 700V DC link
- 2x 100kW electric motors, 950Nm (cont), 96% efficiency 3000rpm max speed.
- 12kWh – 50kW battery pack

Biofuels Blends

	Biodiesel	Bioethanol	Biomethane	Hydrogen
Bi-fuel		○	○	
Dual fuel	○	○		
	○		○	
			○	○
Research in progress	○			○
		○		○


Dual fuel biomethane-diesel tractor

Bio Energy Production

- Some traditional agricultural crops such as maize, barley and rye are being used as a renewable energy and are an alternative business for farmers
- Some biomass comes from untraditional agricultural crops specifically grown for bio-conversion processes
  - Examples of herbaceous crops used as a bio-feedstock include:
    - Miscanthus
    - Switchgrass
    - Sweet sorghum

  - Examples of woody coppice crops used as a bio-feedstock include:
    - Eucalyptus
    - Poplar
    - Willow

- Traditional harvesting equipment is being "tuned" for the new crops and some specialty equipment is under development

Biomass Production

Air cart seeder for seeding bio - feedstock like switchgrass

Harvesting Biomass

Woody crop harvesting for electric generation and 2nd gen ethanol

Cob & stover collection for direct combustion and 2nd gen ethanol

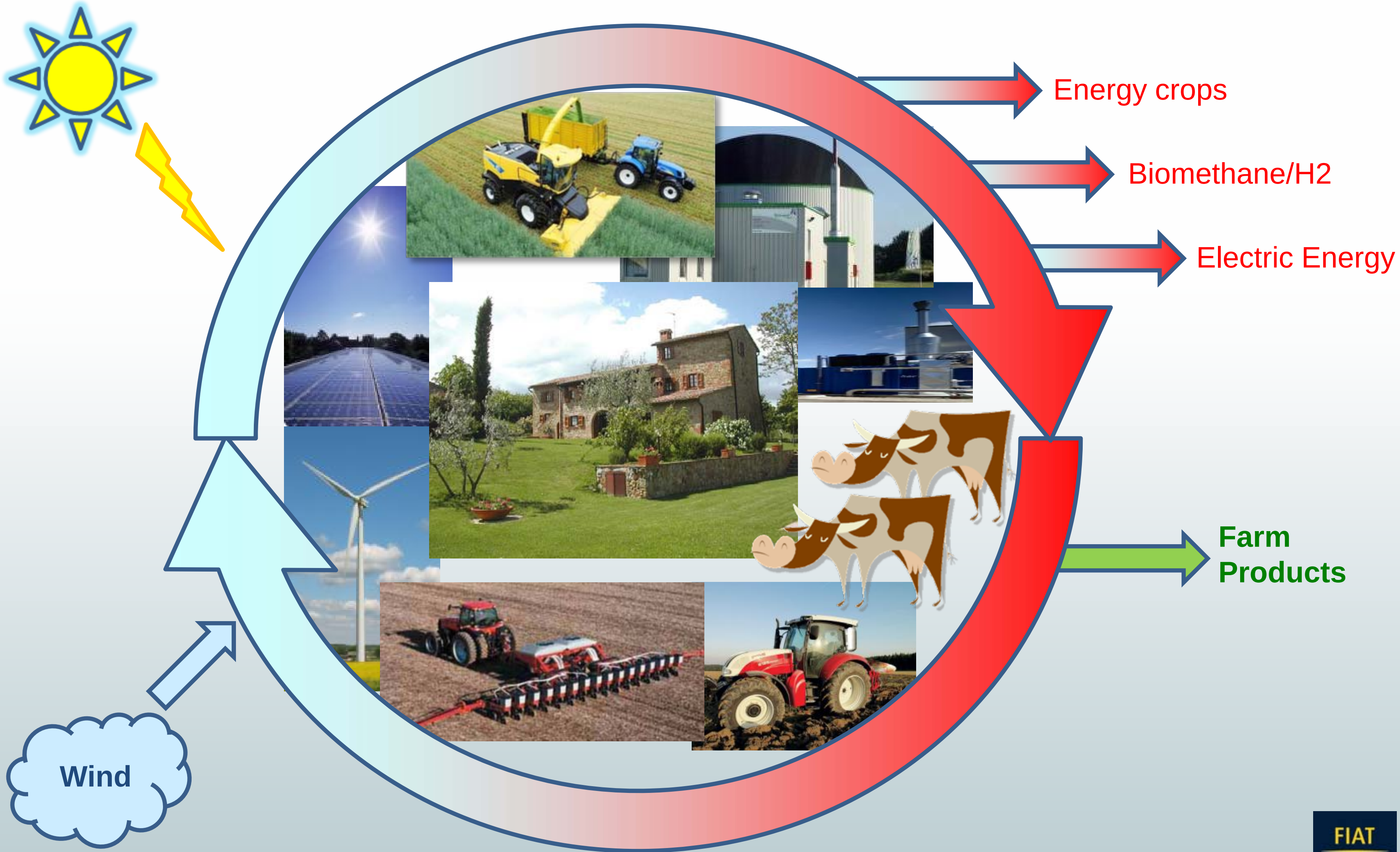
Harvesting Biomass

Sugarcane for 1st gen ethanol and electricity

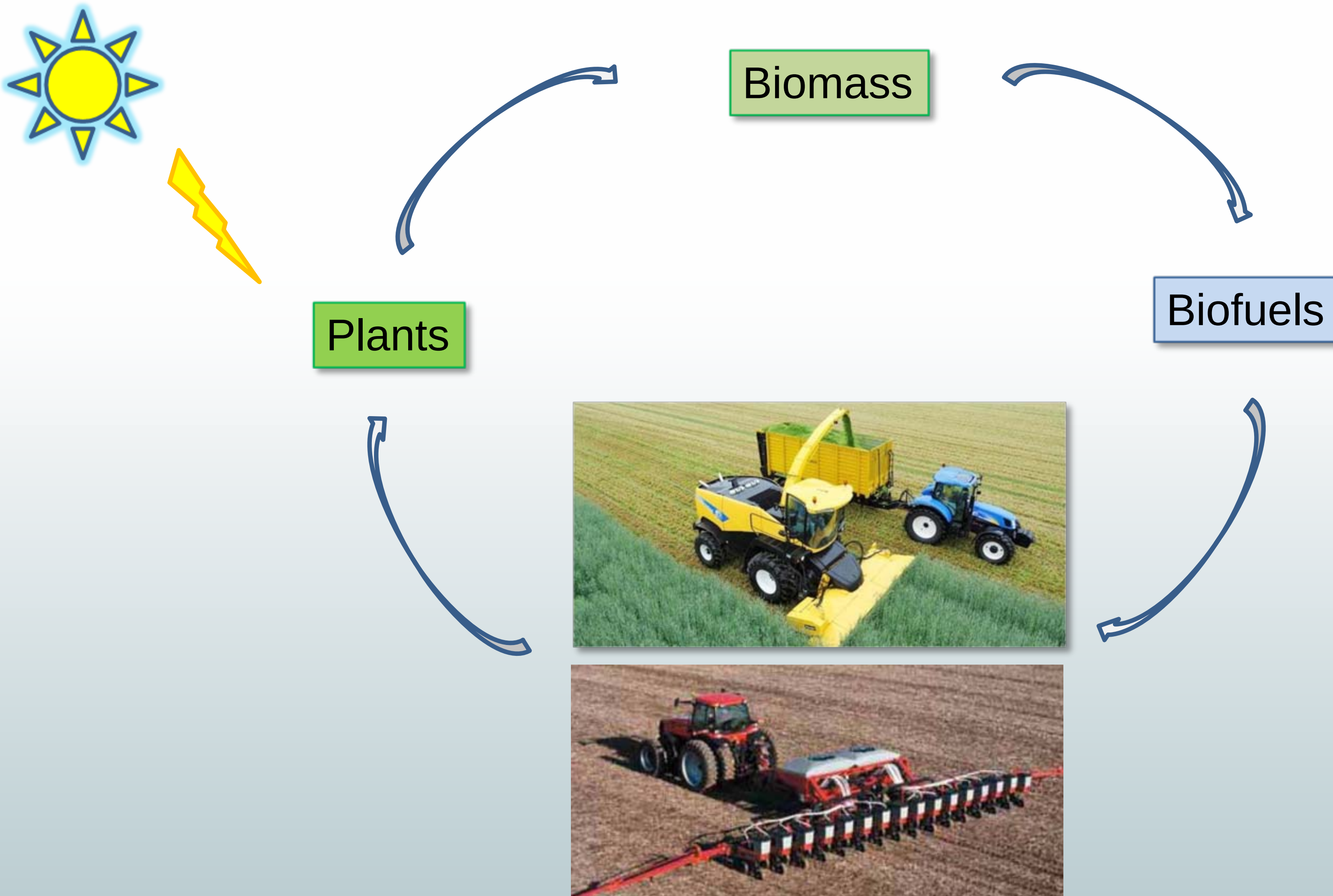
Maize for methane generation

Switchgrass for 2nd gen ethanol and direct combustion

Energy Independent Farm



Virtuous Circle



Challenges

- Availability and use of land
- Use of water
- Competition with food crops
- Fossil energy balance (biofuel energy / fossil energy input to produce the biofuel)
- Energy efficiency (biofuel energy / total energy input to produce the biofuel)

Agricultural mechanization is a key part of the answer:

- It can guarantee the land and crop productivity improvement necessary to keep Europe competitive in the production of biofuels
- It supports advanced farming practices like no-tillage cultivation
- It optimizes the off road logistic for biomass transportation
- It helps reducing the cost of biofuels
- It supports the energy independent farm

Biofuel Use On Tractors

- Advances in agricultural mechanization will continue to support the production of:
  - Food
  - Feed
  - Fiber
- In addition – agricultural mechanization can also contribute to globally sustainable biofuels

Agricultural mechanization is a key success factor for the achievement of scalable, sustainable biofuels

BACKU
P

References

- **BP Energy Outlook 2030**, January 2011.
- **BP Statistical Review of World Energy**, June 2011.
- **EPA Lifecycle Analysis of Greenhouse Gas Emissions from Renewable Fuels**, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, EPA-420-F-09-024, May 2009.
- De Zanche C., Frisio D: "**La trattrice a biogas è ormai una realtà**", m&ma-iMA n.2 1989.
- Eurostat, **Key Figures on Europe**, 2011 Edition, ISSN 1830-7892
- Grigoriev, Igor V. et al., **Fueling the Future with Fungal Genomics,** Mycology, 2011 Apr 29
- International Energy Agency, **2011 Key World Energy Statistics**, Paris, 2011
- L. Wrigth et al., **Biomass Energy Data Book: Edition 2 (draft)**, prepared by the Oak Ridge National Laboratory for the U.S. Department of Energy, Jan 2009.
- http://**make-biodiesel**.org/
- McCormick, Robert L., **Deployment Issues for Biodiesel:Fuel Quality and Emission Impacts,** NREL/PR-540-41868, USA June 2007
- National Renewable Energy Laboratory (NREL), **Clean Cities: Ethanol Basics, Fact Sheet**, October 2008, DOE/GO-102008-2655 (USA).
- National Renewable Energy Laboratory (NREL), **Biodiesel Handling and Use Guide**, December 2009, NREL/TP-540-43672.
- Rutz, Dominik, R. Janssen, **Biofuel Technology Handbook**: WIP Renewable Energies**,** Sylvensteinstr. 2, 81369 München, Germany .
- U.S. Energy Information Administration, **Annual Energy Outlook 2011**, DOE/EIA-0383(2011), April 2011