Energy and CO_2 Emissions in Transport

Amela Ajanovic
Energy Economics Group (EEG)
Institute of Energy Systems and Electrical Drives
Vienna University of Technology
Tel. +43-1-58801-370364
Web: http://eeg.tuwien.ac.at

Contents

1. *Introduction*
2. *Historical developments*
3. *Indicators of recent development*
4. *Technical, economic and ecological aspects*
5. *Energy policies*
6. *Future scenarios and perspectives*

1. Introduction

Basic principle:

$$S=f(E, \eta(Tc), \eta(Tis))$$

Service:
km driven,
Power,
speed

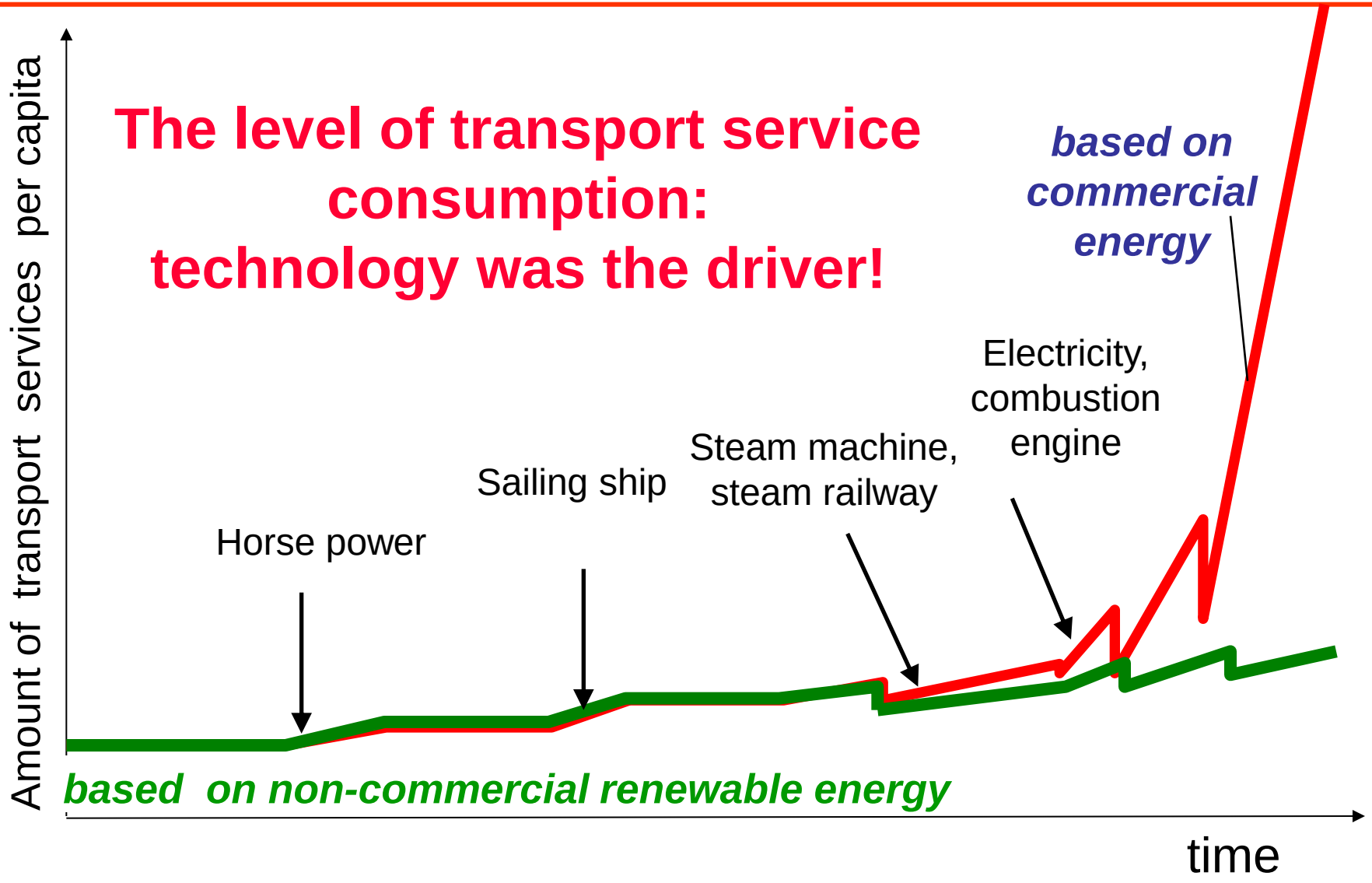
Fuel mix,
Fuel demand

Efficiency:
Liter/100 km

Infrastructur

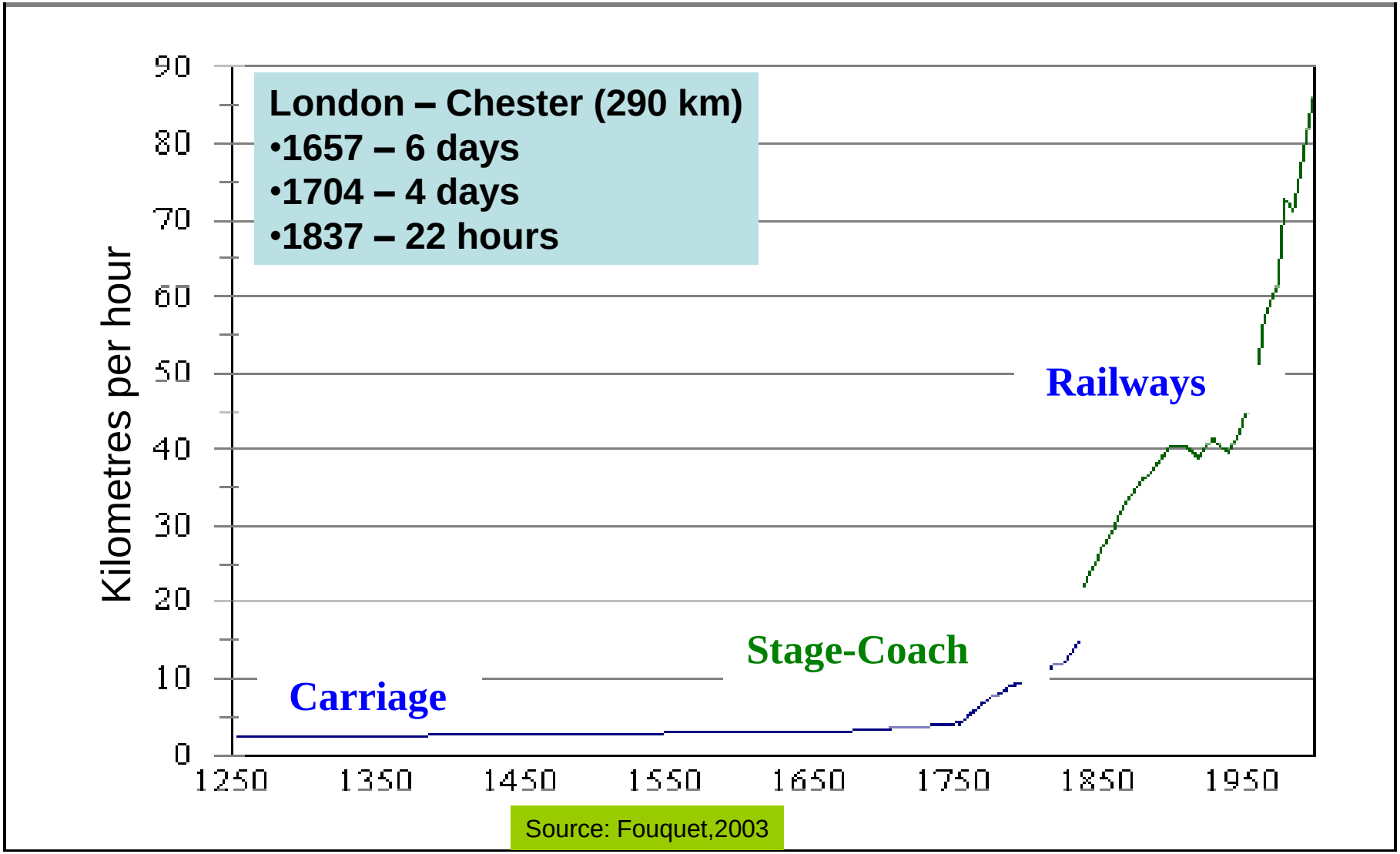
2. Historical developments

2. History


The level of transport service consumption: technology was the driver!
based on commercial energy
Electricity, combustion engine
Steam machine, steam railway
Sailing ship
Horse power
Amount of transport services per capita
based on non-commercial renewable energy
time

2. History

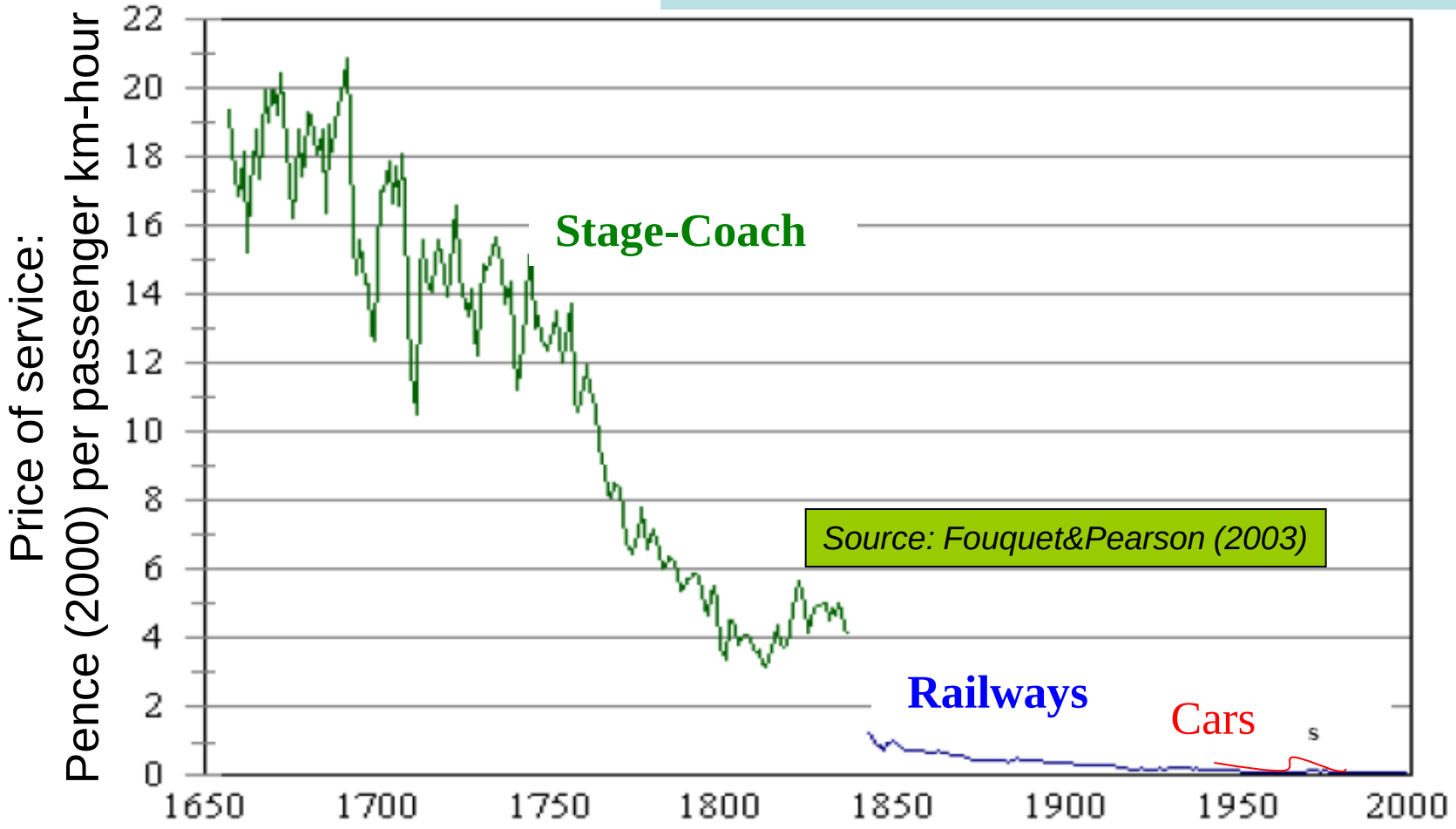
The Speed of Transport (Kilometres per Hour)



2. History

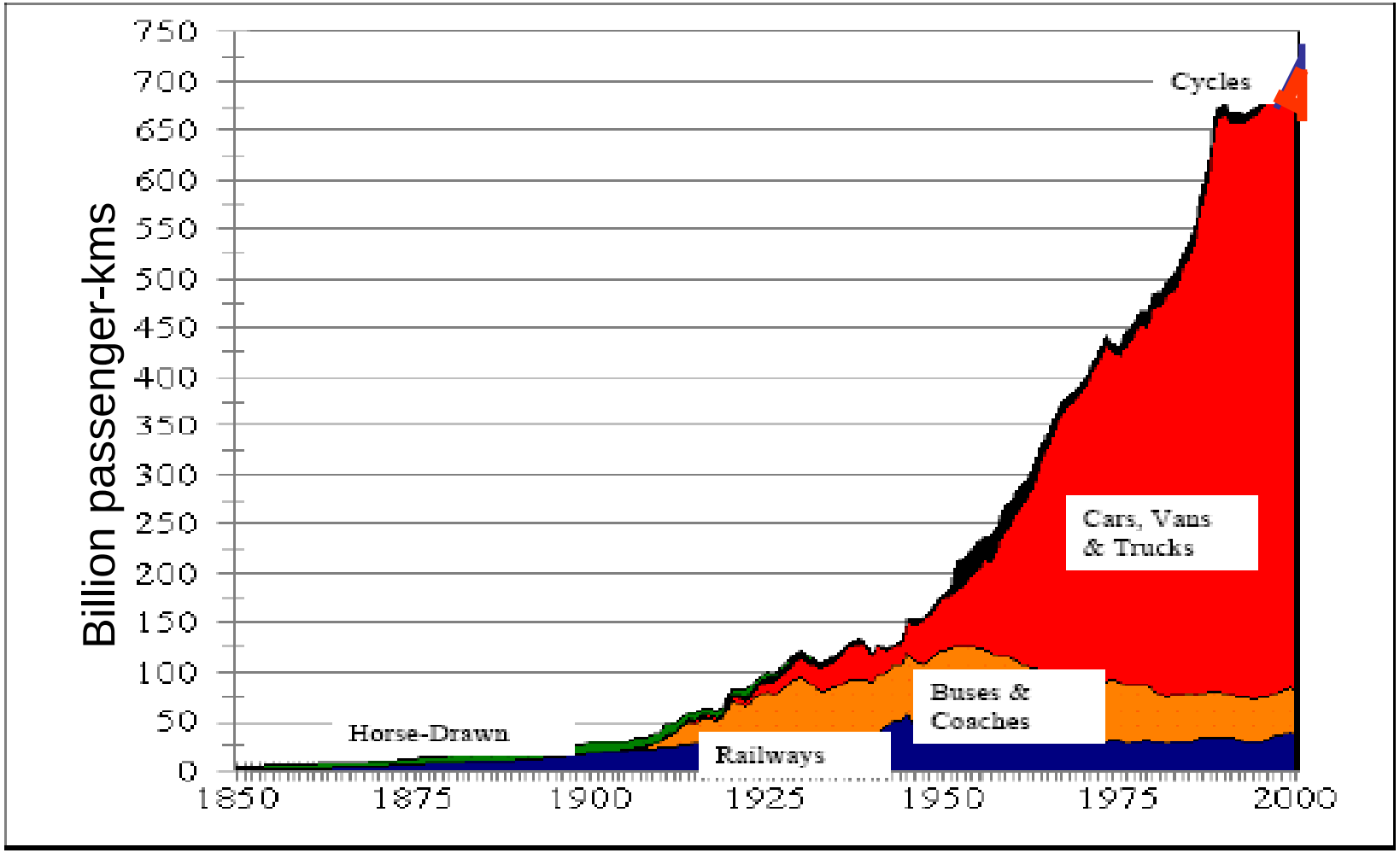
Price of Passenger
Transport (per passenger-kilometer-hour)

The price of service dropped dramatically!



2. History

UK: The Use of Passenger Transport (per Passenger-Kilometre), 1850-2000

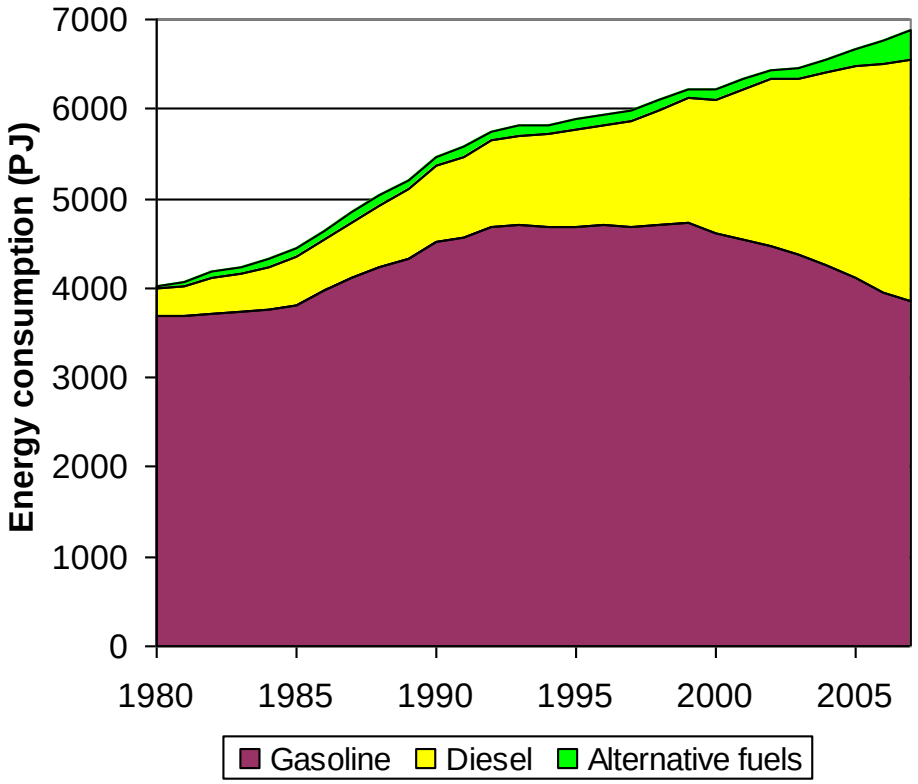


Source: Fouquet,2003

3. Indicators of recent developments, current situation

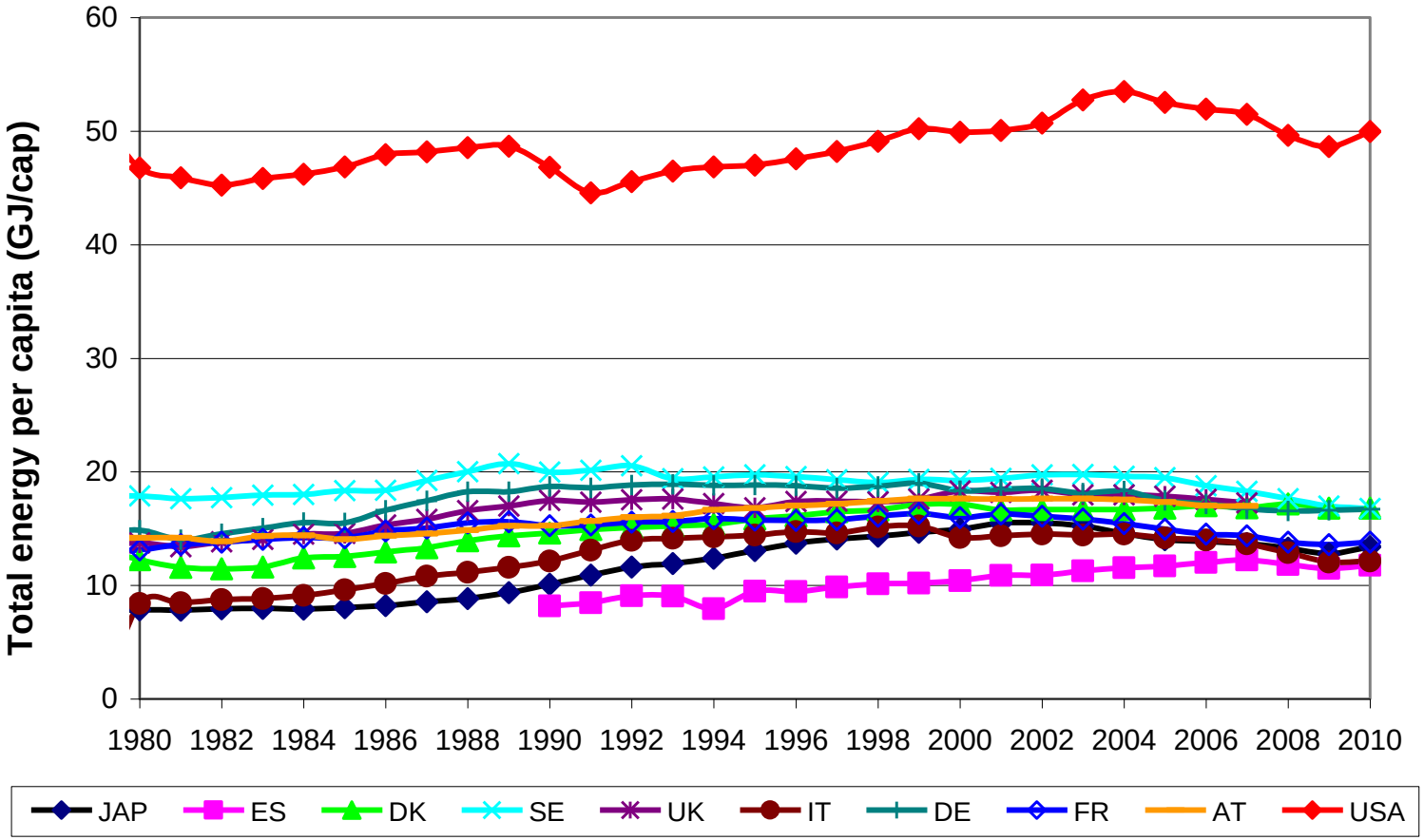
3. Indicators

Energy consumption in car passenger transport in EU-15 by fuel, 1980 – 2007



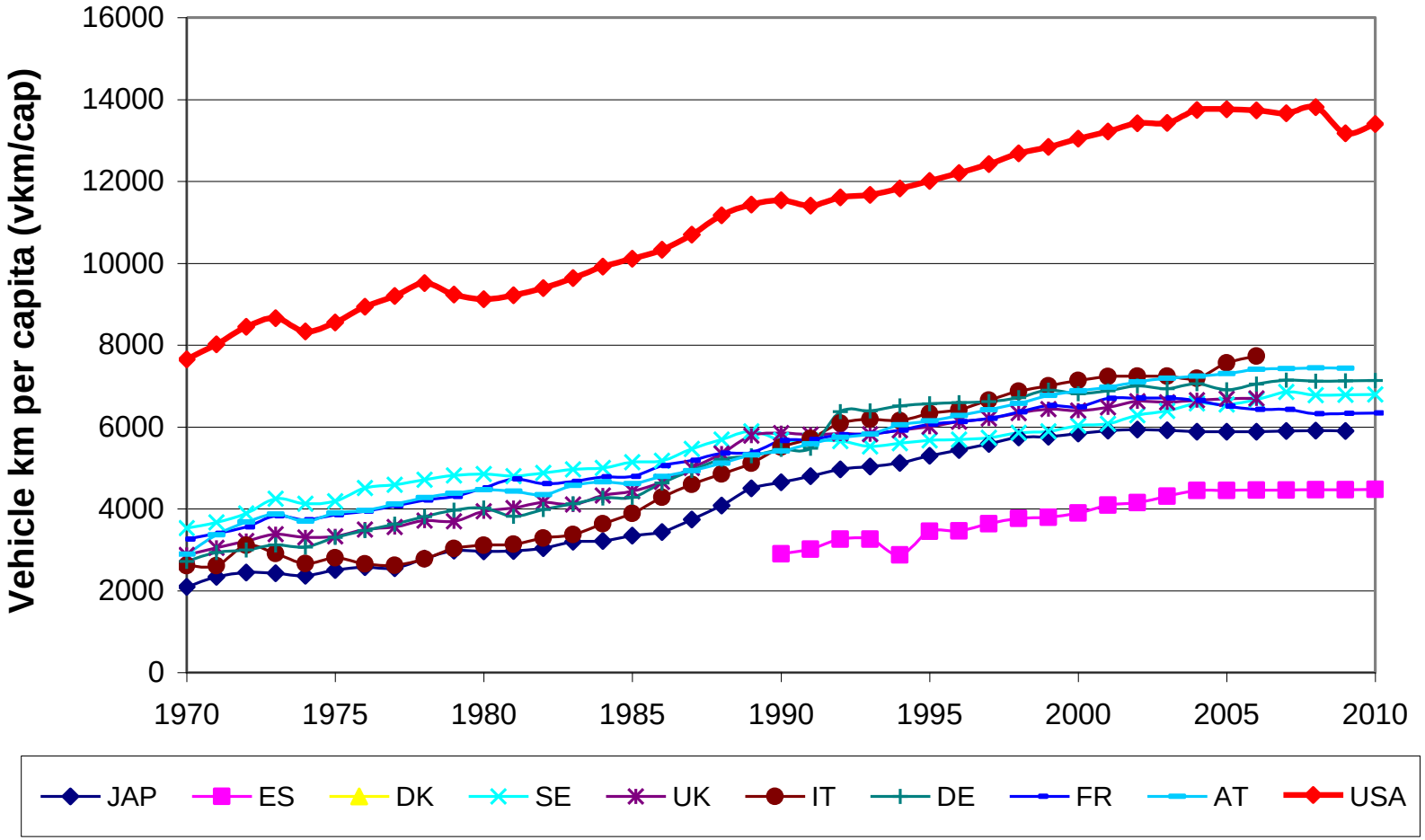
Source: ALTER-MOTIVE, 2009

Energy consumption



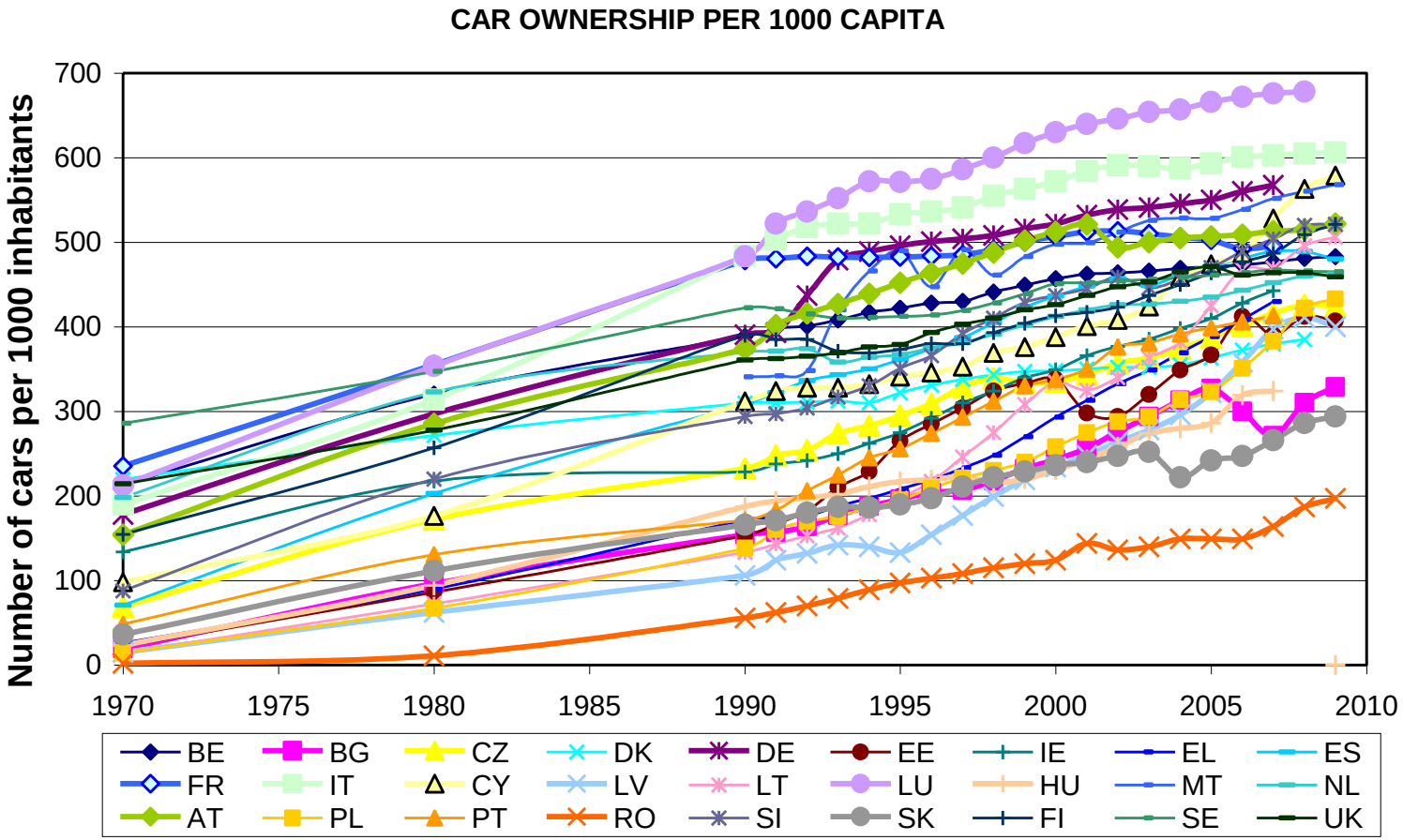
Development of energy use per capita for passenger cars and household light trucks/SUV

Travel activity



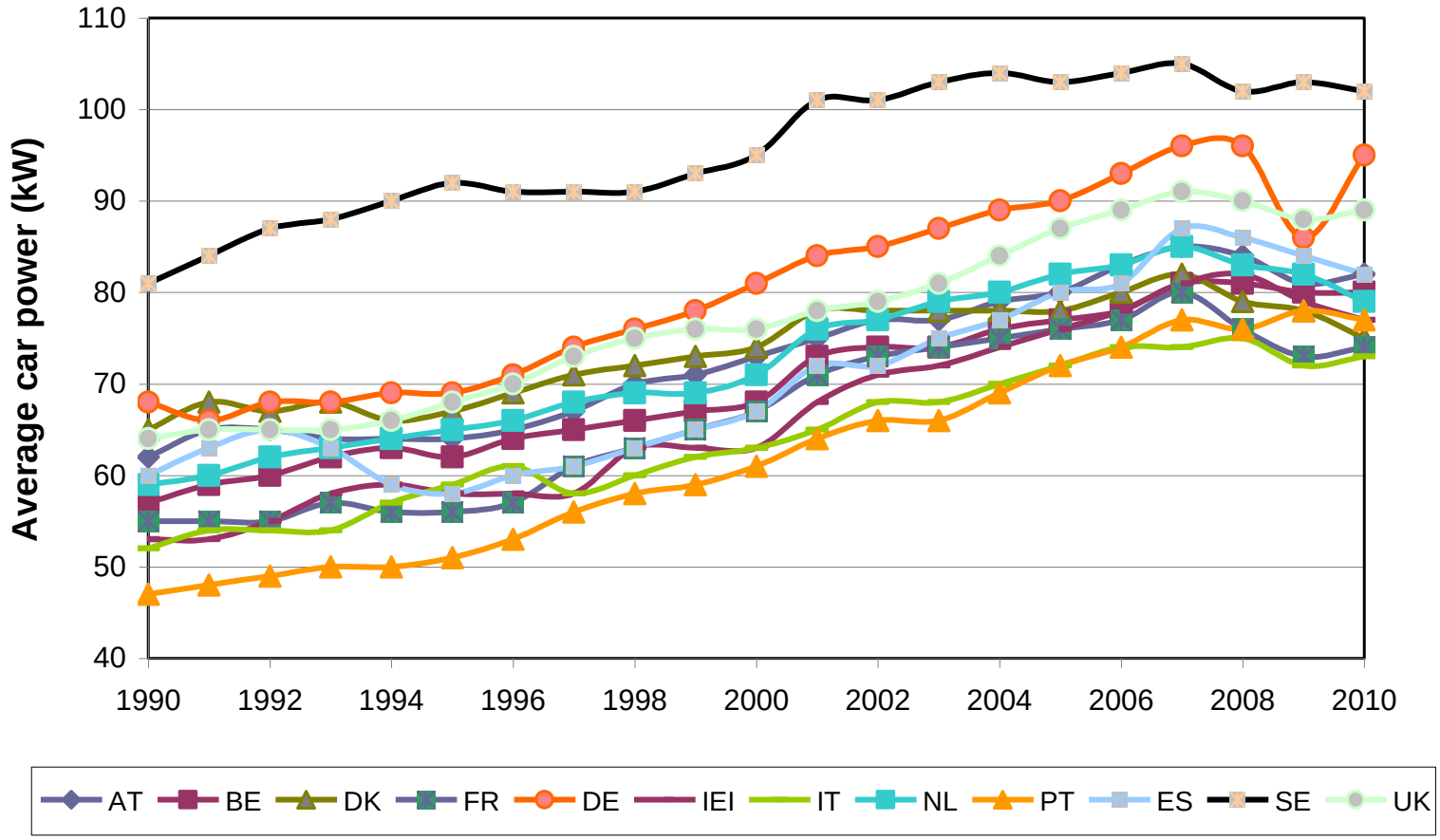
Development of vehicle kilometer per capita

Development of car stock



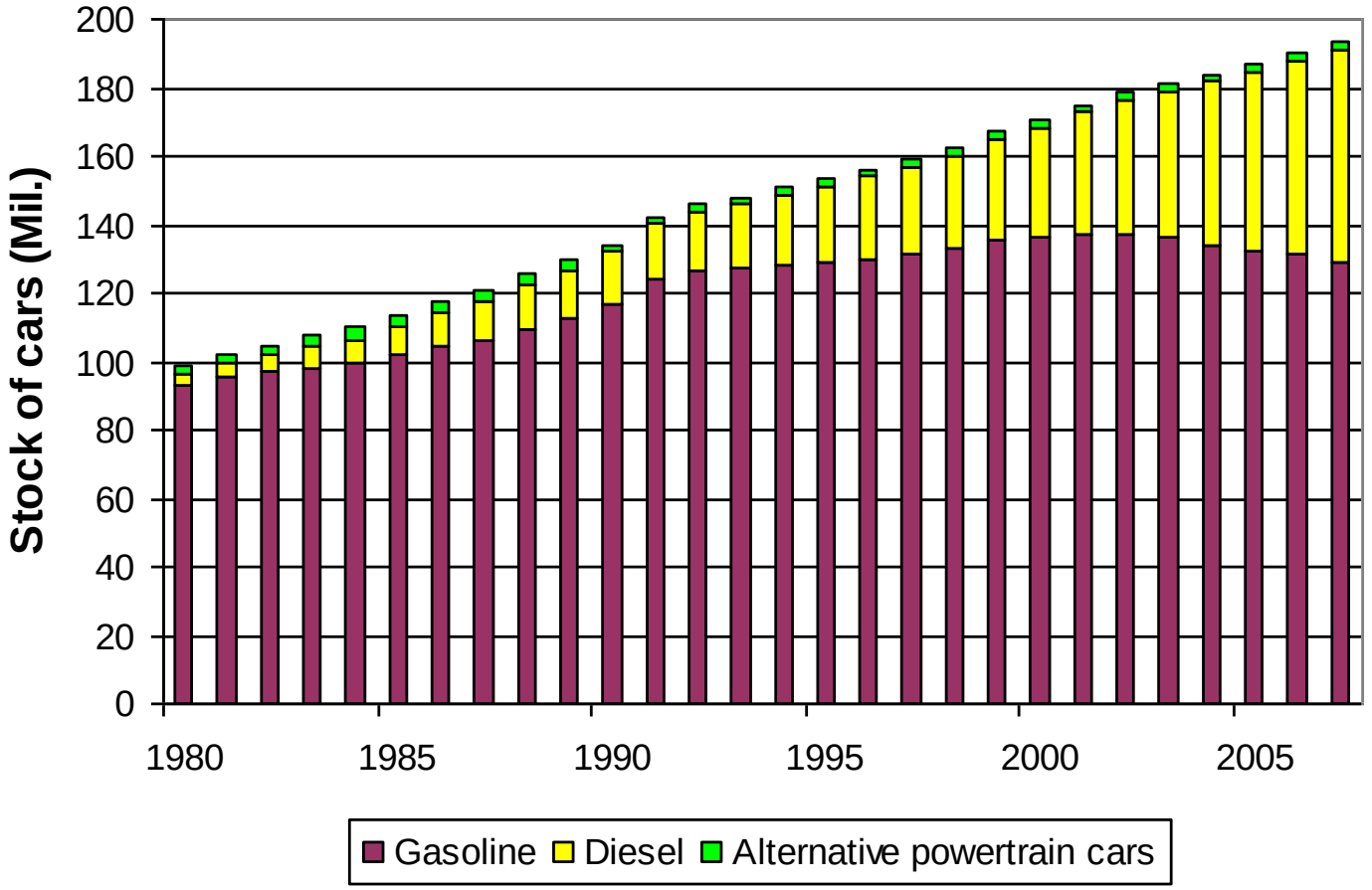
Car ownership per 1000 capita in EU-27 countries 1970 – 2009
(Source: EUROSTAT; ALTER-MOTIVE database)

Increases in power of cars



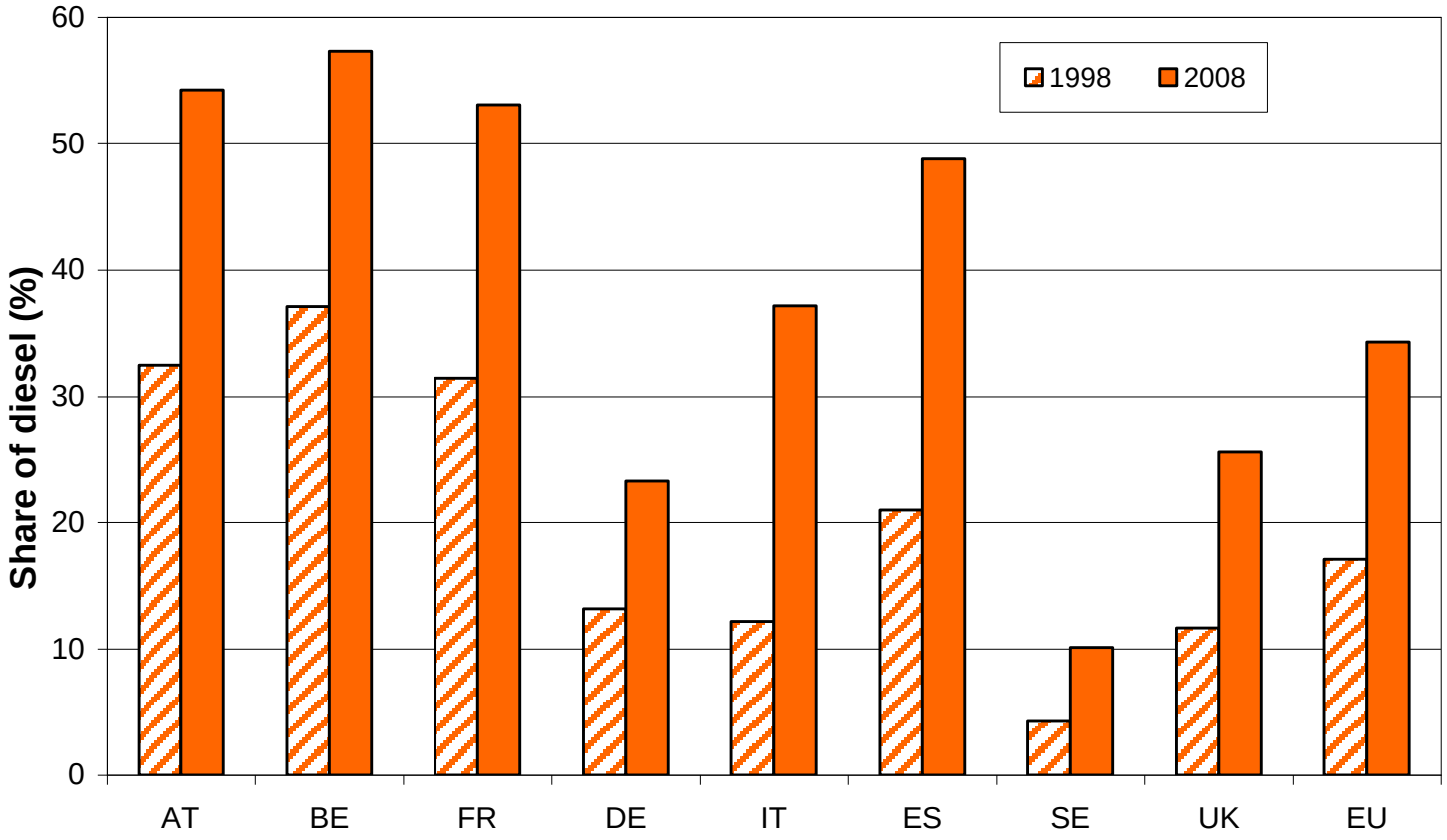
Average developments of car power (kW) of new cars in various EU-15 countries from 1990 to 2010 (Source: (EU-DB, 2009), (EC, 2007)).

3. Indicators



Development of car stock in passenger transport in EU-15, 1980 – 2007

Development of car stock



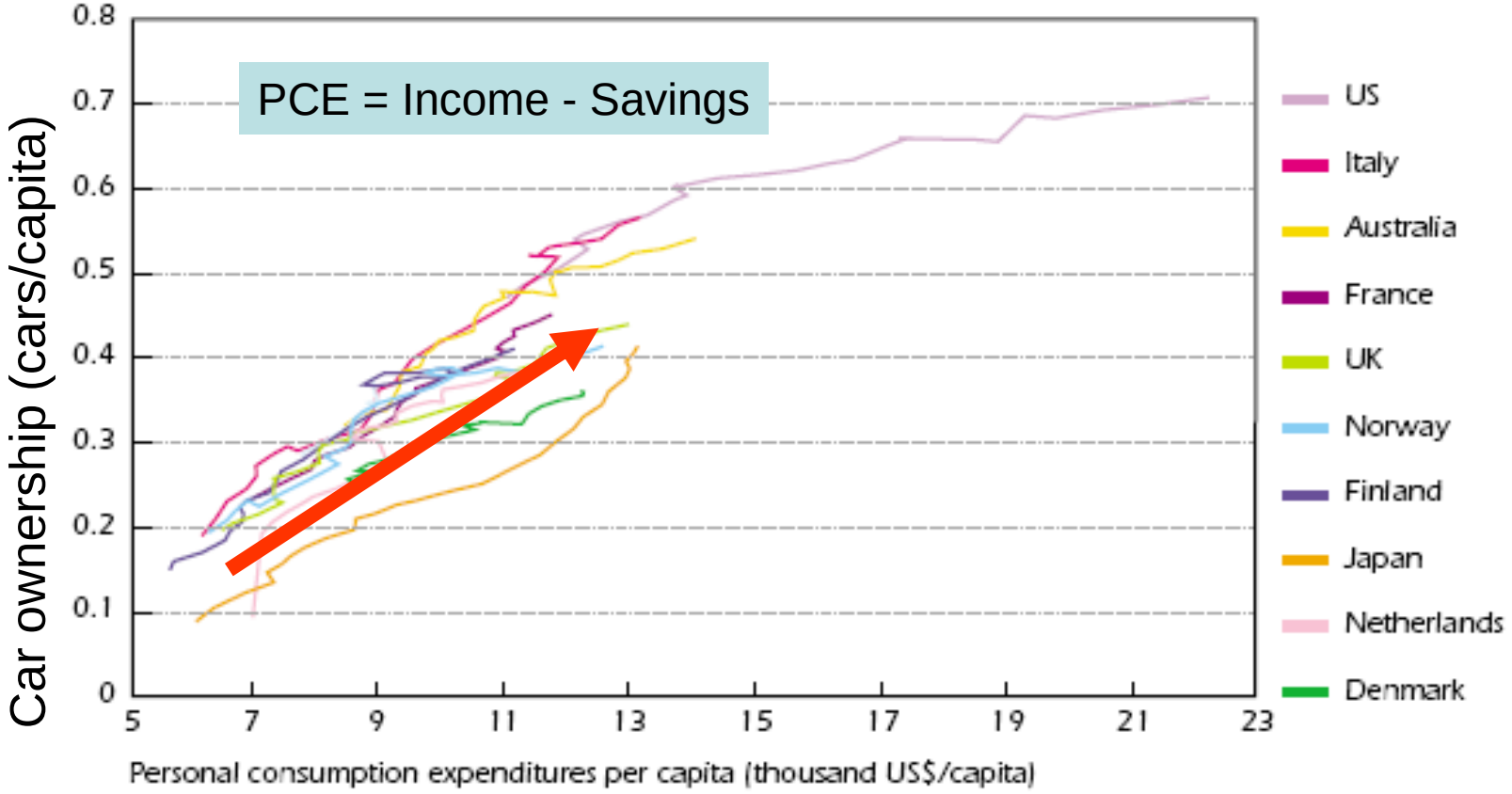
Share of diesel cars, selected EU countries 1998 vs 2008
(data source: ODYSSEE database; ALTER-MOTIVE database)

3. Indicators

Car Ownership and Income

Car Ownership per Capita and Personal Consumption Expenditures, 1970 - 2000

The United States leads the way in both car ownership and income



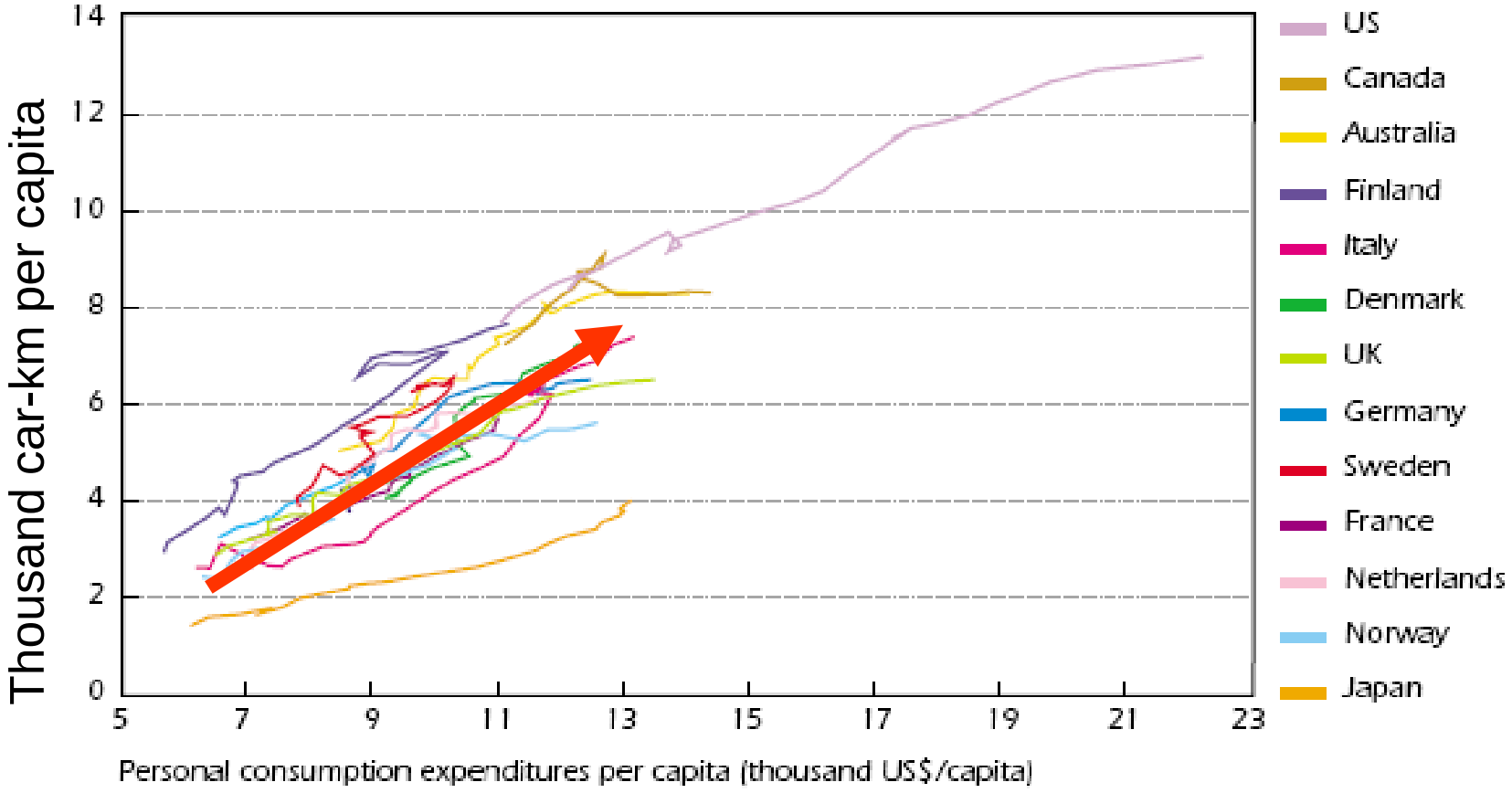
Source: IEA, 2004

3. Indicators

Car Travel and Income

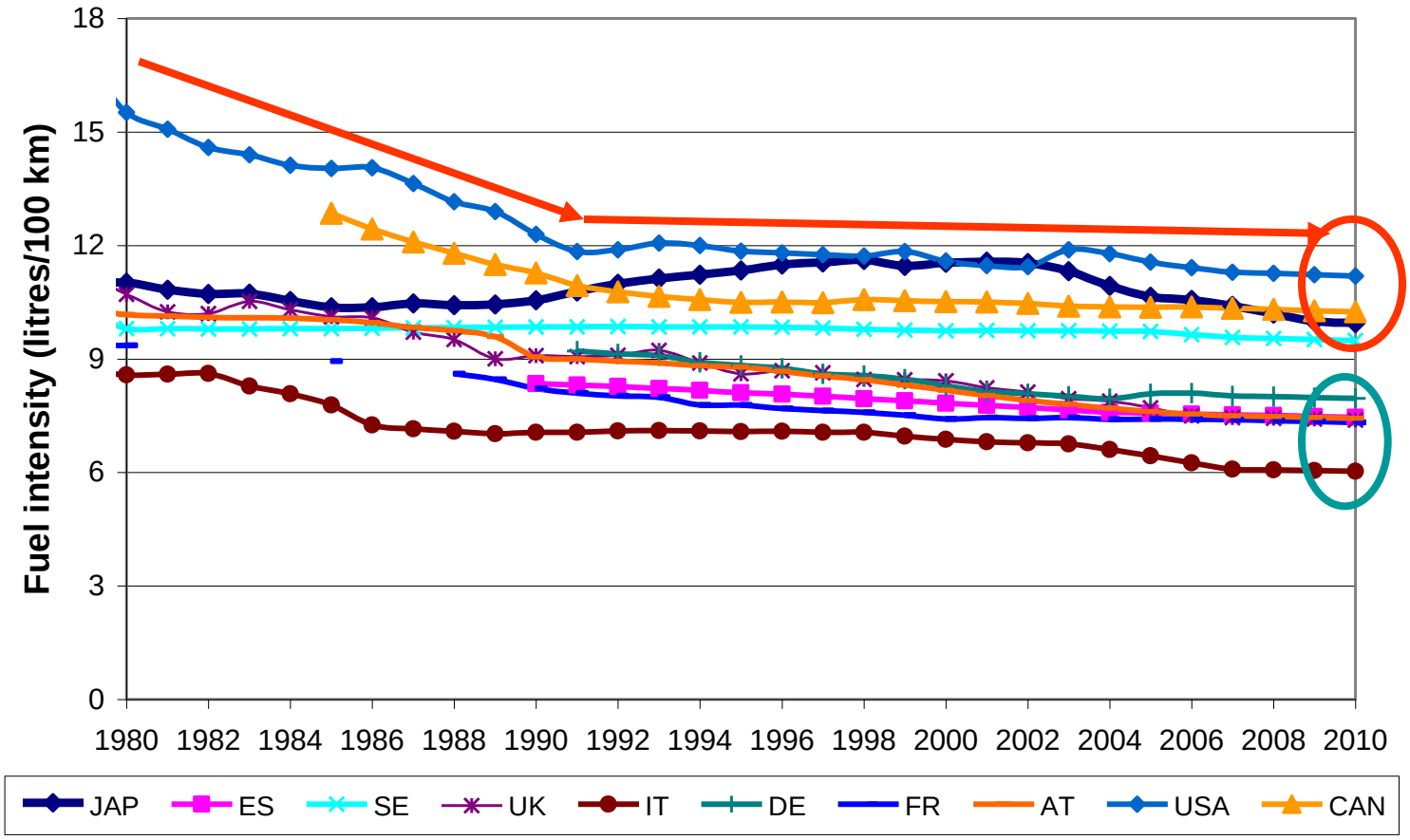
Car-kilometres per Capita and Personal Consumption Expenditures, 1970-2000

The trend for car travel is quite similar to car ownership



Source: IEA, 2004

Fuel intensity



Average on road fuel intensity of stock of cars and household light truck fleet, gasoline equivalent

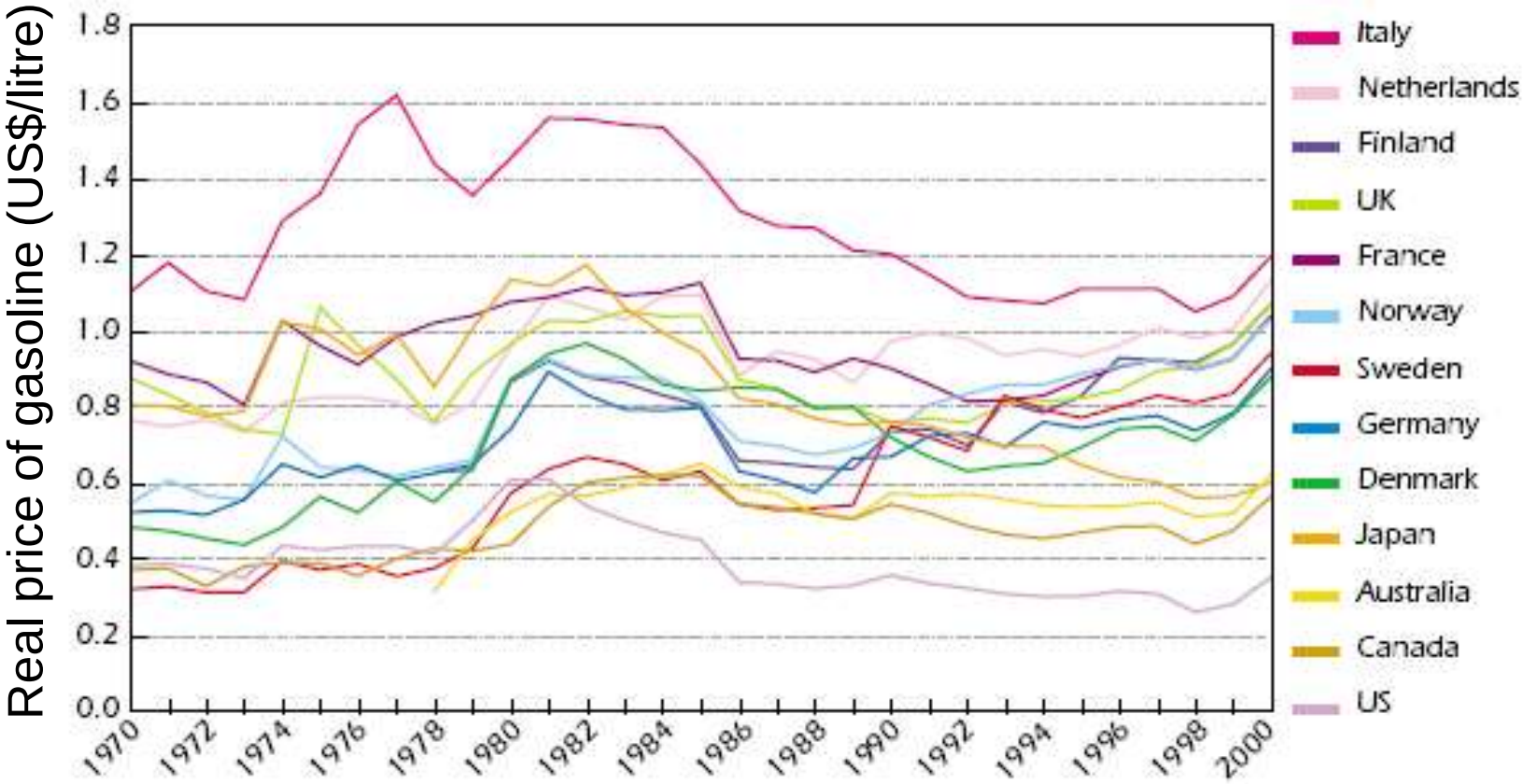
(Diesel is converted to liters of gasoline at their energy content. 1 litre diesel = 1.12 litre gasoline)

3. Indicators

Gasoline Prices

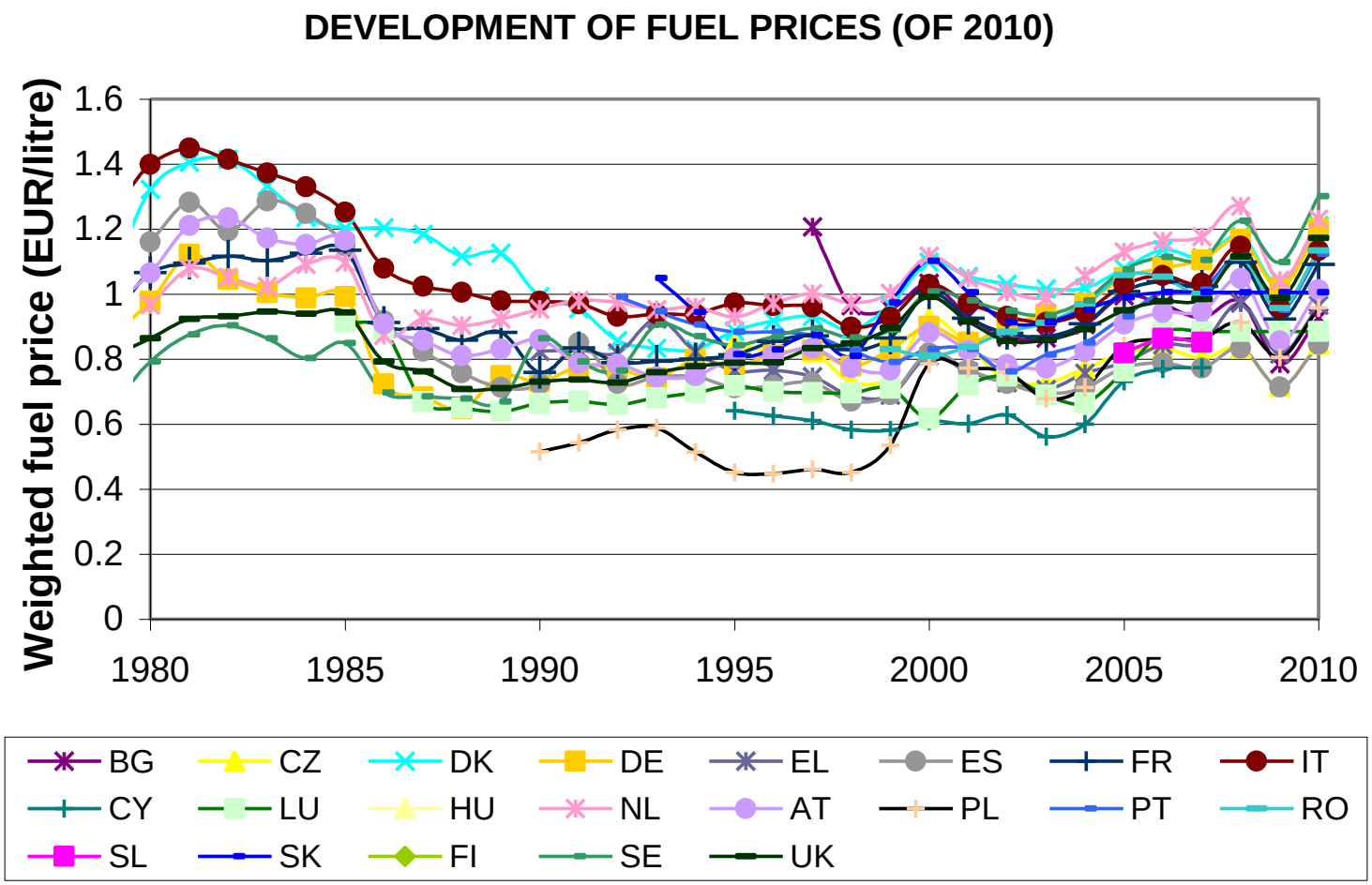
Trends in Retail Gasoline Prices in Real Terms, Including Taxes

Gasoline prices have varied considerably both over time and across IEA countries



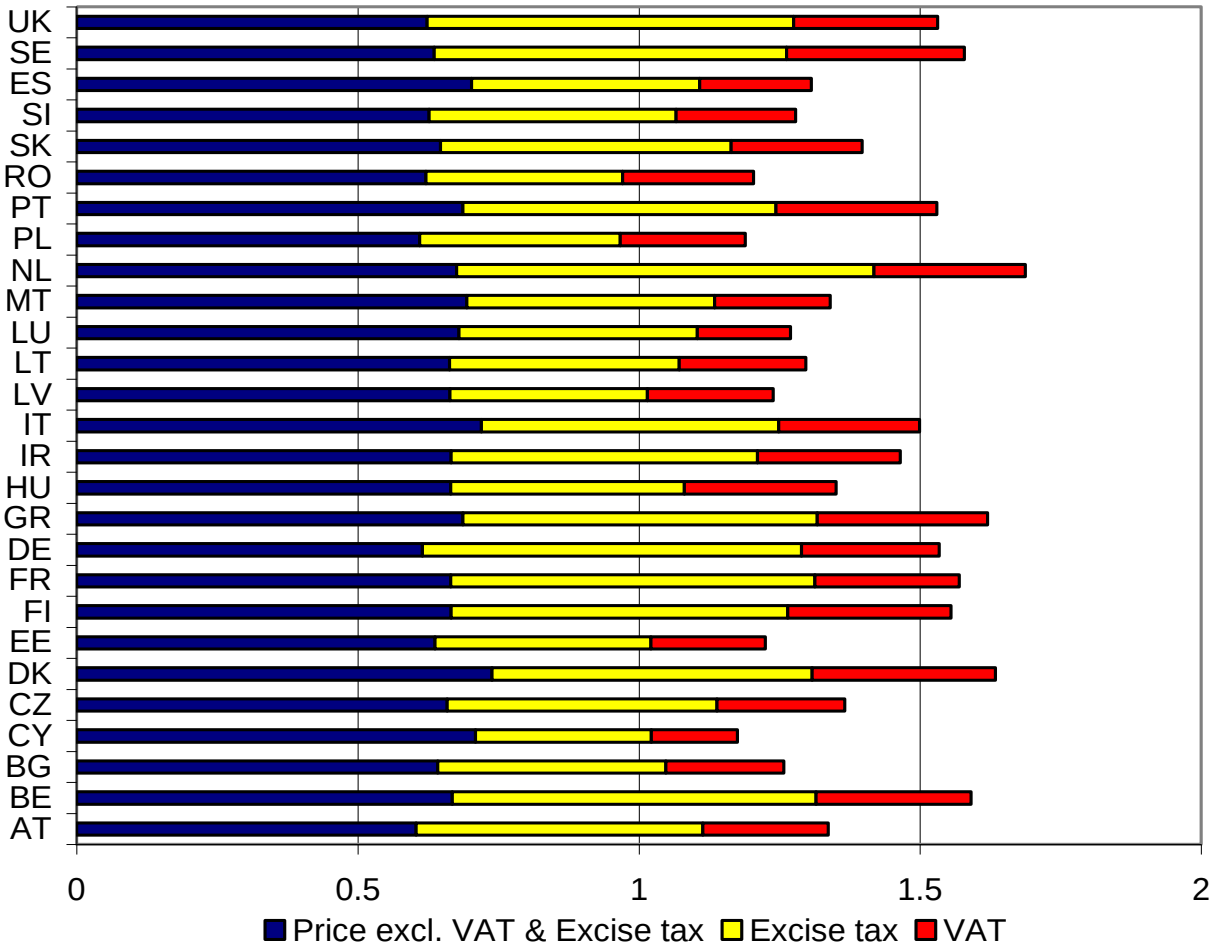
Source: IEA, 2004

Development of fuel prices



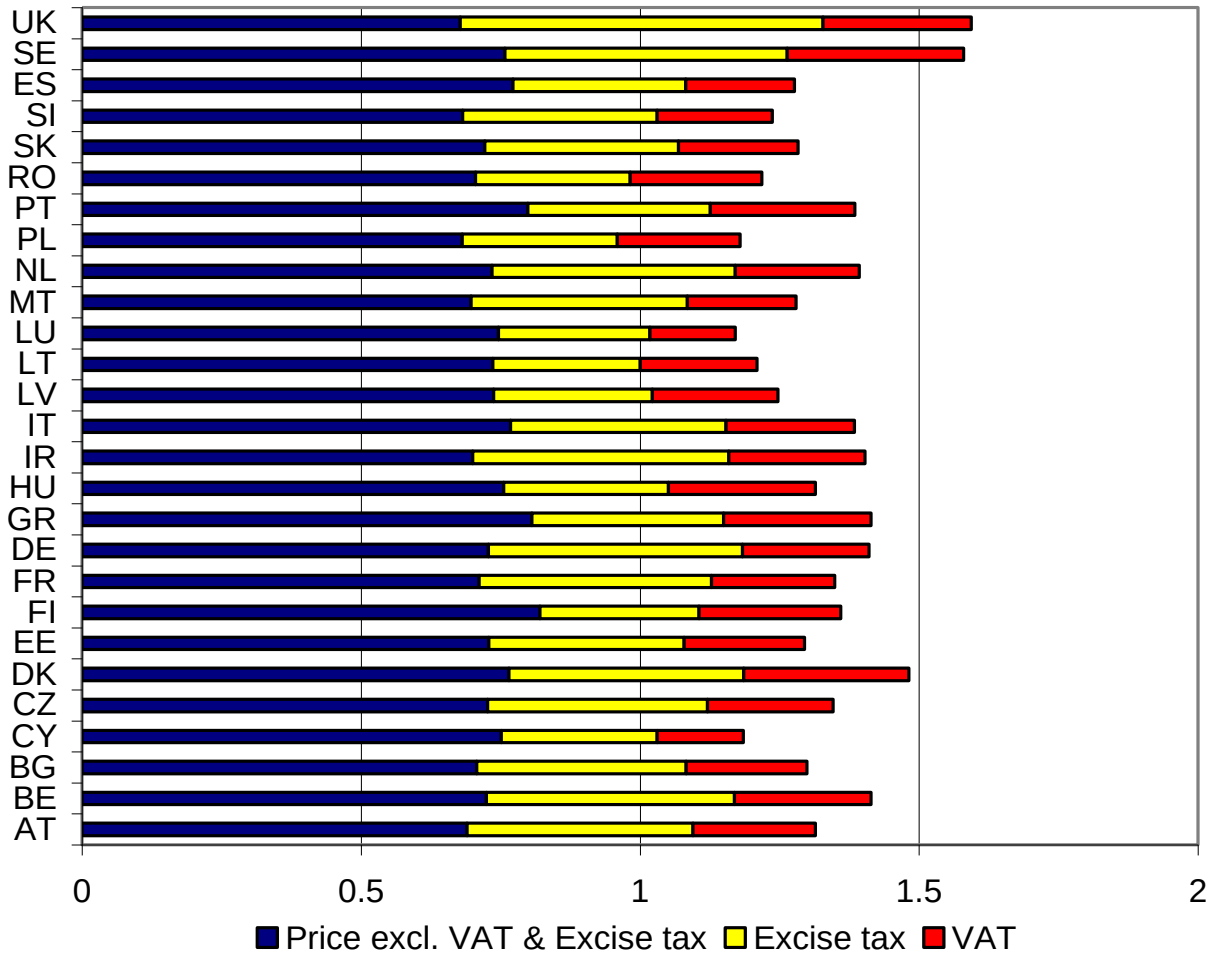
Weighted fuel prices (including all taxes) for EU countries 1980 – 2010
(in prices of 2010, numbers for 2010 preliminary) (Source: EEP; IEA, 2010)

Development of fuel prices



Price structure of gasoline in EU-27 (data source: EEP, 2011 - effective March 2, 2011)

Development of fuel prices



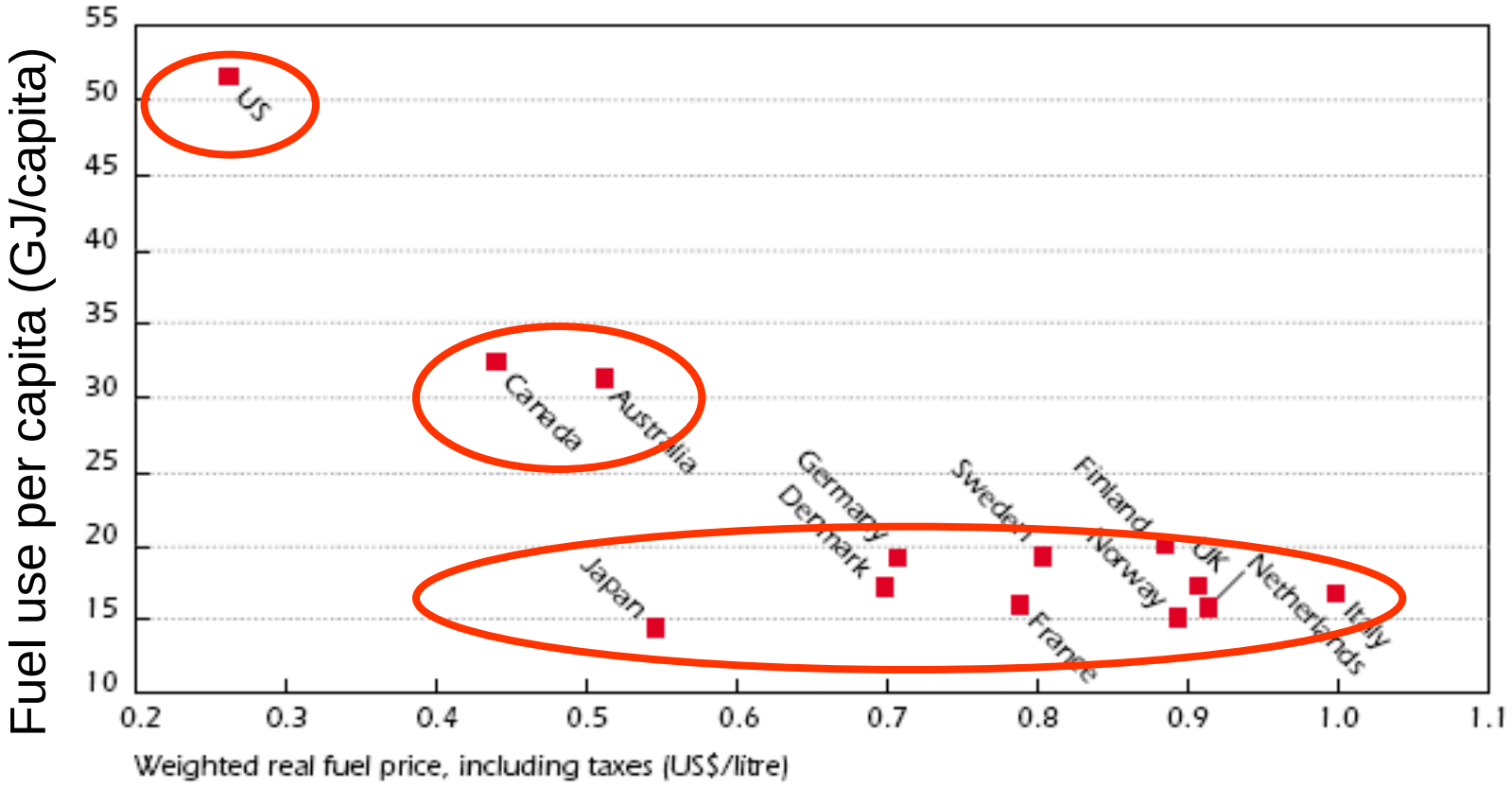
Diesel prices in 2011 for EU-27 (data source: EEP, 2011 - effective March 2, 2011)

3. Indicators

Fuel Use per Capita versus Fuel Prices

Car Fuel Use per Capita versus Average Fuel Price, 1998

Energy use for cars is much higher in countries with low fuel prices



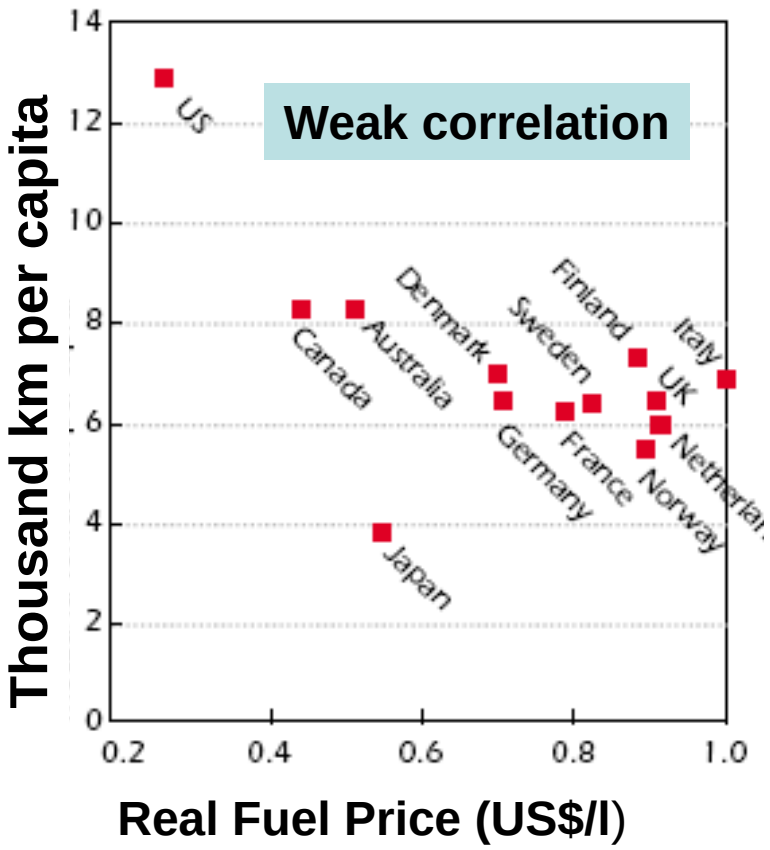
Source: IEA, 2004

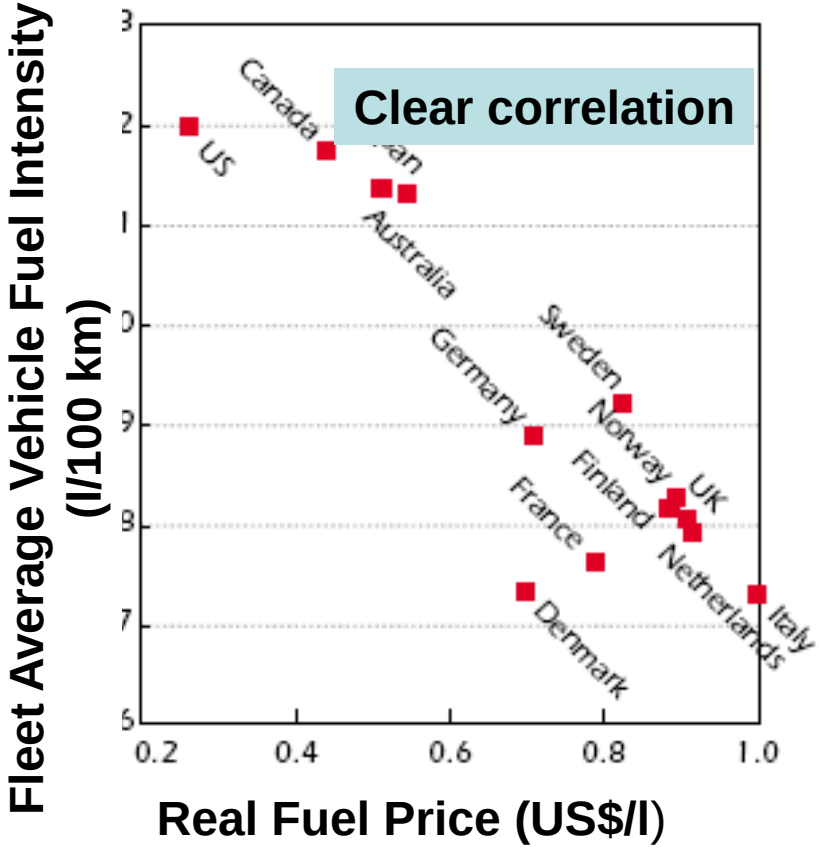
3. Indicators

Vehicle Travel and Intensities versus Fuel Prices

Passenger Car Travel per Capita and Car Fuel Intensity versus Average Fuel Price, 1998

Higher fuel prices correlate with lower vehicle fuel intensity and lower travel per capita, though the travel effect is fairly weak





Source: IEA, 2004

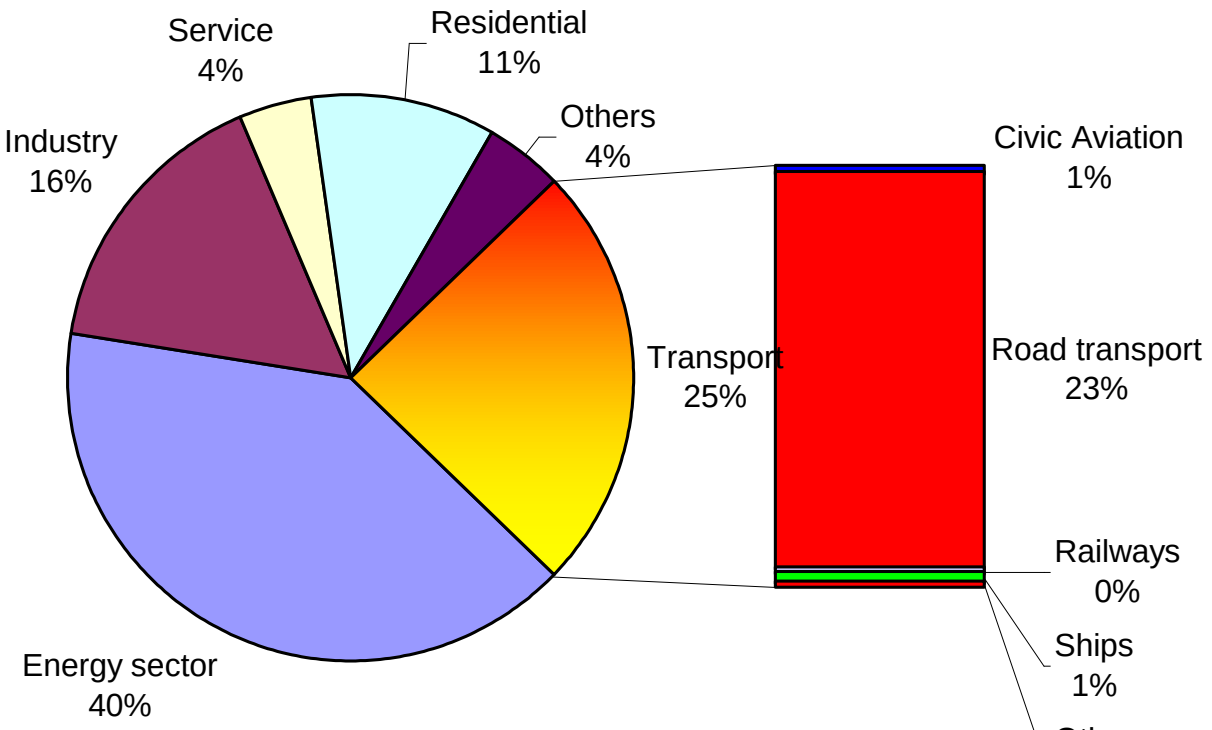
3. Indicators

- Passenger transport is almost exclusively based on petroleum products. Growth in passenger travel has been the biggest contributor to increased oil demand.
- Changes in passenger transport energy use, as well as its components (travel activity and energy intensity), are related to income growth and changes in fuel prices, among other factors.
- Countries with relatively high fuel prices tend to have lower average vehicle energy intensities and fuel use than countries where fuel prices are low.
- Increases in car ownership and travel levels are closely related to income growth. Together, these relationships help account for large differences in transport energy use per capita among countries.

4. Comparison of technical, economic, and ecological aspects

GHG emissions

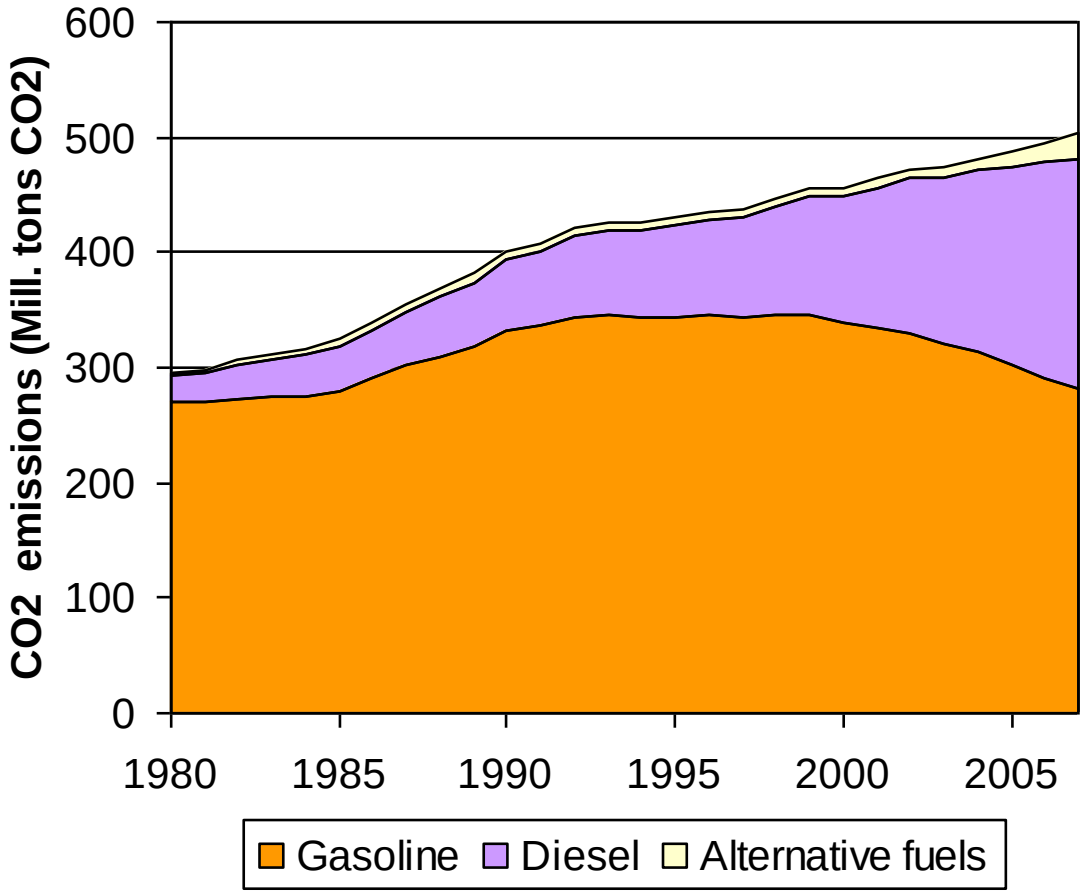
GREENHOUSE GAS EMISSIONS EU-27



TOTAL ENERGY 2007:
4000 Mio tons CO2_equ

Source: EU, 2010

GHG emissions



Development of CO2 emissions of car passenger transport in EU-15 by fuel, 1980 – 2007

Biofuels

Biofuel	Liquid or gaseous fuel for transport produced from biomass

* **Bioethanol** produced from wheat, sugar beet and sugar cane, it is used as a fuel additive to gasoline or as a substitute of conventional fossil gasoline.

* **Biodiesel** is produced from different kinds of vegetable oil (e.g. rape seed, sunflower, and soybean) and a mix of different methyl esters. It is currently used as an additive or substitute for conventional fossil diesel.

Biofuels

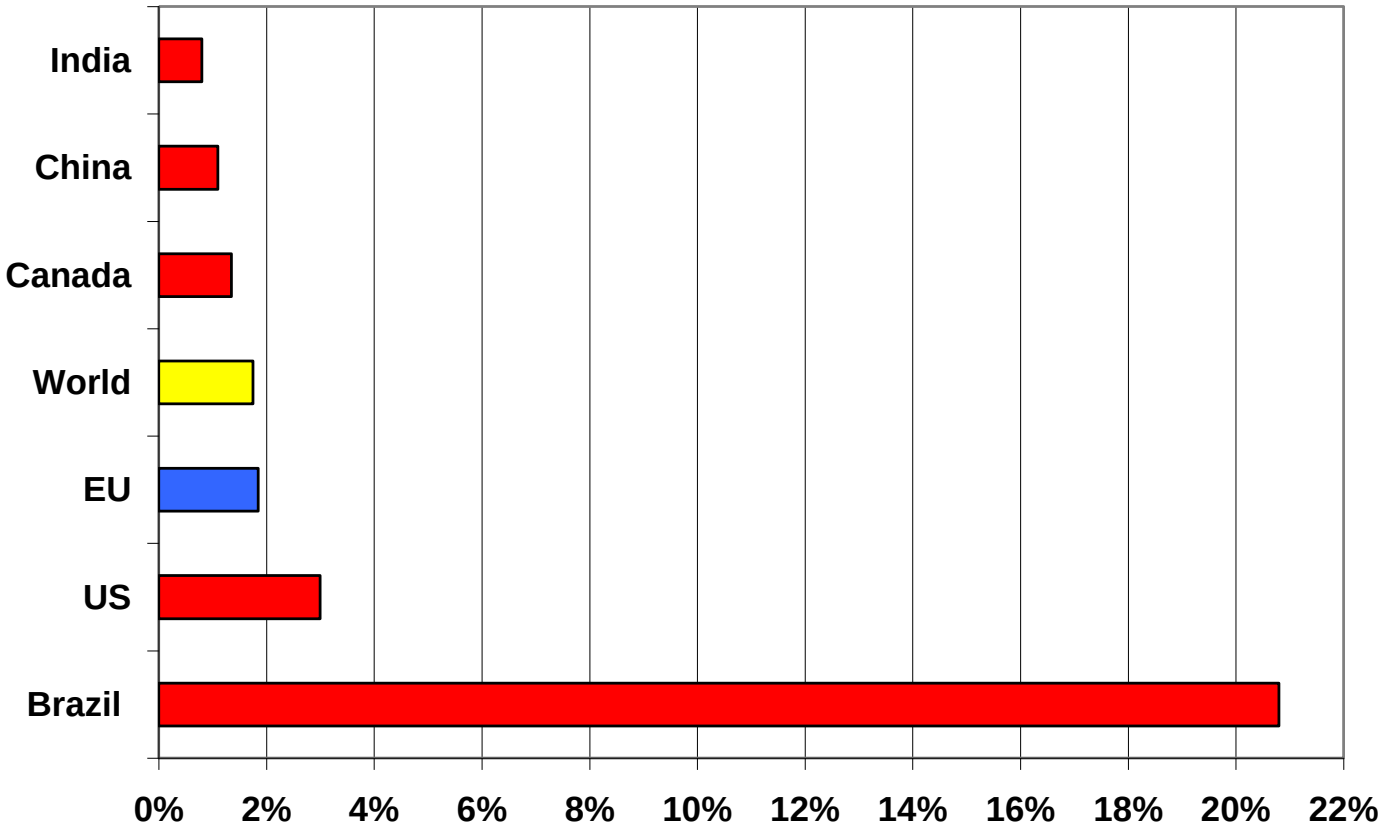
•**Low bioethanol blends**:
From 5 to 22% bioethanol with gasoline known as
E5G or E22G. The particularity from these blends is that they do not require engine modifications and can be supplied with the same infrastructure.

• **High bioethanol blends**:
These blends reach 85 % bioethanol content in
gasoline. They require special engine modifications and have widely been used in flexible fuel vehicles (FFV).

• **Biodiesel**:
Currently used in different mixtures and blends from 100% or
known as pure biodiesel B100. Existing blends also vary in content from 5% known as B5 with 95% fossil diesel, B20 and more.

Share of biofuels in total road-fuel consumption in energy terms, 2007

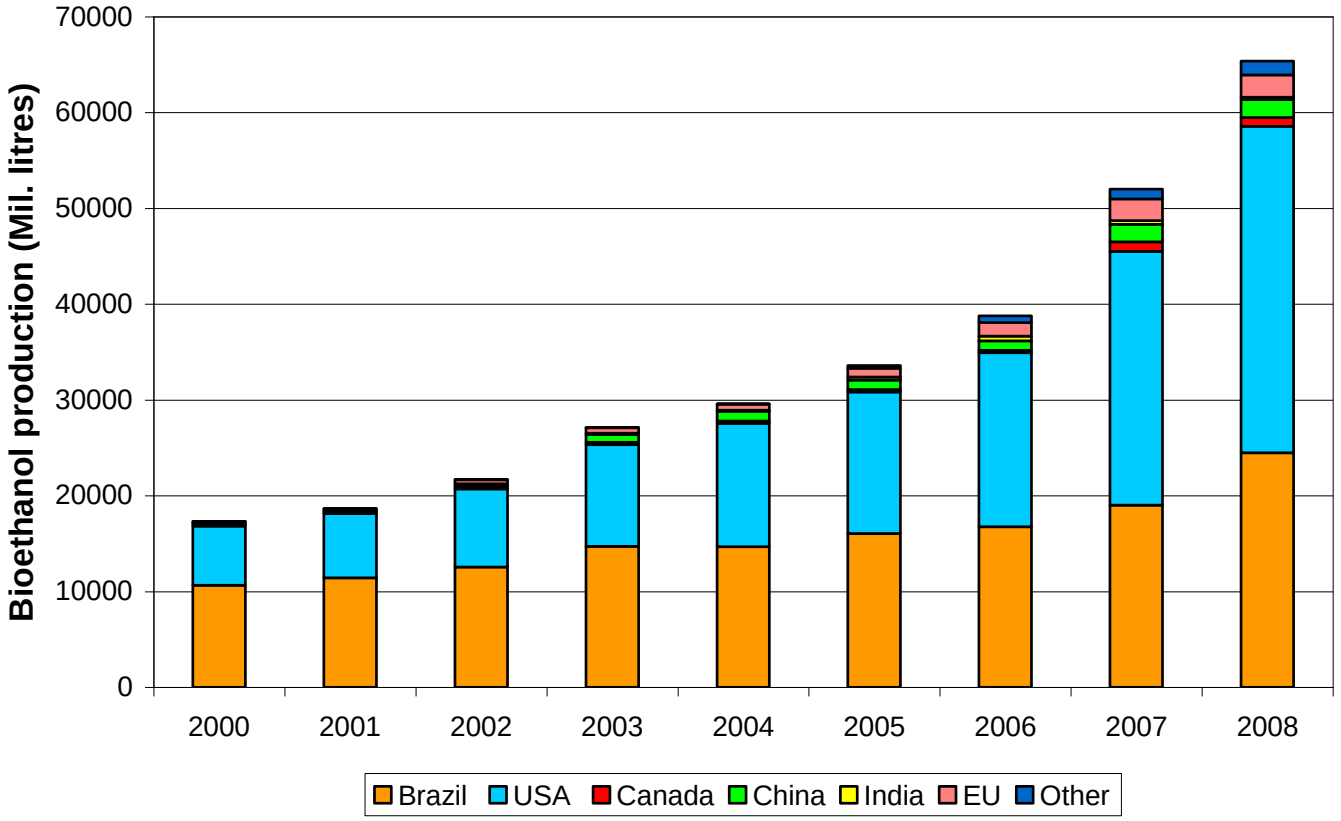
Biofuels currently meet less than 2% of road-fuel demand worldwide, but close to 21% in Brazil



Source: F.O.Licht,IEA

Bioethanol

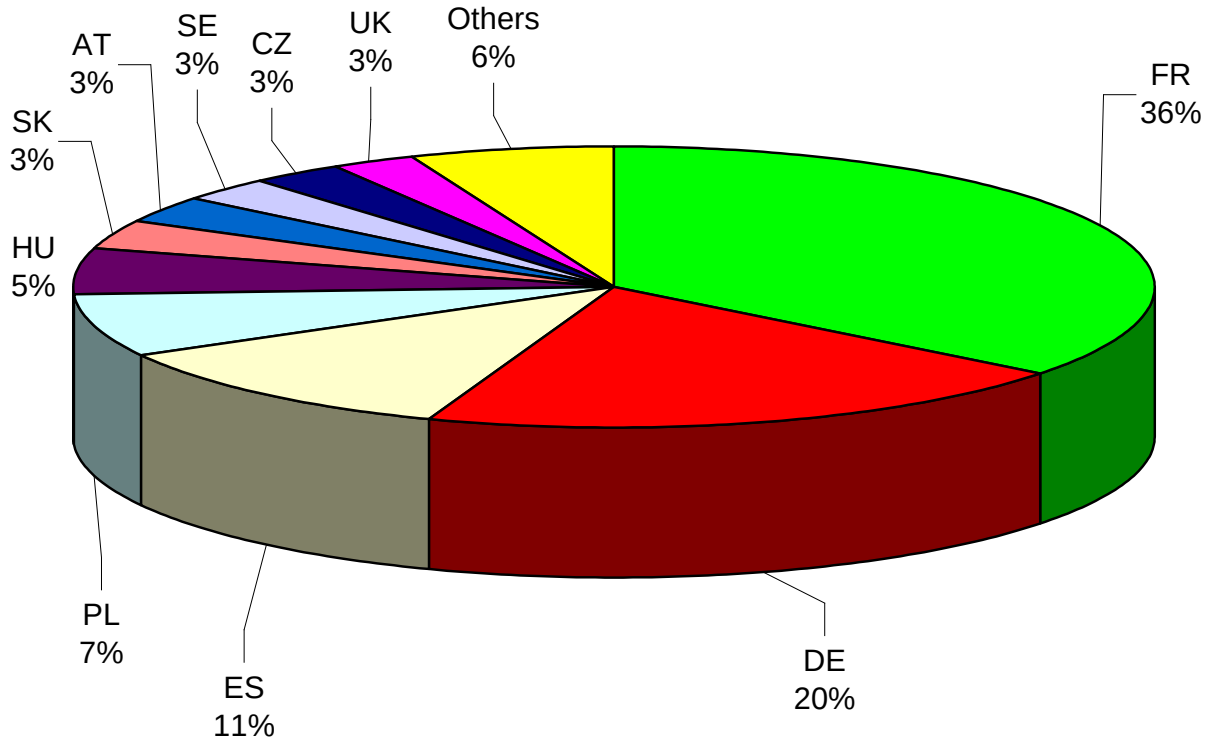
Recent Trends in Ethanol Production



Source: F.O.Licht, IEA, EBTP

Bioethanol

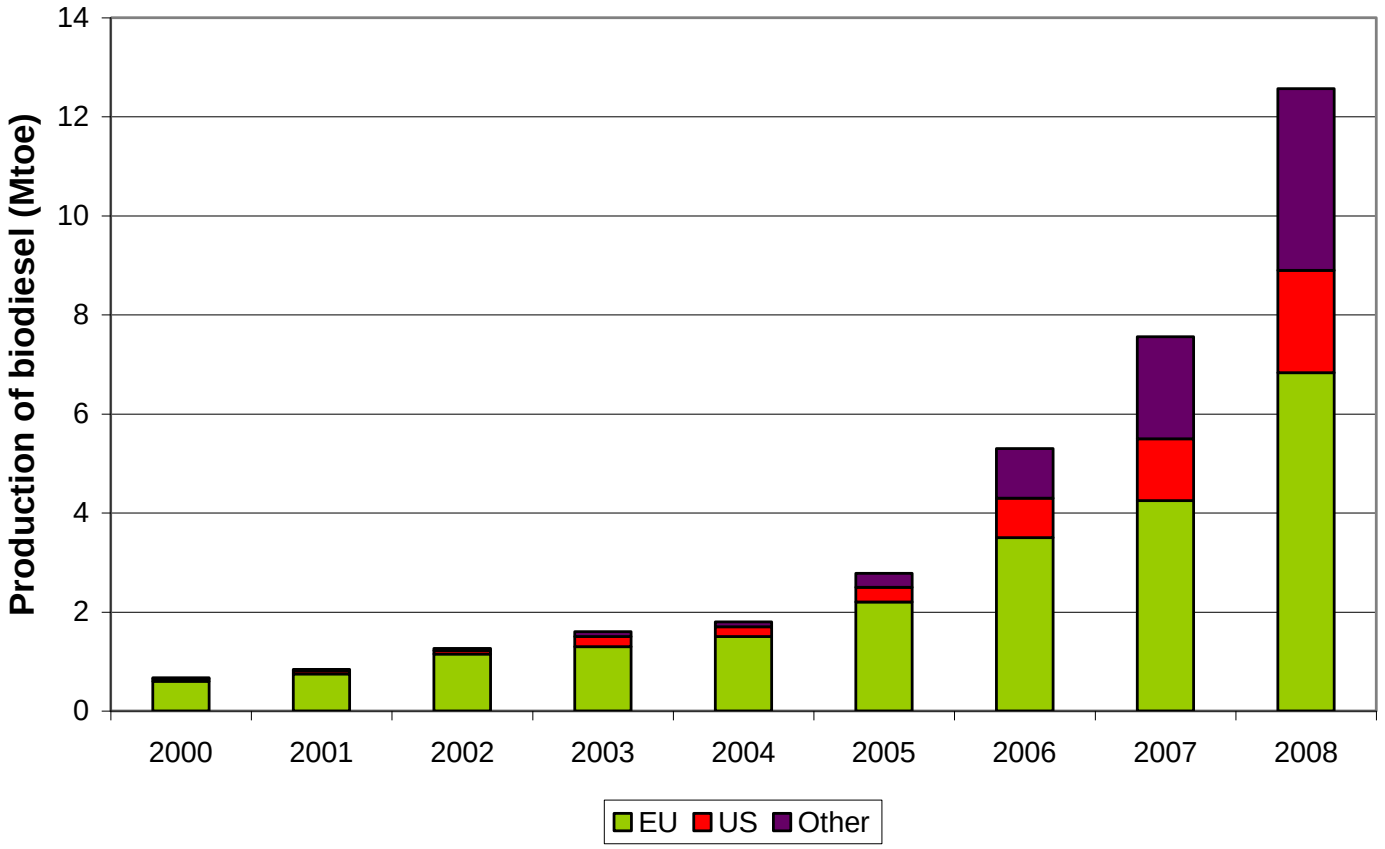
Shares of bioethanol production 2008 in EU-27 countries



Source: EBTP

Biodiesel

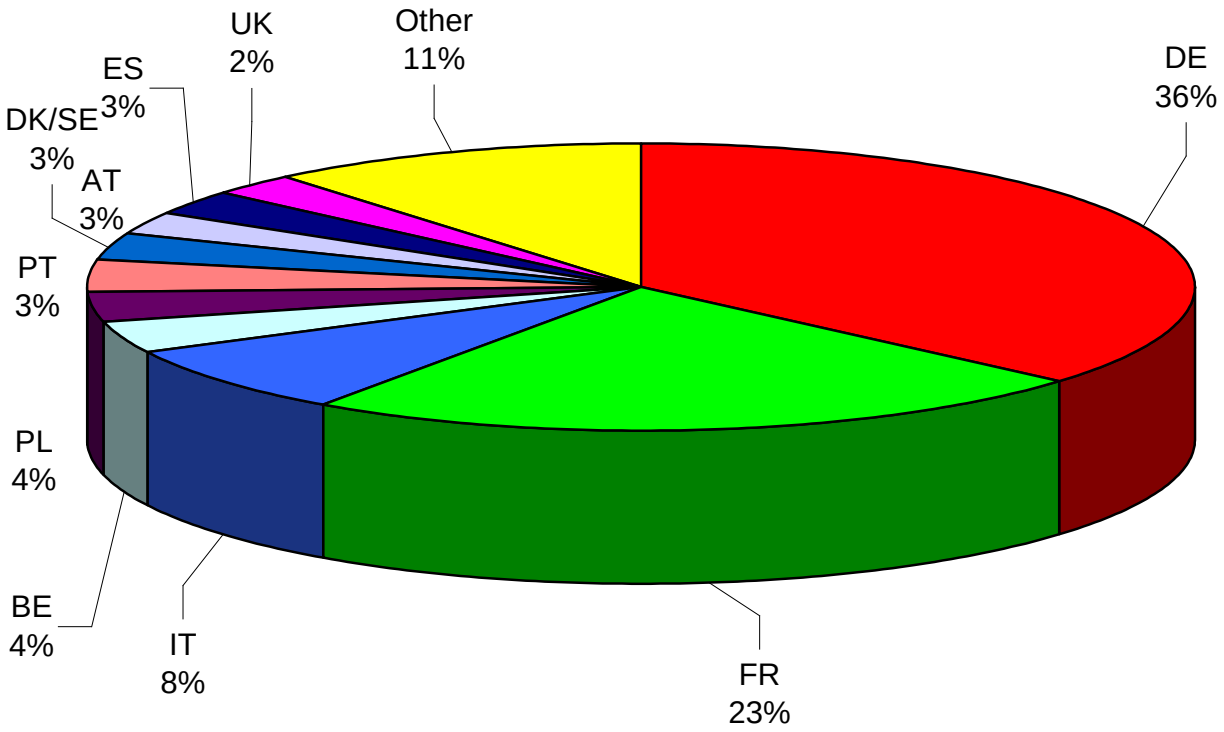
Recent Trends in Biodiesel Production



Source: F.O.Licht, IEA, EBTP

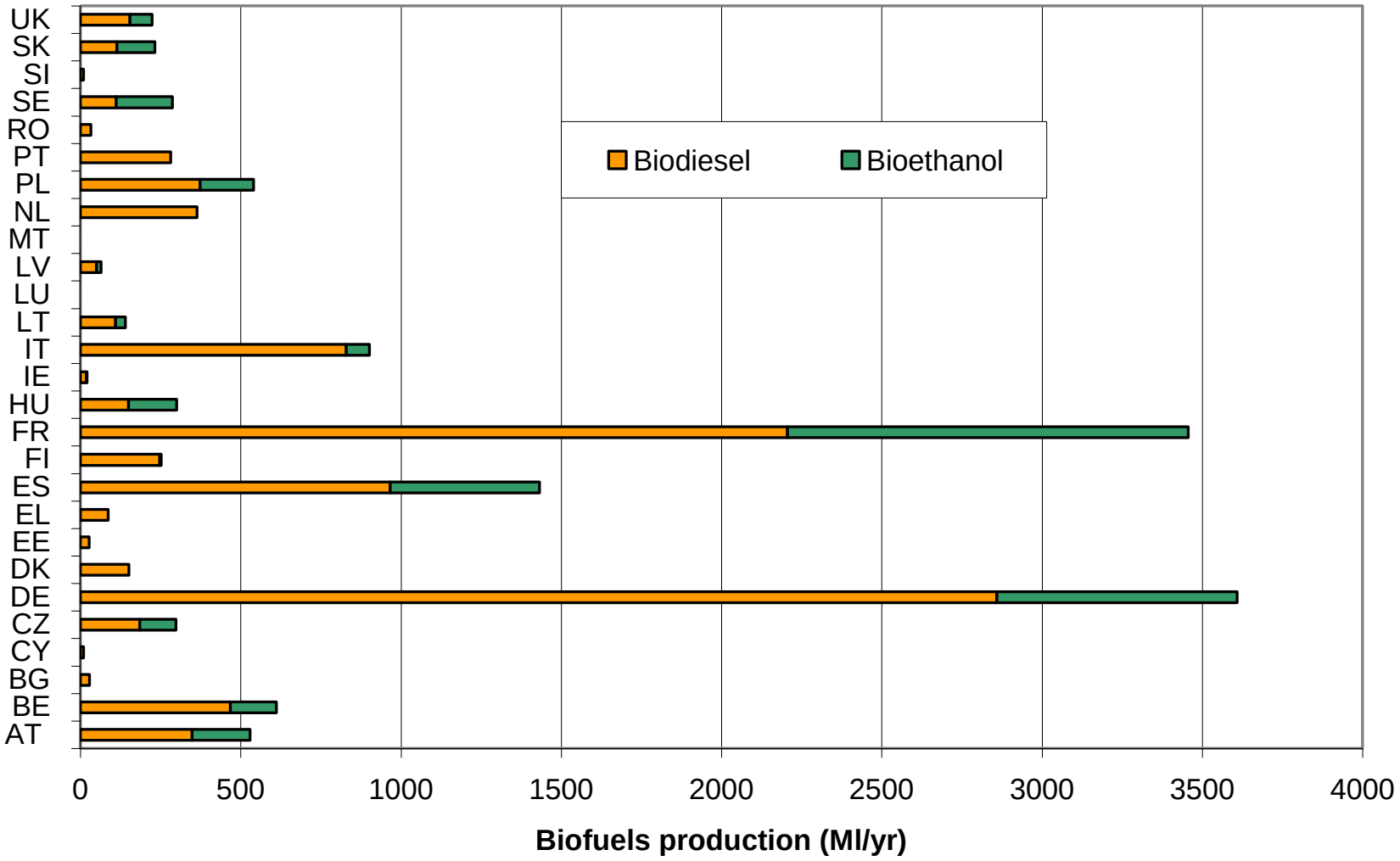
Biodiesel

Shares of biodiesel production 2008 in EU-27 countries



Source: EBTP

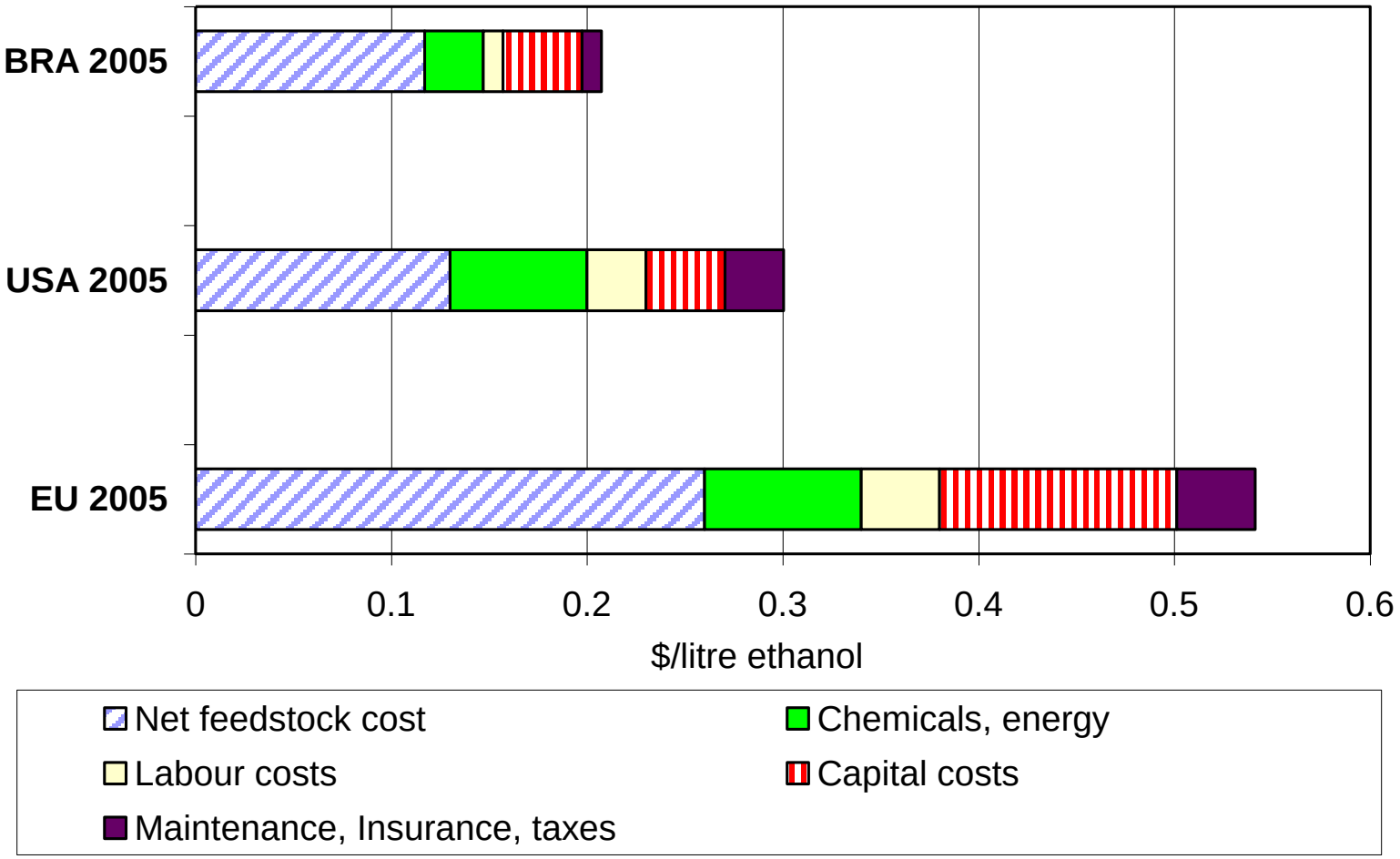
Biofuel production in EU-27, 2008



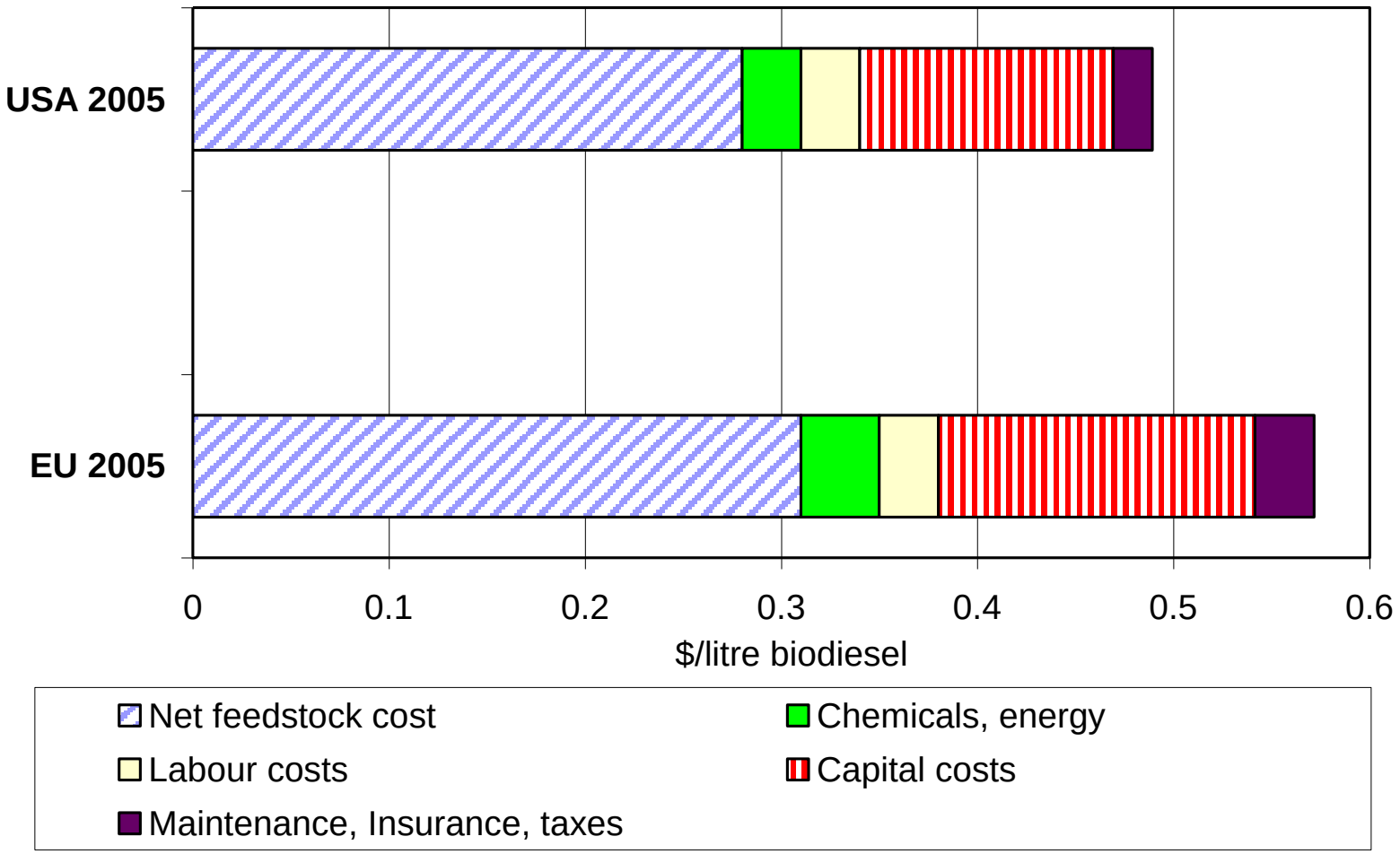
Biofuels

General Cost Component Structure for Biofuels	
Feedstock Costs	
Bioethanol Energy Crops	Biodiesel Energy Crops
Conversion Costs	
Bioethanol Conversion Process	Biodiesel Conversion Process
Total Costs	
Bioethanol Total Costs	Biodiesel Total Costs

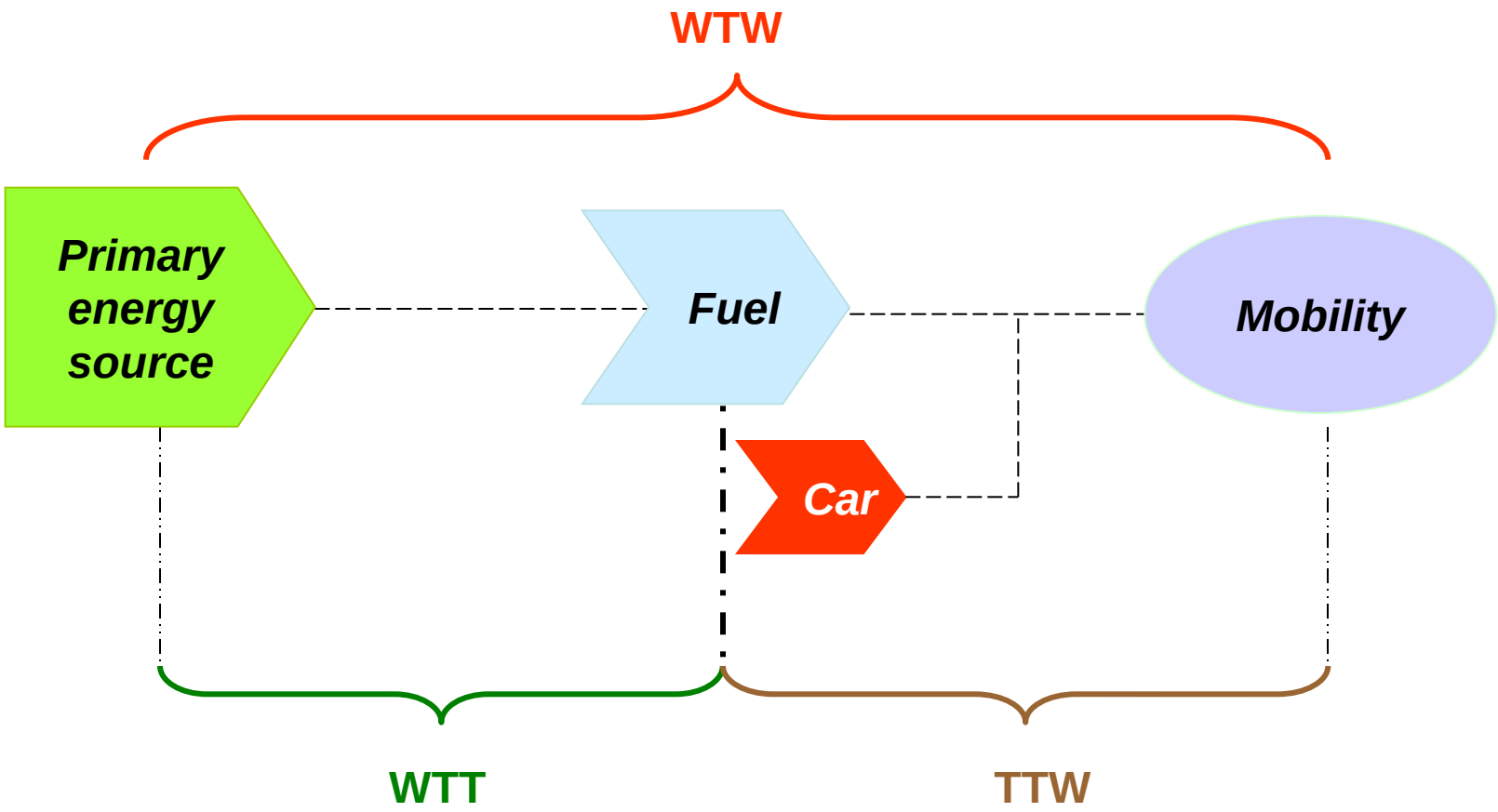
Bioethanol


BRA 2005
USA 2005
EU 2005
0
0.1
0.2
0.3
0.4
0.5
0.6
$/litre ethanol
Net feedstock cost
Chemicals, energy
Labour costs
Capital costs
Maintenance, Insurance, taxes

Biodiesel


USA 2005
EU 2005
0
0.1
0.2
0.3
0.4
0.5
0.6
$/litre biodiesel
Net feedstock cost
Chemicals, energy
Labour costs
Capital costs
Maintenance, Insurance, taxes

Energy chain



Energy service providing chain

WTW-energy

The overall energy used to provide mobility is dependent from total energy in the WTT- and the TTW-part of the chain:

$$E_{WTW} = E_{WTT} + E_{TTW}$$

In the both parts of the energy supply chain we can use fossil and/or renewable energy.
The total energy used in WTT part could be split in a fossil part (FF) and a renewable part (RE):

$$E_{WTT} = E_{RE-WTT_{fuel}} + E_{FF-WTT_{fuel}}$$

$E_{RE\text{-}WTT\text{-}fuel}$.....total renewable energy used for production of fuel
$E_{FF\text{-}WTT\text{-}fuel}$.....total fossil energy used for production of fuel

In TTW part total energy can be divided in four parts:

$$E_{TTW} = E_{RE-TTW_{fuel}} + E_{FF-TTW_{fuel}} + E_{RE_{car}} + E_{FF_{car}}$$

$E_{\mathbf{RE}\text{-}TTW\text{-}fuel}$.....total renewable energy used in cars
$E_{\mathbf{FF}\text{-}TTW\text{-}fuel}$.....total fossil energy used in cars
$E_{\mathbf{RE}\text{-}car}$.....renewable energy used for production and scrappage of car
$E_{\mathbf{FF}\text{-}car}$.....fossil energy used for production and scrappage of car

Driving costs

Total driving costs C_{drive} per year:

$$C_{drive} = IC\ \alpha + P_f FI\ \ skm + C_{O\&M} \qquad \text{[€/car/year]}$$

IC……investment costs [€/car]
α……..capital recovery factor
skm…..specific km driven per car per year [km/(car.yr)]
Pf……..fuel price incl. taxes [€/litre]
$C_{O\&M}$…operating and maintenance costs
FI……..fuel intensity [litre/100 km]

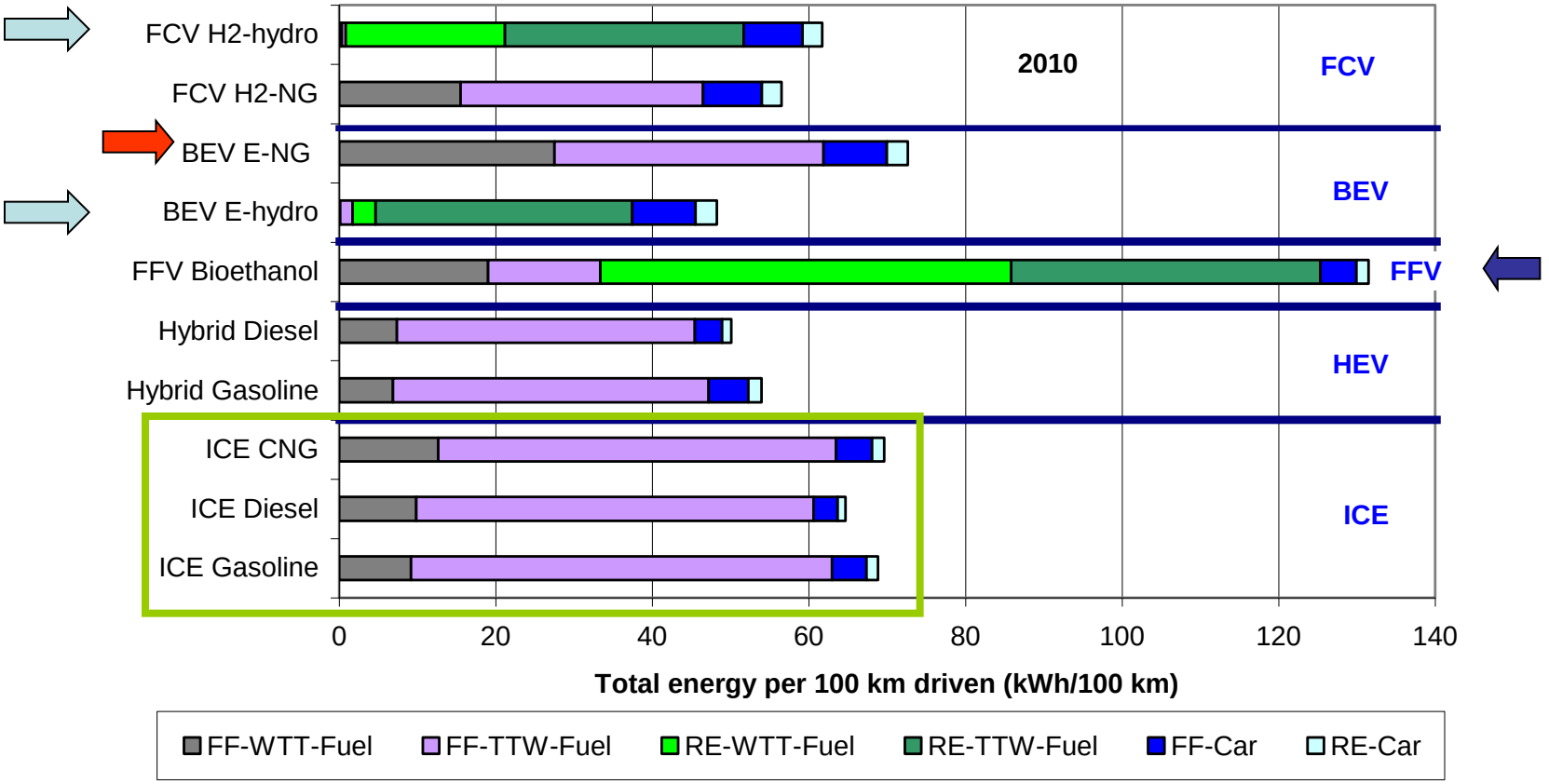
The costs per km driven C_{km} are calculated as:

$$C_{km} = \frac{IC \cdot \alpha}{skm} + P_f \cdot FI + \frac{C_{O\&M}}{skm} \qquad \text{[€/100 km driven]}$$

The fuel price depends on the cost of fuel C_f, and possible VAT, excise and CO_2 taxes:

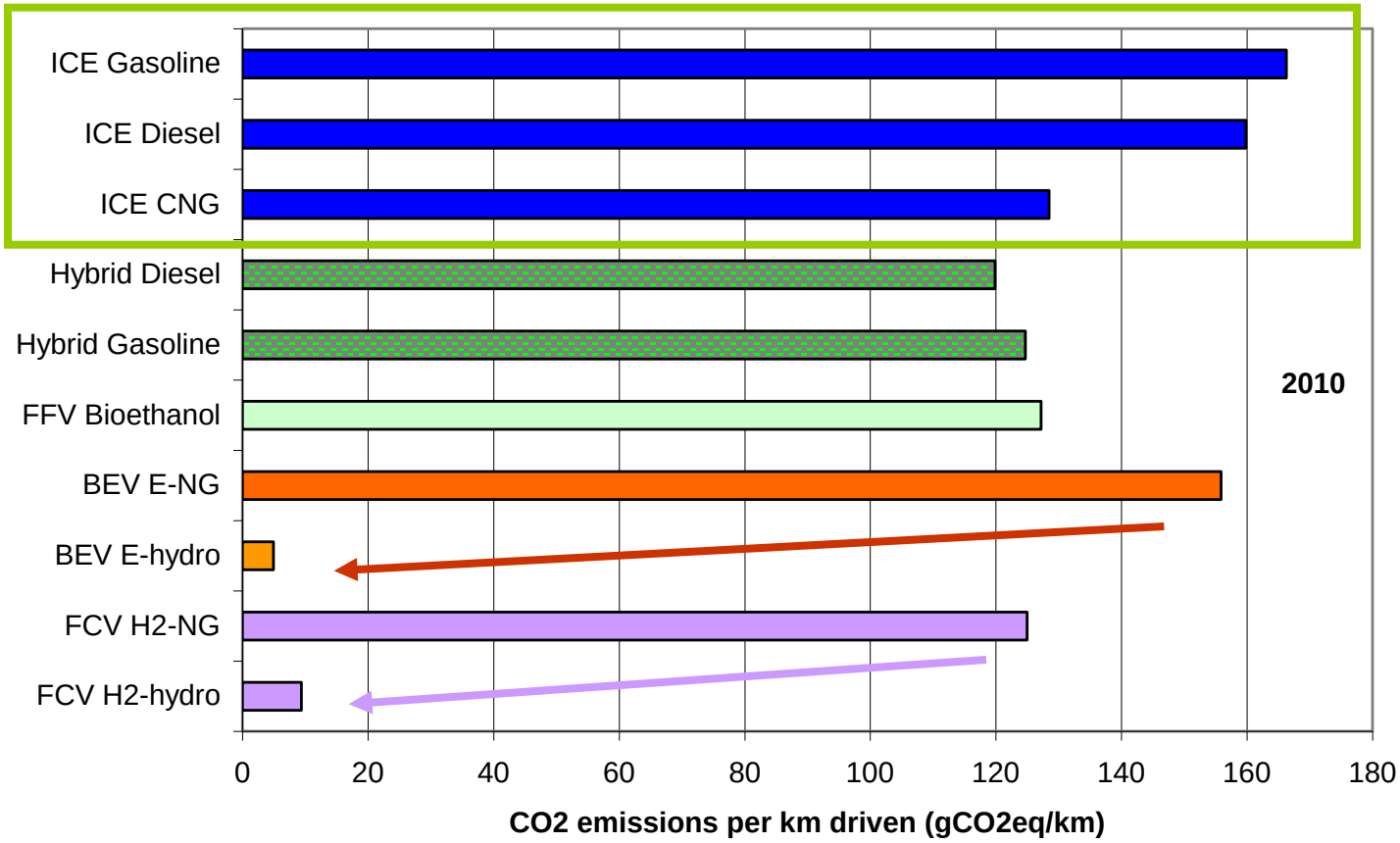
$$P_f = C_f + \tau_{CO_2} + \tau_{VAT} + \tau_{exc}$$

Energetic performance



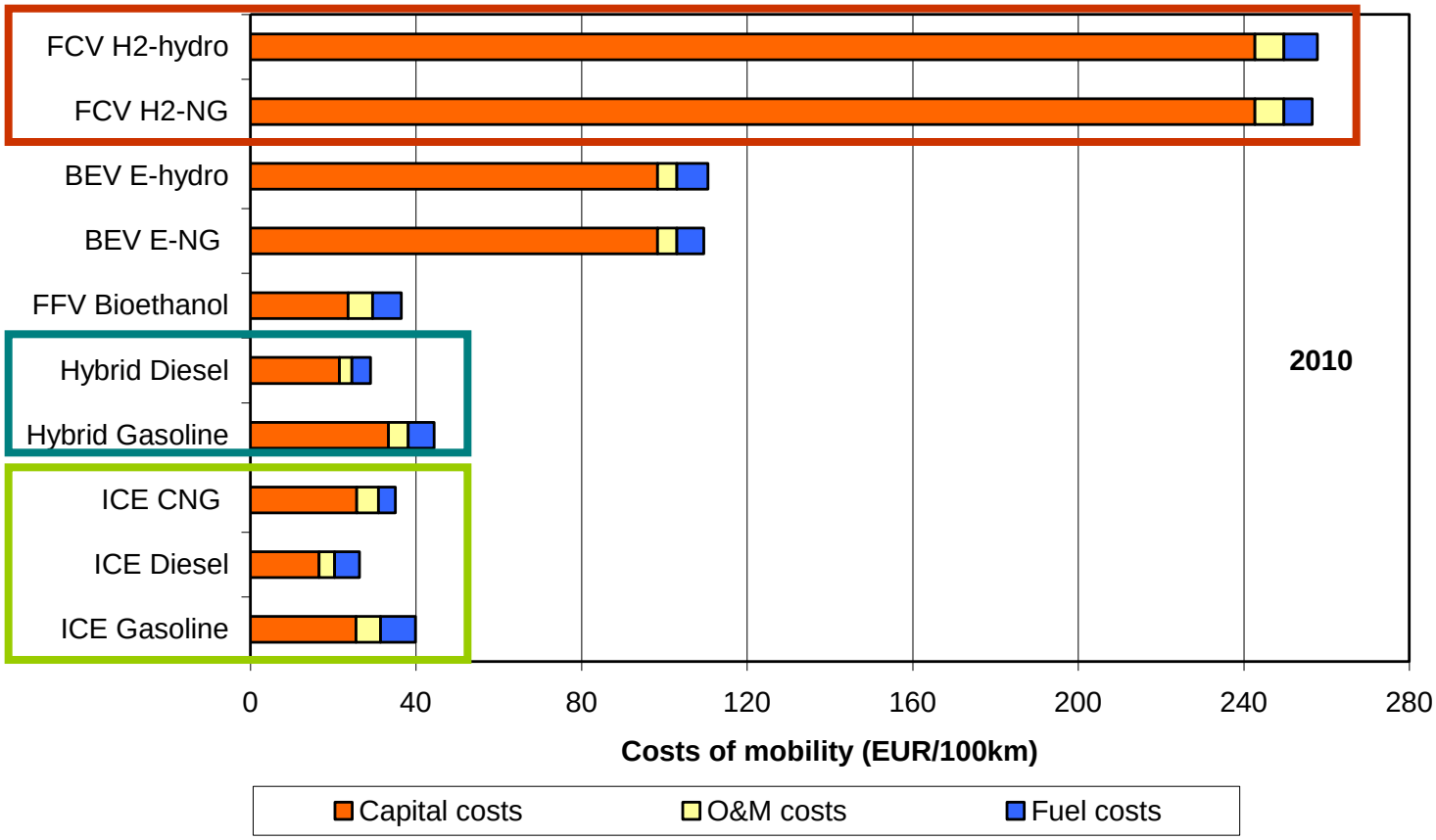
Renewable and fossil energy shares in the whole WTW energy service provision chain in 2010 for AAMT and alternative fuels in comparison with conventional ICE vehicles powered by fossil fuels

Ecological assessment



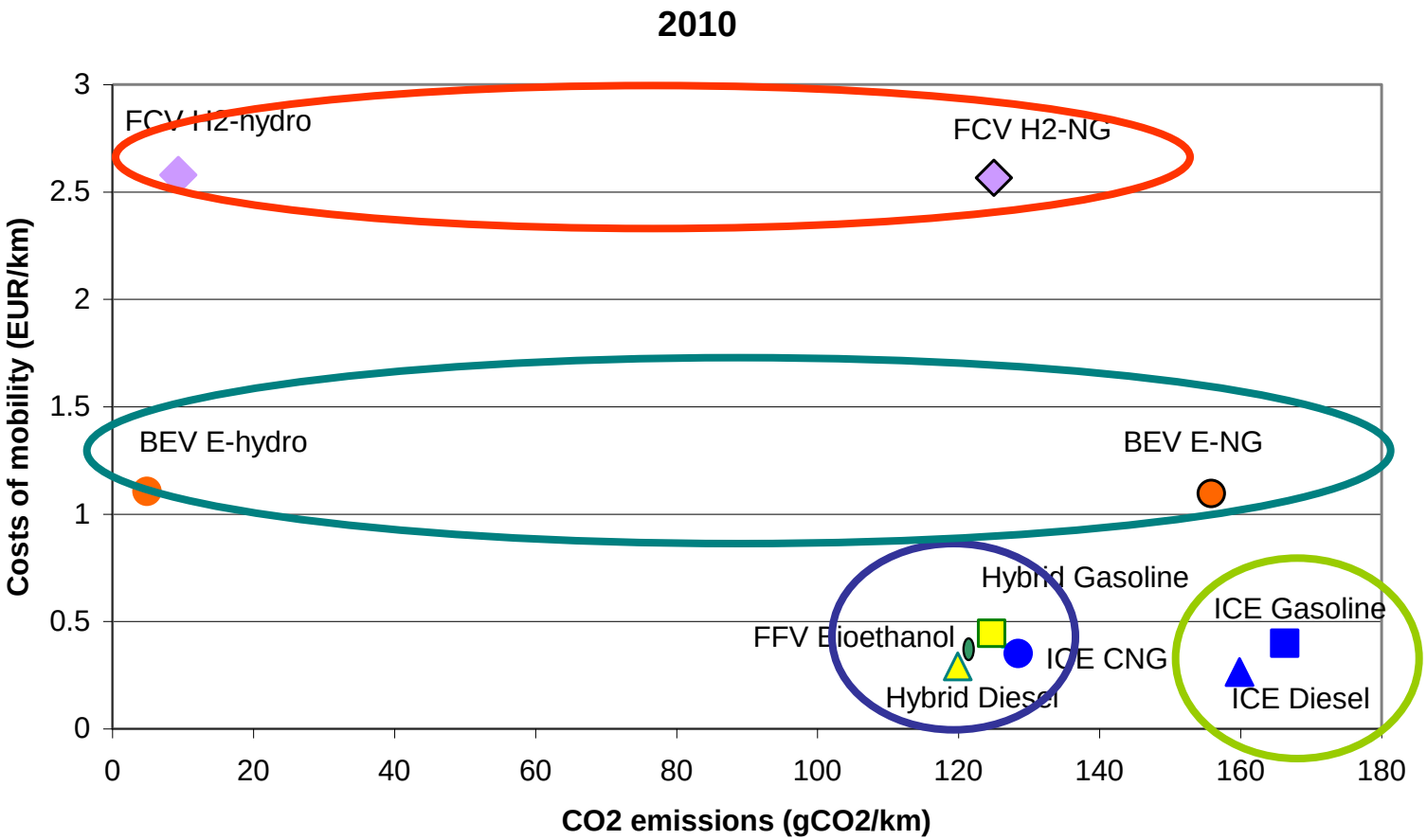
Comparison of specific CO2 emissions of conventional vehicles with AAMT in 2010

Economic assessment



Total costs of mobility in passenger cars in 2010

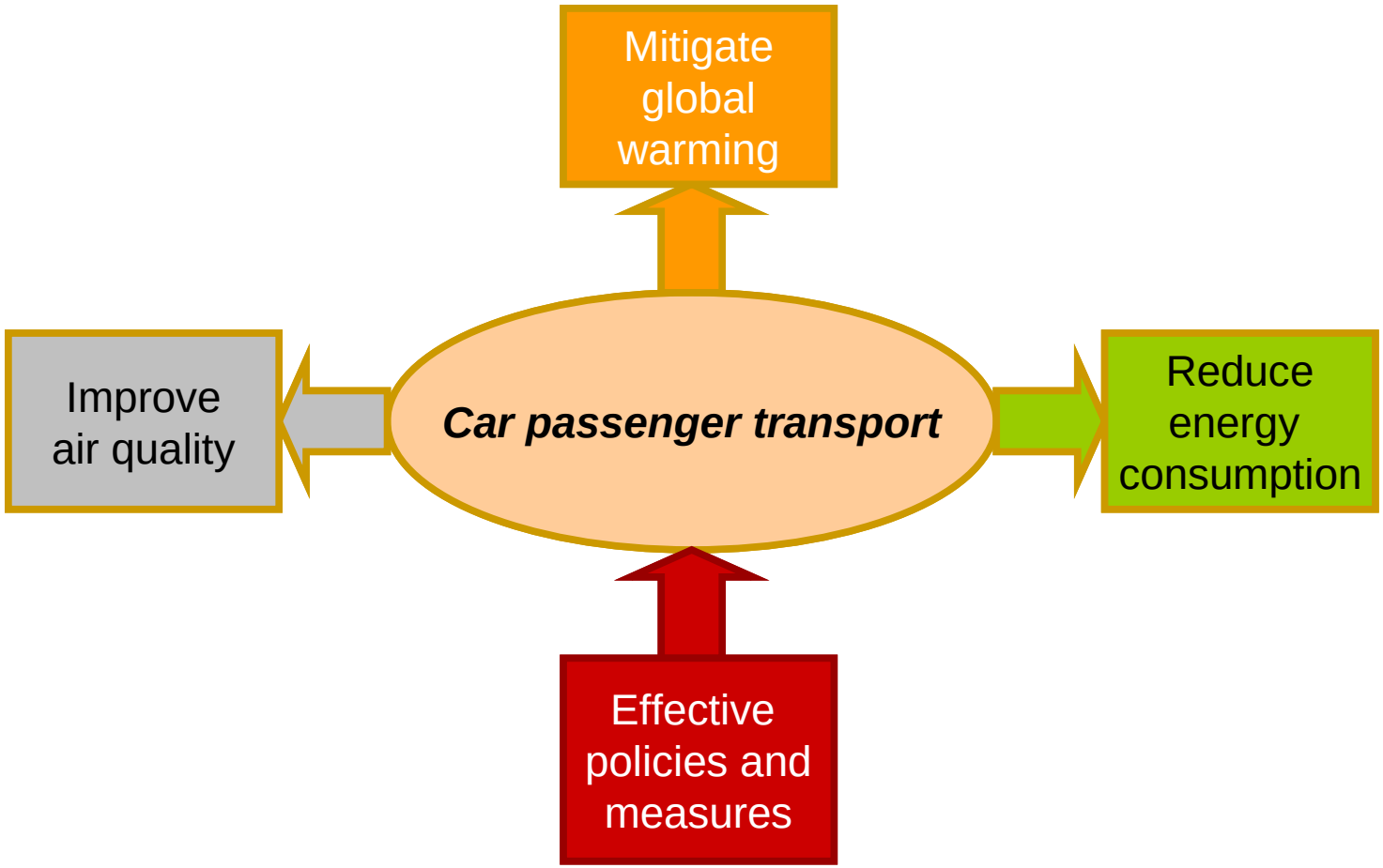
Economic assessment



Comparison of specific CO2 emissions and driving costs of conventional vehicles with alternative automotive vehicles in 2010

5. Energy policies

Energy policy



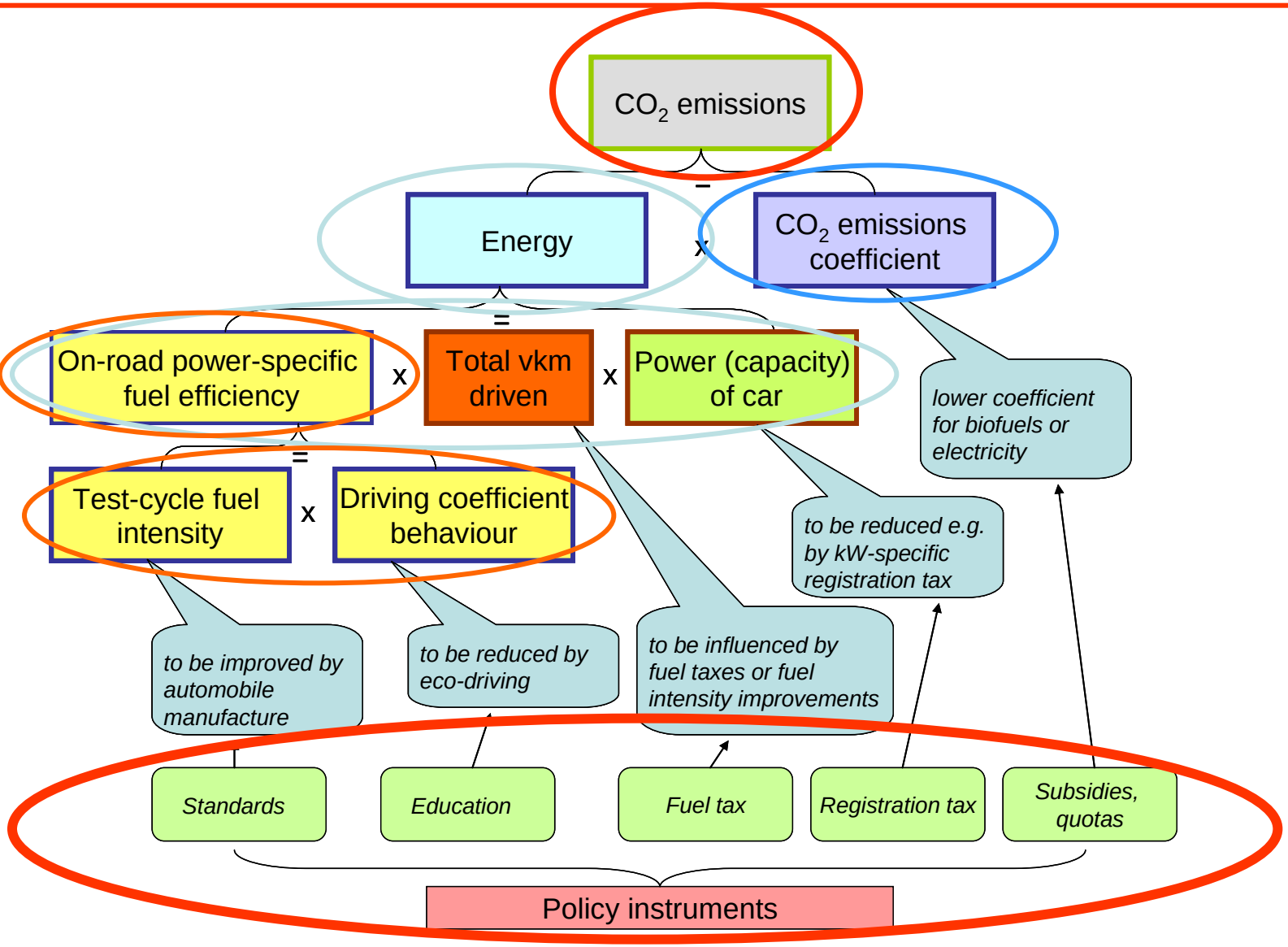
The challenges for EU climate and energy policies

Energy policy

At European Union level, a number of energy policies are already in place and aim to promote actively renewable energy sources including biofuels.

- Increase the use of renewable energy sources
- Promote electricity from renewable energy sources
- Replacement of diesel and gasoline fuels by alternative fuels

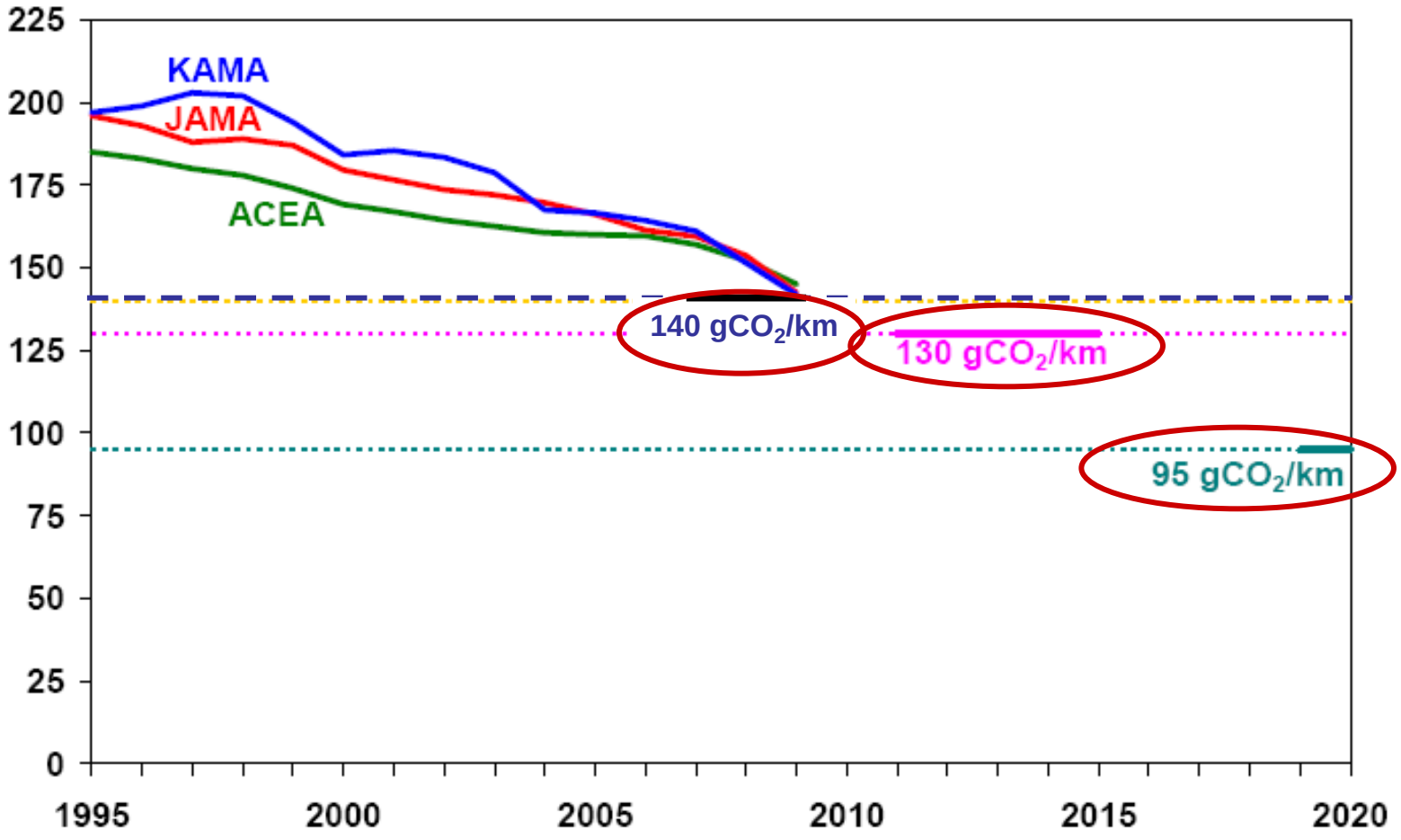
Energy policy



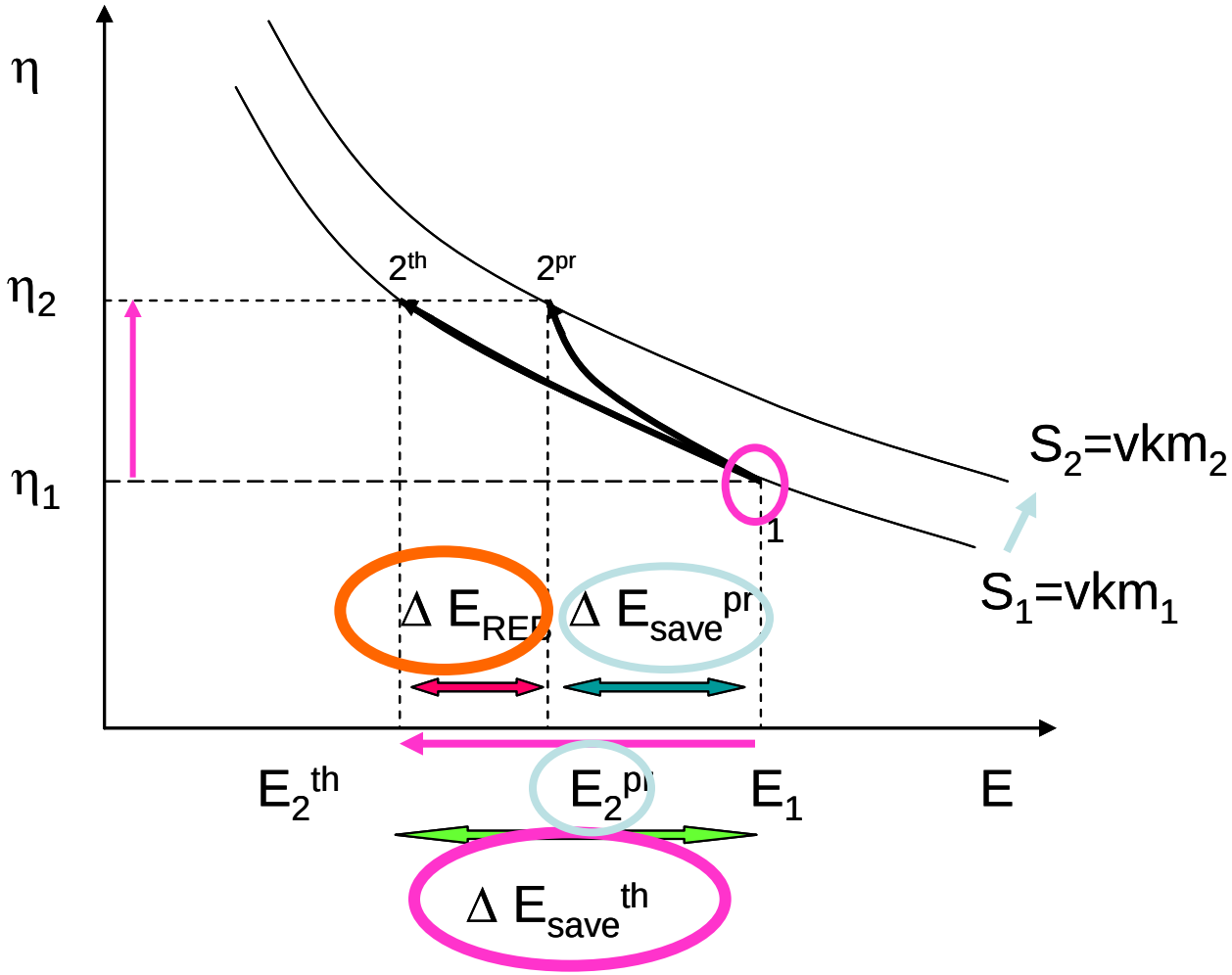
Impact factors on CO2 emissions in the car passenger transport sector

Energy Policy

Evolution of CO2 emissions from new passenger cars by the European (ACEA), Japanese (JAMA) and Korean (KAMA) car manufacturer associations

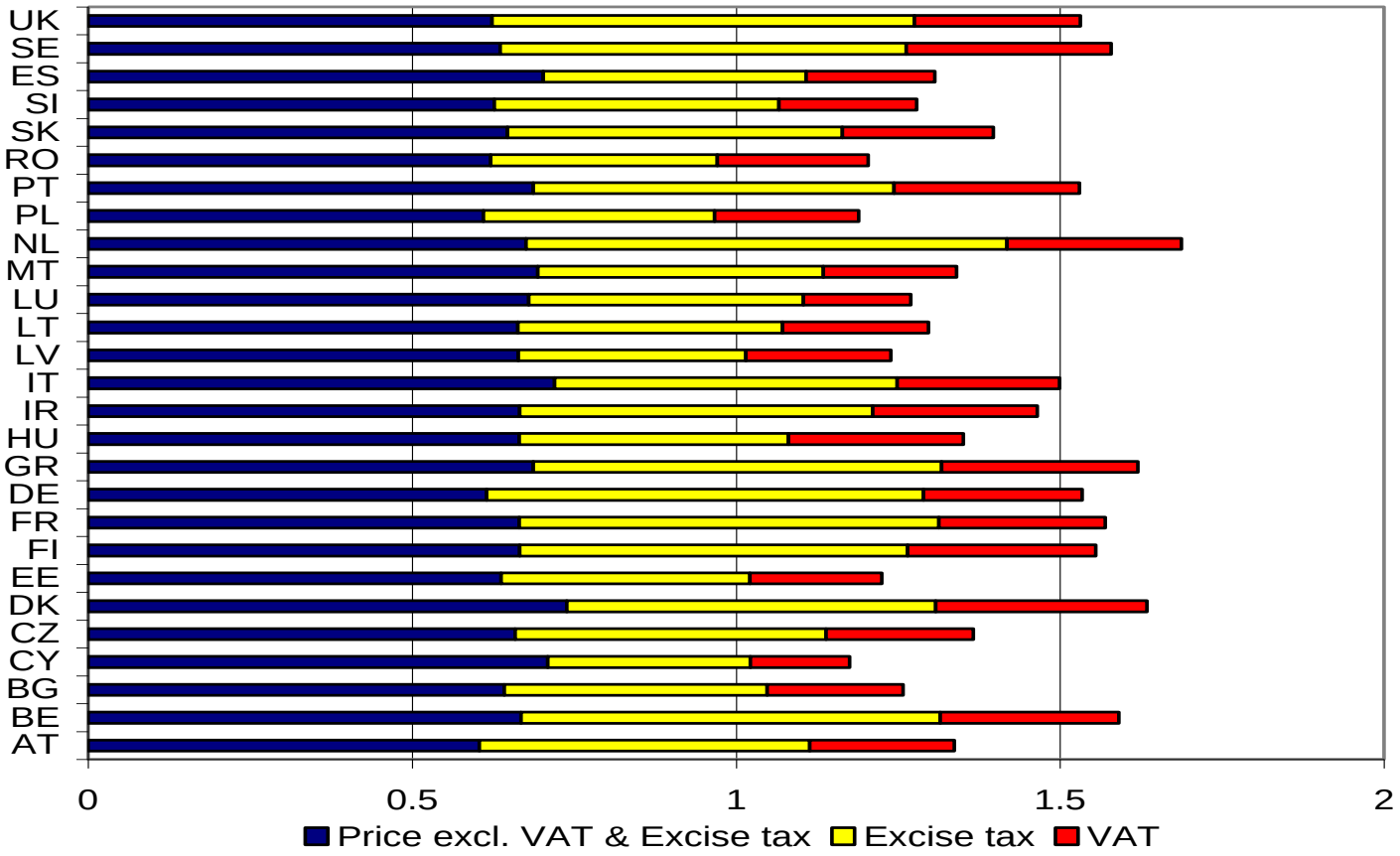


Rebound-effect



The rebound effect

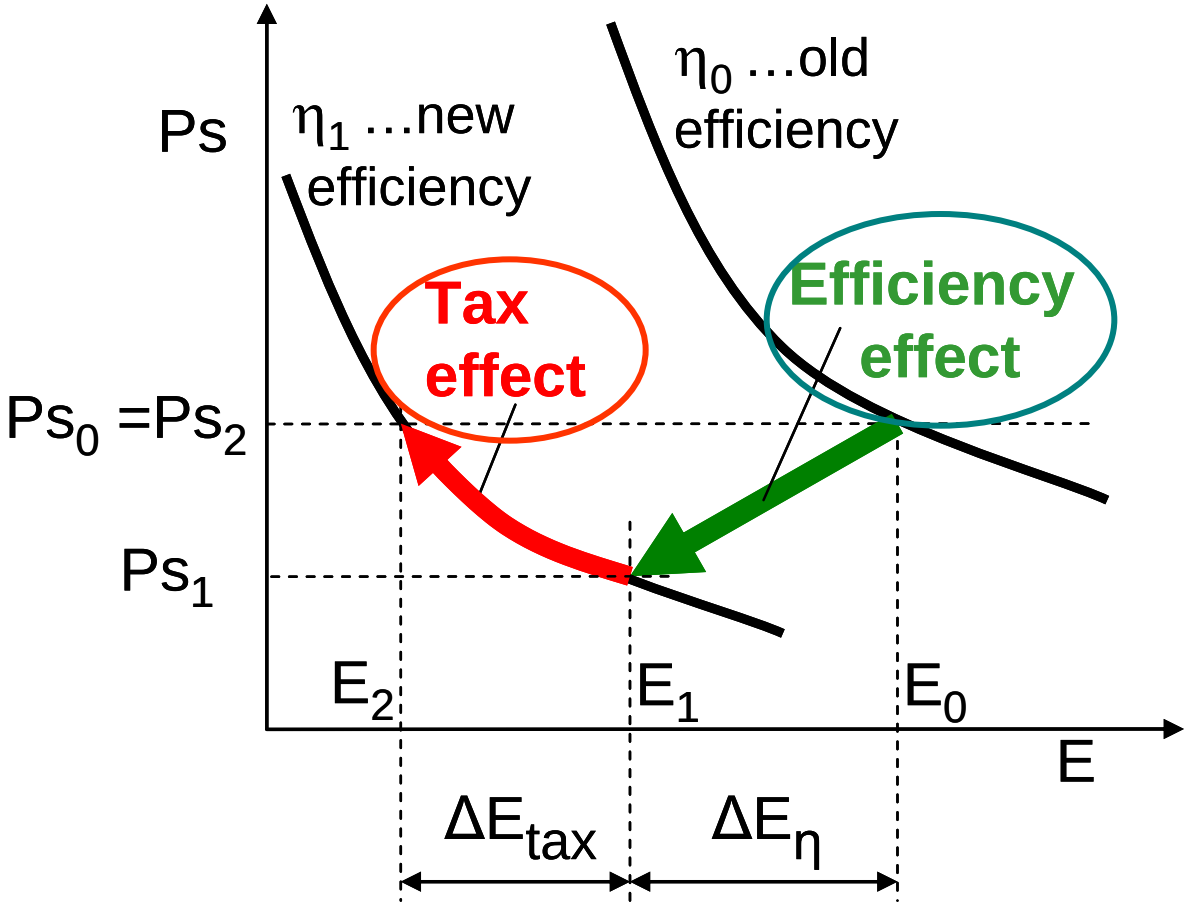
Energy Policy



Price structure of gasoline in EU-27

(data source: EEP, 2011 - effective March 2, 2011)

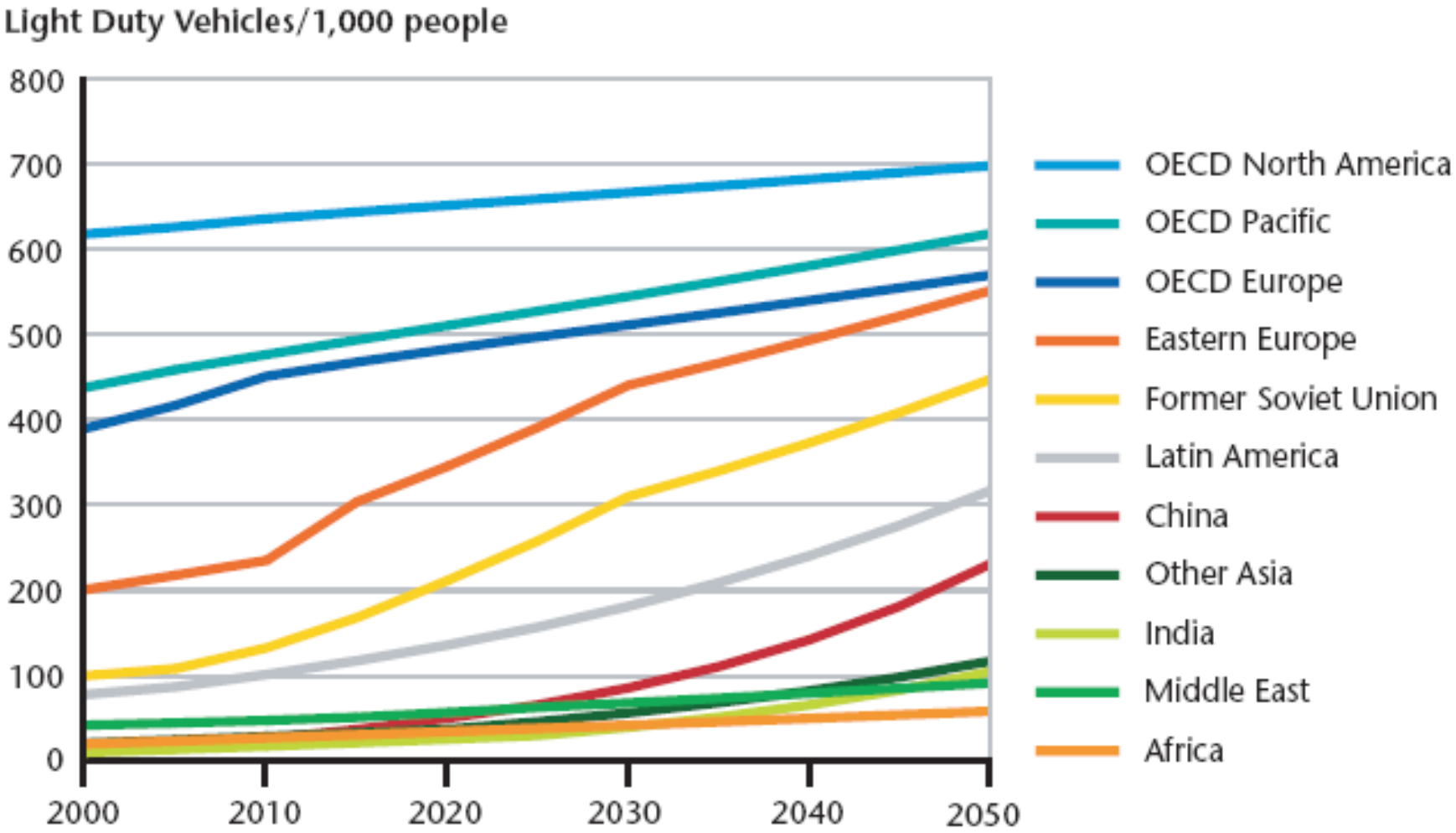
Standards & taxes



How taxes and standards interact and how they can be implemented in a combined optimal way for society

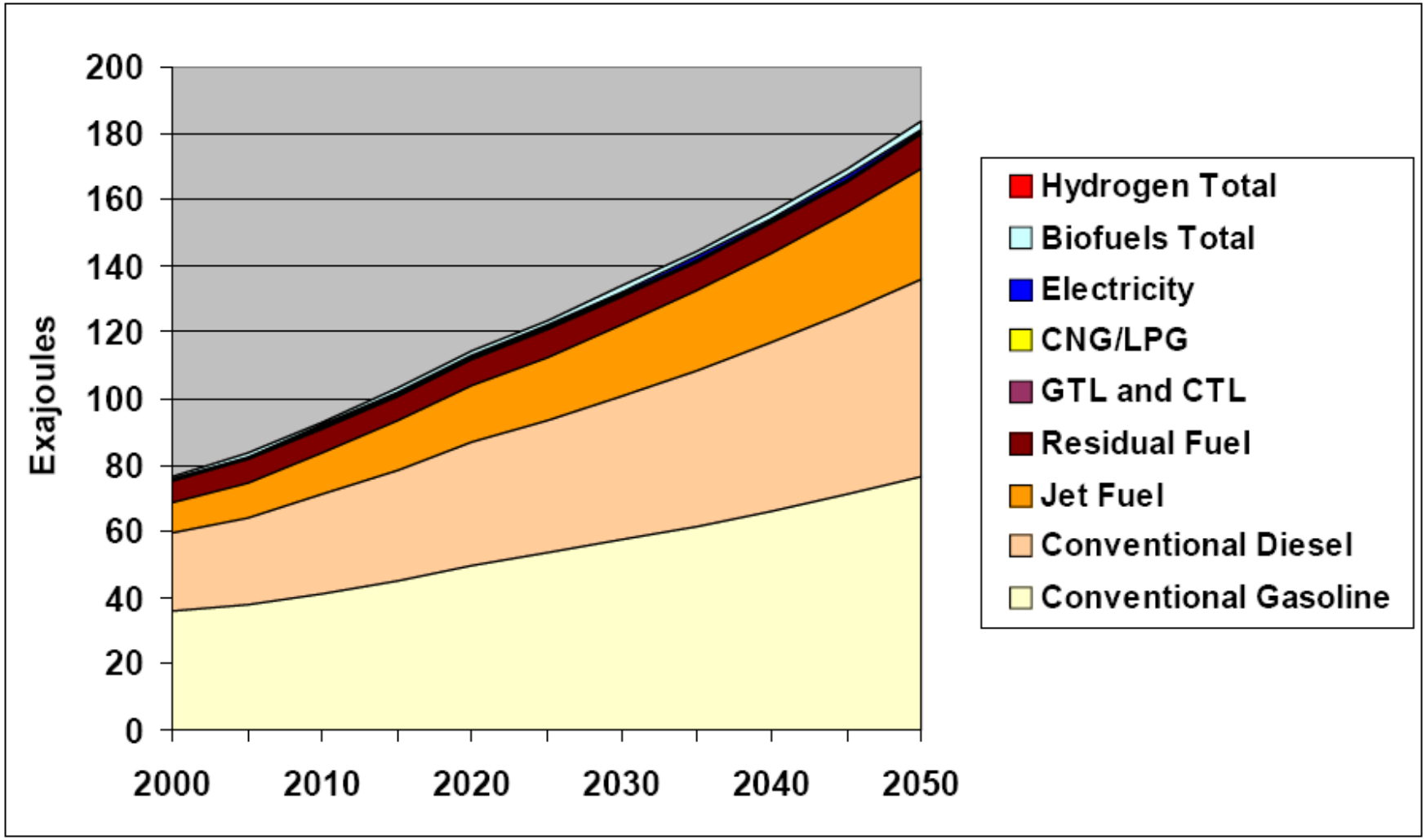
6. Future scenarios and perspectives

Vehicle Ownership



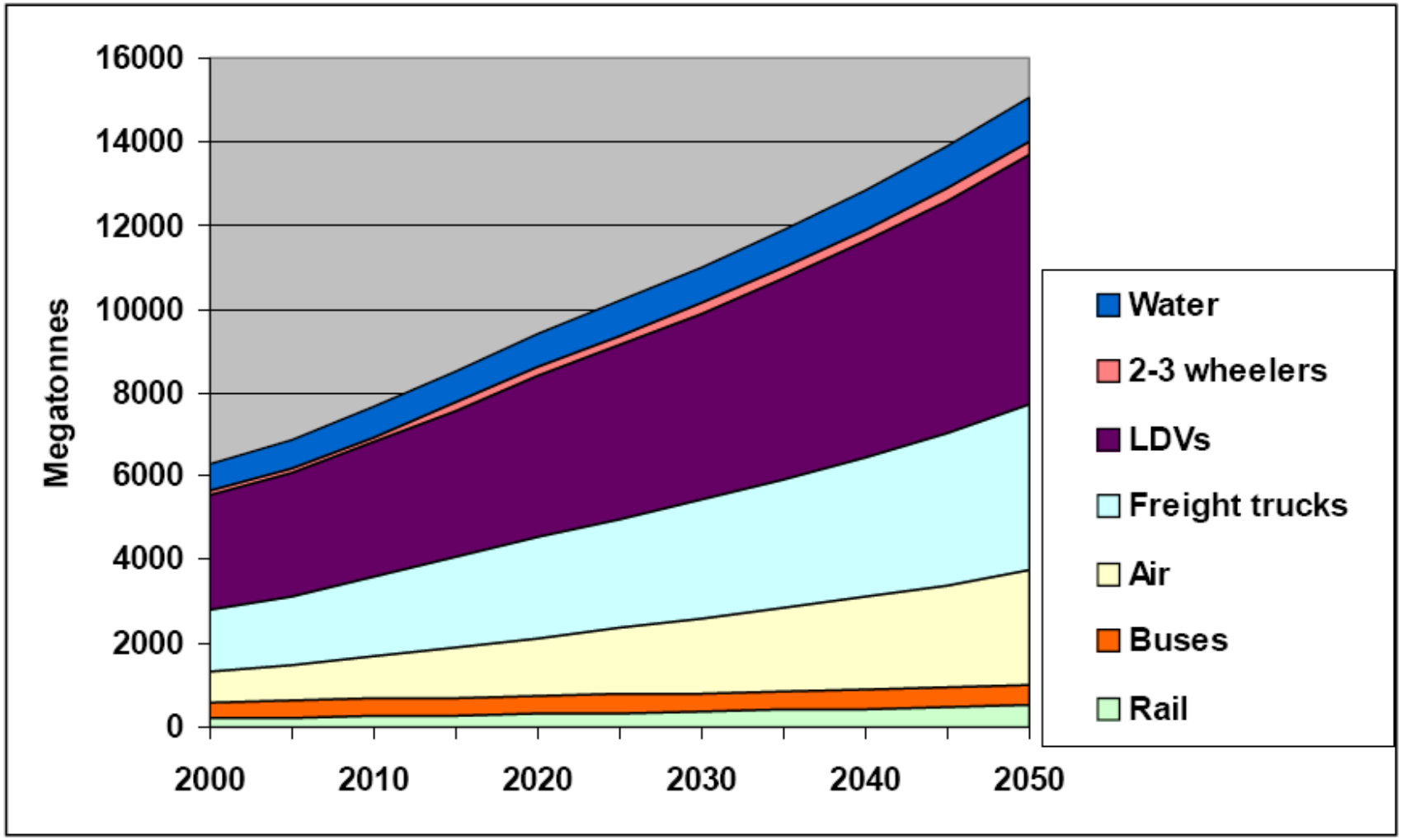
Source: WBCSD,2004

Ref. Case: Fuel Use



Souce: IEA, 2007

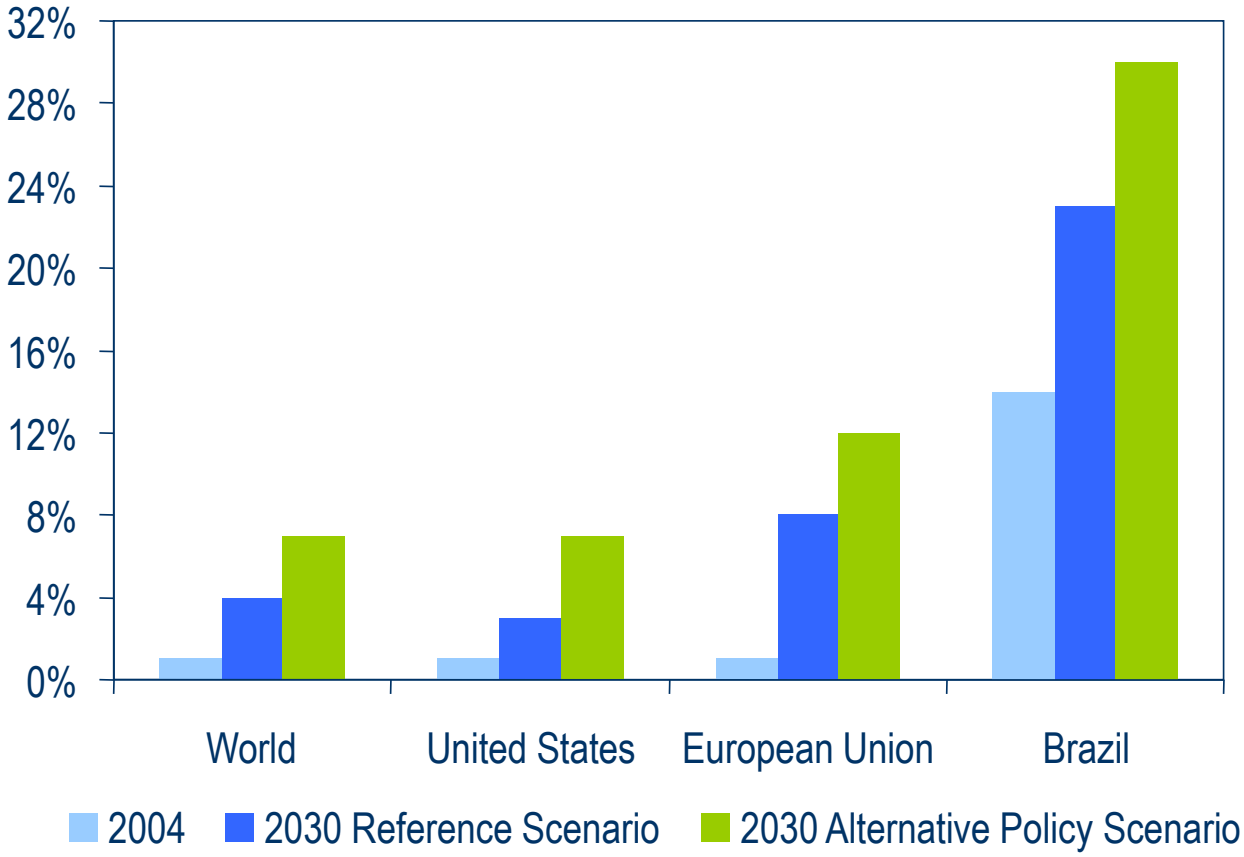
Ref. Case:
Emissions by Mode (WTW)



Souce: IEA, 2007

Outlook for Share of Biofuels in Total Road-Transport Fuel Consumption

The share of biofuels in road-transport fuel use grows rapidly, reaching 7% worldwide in the Alternative Policy Scenario

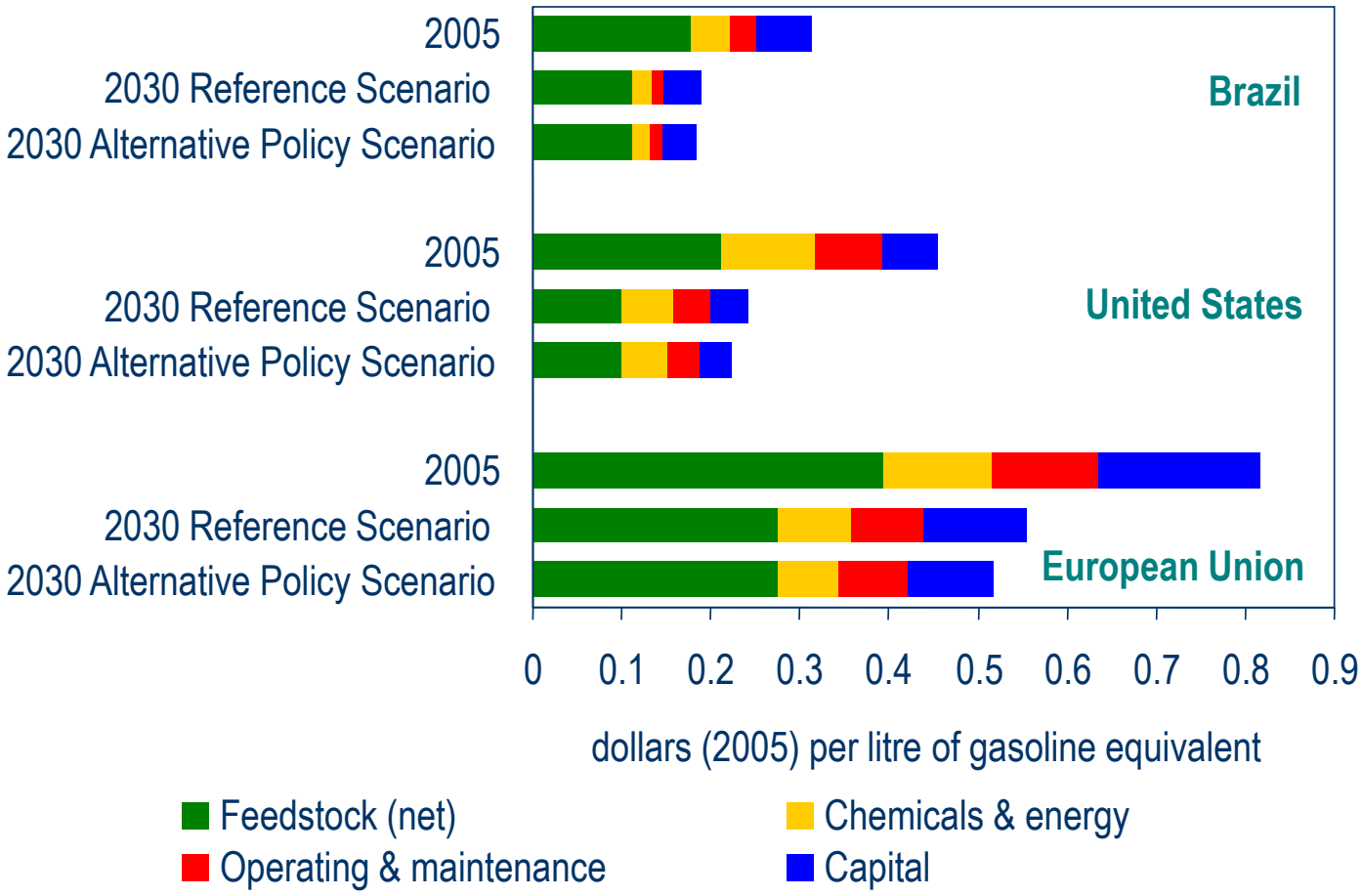


1st generation biofuels are expected to play a larger role in meeting world road-transport fuel demand

Source: IEA, 2006

1st-Generation Biofuels Production Costs

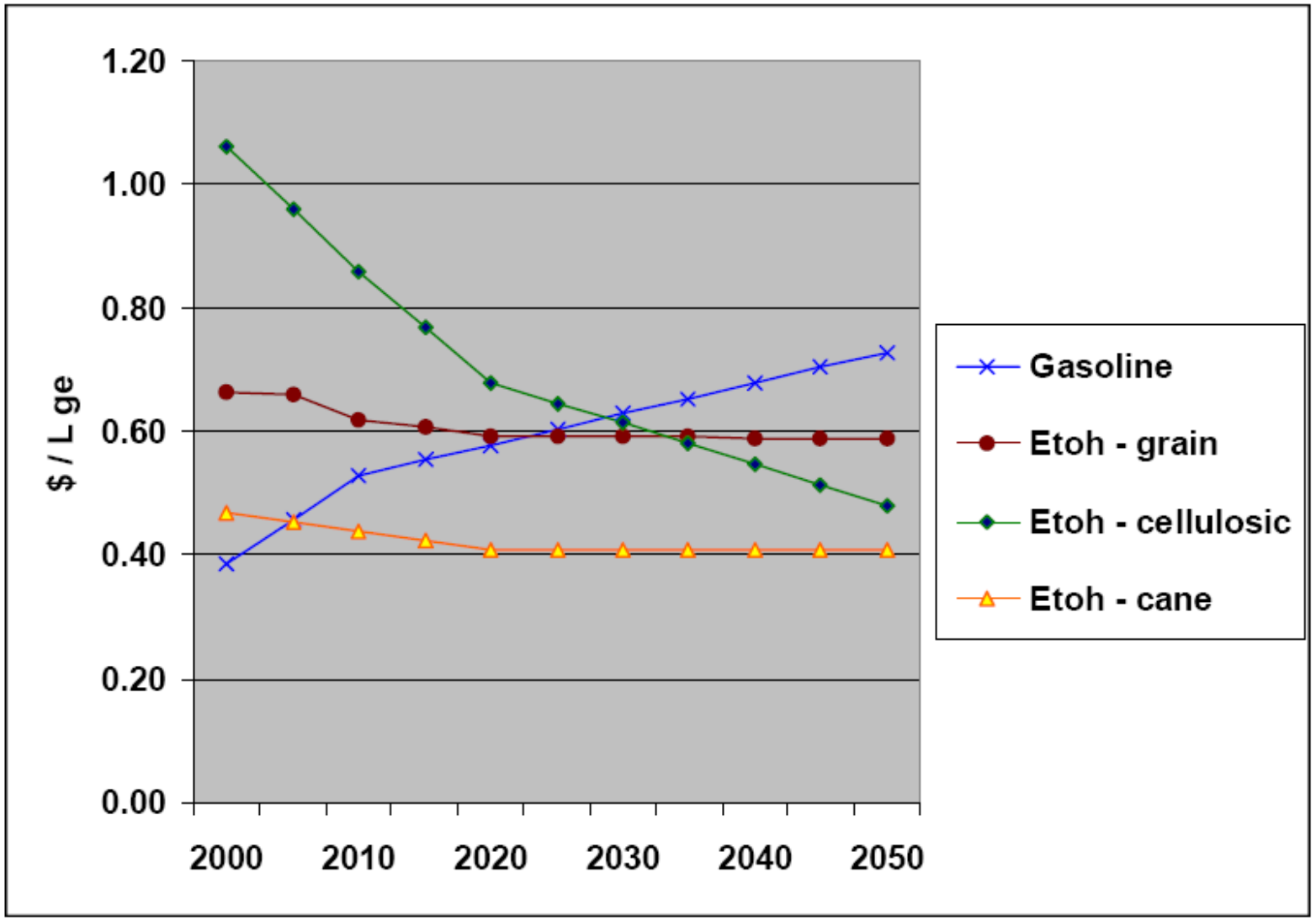
Production costs are expected to drop in all regions, with Brazil remaining the lowest-cost producer



Source: IEA, 2006

Ethanol Price Projections

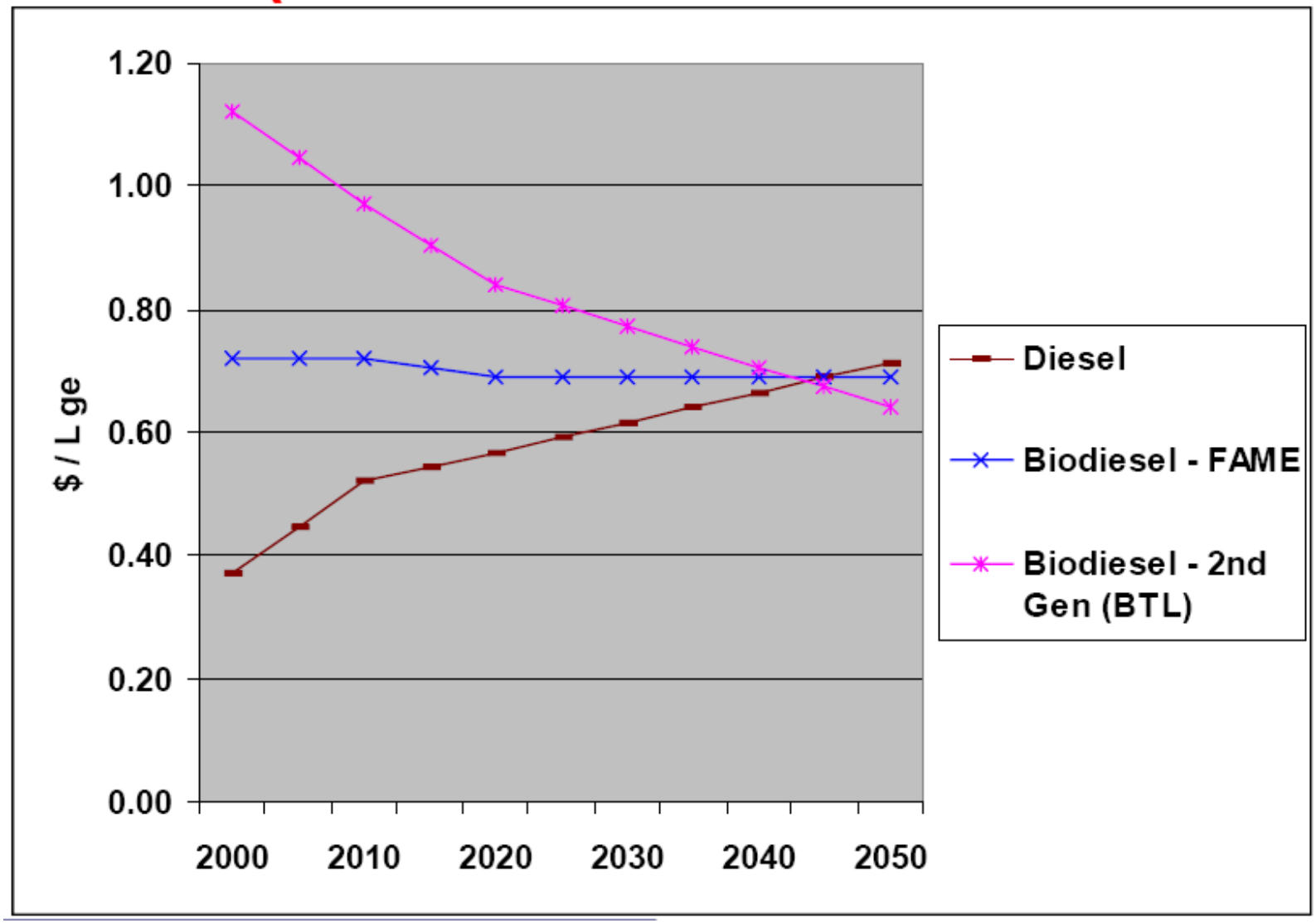
(preliminary: retail, untaxed)



Souce: IEA, 2007

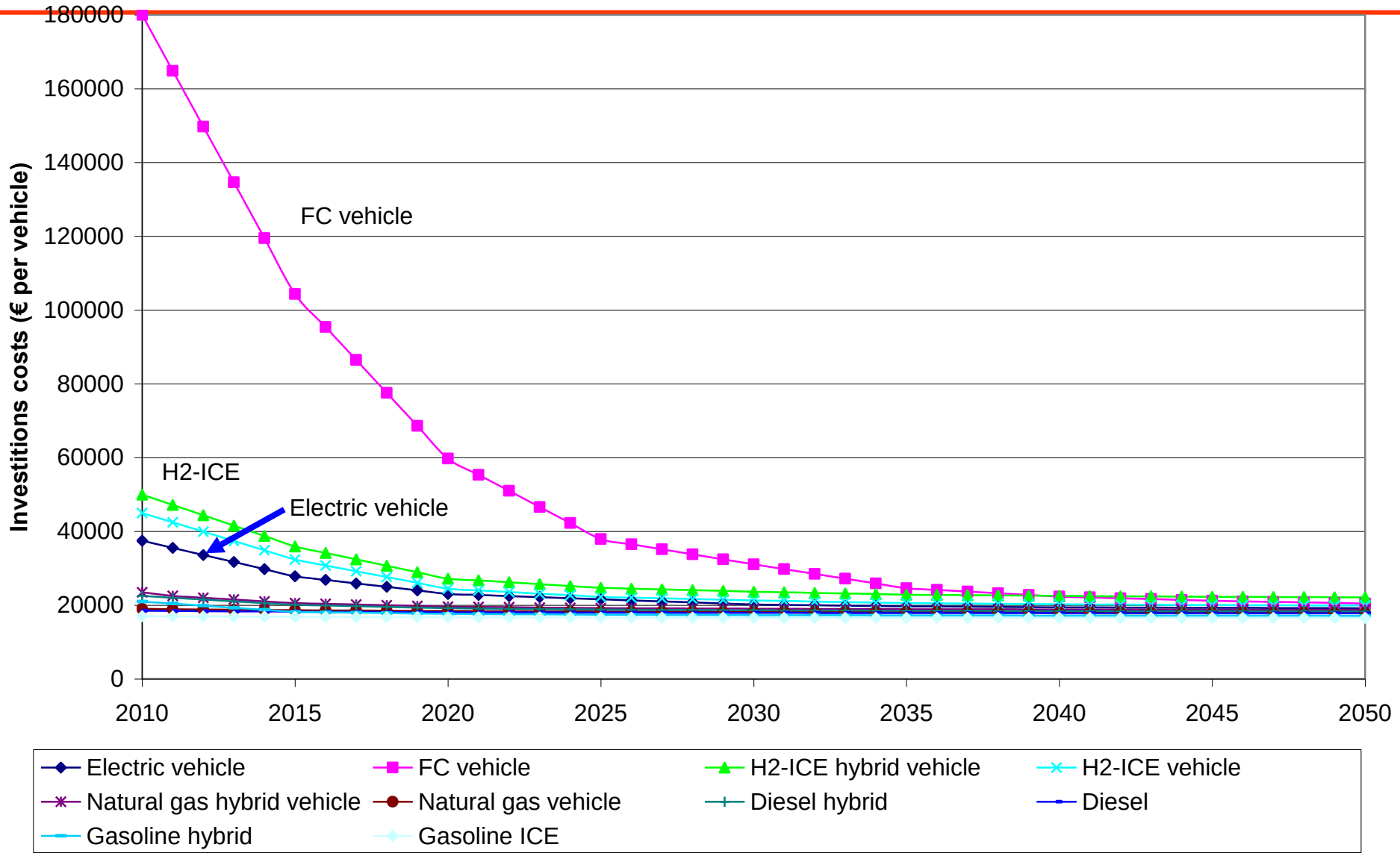
Biodiesel Price Projections

(preliminary: retail, untaxed)

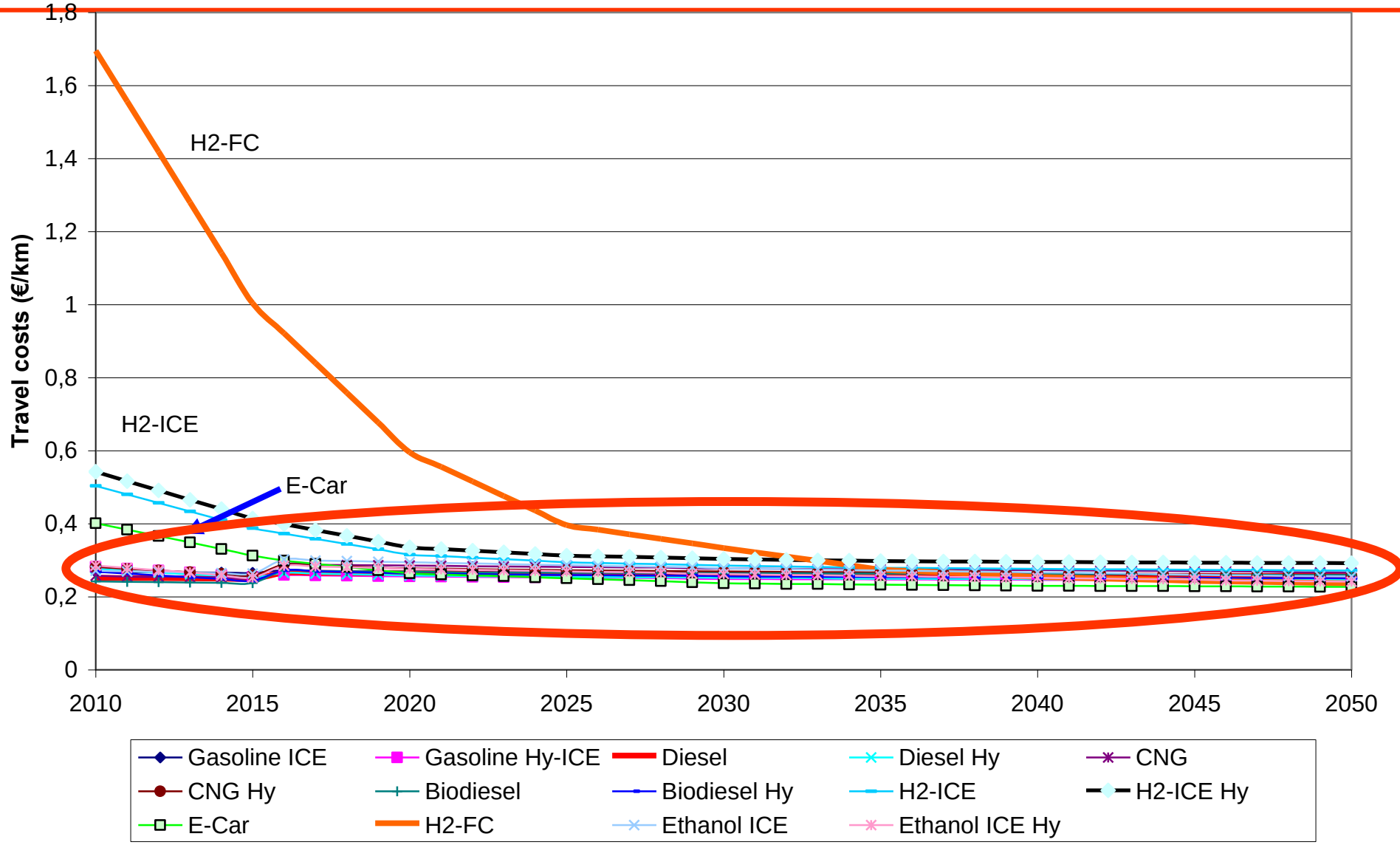


Souce: IEA, 2007

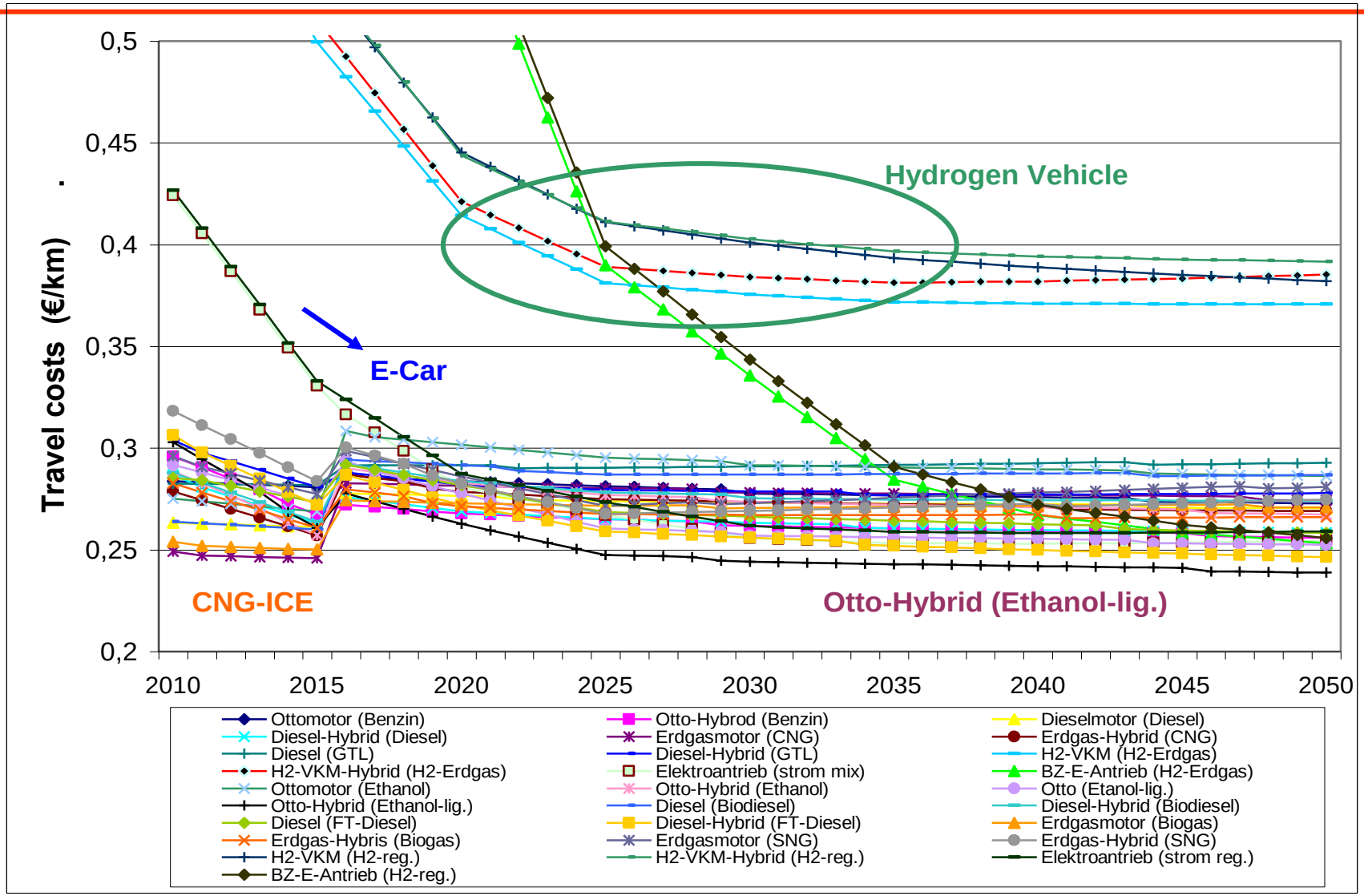
Costs per vehicle



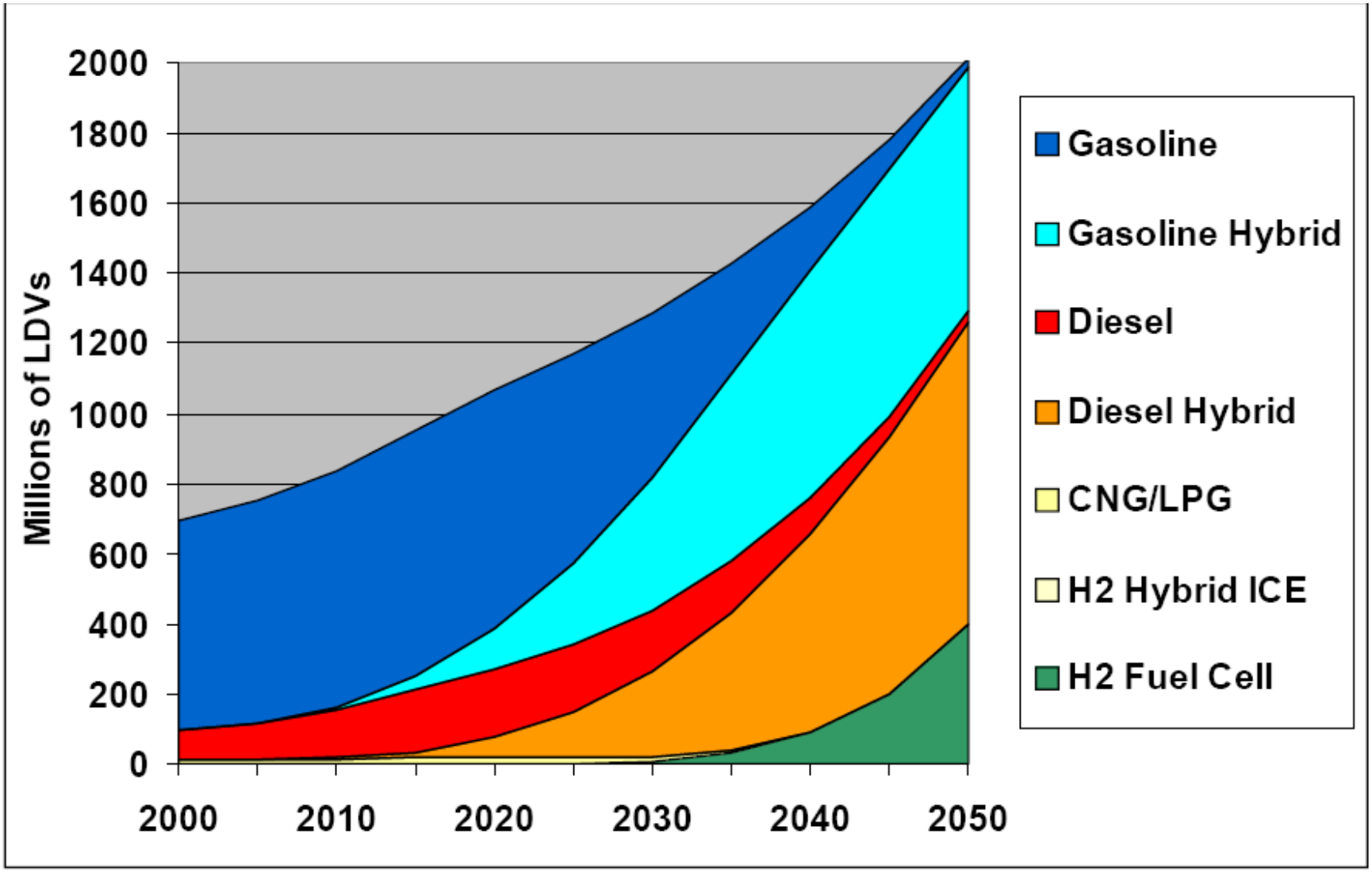
Total transport costs



Total transport costs



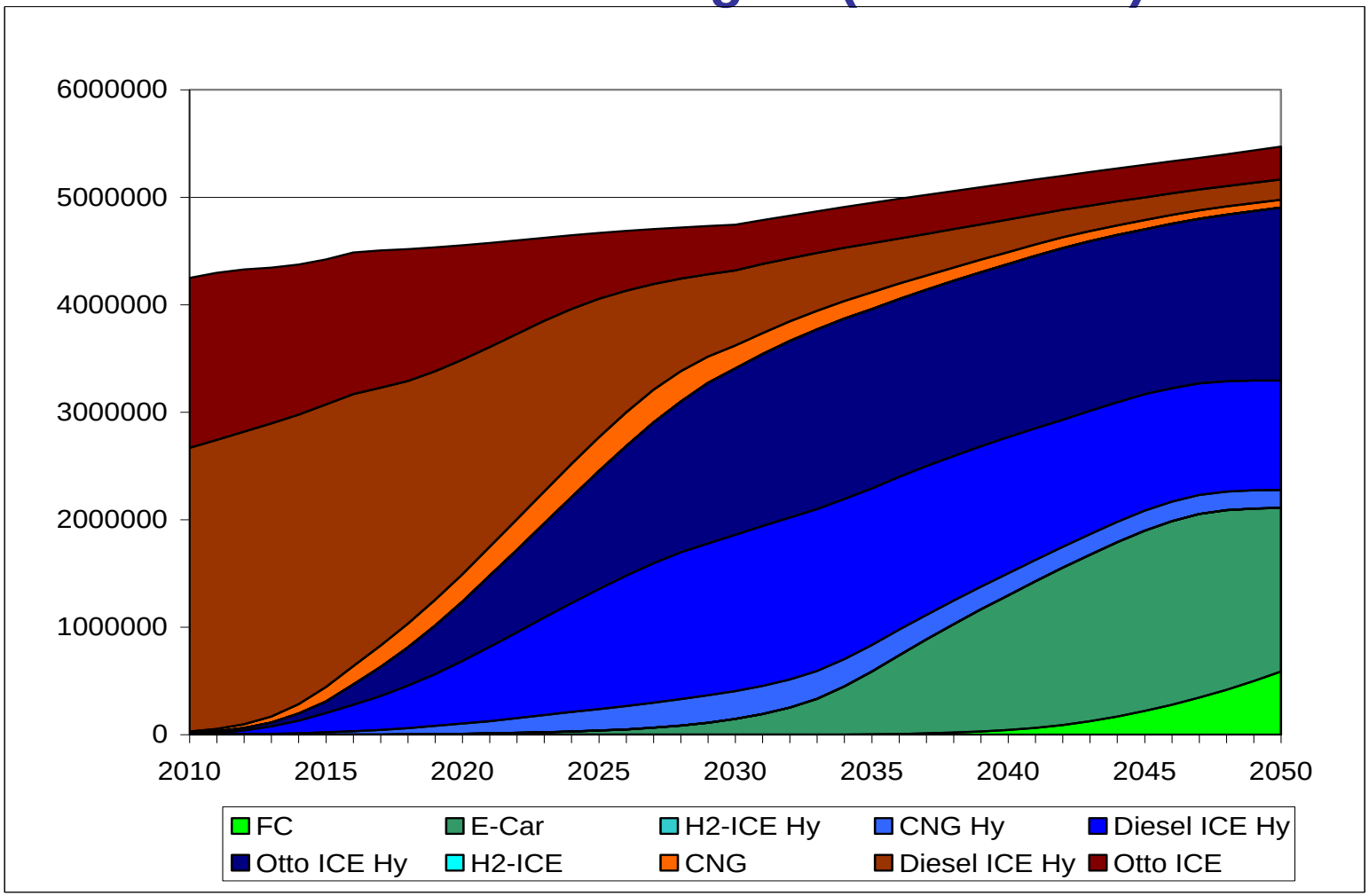
LDV Stock Projections



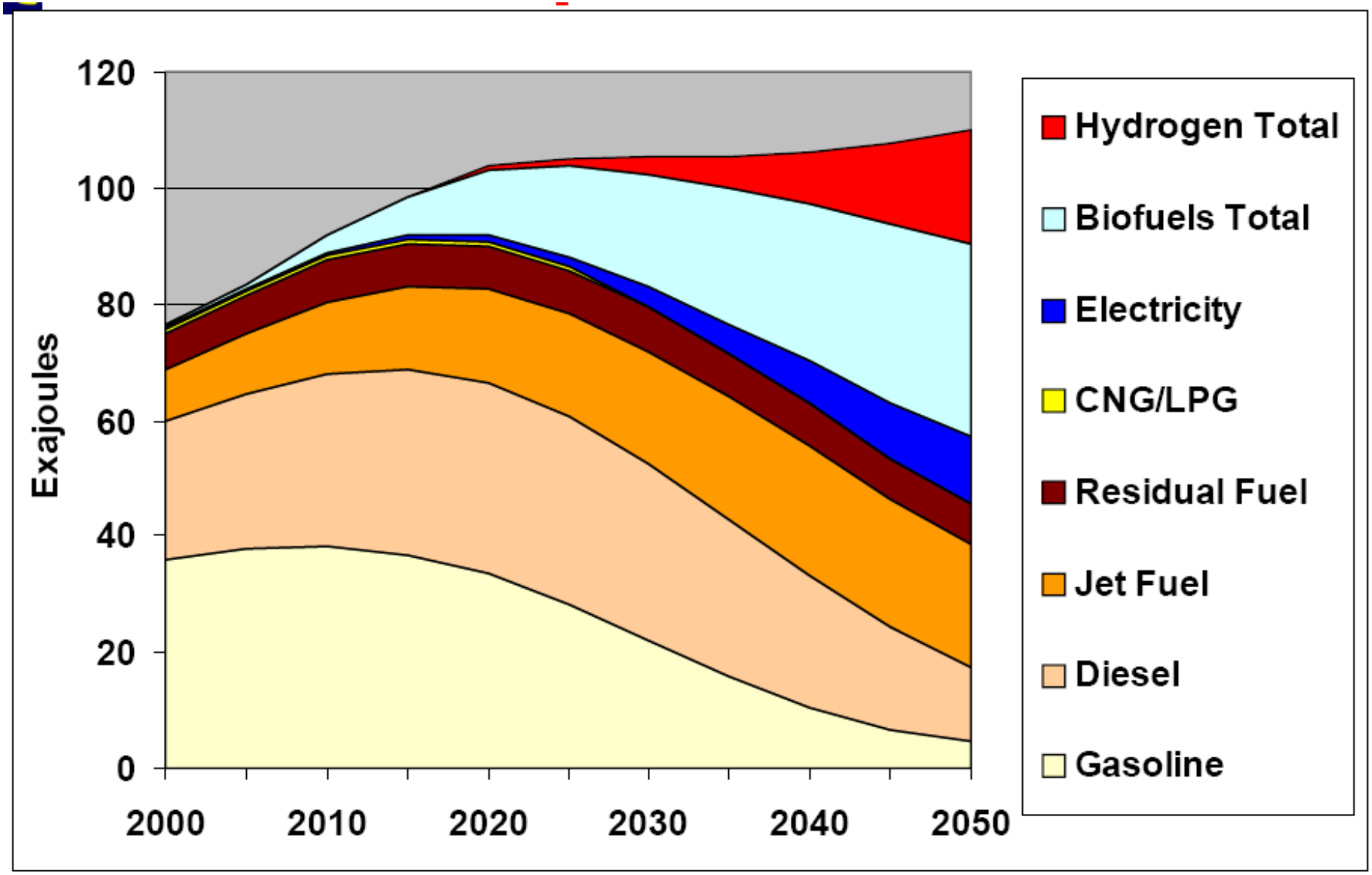
Souce: IEA, 2007

Austria

Distribution of overall vehicle stock broken down by vehicle technologies (2010-2050)

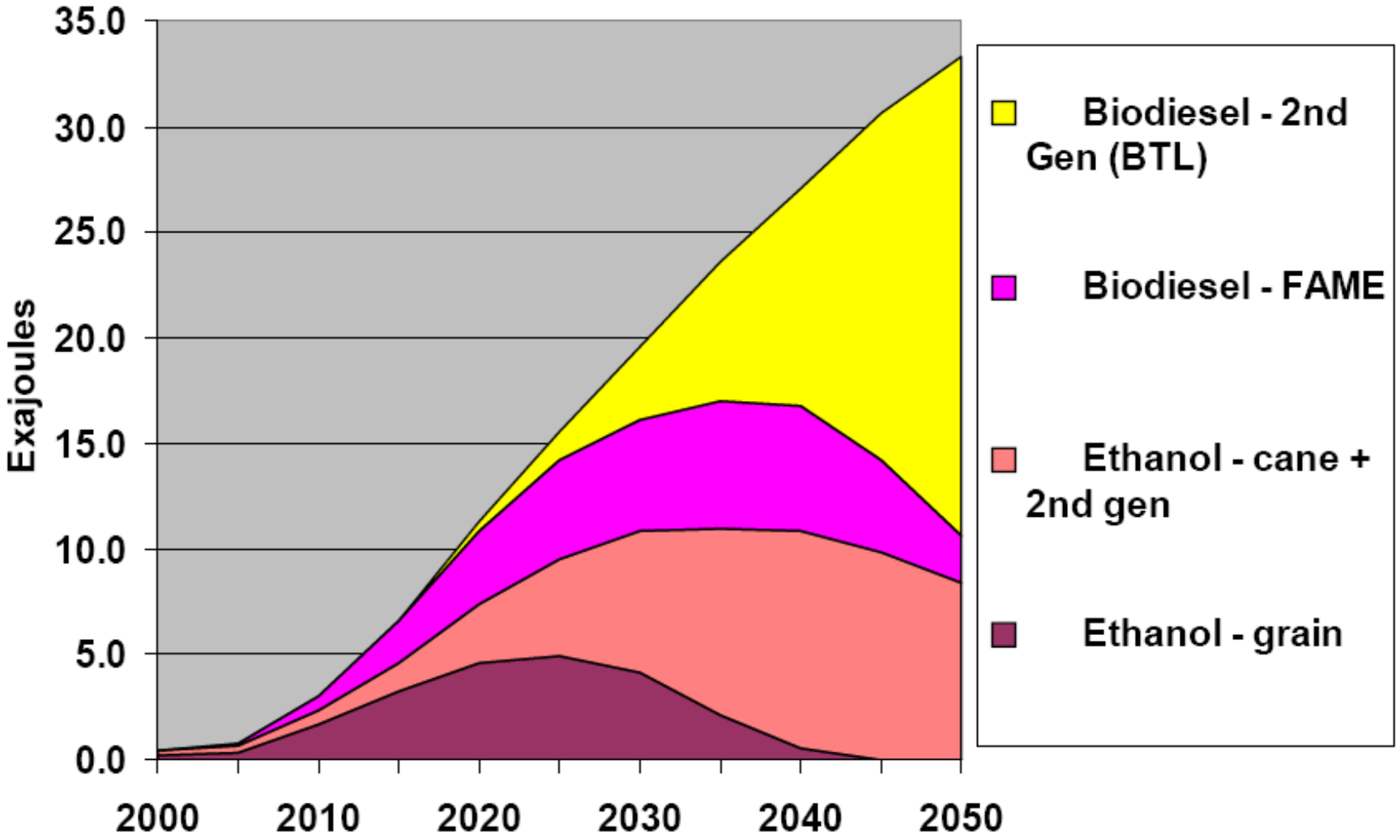


Alternative Scenario (AS): Transport Fuel Use

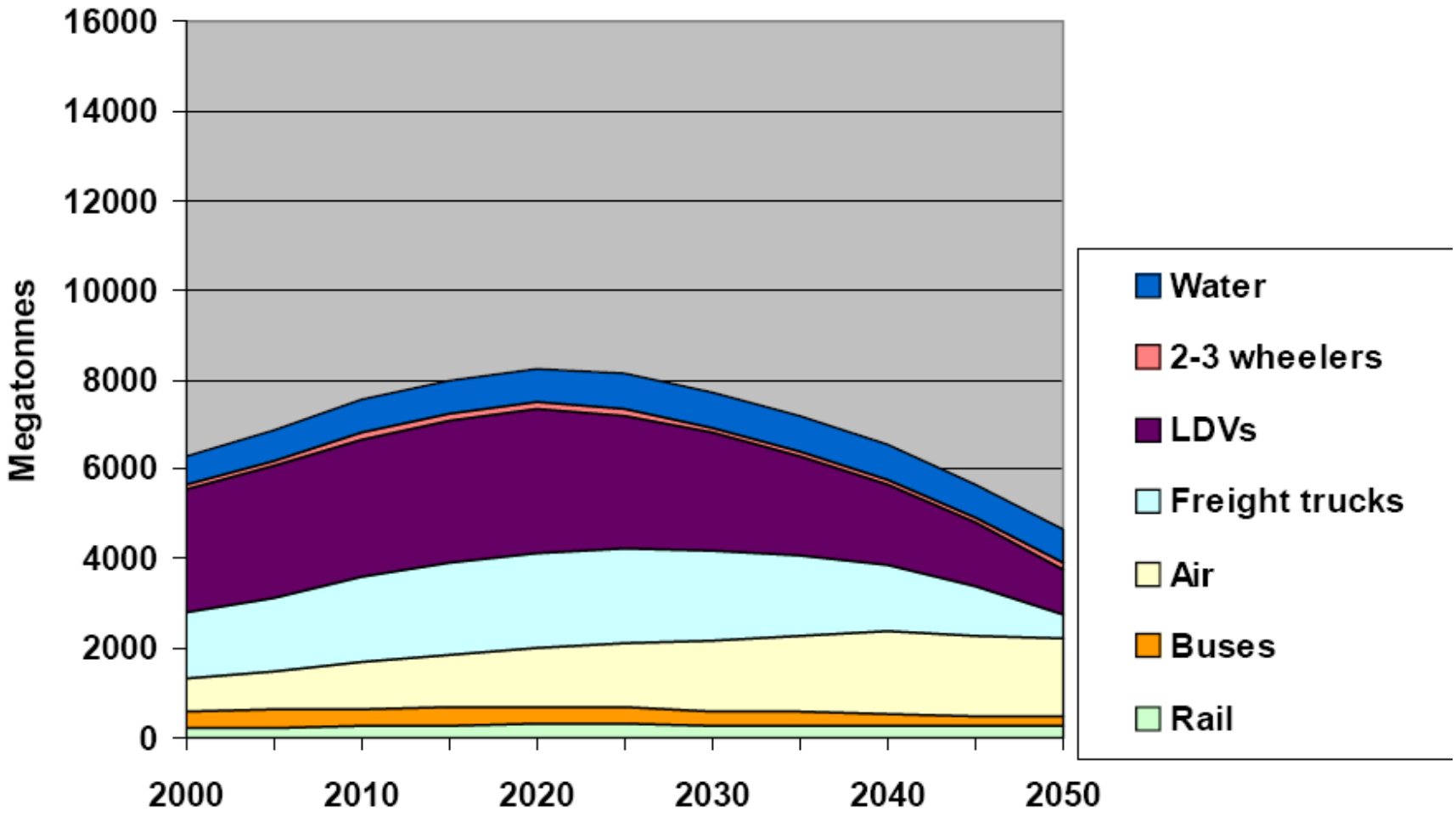


Souce: IEA, 2007

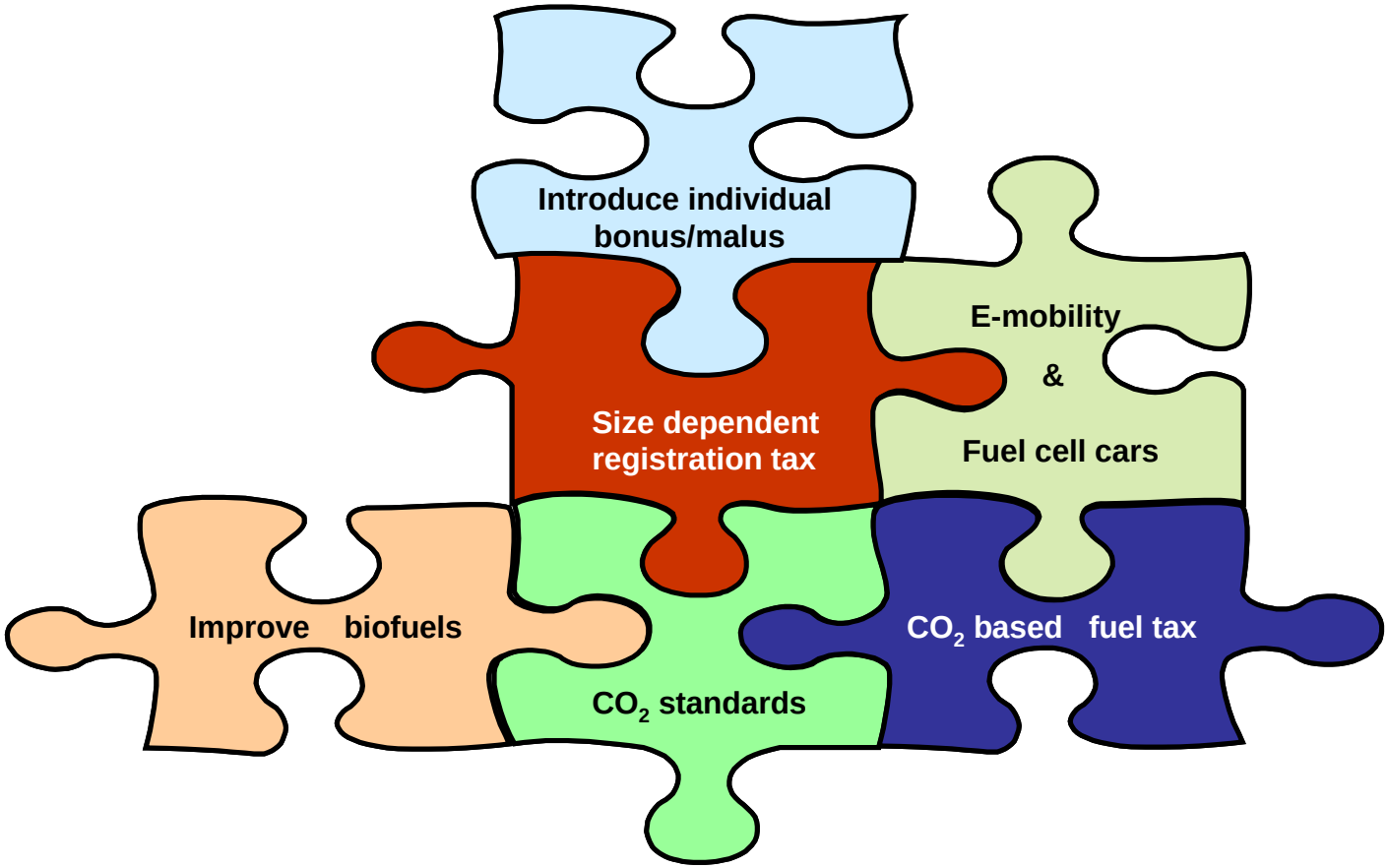
AS: Biofuels Breakdown



AS: GHG Emissions by Sector



Conclusions



ajanovic@eeg.tuwien.ac.at