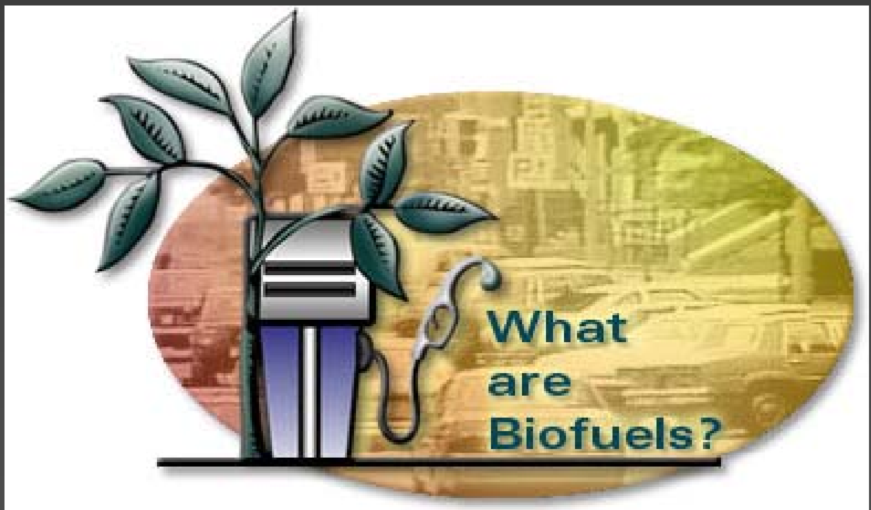
Biofuels Primer: Technology, Energy & Environmental Balance



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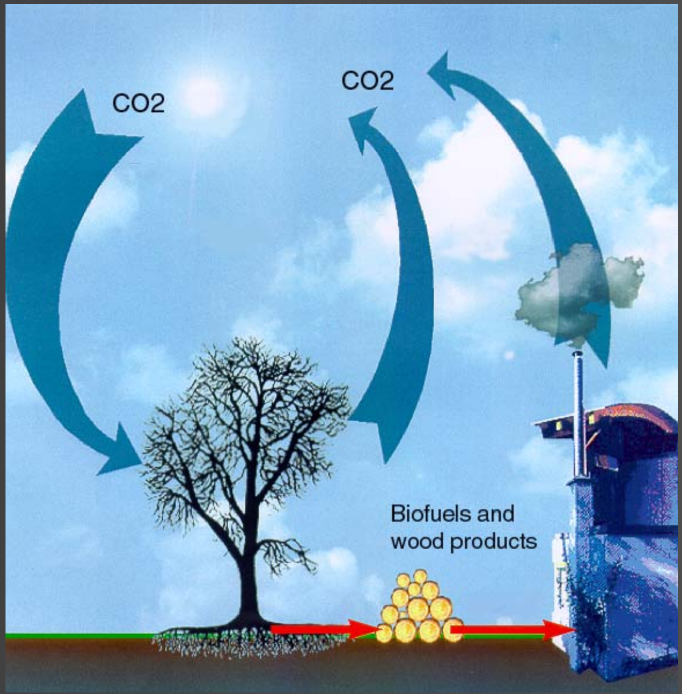
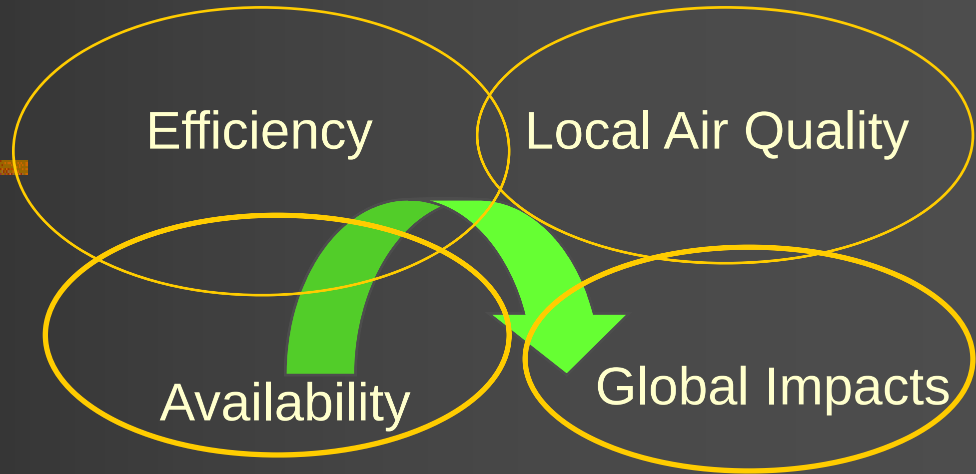
Outline



- Rationale
- Definitions
- Key Fuels: Technologies and Properties
- Environmental & Energy Balance
- Comparative 'Well-to-Wheel' Analyses
- Conclusions
- Recommendations

Why Biofuels?



- Energy Security –
  - Lessens dependence on imports
  - Produced domestically in many parts of the world
- Environmental Impacts
  - Reduces local air pollution from exhaust emissions
  - Contributes to global CO2 emission reduction
- Economic Impact
  - Derived from renewable sources
  - Provides income to farmers and rural areas

- Not all Biofuels are the same
  - “first generation” vs. “second generation” Biofuels
  - Differences exist also between Biofuels of the same “generation”
  - Depend on feedstocks and production process utilized

Biofuels: Generational Differences

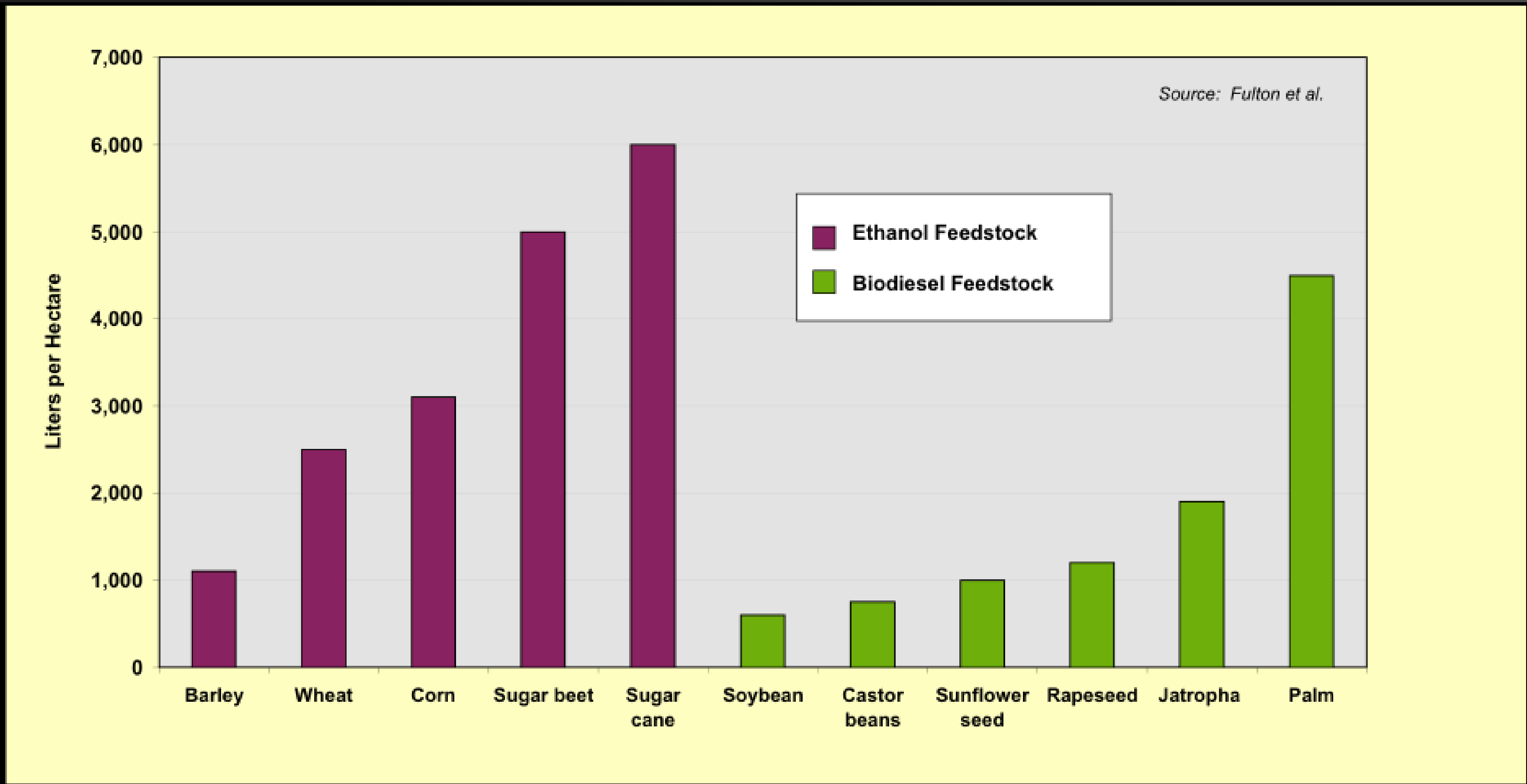
First-generation -

- Made from food crop feedstocks
- Two main types are used commercially
  - Ethanol and Bio-esters
- Ethanol is made by fermenting plant sugars
  - Sugar cane, corn, sugar beets
- Bio-esters are produced by a chemical reaction between vegetable oil (e.g. rapeseed or soyabean oil) and an alcohol
  - Biodiesel is a blend of bio-esters with commercial diesel fuel

Second-generation -

- Produced from agriculture and forestry waste
  - Woodchips, straw, non-food crops
- Based on breaking down the cell lignin structure
  - Most notable are cellulosic ethanol and butanol
- Gasification of woody feedstock can be used to produce high quality synthetic fuels
  - Known as ‘Biomass-to-Liquids’ (BTL)

1st Generation Biofuels Yield: *Selected Ethanol and Biodiesel feedstock*



Source: IEA, Biofuels for Transport, 2004

Bioethanol: Conventional Production *(First Generation)*

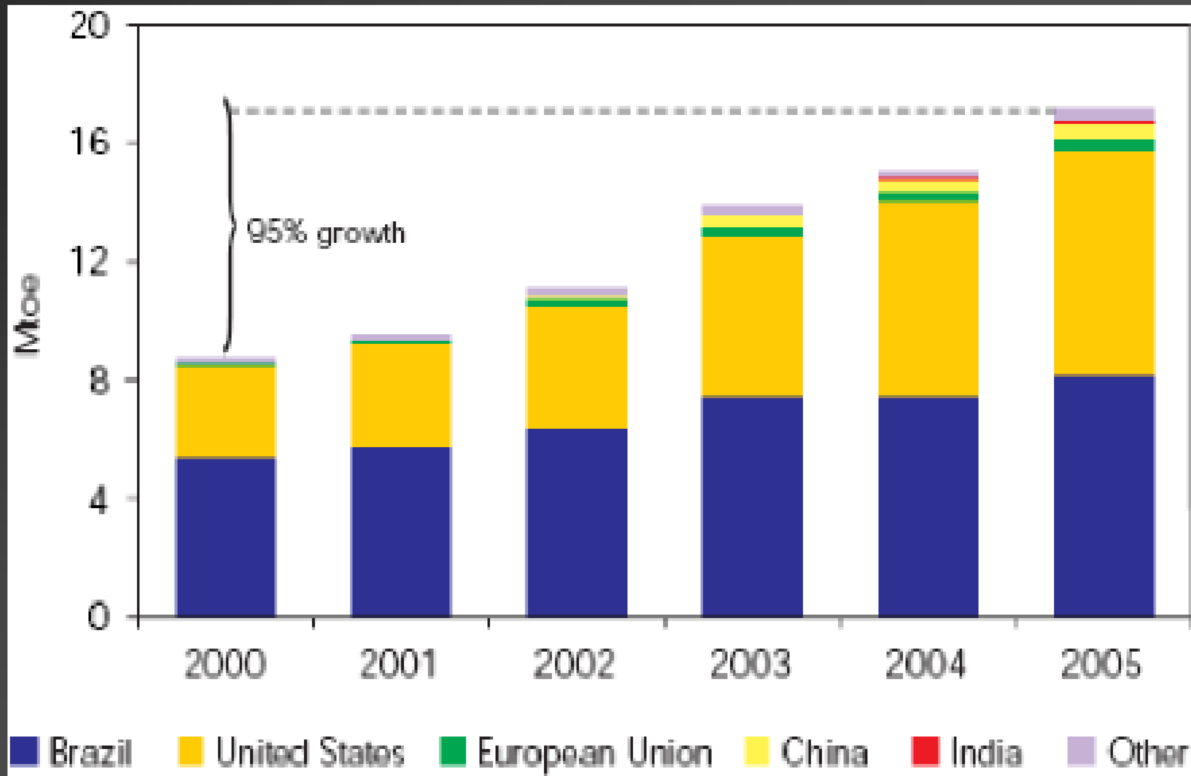
- Bioethanol is the most common Biofuel, accounting for more than 90% of total Biofuels usage
- Conventional production includes:
  - Conversion of starchy biomass into sugars, and
  - Fermentation of 5-6 carbon sugars with final distillation of ethanol to fuel grade.
- Conventional Ethanol can be produced from many feedstocks,
  - Cereal crops, corn (maize), sugar cane, sugar beets, potatoes, sorghum, cassava.
  - Co-products (e.g animal feed) help reduce production cost
  - If sugar cane is used, conversion into sugar is easier.
- Crushed stalk (bagasse) can be used to provide heat and power for the process and for other energy applications.

Current Ethanol Use and Properties

- High octane (100+)
  - Enhances octane properties of gasoline,
  - Used as oxygenate to reduce CO emissions.
- 27% - 36% less energy content than gasoline
  - OEM's estimate 15% - 30% decrease in mileage efficiency
- Ethanol is used in low 5%-10% blends with gasoline (E5, E10) but also as E-85 in flex-fuel vehicles
  - Current blends in the U.S. are 5.7%
- Current technical drawbacks and limitations
  - Increases fuel volatility leading to more Ozone formation
  - Cannot be pre-blended into gasoline or transported via pipelines

World Ethanol Picture

- The world's largest producers of bio-ethanol:
  - Brazil - sugar-cane ethanol
  - United States - corn ethanol
- In Brazil, gasoline must contain a minimum of 22% bioethanol.



Source: IEA analysis based on F.O.Lichts - IEA World Energy Outlook 2006

Bioethanol: Advanced Production *(Second Generation)*

- Advanced processes utilize all available ligno-cellulosic materials,
  - Cellulosic wastes; straw; food-processing wastes, and/or
  - Dedicated fast-growing plants such as poplar trees and switch-grass
- Cellulosic feedstock could be grown on non arable land or be produced from integrated crops
- New chemical and enzymatic processes are investigated to provide for better conversion
  - pre-treatment, hydrolysis, fermentation
- Solid residues and co-products such as lignin, may inhibit hydrolysis
  - Can be extracted and used as a fuel in the production process, thus reducing cost and emissions.

Key Steps to Advanced Bio-Alcohol Production

- Ethanol production from ligno-cellulosic feedstock includes
  - Biomass pre-treatment to release cellulose and hemicelluloses,
  - Hydrolysis to release fermentable 5- and 6-carbon sugars
  - Fermentation of sugars
  - Separation of solid residues and non-hydrolyzed cellulose, and
  - Distillation to fuel grade
- Other bio-alcohols can be also produced and used as blend stocks for gasoline
- New R&D focus on Bio-Butanol
  - Can be easily added to conventional gasoline, due to better match and lower vapor pressure

Biobutanol: The Other Bio-Alcohol

- Has an energy content closer to that of gasoline
  - less of a compromise on fuel economy
- Can be blended at higher concentrations than bioethanol for use in standard vehicle engines
  - Currently biobutanol can be blended up to 10%v/v in the EU and 11.5%v/v in the U.S.
  - Future potential for maximum allowable limit of 16%v/v in gasoline
- Less susceptible to separation in the presence of water than ethanol/gasoline blends,
  - Allows the use of existing distribution infrastructure
  - Does not require modifications in blending facilities, storage tanks or retail station pumps.
- Suitable for transport in pipelines

Biodiesel: Conventional Production *(First Generation)*

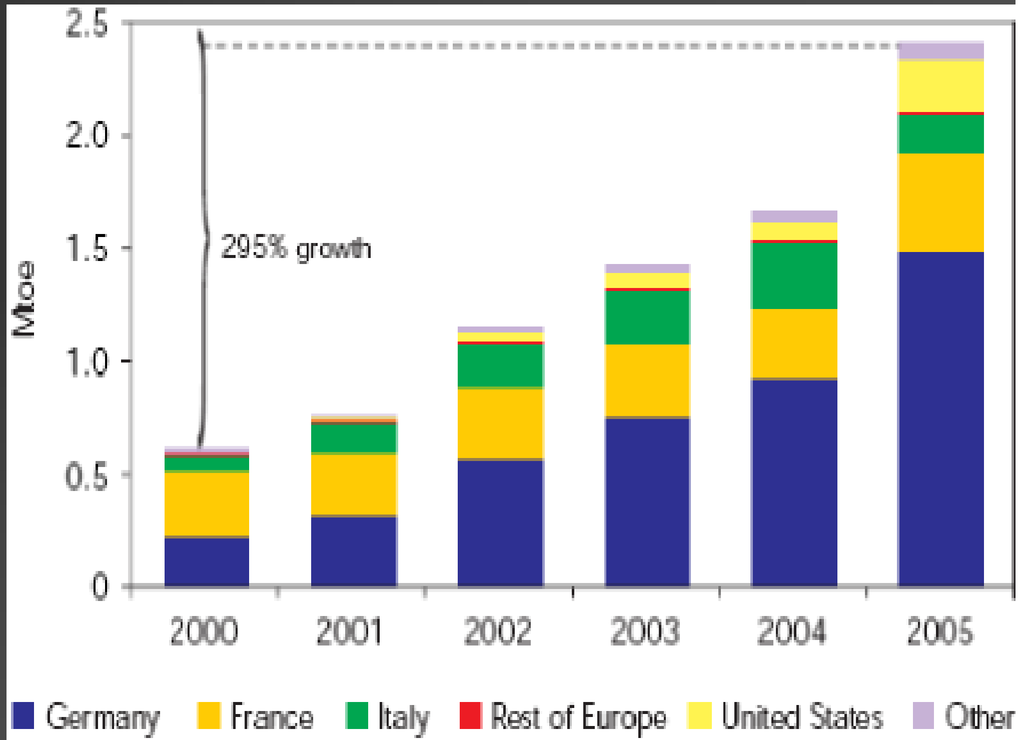
- Conventional production
  - based on trans-esterification of vegetable oils and fats through the addition of methanol (or other alcohols) and a catalyst,
  - Glycerol is a co-product of the process
  - Feedstock includes rapeseeds, sunflower seeds, soy seeds and palm oil seeds, with oil extracted chemically or mechanically
- Advanced processes
  - Replacement of methanol of fossil origin, by bioethanol to produce fatty acid ethyl ester instead of fatty acid methyl ether
  - New processes have been developed to use recycled cooking oils and animal fats

Biodiesel Properties and Uses

- Nontoxic, biodegradable, and reduces some air pollutants
- B20 (20% biodiesel, 80% petroleum diesel) can generally be used in unmodified diesel engines;
  - In pure form (B100), but may require engine modifications.
  - B20 contains 9% less energy content per gallon than #2 diesel
- New production process that includes hydrogenation of oils and fats is entering the market
  - Can produce a biodiesel that can be blended with fossil diesel up to 50% without any engine modifications
- Has a higher cetane number and provides more lubricity
- Potential issues with cold starting
  - Cold weather storage requires additional steps to keep Biodiesel usable

World Production of Biodiesel

- Biodiesel is the fastest growing Biofuel
  - Started from a lower base than ethanol
- Production accelerated from 2004 to 2005
  - 75% increase in Germany, France, Italy, and Poland
  - Over 300% increase in the United States
- Important blending stock to achieve ultra low-sulfur diesel



Source: IEA analysis based on F.O.Lichts - IEA World Energy Outlook 2006

Benefits and Costs of Biofuels

Benefits

- Reduced oil imports and improved energy security
- Lower GHG emissions
- Reduced air pollution
- Improved vehicle performance
- Higher agricultural income and creation of rural jobs
- Reduction in solid wastes (biomass, grease, etc.)

Costs

- Higher fuel production costs
- Extra costs for vehicles & fuels system modifications
- Increases in some pollutant emissions
- Higher crop and crop product prices
- Other environmental impacts (e.g. fertilizers runoff)

Biofuels Basic Tenets

- Biofuels are produced from biomass
  - Plants or organic waste
- Biofuels can be blended at low concentrations with gasoline or diesel for use in today's vehicles
- Biofuels have the potential to cut CO_2 emissions
  - CO_2 is absorbed by the plants as they grow
- Biofuels are not completely "carbon neutral"

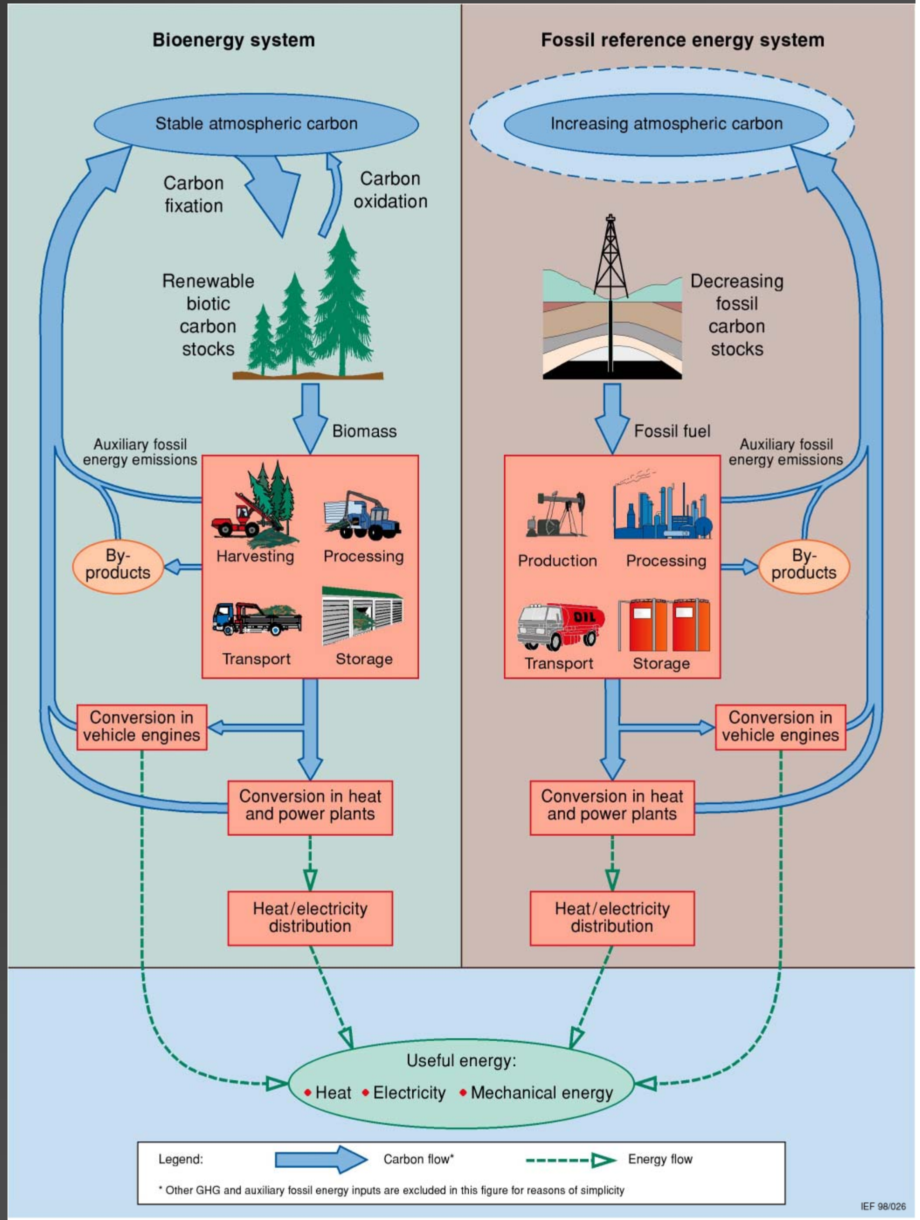
Overall energy and CO_2 benefits of Biofuels must be assessed by full life cycle "Well-to-Wheels" studies.

The Biofuel Life Cycle includes all the processes from the growing of the plant right through to the vehicle exhaust emissions.

Well-to-Wheel (W-t-W) Methodology

Factors to be considered

- Carbon stock dynamics
- Trade-offs and synergies
- Permanence of reductions
- Emission factors
- Efficiency
- Energy inputs
- By-products
- Other GHG's

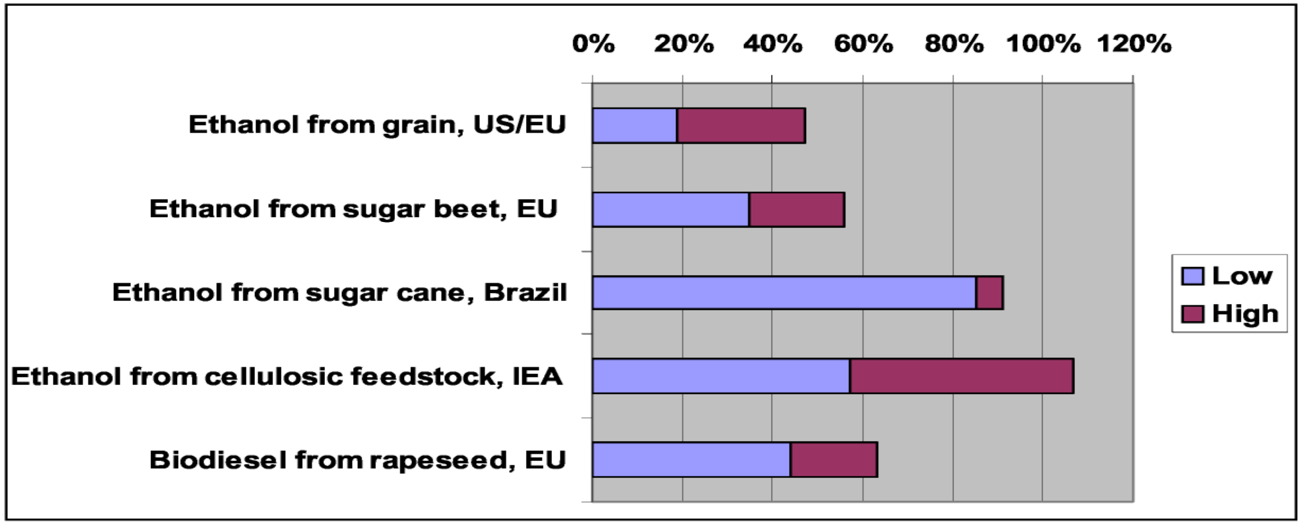


Source: IEA BioEnergy, Task 38

GHG Reductions from Biofuels Vary by Feedstock and Technology

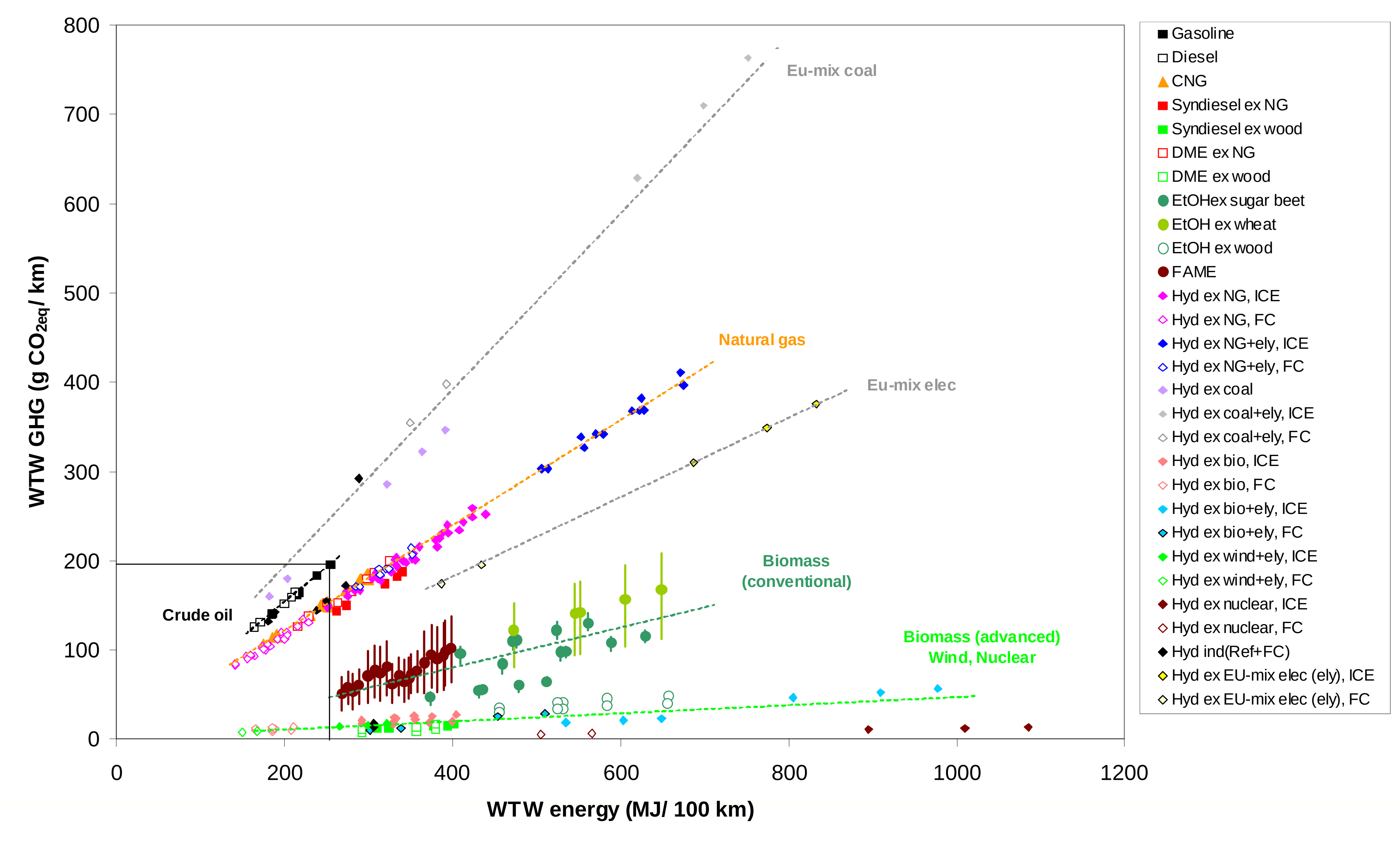
- Range of estimated percent reductions in Well-to-Wheel CO_2-equivalent GHG emissions (per km)

  - Comparison of %Reductions for:
    - Ethanol
    - Biodiesel
  - Comparison Base is fossil fuel production



Source: IEA, Biofuels for Transport, 2004

Vast Differences between 1st and 2nd Generation Biofuels



Source: European Petroleum Industry Association, 2002

2nd Generation Biofuels:

Key Findings from Current Analyses

- Used at 100% concentration, 2nd Generation Biofuels could reduce well-to-wheels CO_2 production by up to 90%
- 2nd Generation biofuels offer the potential to be the most cost-effective route to renewable, low-carbon energy for road transport
- 2nd Generation biofuels will not be available in significant commercial quantities for 5 to 10 years
- 2nd Generation Biofuels ought to be integrated with other Bioenergy considerations
  - Land-use for high-yield crops needs to be optimized with combined heat and power generation in conjunction with Biofuels production

Are We There Yet?
Cellulosic Ethanol is Arriving

- Three major approaches to cellulosic ethanol production
  - Concentrated acid hydrolysis
  - Thermochemical hydrolysis
  - Pretreated enzymatic hydrolysis

Production Method	Advantages	Disadvantages
Acid Hydrolysis	■ Proven Technology ■ High sugar recovery	■ Capital intensive
Thermochemical	■ Feedstock flexibility	■ Conversion difficult ■ Energy intensive
Enzymatic	■ potential for efficiency ■ Potential for cost saving	■ Hi cost of enzymes ■ Variable w/feedstock

Synthetic Diesel: Biomass-to-Liquid (BTL)

- Several variations exist of the basic process
- Common Steps in BTL Production
  - Pellets formed from dried wood, straw, corn husks, garbage, and sewage-sludge.
  - Biomass-pellets are converted into a gas and charcoal
  - Low temperature gasification process is followed by purification
  - Gas is liquefied in a so called “Fischer–Tropsch” reaction
  - “Paraffin-like” liquid formed is isomerized to increase stability
  - Liquid is then distilled or “hydro-treated”.
- 60% of the distillate can be used directly as a diesel fuel
  - Remainder can be used in the chemical industry
  - Can also be further processed into gasoline or kerosene

Market Transforming Projects
(U.S. DOE Grants)

- The U.S. Biofuels Initiative is designed to lead to the wide-scale use of non-food based biomass
  - To enable use of agricultural waste, trees, forest residues, and perennial grasses, and
  - To produce transportation fuels, electricity, and other products
- U.S. DOE will invest up to $385 million for six Biorefinery projects to incentivize introduction of cellulosic ethanol
- These projects are expected to play a critical role in transforming the market
  - Expected to produce over 130 million gallons annually
  - Investigate how to produce cellulosic ethanol more cost effectively
- Industry cost share, for these projects, is expected to be more than $1.2 billion over the next four years

Cellulosic Ethanol - U.S. DOE Incentives

Companies	Grant	Production	Feedstock
Abengoa Bioenergy Biomass, Kansas	$76 million	11.4 million gallons annually	700 tons/day of corn stover, wheat straw, milo stubble, and switchgrass
ALICO, Inc, Florida	$33 million	13.9 million gallons annually, (+ 8.8 tons H2 and 50 tons of NH3/day)	770 tons/day of yard, wood, and vegetative wastes
BlueFire Ethanol, Inc., California	$ 40 million	19 million gallons annually	700 tons/day of sorted green waste and wood waste
Broin Companies, South Dakota	$ 80 million	125 million gallons annually (25% cellulosic)	842 tons/day of corn fiber, cobs, and stalks
Iogen Biorefinery Partners, Virginia	$ 80 million	18 million gallons annually	700 tons/day of agricultural residues including wheat, barley and rice straw
Range Fuels, Colorado	$ 76 million	40 million gallons annually (+ 9 million gallons of methanol	1,200 tons/day of wood residues and wood based energy crops

U.S. DOE Bioenergy Research Centers

- DOE Selected three lead institutions for these centers
  - Oak Ridge National Laboratory (ORNL),
  - University of Wisconsin-Madison (UWM),
  - Lawrence Berkeley National Laboratory (LBNL)
- The three Centers are leading collaborative efforts under complementary scientific agendas
  - ORNL will focus on the resistance of plant fiber to breakdown into sugars;
  - UWM is studying a range of plants to increase plant production of starches and oils; it also has a major focus on sustainability, examining the environmental and socioeconomic implications of moving to a Biofuels economy
  - LBNL will concentrate on “model” crops of rice and Arabidopsis, breakthroughs in basic science, and microbial-based synthesis of fuels beyond ethanol
- The centers represent multi-institutional partnerships
  - Seven DOE national laboratories, 18 universities, one nonprofit organization, and private companies

Bioenergy Production Potentials for Selected Biomass Types, 2050

Biomass Type	Bioenergy Potential (exajoules)
Agricultural Residues	15–70
Organic Wastes	5–50
Animal Dung	5–55 (or possibly 0)
Forest Residues	30–150 (or possibly 0)
Energy Crop Farming (current agricultural lands)	0–700 (100–300 is more average)
Energy Crop Farming (marginal lands)	60–150 (or possibly 0)
Biomaterials	Minus 40 – 150 (or possibly 0)
TOTAL	40–1,100 (250–500 is more average)

Source: Andre Faaij, Copernicus Institute, Utrecht University, report submited to Worldwatch Institute, 17 January 2005

In Summary

- Interest in producing and using Biofuels is increasing
  - long-term technical and political targets
  - Risks associated with taking a very narrow perspective
- The world of fuels is becoming increasingly diverse
  - fossil fuels will remain with us for a long time to come,
  - international trading of bio-components between producers and importers is already occurring,
  - locally-adapted fuels have a role to play in specific markets,
  - Introducing 1st generation fuels may not reduce emissions or add to energy security when relying on imports.
- Advanced Biofuels derived from ligno-cellulosic feedstock are now becoming available
  - Invest in biotechnology research to advance Biofuels production processes and reduce cost

Recommendations

- Assess the energy & environmental balances prior to the introduction of Biofuels
- Verify suitability of Biofuels blends for engines in the market
  - Significant attention should be applied to detail to ensure fuels & engine compatibility as for existing fossil fuels
- Adhere to strict fuel quality standards to avoid contaminated fuels from entering the market
- Provide low concentration blends suitable for all potential users rather than ‘niche applications’ requiring costly infrastructures

Biofuels have many benefits but specific applications should account for economic, social environmental and technological grounds in order to make them truly sustainable

Thank You

Contact Information

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