Altermotive Conference

Biofuels & WTT emissions

Vienna, TU Wien, 20/04/2010

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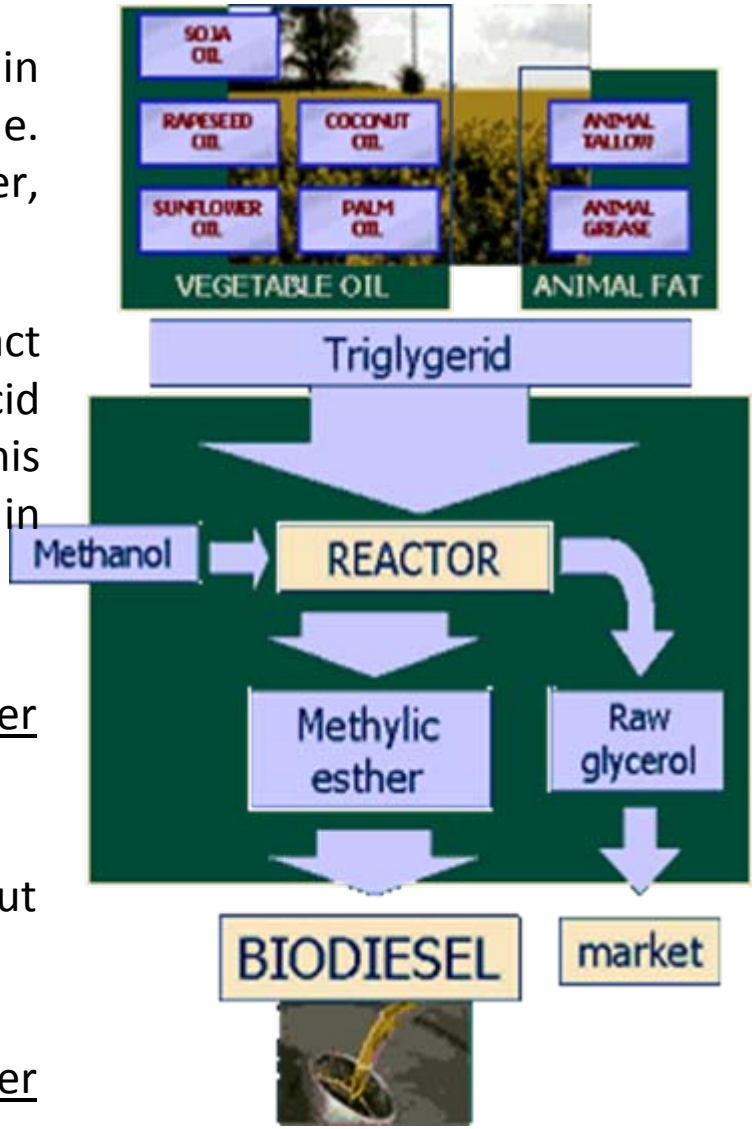
- Biofuels outline
- Litterature reviewed and analysed
  - Major outcome
- Results in terms of emissions
  - Critical points
    - Land use
  - Solutions/improvements expected
    - To make more consistent the upstream with downstream database.
    - Better clarify differences in results

Technical Characteristics: **Standard Biodiesel**

- **Feedstocks**: vegetable oils like sunflower, rape (in particular in Europe), soya. Palm and fatty oils (i.e. animal fatty oils) can be used but, even if cheaper, imply quality problems

- **Process** (transesterification): vegetable oils react with an alcohol (methanol) to produce Fatty Acid Methyl Esters (FAME). Glycerin is obtained by this process as byproduct and it is employed in pharmaceutical industry

- **Quality**:
  - heating power and cetane number are lower than in fossil diesel;
  - no content of Sulphur;
  - it can be used in blending up to 20-30% without any engine modification;
  - quality depends on feedstocks;
  - hydrophilic product (problems with water content).



Main Biodiesel Feedstocks

Fresh plant oils

Soybean Oil

⇩

SME

Rapeseed Oil

⇩

RME

Palm Oil

⇩

PME

Peanut Oil

Canola Oil

Used cooking oils and animal fats

Used Frying Oil

Yellow Grease

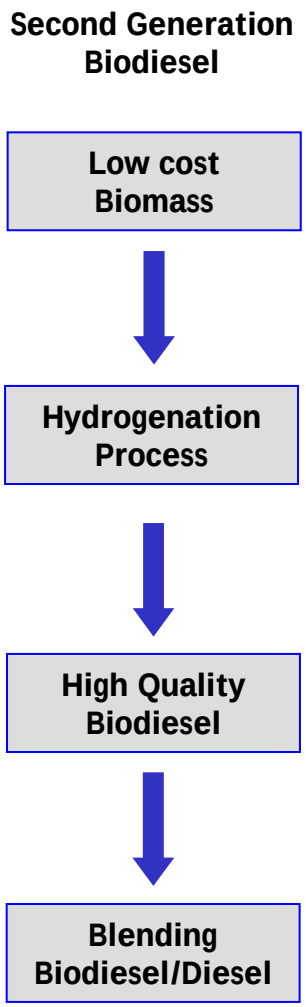
Animal Fat

Chicken Fat

Source: BDI Biodiesel International

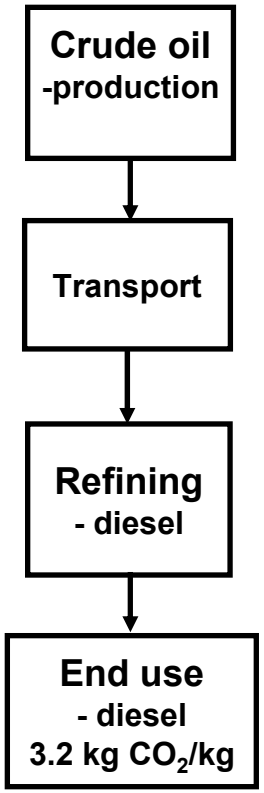
Technical Characteristics: **2nd generation Biodiesel**

- **Feedstocks**: as for standard biodiesel but with higher feed flexibility and final product stability
- **Process:** the biomass goes through an hydrogenation process (hydro-isomerization) that eliminates oxygen from feedstock and produces an hydrocarbon mix similar to fossil diesel. So, hydrogen reliable supply source is needed (i.e. refineries, petrochemical plants)
- **Quality**:
  - cetane number is higher than in fossil diesel
  - no content of Sulphur
  - quality is independent from the feedstock
  - CO_2 emissions are even lower than conventional Biodiesel
  - very good cold properties



Comparison of CO_2 emissions

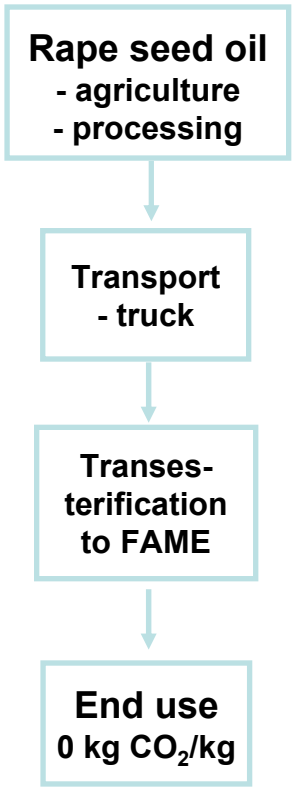
Fossil Diesel



∑ 3.8 kg CO_2/kg fuel

Source: Concawe/Eucar WTW 2004

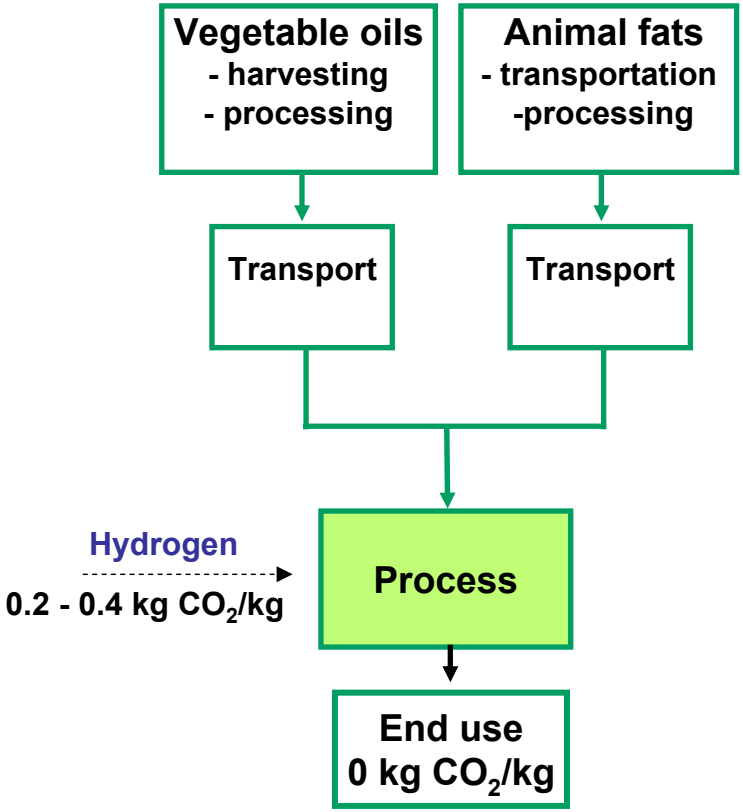
Standard biodiesel



∑ 1.4 - 2.0 kg CO_2/kg fuel

Source: Concawe, Shell, WTW

2nd generation biodiesel



∑ 0.7 - 1.6 kg CO_2/kg fuel

BioEthanol Technical Characteristics

- **Feedstocks**:

  - synthetic ethanol derives from crude oil, gas and coal

  - agricultural ethanol derives from grains, molasses, fruit, sugar cane juice, cellulose and numerous other sources

- **Process:** it mainly produced through fermentation of seeds rich of sugar or starch (95% of world production). The rest is from synthetic origin

- **Quality**:

  - as for current specifications, it can be blended in gasoline by max 5% v/v. Higher percentages (like for E85) are possible only in special cars (flexible fuel vehicle)

  - it is a good octane booster (alternative to MTBE)

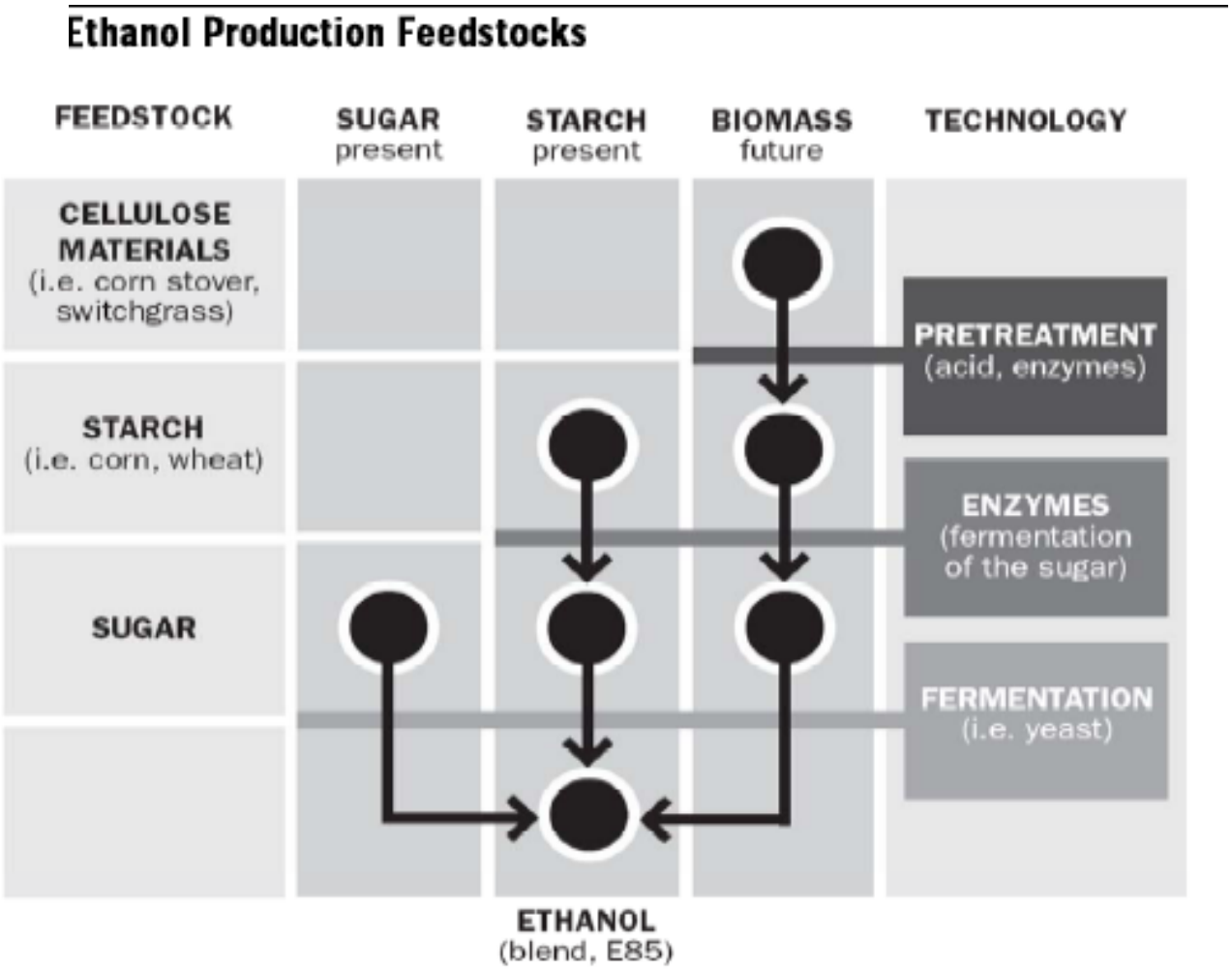
  - low water tolerance and high vapour pressure

  - it easily blends with gasoline but not with diesel: special emulsifiers are needed to obtain the so called “Diesohol”

BioEthanol Technical Characteristics

Distinction by:		
Feedstock	**Synthetic ethanol**	**Agricultural ethanol**
Composition	**Anhydrous ethanol** is free of water and at least 99% pure. It can be used as fuel blend without modification of vehicle technology	**Hydrous ethanol** contains some water, usual purity about 96%. Can be used as 100% fuel substitute in vehicles with dedicated engines
End use	**Industrial applications** as solvents, primarily utilized in the production of paints, coatings, pharmaceuticals, adhesives inks and other products	**Food and beverage**, only hydrous ethanol is used, usually ethanol for drinking purpose is heavily taxed

Ethanol Feedstocks



World Ethanol Market: Drivers and Restraints

Market Drivers

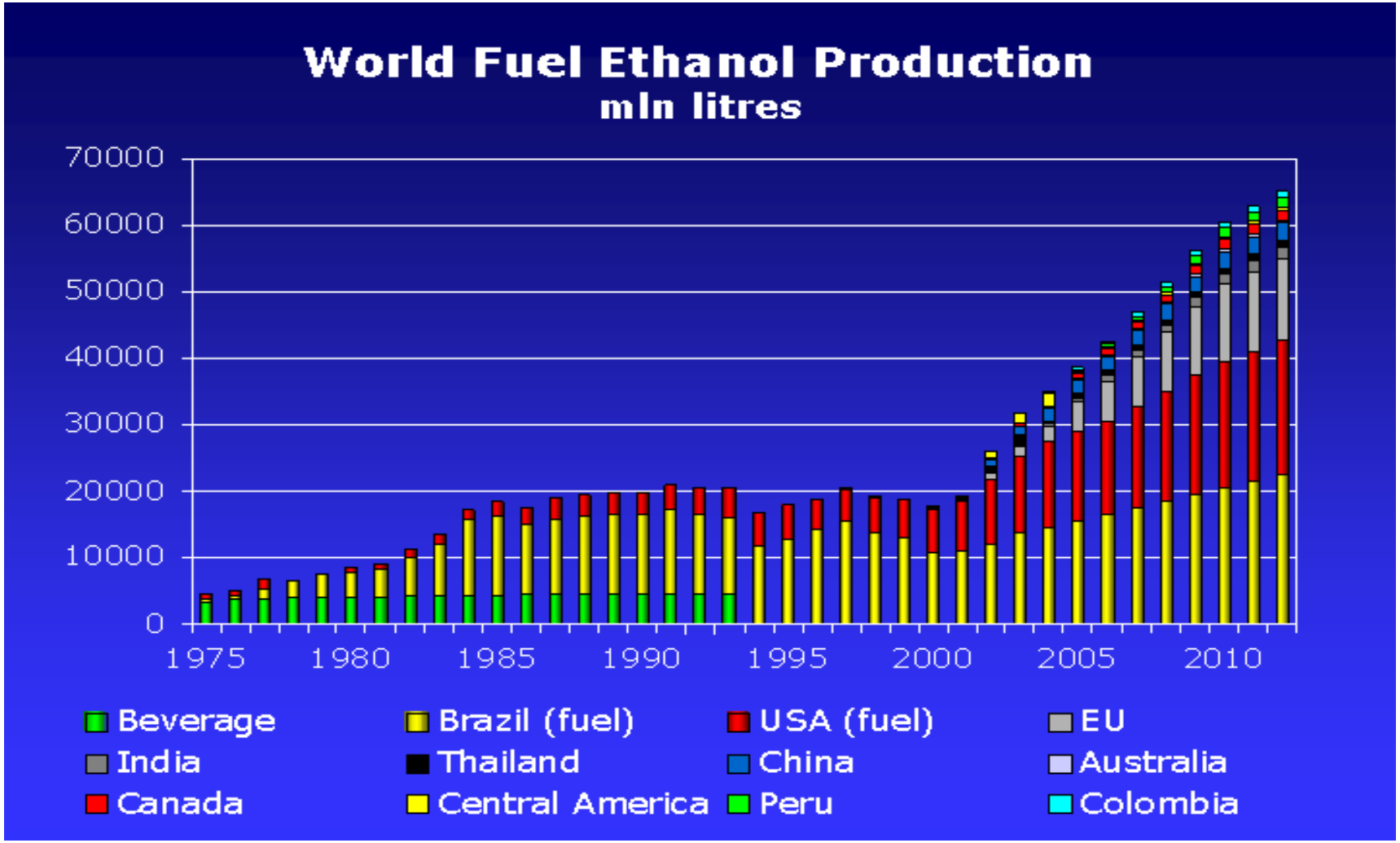
- Concern over MTBE opens market for ETBE
- Existing fuel specs allow Ethanol/ETBE blending
- ETBE can be produced using existing infrastructure
- No engine modification is required
- Diverse feedstock means no pressure on supply
- Feedstocks can be produced in all climates

Market Restraints

- Ethnol blending will increase the surplus of gasoline in the market
- Blending ethanol raises the vapour pressure limit of gasoline
- BioEthanol blends require careful storage and handling
- Fuel specs put limit on market size
- Use of high ethanol concentrations requires a flexi-fuel car

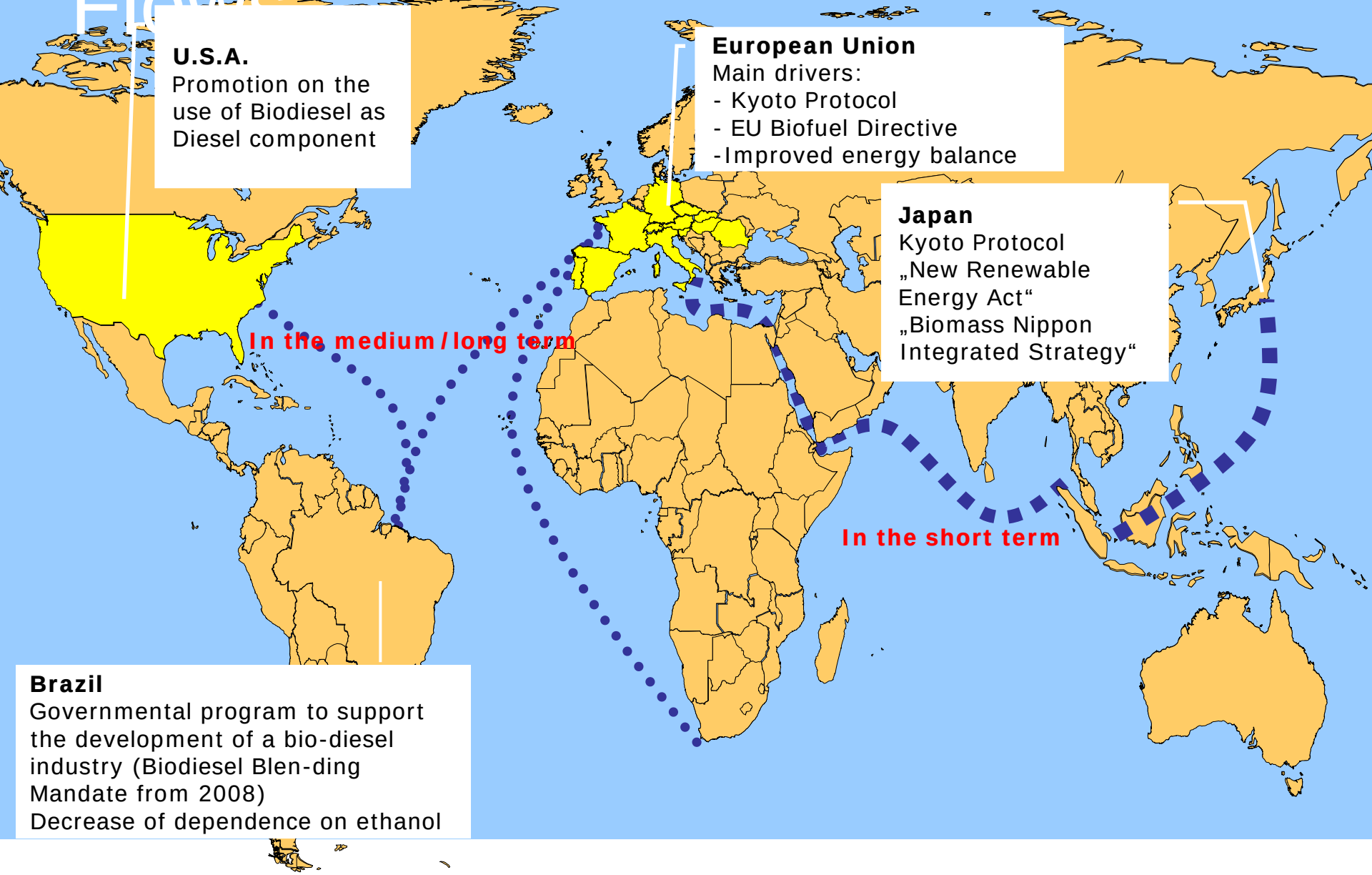
World Ethanol Market

- Production is foreseen in strong increase in USA and in Europe
- Brazil production will continue to rise for exports



Source: http://www.distill.com

World Potential Biodiesel Trade Flows



Litterature on LCA

- Major studies
  - NREL (1998)
  - US EPA (2002)
  - IFEU(5/2005)
    - A value added from IFEU introduces some modifications on the RME assessment.
    - New data on the nitrous oxide emissions trigger numerically more favourable results in the categories ozone depletion and greenhouse effect.
    - honey production and its co-products only marginally affect the overall assessment
  - ESU (2008),
  - Argonne (2009)
- Methodologies
  - Pathways described
- Which study selected
  - **CONCAWE 2008** SEEMS TO PRESENT
    - UPDATED,
    - CONSISTENT (COMPARISON WITH OTHER STUDIES)
    - DATA PRESENTED TO BE COMPARABLE

PATHWAYS

- **Production and conditioning at source**
  - Includes all operations required to extract, capture/cultivate the primary energy source. In most cases, extracted or harvested energy carrier requires some of the treatment or conditioning before it can be transported.
- **Transformation at source**
  - Used for the cases where a major industrial process is carried out at or near the production site of the primary energy (i.e.: gas-to-liquids plant).
- **Transportation to EU**
  - Is relevant to energy carriers produced outside the EU and request long distance transport. This step is used also when a significant transport vector is required to move the raw materials to a processing plant (i.e.: biomass).
- **Transformation in EU**
  - Includes the processing and transformation taking place near market place to produce a final fuel according to specification (oil refineries, hydrogen reformer).
- **Conditioning and distribution**
  - It refers to the final stage required to distribute the fuels from import or production point to the refuelling sites (road transport) available to the vehicle tank (natural gas compression).

RESULTS IN TERM OF EMISSIONS
THE WTT DATABASE

WTT EMISSIONS: rape seed to FAME

- **GLYCERINE AS BY-PRODUCT**
  - **ANIMAL FEED (0.13MJ)**
  - **PHARMAC. (18 Mj)**
- **TRANSPORT TO 50 KM**

WTT Emissions		Small Scale
Cultivation	g CO2eq/MJ	**29,61**
Transport to plant	gCO2eq/MJ	**0,42**
Oil Mill	g CO2eq/MJ	**2,84**
Esterification	g CO2eq/MJ	**10,38**
Distribution & Retail	g CO2eq/MJ	**1,27**
Total WTT Emissions	g CO2eq/MJf	**43,5**

WTT EMISSIONS: sunflower to FAME

- **GLYCERINE AS BYPRODUCT**
  - **ANIMAL FEED (0.13MJ)**
  - **PHARMAC. (18 Mj)**
- **TRANSPORT TO 50 KM**

WTT Emissions		Small Scale
Cultivation	g CO2eq/MJ	**17,22**
Transport to plant	gCO2eq/MJ	**0,28**
Oil Mill	g CO2eq/MJ	**2,73**
Esterification	g CO2eq/MJ	**10,38**
Distribution & Retail	g CO2eq/MJ	**0,83**
Total WTT Emissions	g CO2eq/MJf	**32,2**

WTT EMISSIONS: soja to FAME

Transport to plant:

2,88 + 8,93 transport to EU

WTT Emissions		Small Scale
Cultivation	g CO2eq/MJ	**18,56**
Transport to plant	gCO2eq/MJ	**11,81**
Oil Mill	g CO2eq/MJ	**5,46**
Esterification	g CO2eq/MJ	**10,38**
Distribution & Retail	g CO2eq/MJ	**1,27**
Total WTT Emissions	g CO2eq/MJf	**47,50**

WTT EMISSIONS: palmoil to FAME

- **Transport&Storage:**
  - **Oil shipping equal to 3,3 gCO2eqMJ**

WTT Emissions		Small Scale
Cultivation	g CO2eq/MJ	**14,2**
Transport to plant	gCO2eq/MJ	**4,35**
Oil Mill	g CO2eq/MJ	**22,52**
Esterification	g CO2eq/MJ	**10,38**
Distribution & Retail	g CO2eq/MJ	**1,27**
Total WTT Emissions	g CO2eq/MJf	**52,8**

WTT EMISSIONS: BE from wheat

- **Ethanol Plant:**
  - **Conventional process: heat for ethanol plant provided from NG-fired steam boiler; electricity imported from the grid**

WTT Emissions		Small Scale
Cultivation	g CO2eq/MJ	**23,43**
Transport to plant	gCO2eq/MJ	**0,38**
Ethanol Plant	g CO2eq/MJ	**21,12**
Distribution & Retail	g CO2eq/MJ	**1,54**
Total WTT Emissions	g CO2eq/MJf	**46,5**

WTT EMISSIONS: BE from sugarbeet

- **Energy expended for cultivation:**
  - **Total primary MJx/Mjf 0.11**

WTT Emissions		Small Scale
Cultivation	g CO2eq/MJ	**11,54**
Transport to plant	gCO2eq/MJ	**0,84**
Ethanol Plant	g CO2eq/MJ	**9,47**
Distribution & Retail	g CO2eq/MJ	**1,54**
Total WTT Emissions	g CO2eq/MJf	**23,4**

WTT EMISSIONS: BE from sugarcane

- **No allocation required, excess bagasse not considered**

WTT Emissions		Small Scale
Cultivation	g CO2eq/MJ	**14,45**
Transport to plant	gCO2eq/MJ	**0,85**
Ethanol Plant	g CO2eq/MJ	**0,6**
Ethanol shipping	g CO2eq/MJ	**7,69**
Distribution & Retail	gCO2eq/MJ	**0,44**
Total WTT Emissions	g CO2eq/MJf	**24,2**

WTT EMISSIONS: BE lignocell (wood)

WTT Emissions		Small Scale
Cultivation	g CO2eq/MJ	6,28
Transport to plant	gCO2eq/MJ	0,88
Ethanol Plant	g CO2eq/MJ	13,33
Distribution & Retail	gCO2eq/MJ	1,54
Total WTT Emissions	g CO2eq/MJf	22,0

WTT EMISSIONS: BE lignocell (straw)

WTT Emissions		Small Scale
Cultivation	g CO2eq/MJ	0,95
Transport to plant	gCO2eq/MJ	3,19
Ethanol Plant	g CO2eq/MJ	13,33
Distribution & Retail	gCO2eq/MJ	1,54
Total WTT Emissions	g CO2eq/MJf	19,0

WTT EMISSIONS: biogas

- **Liquid or dry manure is collected from farms and turned into biogas in a central plant.**
- **The biogas is treated and upgraded before being fed into an existing NG grid to be used as fuel.**
- **For dry manure, road transport value is 0,68; for dry manure total WTT is 11,2 (9,9-12,2)**

WTT Emissions		Small Scale
Road Transport	g CO2eq/MJ	**2,14**
Fermentation&upgrading	gCO2eq/MJ	**7,64**
Pipeline	g CO2eq/MJ	**0,00**
Filling station	gCO2eq/MJ	**2,86**
Total WTT Emissions	g CO2eq/MJf	**12,60**

WTT EMISSIONS: BTL(FT)

WTT Emissions		Small Scale
Wood farming &chipping	g CO2eq/MJ	5,0
Transport to plant	gCO2eq/MJ	0,7
Gasifier+FT plant	g CO2eq/MJ	0,00
Distribution&Retail	gCO2eq/MJ	1,2
Total WTT Emissions	g CO2eq/MJf	6,9

WTT EMISSIONS: BTL(FT) woodchip

WTT Emissions		Small Scale
Wood farming &chipping	g CO2eq/MJ	0,8
Transport to plant	gCO2eq/MJ	2,9
Gasifier+FT plant	g CO2eq/MJ	0,00
Distribution&Retail	gCO2eq/MJ	1,2
Total WTT Emissions	g CO2eq/MJf	4,8

WTT EMISSIONS: hydrogen production (NG from Russia)

WTT Emissions		Small Scale
NG extraction&process	g CO2eq/MJ	5,7
Transport to plant	gCO2eq/MJ	22,1
Distribution	g CO2eq/MJ	0,8
On site reforming Compression	gCO2eq/MJ gCO2eq/MJ	84,7 10,0
Total WTT Emissions	g CO2eq/MJf	123,2

WTT EMISSIONS: hydrogen production (NG EU mix)

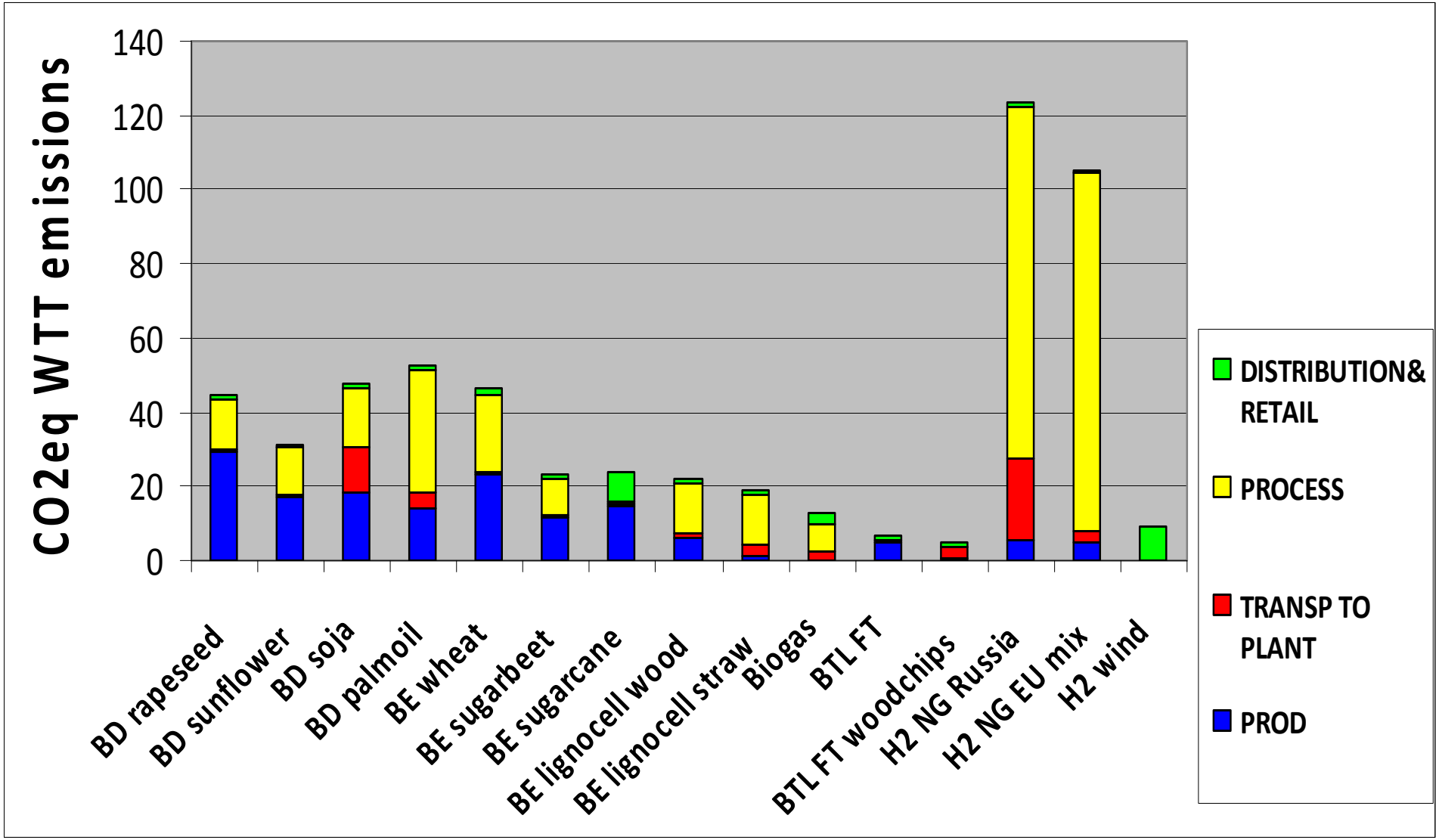
WTT Emissions		Small Scale
NG extraction&process	g CO2eq/MJ	4,9
Transport to plant	gCO2eq/MJ	2,8
Distribution	g CO2eq/MJ	0,9
On site reforming Compression	gCO2eq/MJ gCO2eq/MJ	86,6 10,0
Total WTT Emissions	g CO2eq/MJf	105,2

WTT EMISSIONS: hydrogen production (wind offshore)

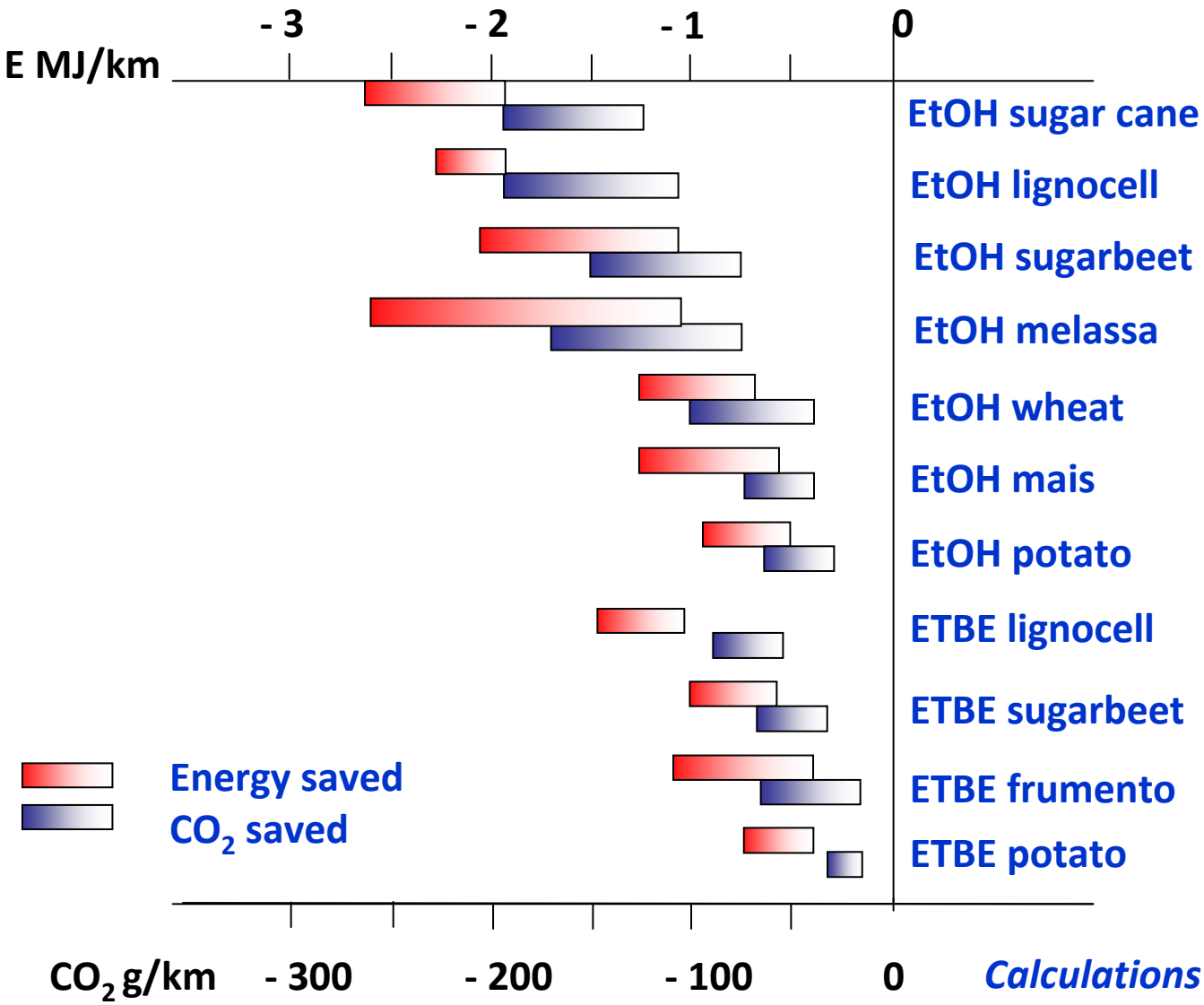
WTT Emissions		Small Scale
Wind offshore	g CO2eq/MJ	0
Electricity distribution	gCO2eq/MJ	0
Electrolysis(central)	g CO2eq/MJ	0
Gaseous hydrogen distribution&Compression	gCO2eq/MJ	9,1
Total WTT Emissions	g CO2eq/MJf	9,1

Comparison of WTT Total Emissions

(gCO2eq/MJf)

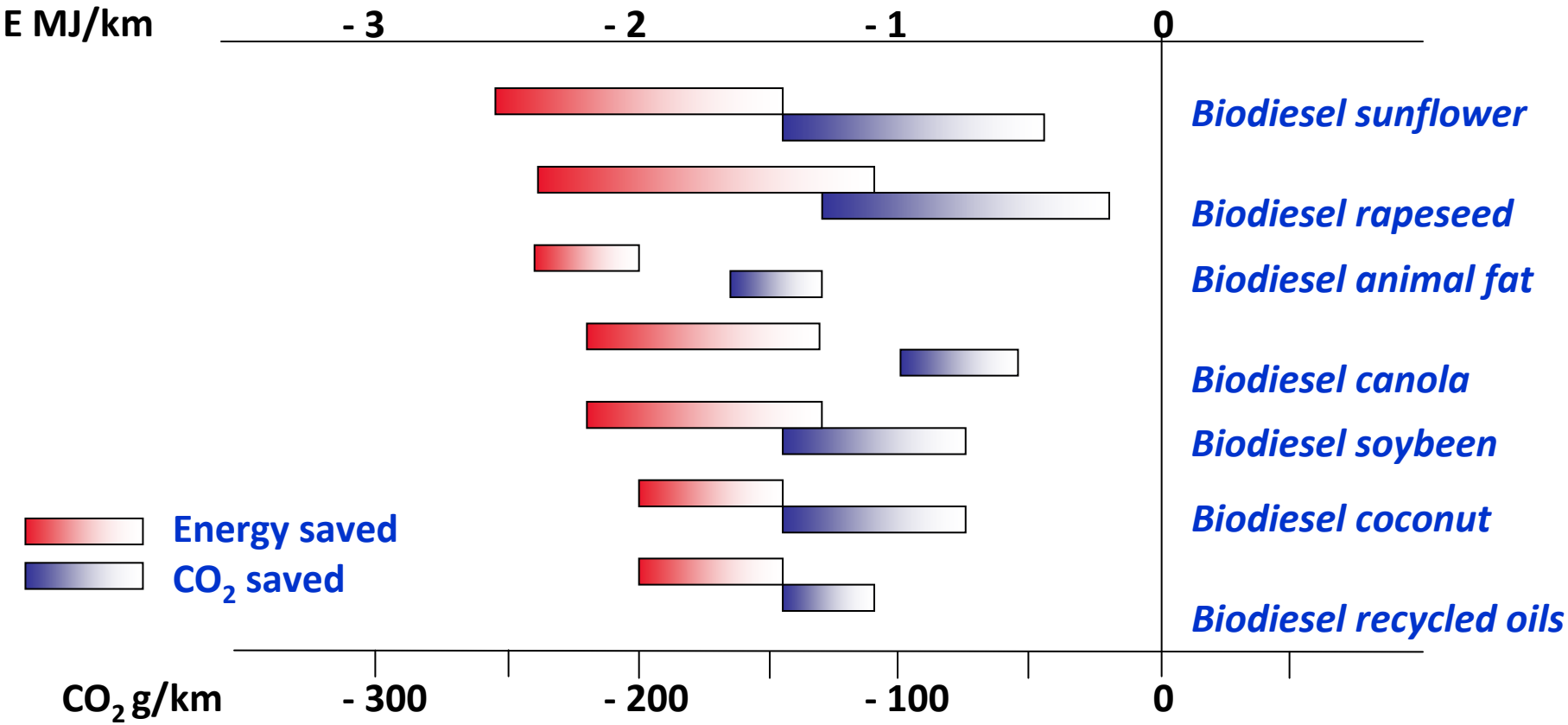


Bioethanol/ETBE



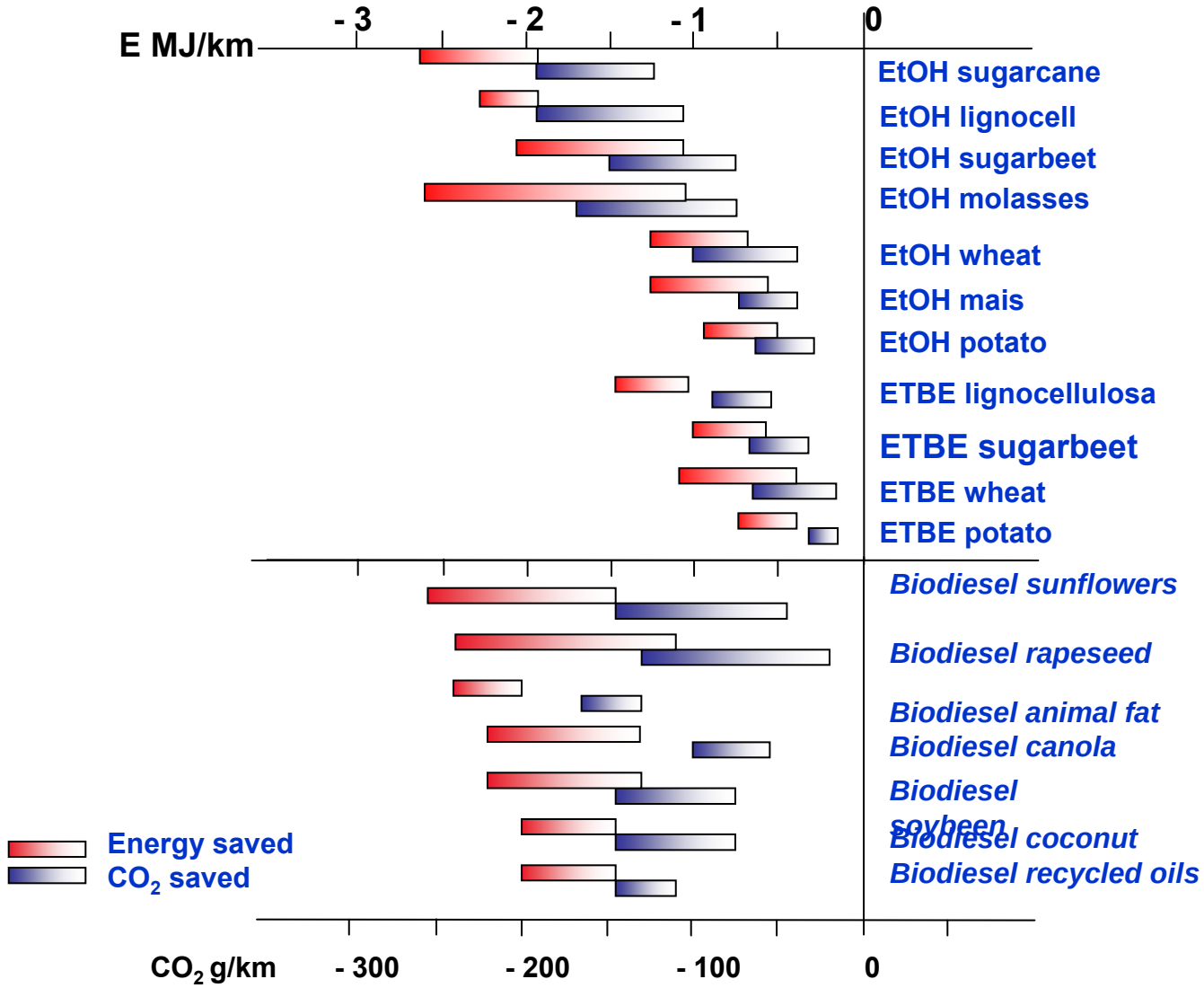
Calculations from IFEU 2005

Bio-diesel

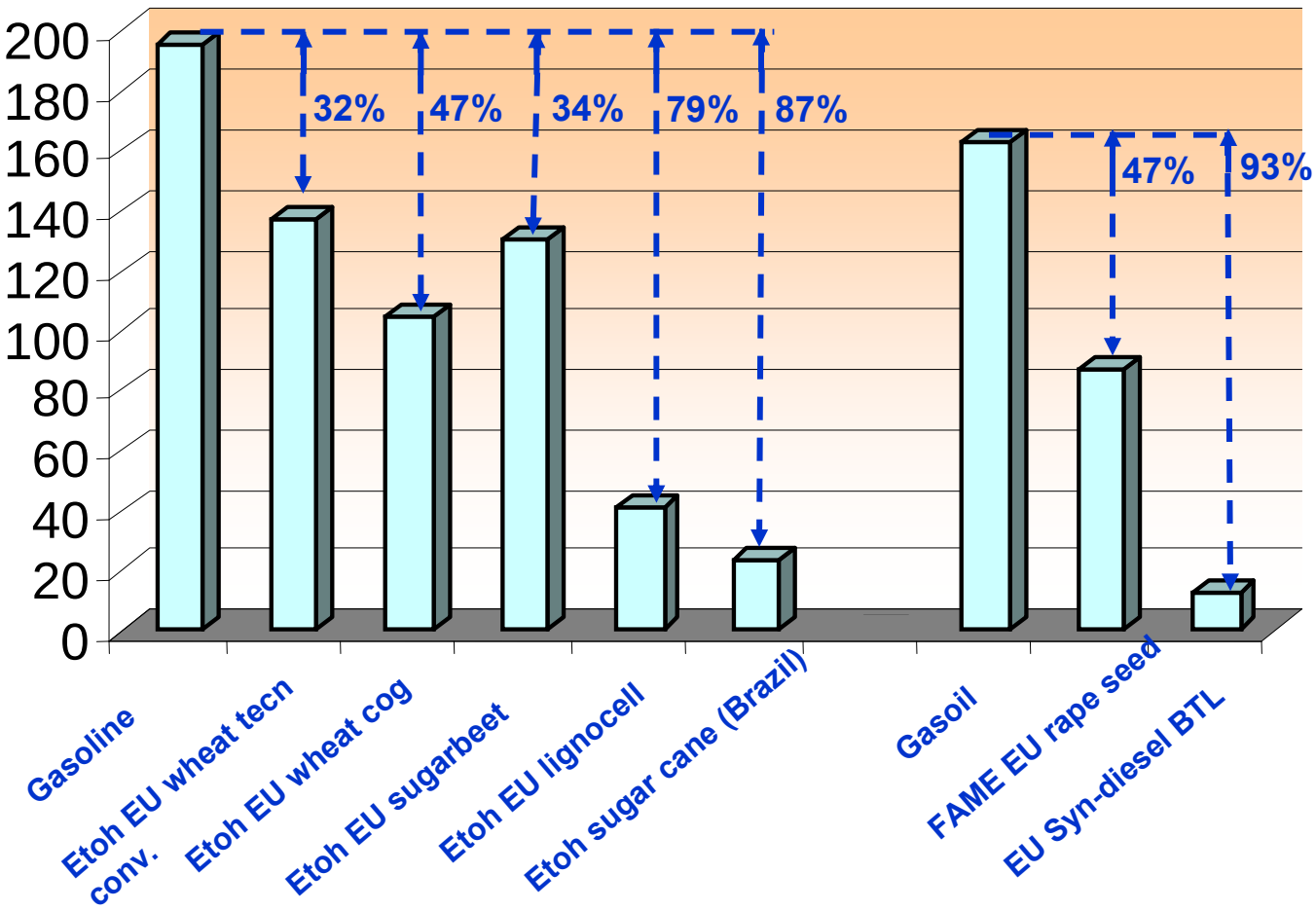


Calculations from IFEU 2005

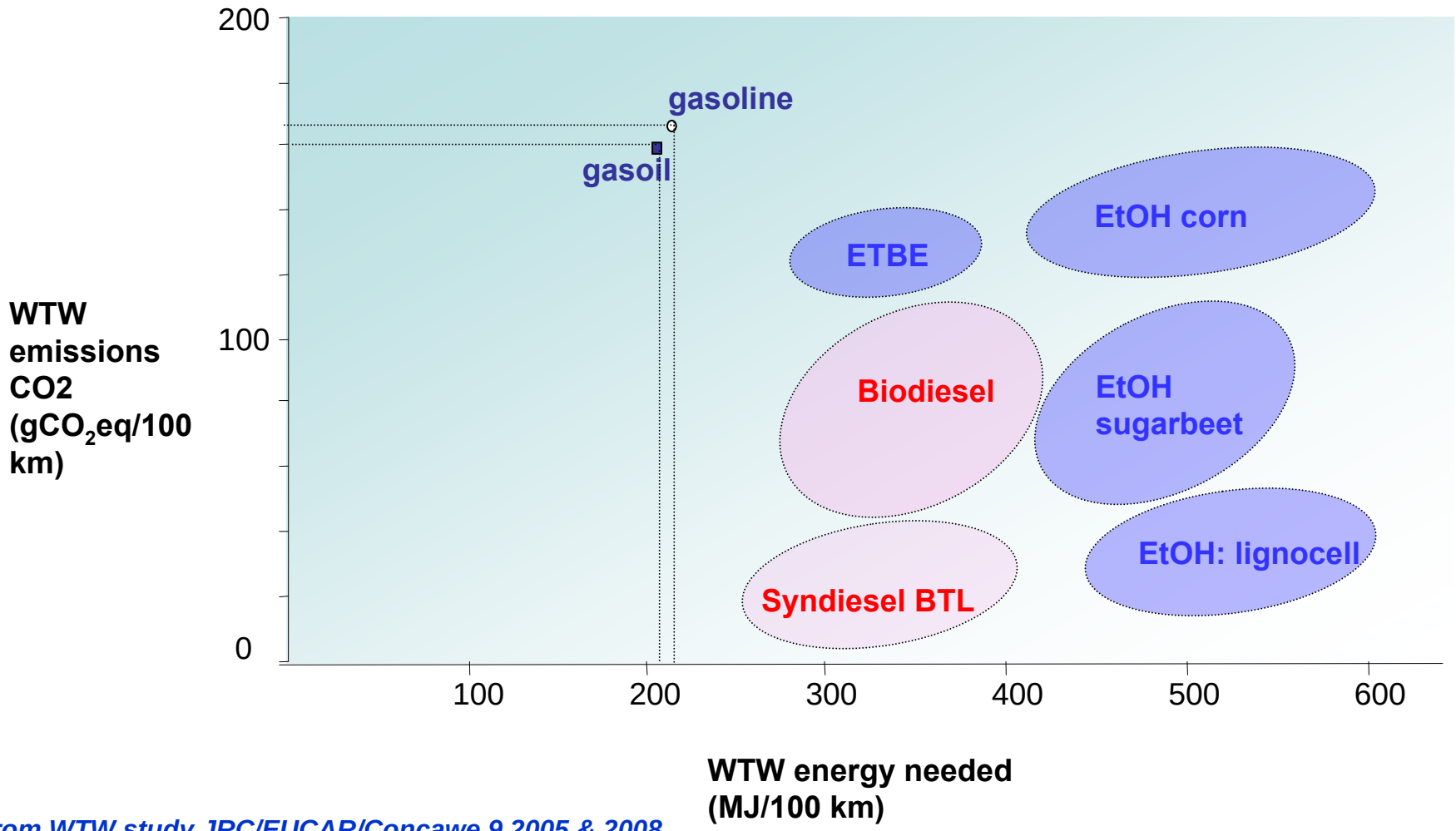
Bio-fuels


E MJ/km
- 3
- 2
- 1
0
EtOH sugarcane
EtOH lignocell
EtOH sugarbeet
EtOH molasses
EtOH wheat
EtOH mais
EtOH potato
ETBE lignocellulosa
ETBE sugarbeet
ETBE wheat
ETBE potato
Biodiesel sunflowers
Biodiesel rapeseed
Biodiesel animal fat
Biodiesel canola
Biodiesel soybeen
Biodiesel coconut
Biodiesel recycled oils
Energy saved
CO2 saved
CO2 g/km
- 300
- 200
- 100
0

GHG emissions g CO2 eq/km



Comparison



from WTW study JRC/EUCAR/Concawe 9.2005 & 2008

Conclusions

- 1° generation vs 2° generation biofuels
  - Food competition, reduced emissions
- Environmental analysis:
  - Define and make clear (for impacts and policies):
    - Time orizon
    - Geographical dimension
- Obstacles to diffusion
  - Consistent policies (standards, regulations, taxation, comparative advantages with other options)