Fuels and Biofuels:
Future Demand and Quality

Kenneth D Rose
CONCAWE Technical Coordinator for Fuel Quality and Emissions

SAE International Conference
Florence, Italy
15-17 June, 2009

concawe

CONCAWE: Research in Diverse Areas

CONservation of

Clean

Air and

Water in

Europe

The Oil Companies' European association for health, safety and environment in refining and distribution

(founded in 1963)

- Automotive Emissions & Fuel Quality
- Air Quality
- Water/Soil Quality & Waste
- Oil Pipelines
- Safety
- Refinery Technology Support
- Health Science
- Petroleum Products
- Risk Assessment
- Implementation of REACH & GHS

CONCAWE Member Companies

- Open to companies owning refining capacity in the EU
- Currently 39 Members and Associates
  - Representing 100% of European refining capacity

AlmaPetroli	**INEOS**	**Petrogal**
api	**IPLOM**	**Petroplus**
BP	**Koch**	**PKN Orlen**
CEPSA	**KPI**	**Preem**
Chevron	**LOTOS**	**RAFO**
ConocoPhillips	**LUKOIL**	**Repsol**
DOW	**LyondellBasell**	**Rompetrol**
ENI	**MOL**	**SARA**
ERG	**Motor Oil (Hellas)**	**SARAS**
ExxonMobil	**Murco**	**Shell**
Hansen & Rosenthal	**Neste Oil**	**StatoilHydro**
Hellenic Petroleum	**Nynäs**	**Tamoil**
INA (Associate)	**OMV**	**TOTAL**

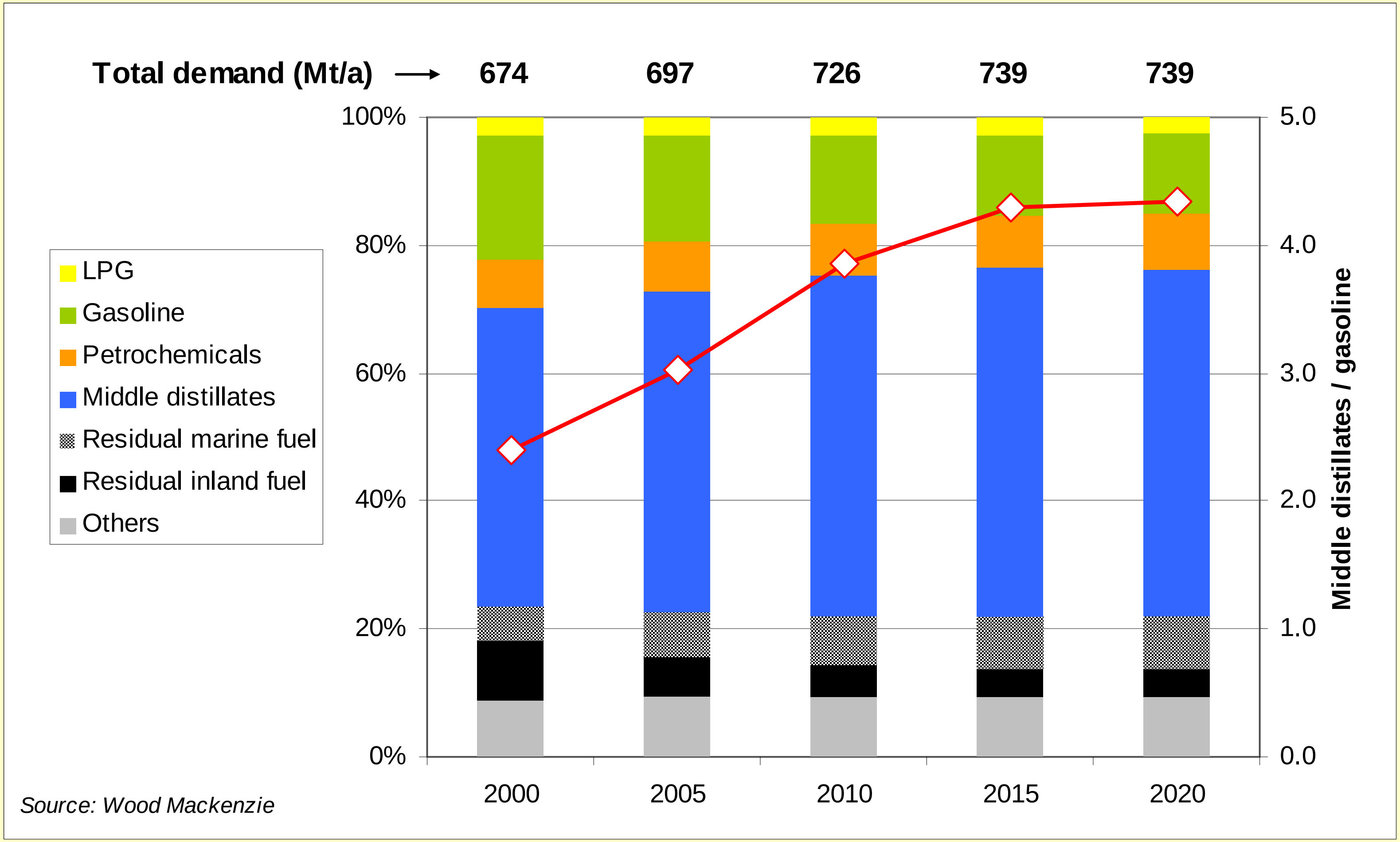
- CONCAWE work is >99% funded by Member Companies

concawe

Fuels and Biofuels: Future Demand and Quality

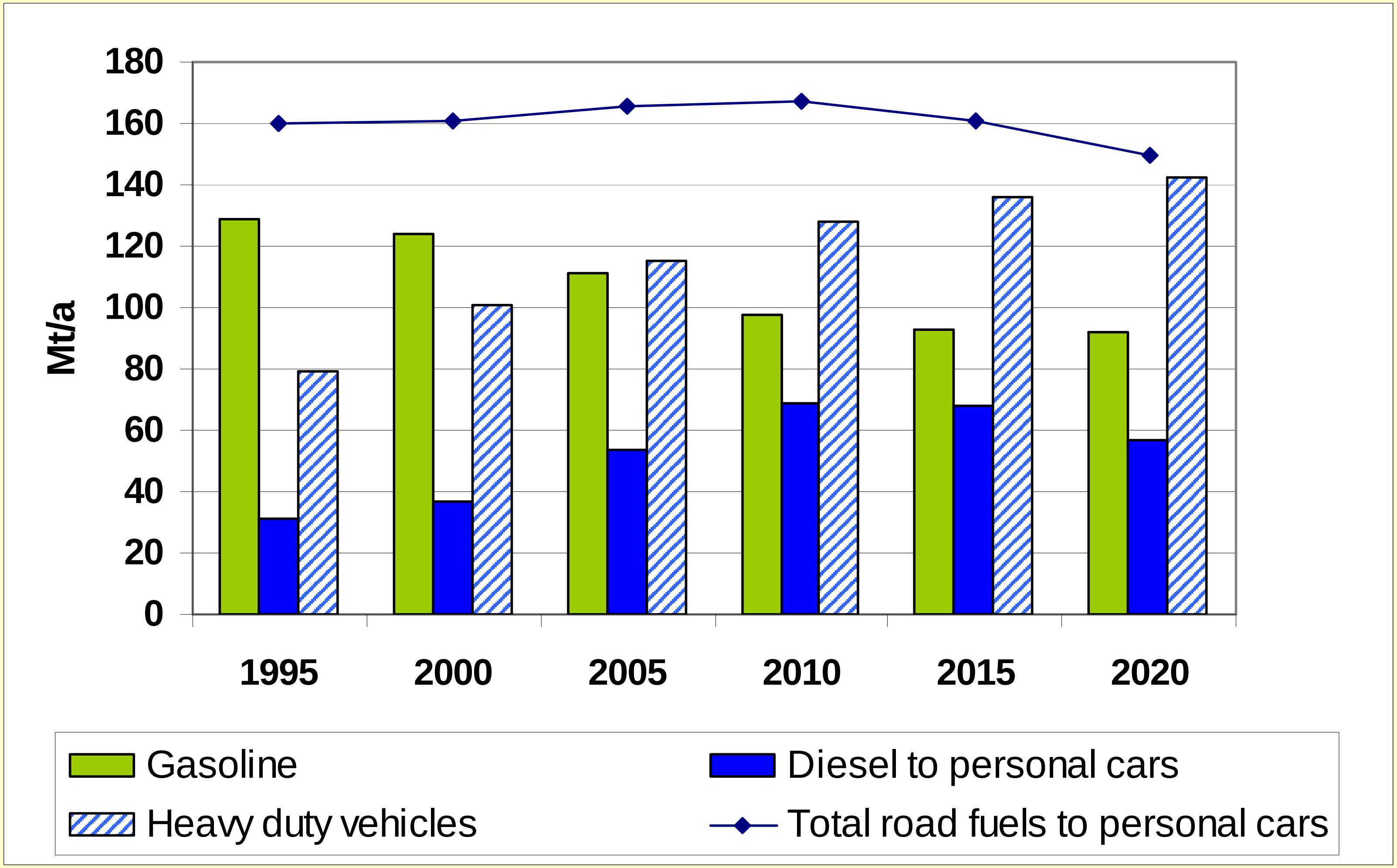
- EU Demand for Petroleum Products
  - EU-27 Road Fuel Demand
  - Diesel/Gasoline Imbalance
  - Key External Factors
- EU Climate and Energy Package Legislation
- Alternative Fuels and Biofuels
  - Product Quality
  - Well-to-Wheels Assessments
  - Biofuels Sustainability
- Changes ahead for Vehicles and Fuels

Trends in EU-27 Petroleum Product Demand



- Moderate growth in total product demand (~0.6% 2005-2020)
- Steady increase in demand for diesel, jet/kerosene, & marine
- Steady decrease in demand for gasoline and fuel oil

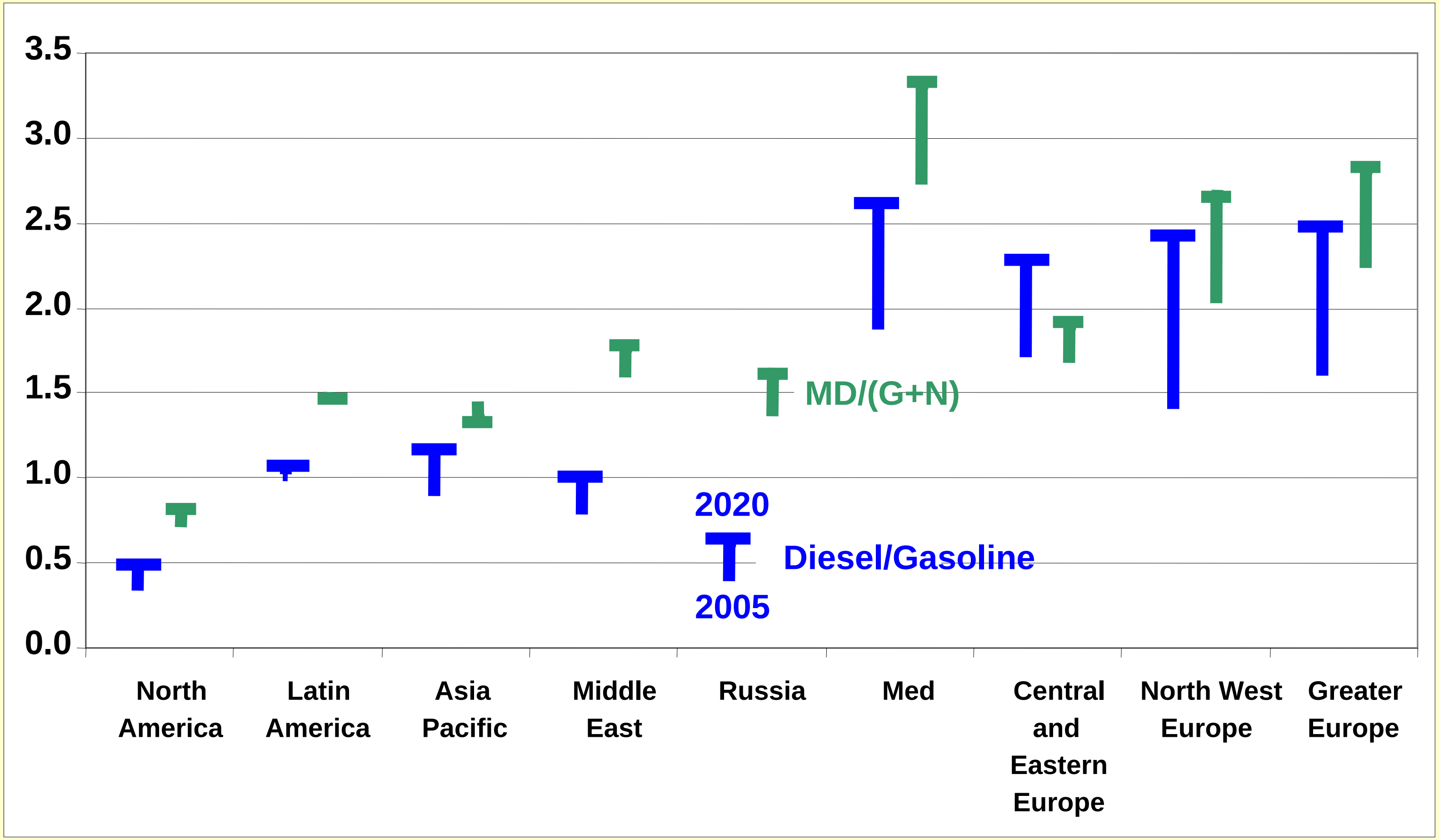
EU-25 Road Fuel Demand



- Road fuel demand dominated by diesel demand through 2020's
- Heavy duty diesel demand growing while light duty peaks and declines

Source: Wood Mackenzie (2006)

Global Diesel/Gasoline Demand Ratios

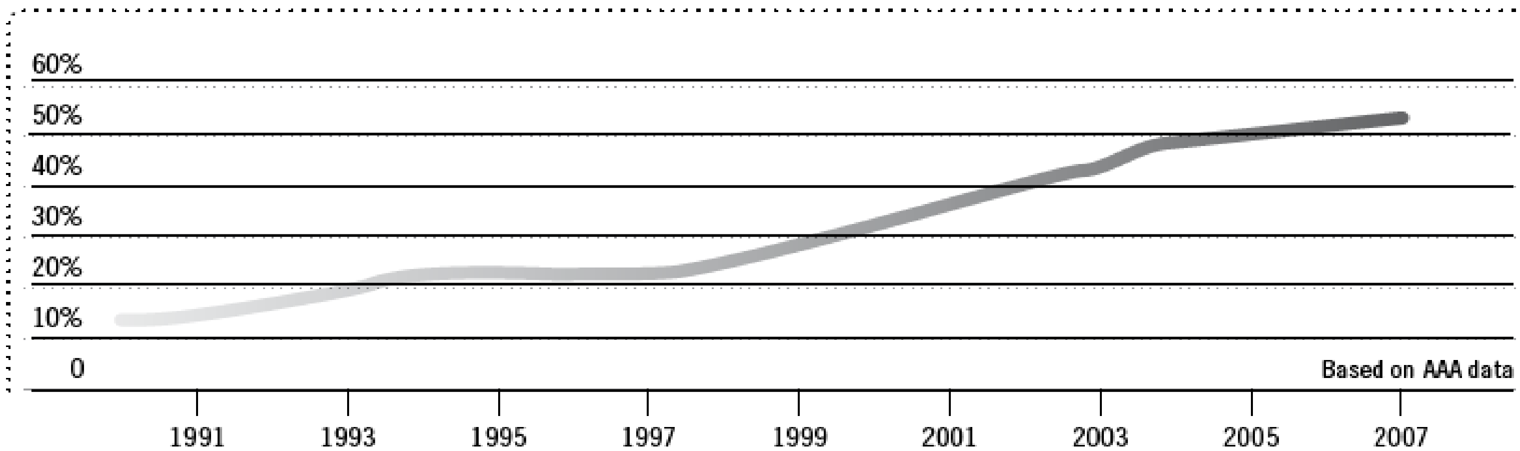


➢ Diesel/Gasoline demand ratios are higher in Europe than in the rest of the world and projected to increase in the next decade

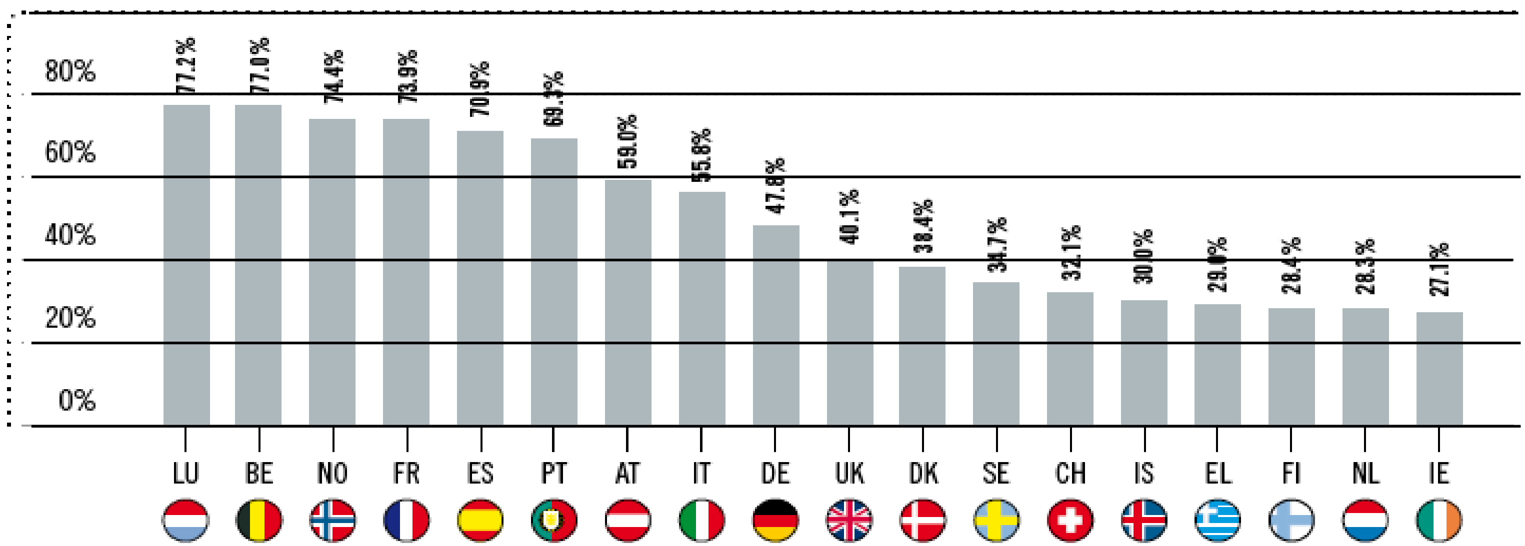
Source: Wood Mackenzie

Diesel Penetration as a % of New Cars Registered

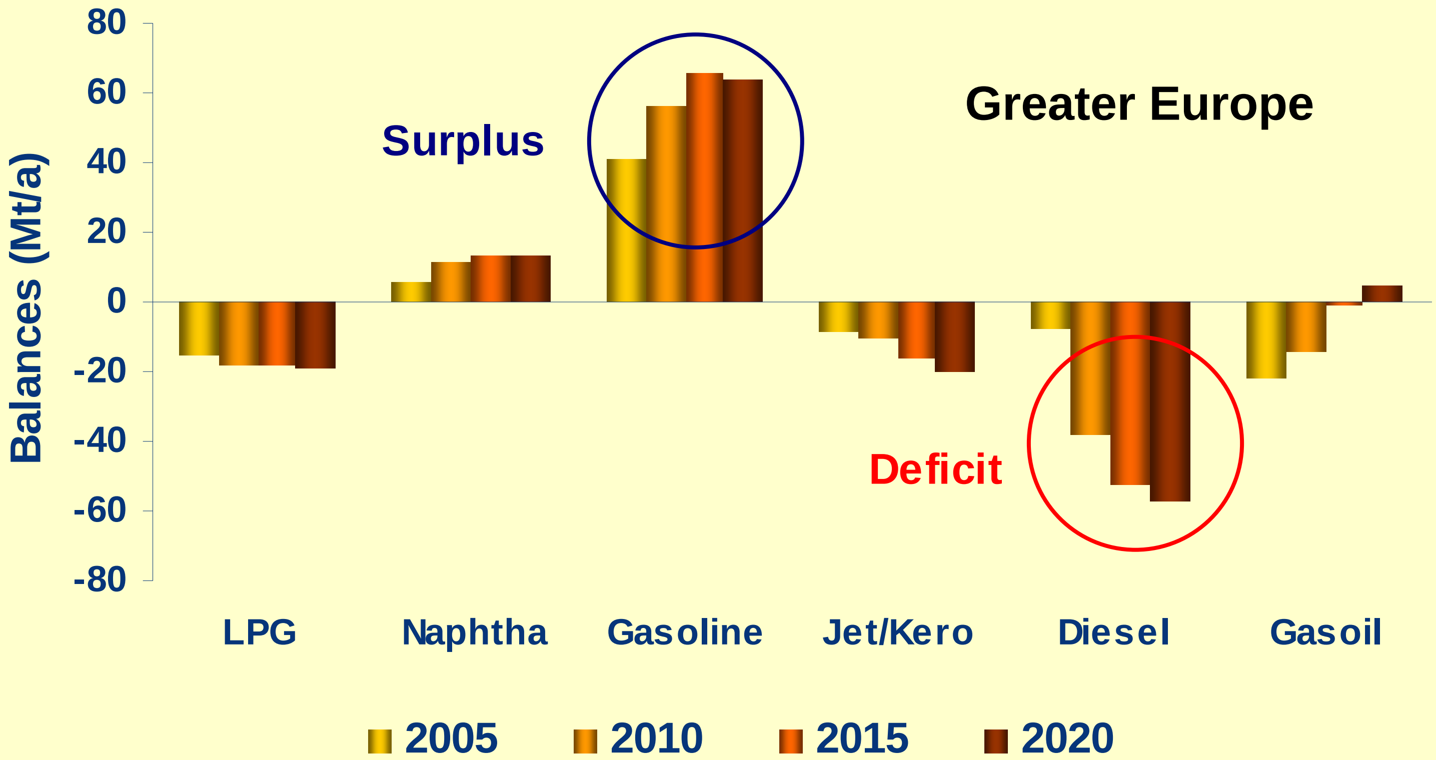
Diesel Penetration in Western Europe | **1990-2007 (% of new cars registered)**



Share of Diesel in the EU15 | **2007 (% of new cars registered)**



Supply/Demand Imbalance Expected to Grow



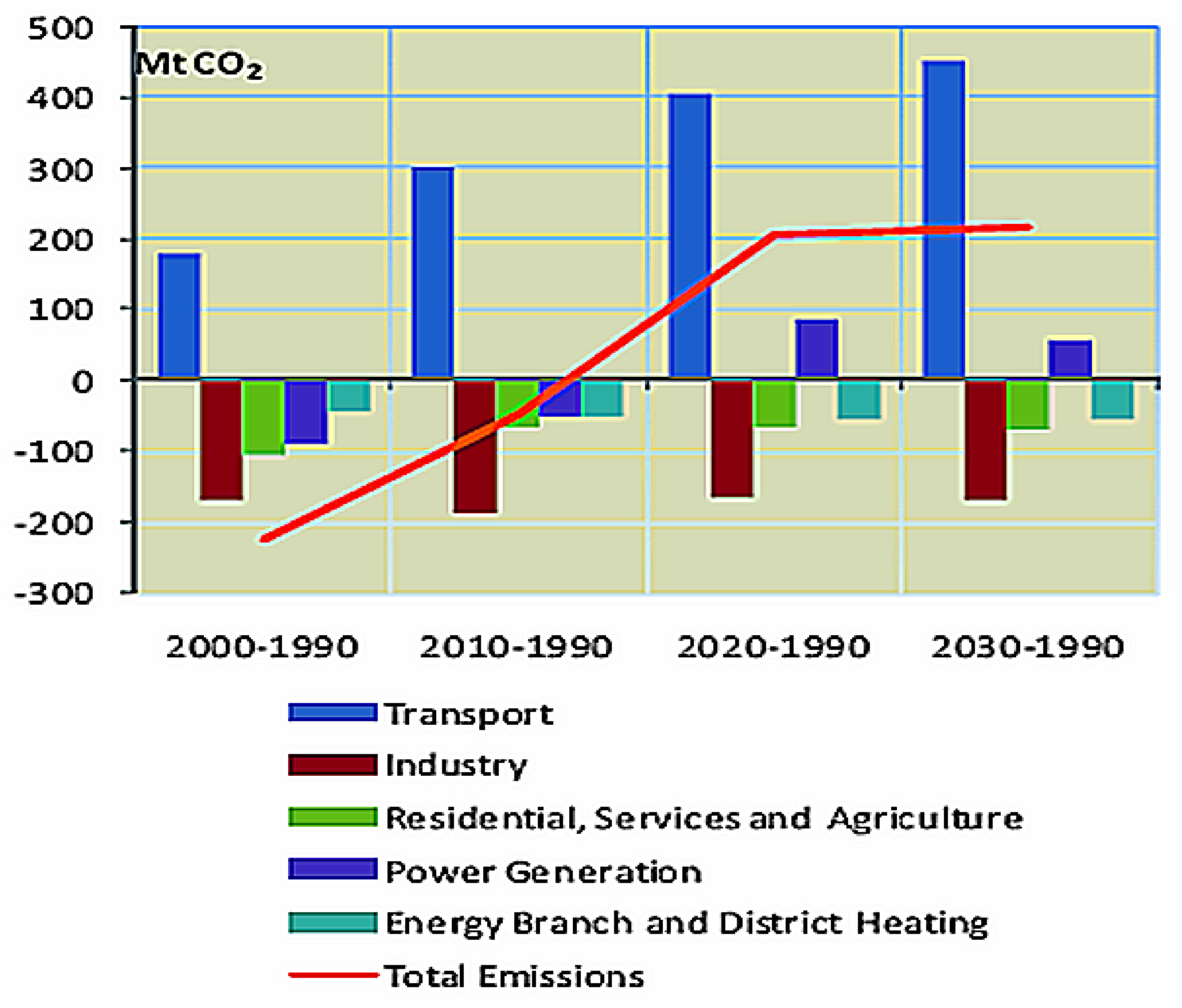
- CONCAWE estimates that holding the diesel/gasoline imbalance at today's level would require:
  - 9-12 G€ of additional refinery investment
  - Increase total refinery CO_2 emissions by over 10%

Source: Wood Mackenzie (2007)

Key External Factors

- Crude Oil Price and Availability
- Global Climate Change Policies
- The New US Administration
- Economic Downturn
  - Lack of investment funding for upgrades & new ventures
  - Loss or delay in pre-commercial research & development
  - Potential loss of experienced engineers and scientists
  - Depressed demand in the near term?

EU-27 Energy-related CO_2 Emissions From 1990



Source: European Energy & Transport 'Trends to 2030' (2007)

EU Legislative Framework is Now In Place

- **Reduce GHG emissions from energy and transport**
  - Energy Efficient Road Transport Vehicles (2008)
    - 130g CO_2/km by 2012 (+10g CO_2/km from extra measures)
    - 95g CO_2/km by 2020 (by diversifying the on-road fleet)
  - Fuel Quality Directive (2008)
    - Mandated 6% reduction in GHG emissions from fuel manufacturing
  - Emissions Trading Scheme (ETS)
  - Geological storage of Carbon Dioxide (2008)
- **Encourage wider use of renewable fuel products**
  - Fuel Quality Directive (2008)
    - Up to 10% v/v ethanol expected in gasoline
  - Renewable Energy Directive (2008)
    - 10% renewables (energy basis) in road fuels by 2020
      - Targets for 1^{st} and 2^{nd} Generation renewable fuels, including hydrogen and electricity
    - Intermediate targets in 2015 and a progress review in 2014

Changes Ahead for Vehicles and Fuels

Modern Engine Systems

- Spark Ignition DI
  - *+ SI Direct Injection*
- Compression Ignition DI
  - *+ CI Direct Injection*

Modern Fossil Fuels

- 10 ppm Sulphur Fuels
- Vapour Pressure
- Cetane Number
- Additive Technology

Urban Air Quality
(CO, HC, NOx, Ozone, Noise)
and
Energy/GHG Reduction
(CO_2, CH_4, N_2O)

Alternative Engines and Powertrains

- Advanced Combustion
  - *+ HCCI, CAI*
- Plug-in Hybrids & Hybrids
- Battery Electrics
  - *+ Hydrogen and Fuel Cells*
- Advanced Aftertreatment

Alternative Fuels

- Bio-fuels
  - *+ 1st and 2nd Generation*
- Compressed Gases
  - *+ LPG, CNG*
  - *+ DME, Biogas, H_2*
- Advanced Aftertreatment

Outlook for Alternative Fuels (1)

- Diesel and gasoline will continue to be the dominant fuels for road transport over the next several decades
  - Continued performance improvements expected in advanced IC engines with a greater fraction going to lower fuel consumption
  - More downsizing, hybridization, turbocharging, etc.
  - "Systems" approach to capture losses from entire vehicle

- LPG will continue to be a niche market fuel and is not expected to grow significantly

- CNG has advantages as a fuel especially for captive fleets
  - Natural Gas is in high demand for stationary applications
    - Europe imports a growing percentage of its NG needs
  - GHG savings similar to diesel, better than gasoline
  - Cost for refuelling infrastructure makes CNG less attractive for general market but CNG refueling is becoming more common in Sweden, Switzerland, and a few other countries
    - Usually more attractive for captive fleets (e.g. urban delivery trucks) where the infrastructure investment can be justified
    - Substitution of diesel by CNG captive fleets could help relieve the diesel/gasoline imbalance

Outlook for Alternative Fuels (2)

- X-to-Liquids (XTL) products (where X = Biomass, Gas, or Coal)
  - Specifications for XTL products as neat fuels defined by CEN Workshop Agreement (CWA 15940, February 2009)
  - GTL production projected to be ~4% of world diesel demand by 2020 but economic conditions are impacting development
  - CTL interest in countries with coal reserves but significant CO_2 increases will occur unless CO_2 Capture & Storage (CCS) is also implemented
  - BTL is in pilot development but sourcing sufficient biomass feedstock is a logistical challenge

- Biogas from waste can provide significant GHG savings
  - Technology is available and costs are moderate
  - GHG savings achievable regardless of the end use of the biogas

- Hydrogen not expected to have broad market impact until after 2020
  - Fuel cells remain costly and more development is needed
  - Separate hydrogen supply infrastructure is needed
  - Hydrogen from natural gas only mitigates GHG emissions if used in conjunction with a fuel cell vehicle

concawe

Replacing Fossil Fuels by Biofuels

- Availability of 1st Generation bio-components is growing
  - Ethanol will be more available than biodiesel components over the coming decade
  - Biodiesel components are needed to counterbalance the ever-increasing diesel/gasoline ratio
  - Biofuels are not 100% renewable and contribute only partly to GHG emission reductions
  - Methodology not yet developed to define sustainable biofuels and certify them for use in road fuels

- 1st Generation bio-components will be the mainstay of the road fuel pool for the foreseeable future while 2nd Generation products slowly enter market

concawe

Pace of Bio-technology Developments

	Defined By Feedstock Utilisation		Defined By Technology Maturity
"1st Generation"	▪ Ethanol from sugar cane, grains, sugar beets, etc.	▪ FAME from: ▪ vegetable oils ▪ animal, waste oils	Widely available <u>commercial technology:</u> ▪ Fermentation ▪ Etherification ▪ Esterification
"2nd Generation"	▪ Ethanol from biomass ▪ DME from black liquor	▪ Hydrogenated oils ▪ FAME from: ▪ non-edible seeds (jatropha, karanja) ▪ new seed oils (cuphea, crambe, cotton seed) ▪ Biomass to Liquids	Being implemented or <u>at pilot plant stage:</u> ▪ Hydrogenation ▪ Hydrotreating ▪ Gasification/synthesis ▪ Lignocellulose process
"3rd Generation"	▪ Biogas from waste ▪ Biohydrogen	▪ Biodiesel from algae	<u>At research stage:</u> ▪ Pyrolysis ▪ Hydrothermal upgrade

Winning technologies must:

- Reduce GHG emissions on a Well-to-Wheels basis
- Be energy efficient, sustainably produced, and cost-competitive
- And perform well in customer's vehicles!

Biofuels: Blends in the EU27 Marketplace

<u>Current European CEN Specifications:</u>

- For pure bio-components:
  - Ethanol: EN15376 (for blending up to 5% in gasoline)
  - Fatty Acid Methyl Esters (FAME): EN14214
- For gasoline: 5% v/v (E5) ethanol and 2.7% oxygen (EN228)
- For diesel: 7% v/v (B7) FAME in diesel fuel (EN590, Autumn, 2009)
- Generally no limits on addition of 2nd Generation renewable diesel
  - Hydrogenated vegetable oils (HVO) and animal fats
  - Biomass-to-Liquids (BTL)

<u>Member State Initiatives:</u>

- France: B7 (2008) and B30 for captive fleets
- Germany: B7 plus 3% renewable diesel (2008), B100 for specially adapted vehicles
- Other Countries:
  - B20 (Poland) and B30 (Czech Republic) for captive fleets
  - E85 in Austria, France, Germany, and Sweden

Standardization of high quality fuels containing bio-components is essential to ensure trouble-free performance in the current/future fleet

Biofuels: Product Quality Concerns

- Gasoline containing ethanol (E5-E10)
  - Increase in gasoline's vapour pressure and distillation due to ethanol
  - Compatibility with fuel system materials, including fuel permeation
    - Especially in older vehicles
  - Impact of ethanol on vehicle's evaporative emissions system
  - Water retention and corrosion of some fuel system parts
  - Contaminants picked up in manufacturing and distribution
    - Dirt, water, and sulfates

- Diesel containing 1st Generation biodiesel components (B7-B10)
  - Oxidative stability leading to:
    - Fuel injector deposits and plugging
    - Change in diesel fuel properties during long-term storage
  - Cold flow and filterability properties that are not easily corrected with diesel additives
  - Lube oil dilution through retention of higher-boiling components
  - Contaminants picked up in manufacturing and distribution
    - Dirt, water, and ash
  - Regeneration and plugging of Diesel Particulate Filters (DPFs)
  - Compatibility with some fuel system materials
    - Especially in older vehicles

concawe

Typical Well-to-Wheels "Pathway"

Well

Produce primary fuel

Transport primary fuel

Produce road fuel

Distribute road fuel

Fuel vehicle

Burn fuel in vehicle

Wheels

Well-to-Tank (WTT)

~15% (production side)

Crude Production
1 – 4%

Refining
8 – 10%

Distribution & Retail
1%

For each "WTW" pathway, calculate:

- **Total energy required**
- **Total GHG emitted**

Tank-to-Wheels (TTW)

~85% (consumption side)

concawe

Well-to-Wheels Pathways

Resource

Crude oil

Biomass

Natural Gas

Coal

Wind

Nuclear

Inc. preliminary views on Carbon Capture and Sequestration

Fuels

Conventional Diesel, Gasoline, & Naphtha

CNG (incl. biogas)

LPG

MTBE / ETBE

Ethanol

Bio-diesel (incl. FAEE)

Synthetic Diesel

Hydrogen (compressed / liquid)

DME

Methanol

Powertrains

Spark Ignition: Gasoline, LPG, CNG, Ethanol, H_2

Compression Ignition: Diesel, DME, Bio-diesel

Fuel Cell

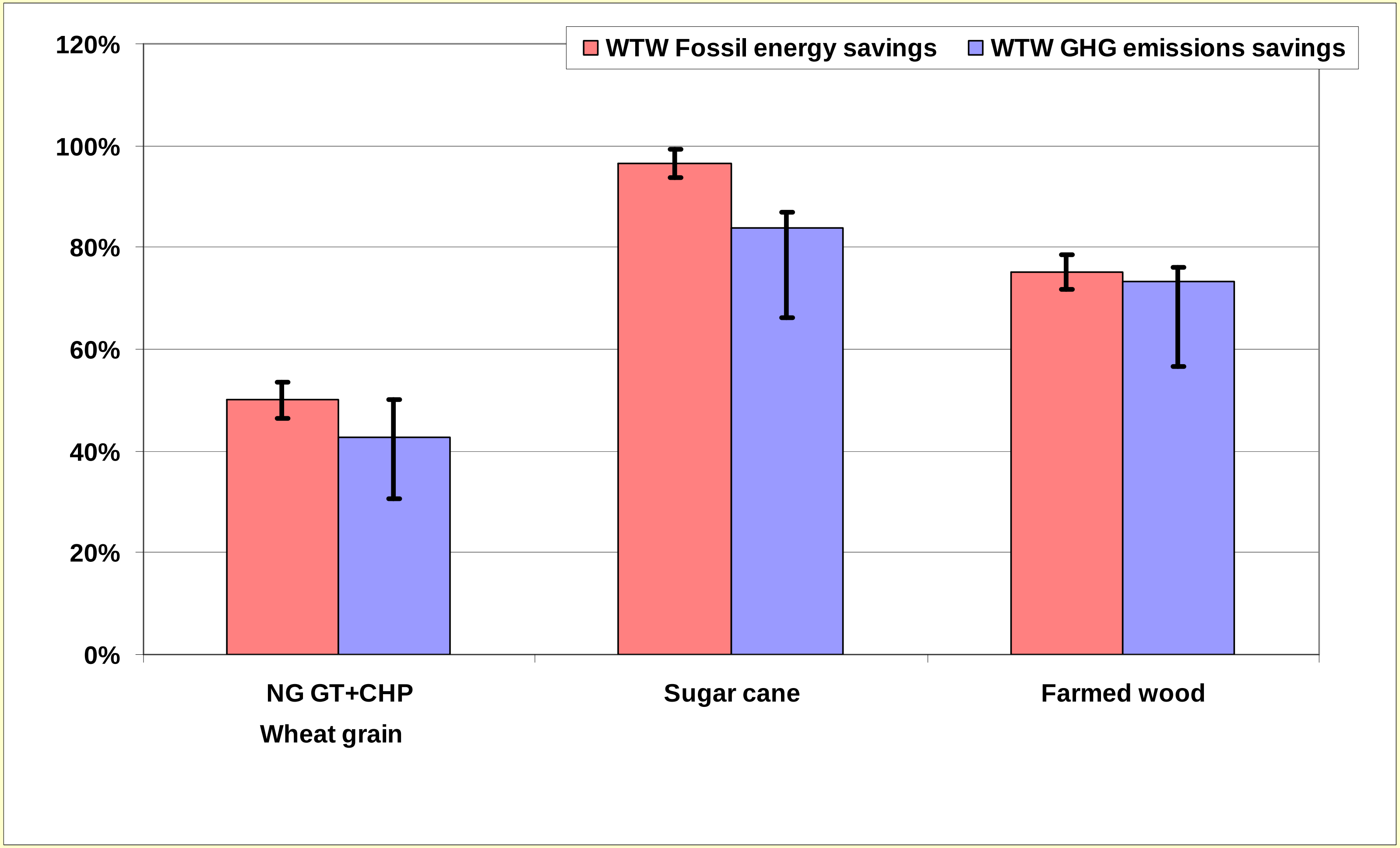
Hybrids: SI, CI, FC

Hybrid Fuel Cell + Reformer

Source: JRC-EUCAR-CONCAWE (JEC) Well-to-Wheels Study (2005)

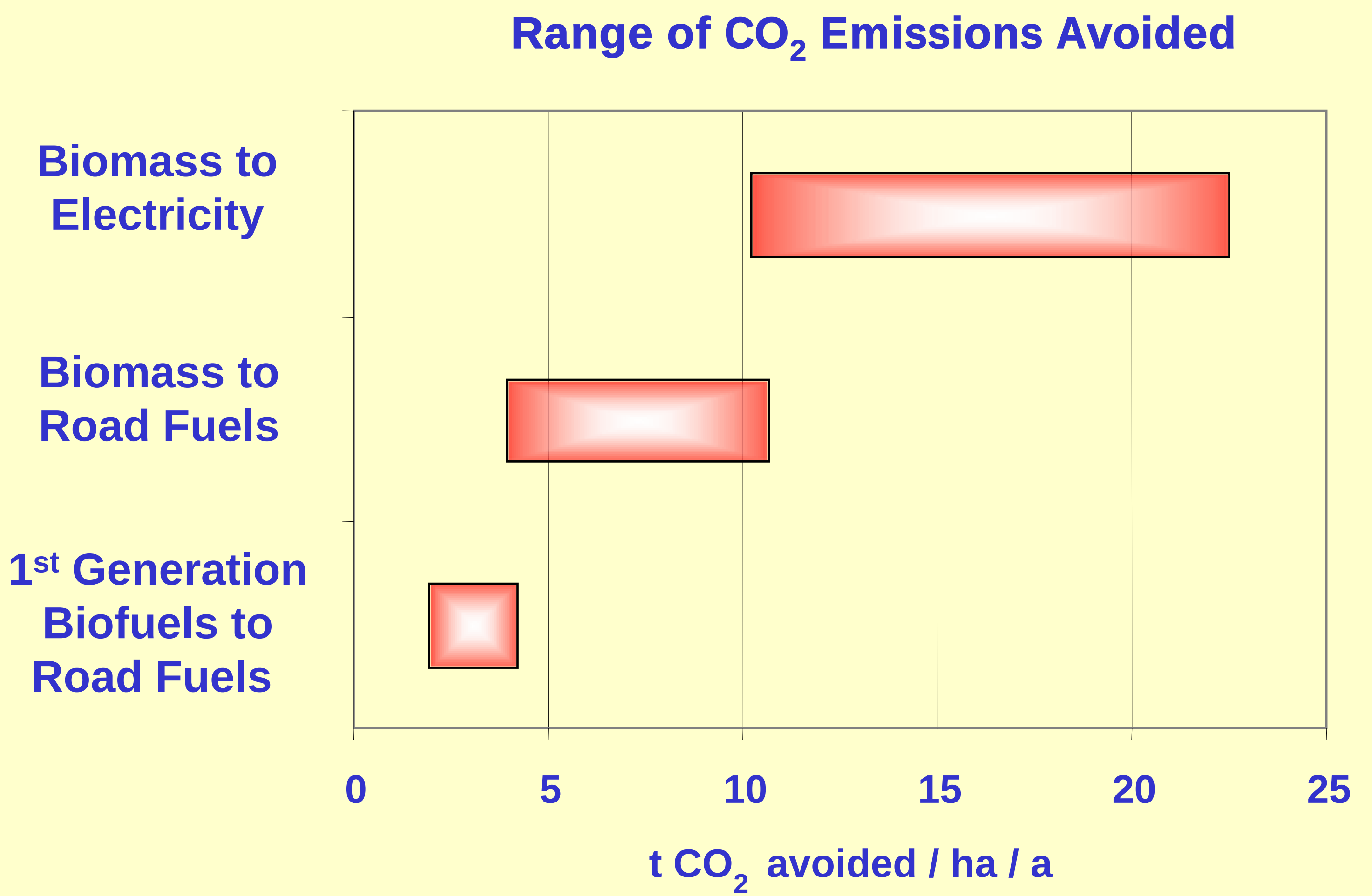
JEC Well-to-Wheels Study: Typical Outcome

- GHG savings by three pathways to ethanol as road fuel



Source: JRC-EUCAR-CONCAWE (JEC) Well-to-Wheels Study (2005)

GHG Avoidance for Biomass Applications



Source: JRC-EUCAR-CONCAWE (JEC) Well-to-Wheels Study (2005)

Biofuels: Sustainability Certification

- Biofuels can bring environmental benefits but a robust and implementable certification system is needed to:
  - Encourage biofuel technology improvements that reduce GHG emissions and energy on a Well-to-Wheels basis
  - Avoid major biodiversity loss and deforestation
  - Aid public understanding
- Some characteristics of a Biofuel Certification Scheme:
  - Clearly demonstrate the environmental benefits, including favourable reductions in GHG and energy
  - Common approach across European countries with the potential for global reach
  - Chain of custody scheme to ensure that relevant information is passed along the chain from production to use
  - Measurement, auditing, and verification methodologies
- Work is in progress in Member States, CEN, ISO, and elsewhere

Many Questions Still to be Answered

- What is the right strategy for limited bio-components and how can technical acceptance be improved?
  - General use in road fuels?
  - Niche market applications for road fuels?
  - General use in transport sector?
  - General use in energy sector?
- How much biodiesel will realistically be available by 2010? By 2020?
- How much of this biodiesel will be 1^{st} vs. 2^{nd} Generation? How quickly will 2^{nd} Gen products displace 1^{st} Gen products?
- What will be the impact of sustainability criteria on availability? What is the best use for available land and crops?
- Will the current and future fleet be compatible with the future fuel mix?

JRC/EUCAR/CONCAWE Biofuels Programme

A three-way partnership

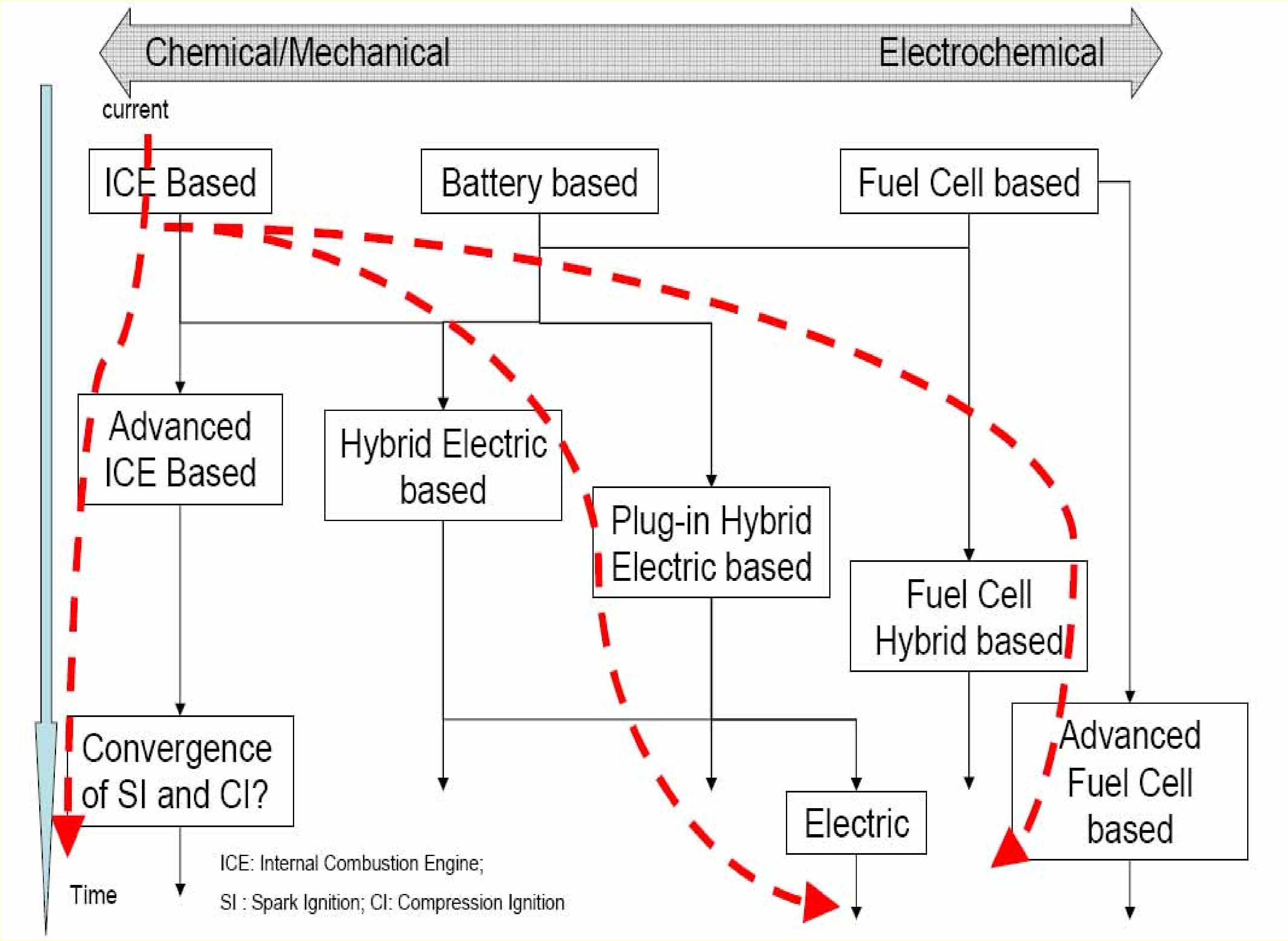
Objectives of the JEC Biofuels Programme:

- Clarify the opportunities and barriers to achieve 10% biofuels (energy basis) in road fuels by 2020
- Ensure that the introduction of biofuel blends to meet the 2020 target is seamless to consumers and results in no detrimental impact on vehicle performance and emissions
- Programme time frame: 3 years (2008-2010)

Programme in Progress:

- **First Step:** Develop a consensus supply picture of biofuel types and availability
- **Second Step:** What are the biofuel performance issues with the existing and near-term fleet?
- **Third Step:** What can the future Light-duty and Heavy-duty fleet handle?

Paths Forward in a Carbon-constrained World



Source: MIT Consortium: "On the Road in 2035" (2008)

Fuels and Biofuels: Future Demand and Quality

- Significant challenges are ahead to meet Global and EU energy and road fuel demands in all segments of energy/road transport while satisfying consumer's demand for personal mobility

- Advanced vehicles and fuels will dominate mainstream road transport for some time to come while vehicle efficiency improves and the on-road fleet continues to diversify

- Renewable fuels must be energy/GHG efficient on a WTW basis and be sustainably produced
  - "1st Generation" fuels: already contributing to road transport
  - "2nd (and 3rd) Generation" fuels: need much more research

- More work is needed on:
  - Well-to-Wheels methodologies
  - Biofuels sustainability scheme
  - "Systems" approach to ensure that energy losses are captured through technology and "non-technology" options