H_2 + Fuel Cell in Cars When and Where?

The role of the oil price

Fuel chain efficiency WtT and TtW

Electricity rather than natural gas based H_2

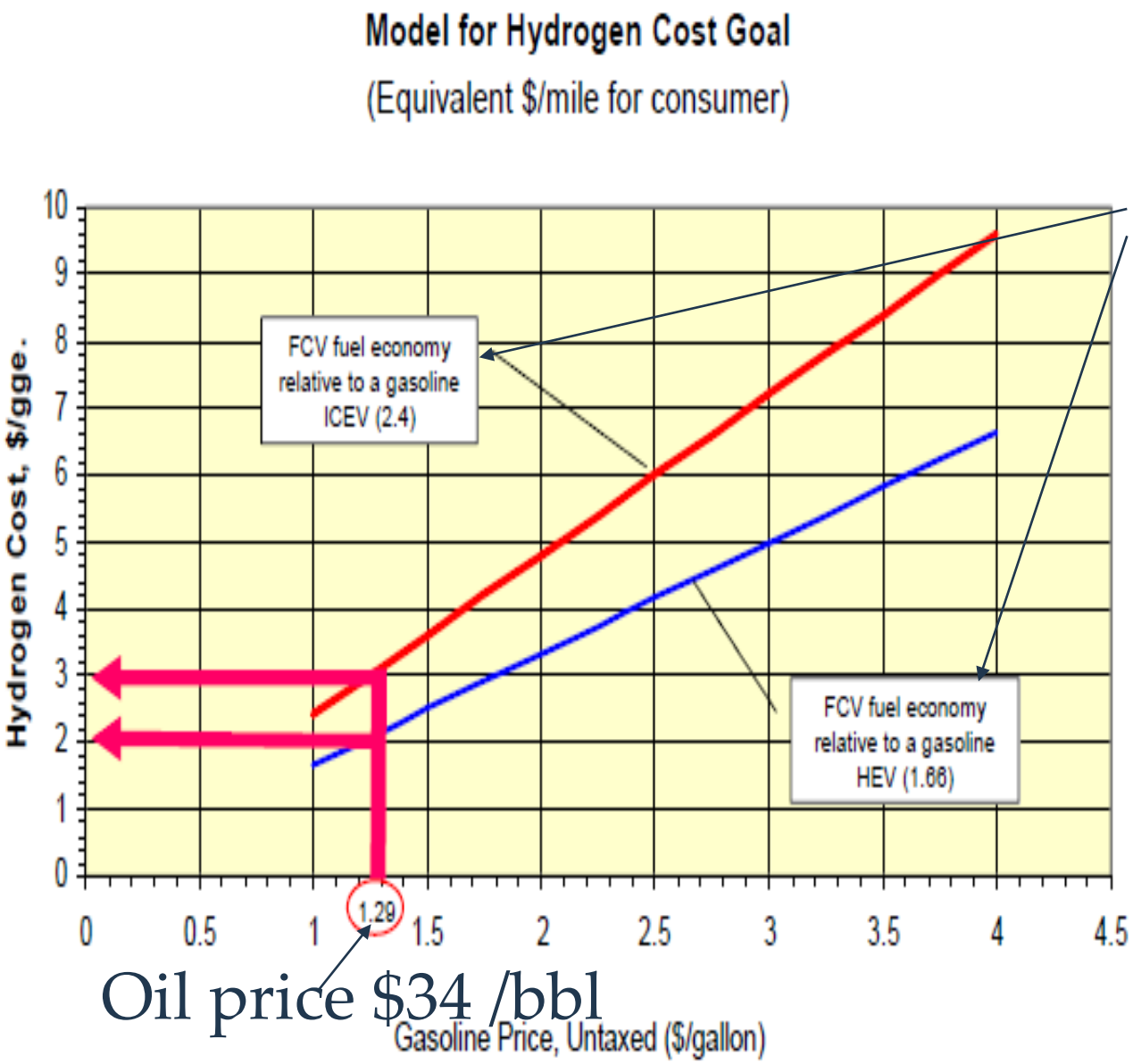
Competitiveness in EU First: Fuel and car taxes

Population, car, and Euro density

Anders Chr. Hansen

Zero Regio
Funded by EU FP6

US DOE Hydrogen cost target = $2-3/kg (GJ/kg = GJ/gge)



Oil price $34 /bbl

- HFC fuel efficiency relative to best petrol/diesel = 1.5 or less
- $34 /bbl not realistic
- Not only petrol, but also NG (and thus 1G H2) depends on oil price

Will NG based H2 be delinked from the oil price?

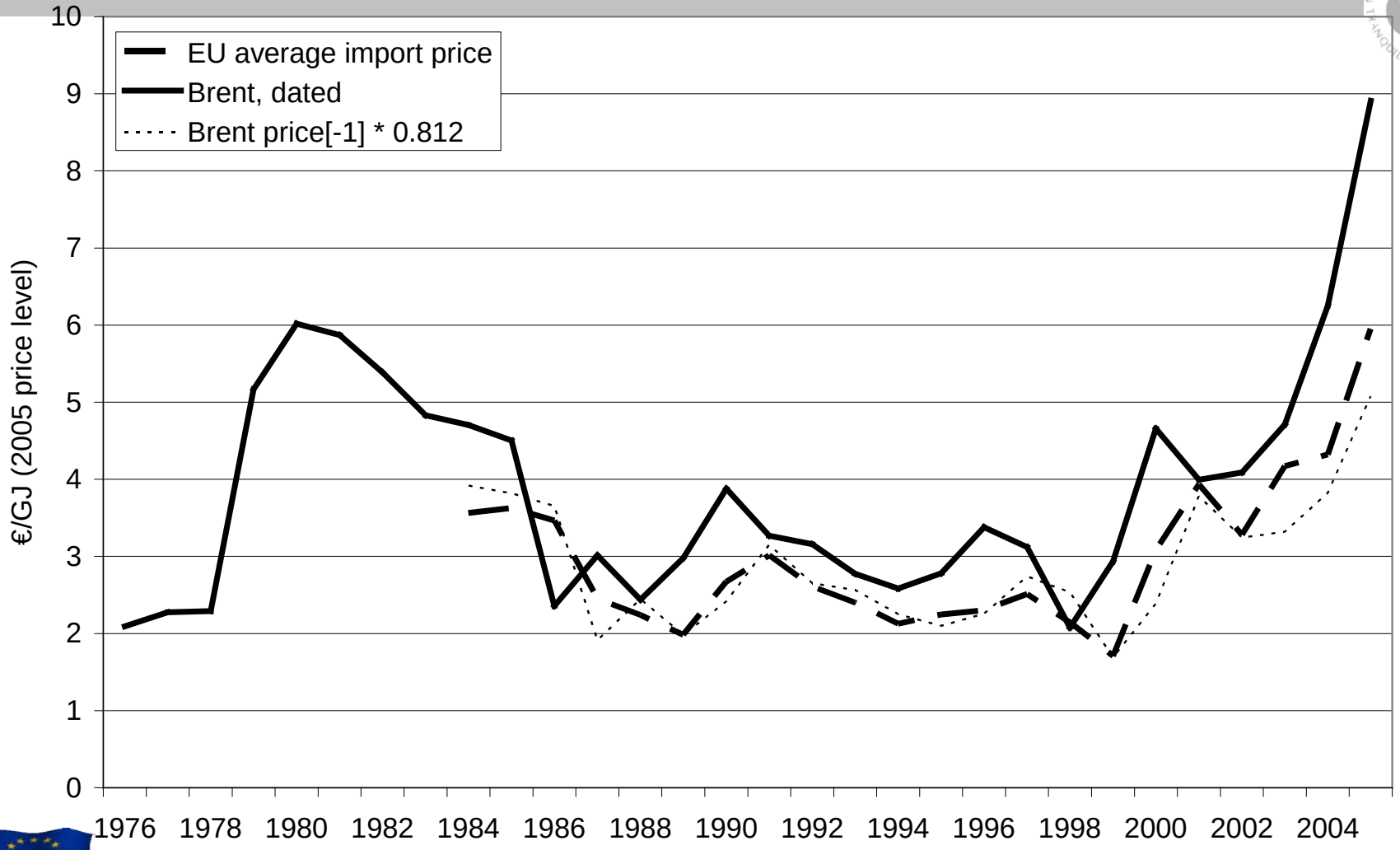


Figure 1. Natural Gas and Oi Prices 1976-2005.

Coal price and oil price

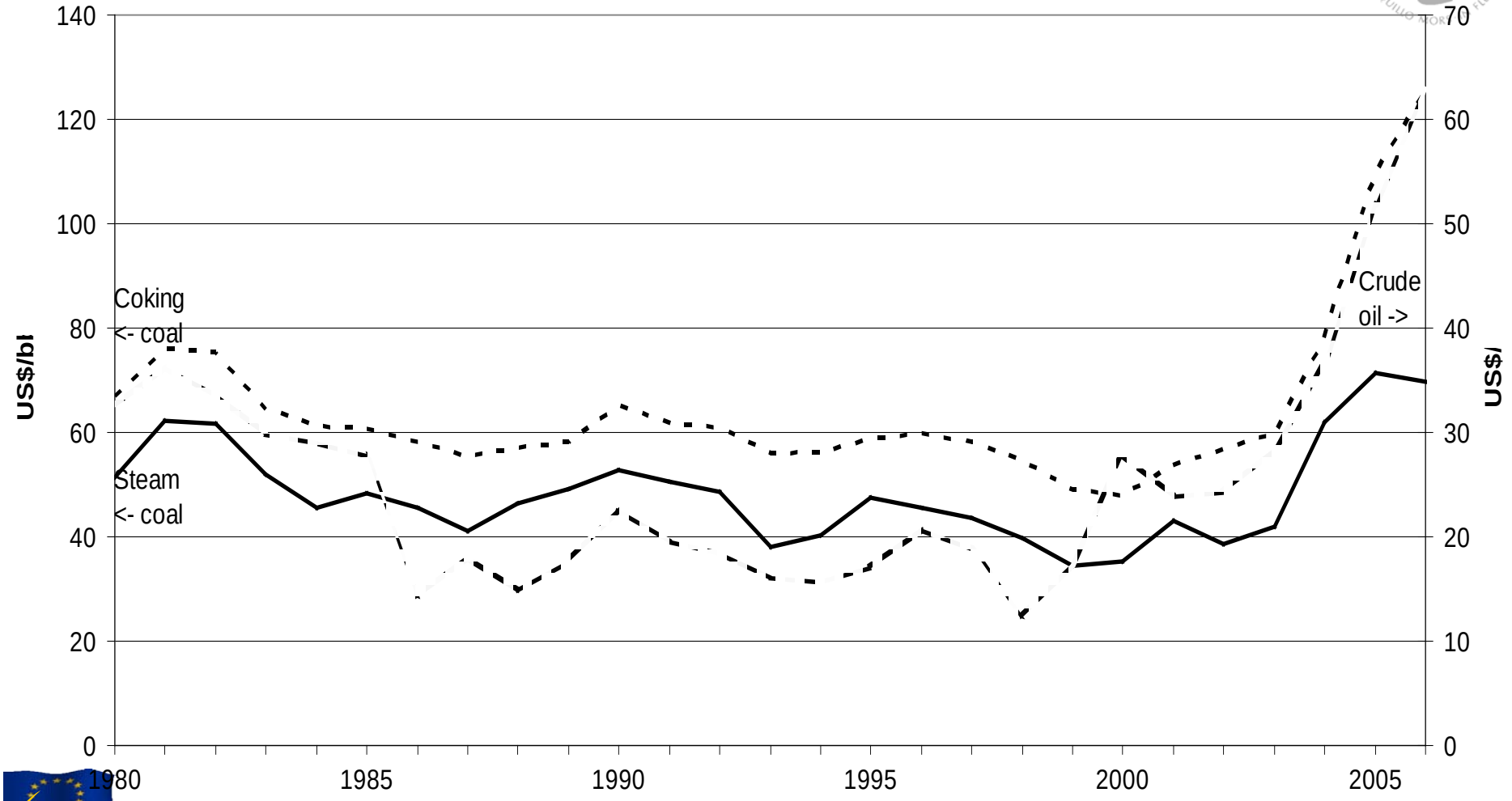
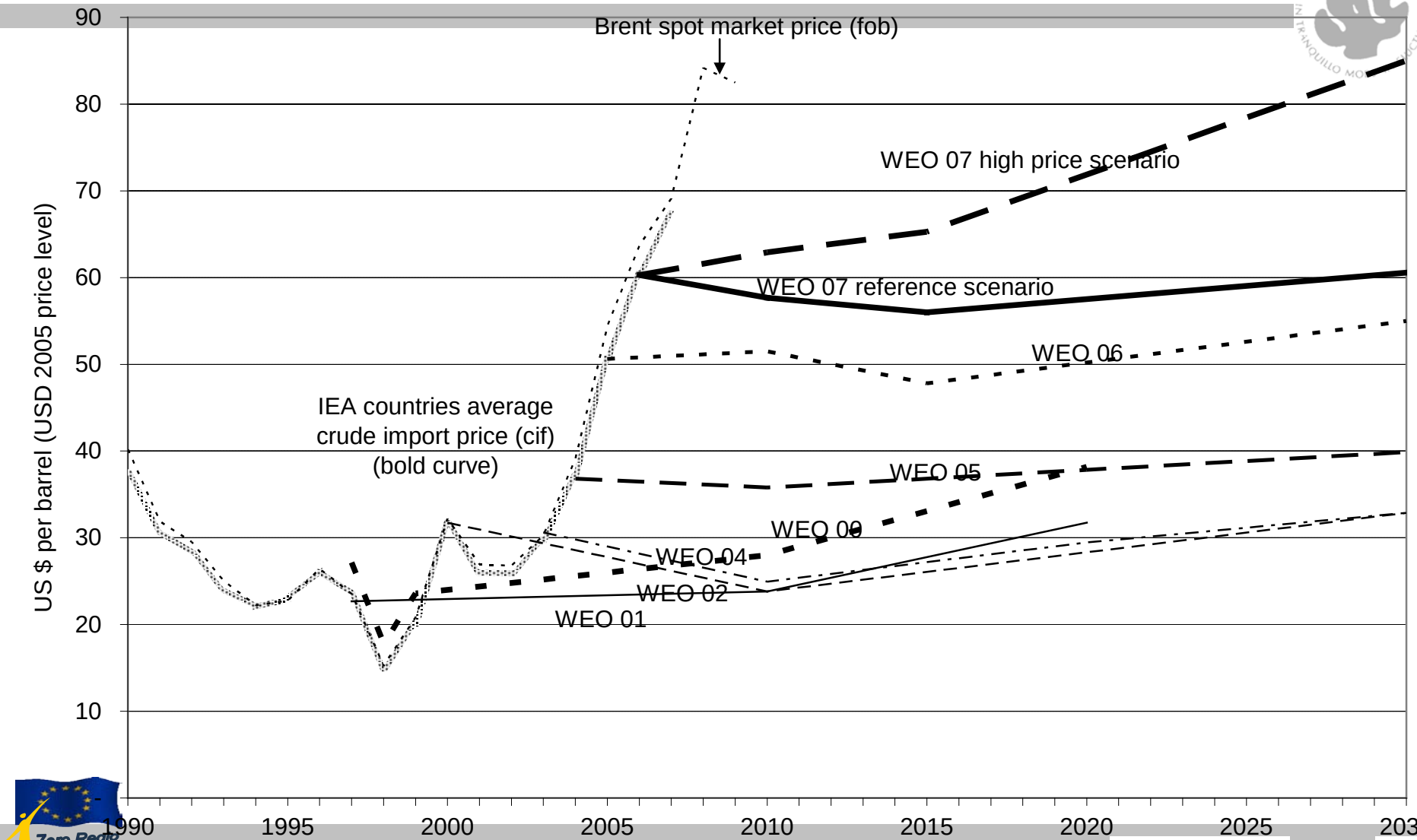


Figure 2. European Coal and Oil Prices 1980-2006.
Source: International Energy Agency (IEA): Energy prices and taxes. Database. http://www.oecd.org, 12.11.07.

Oil price projections



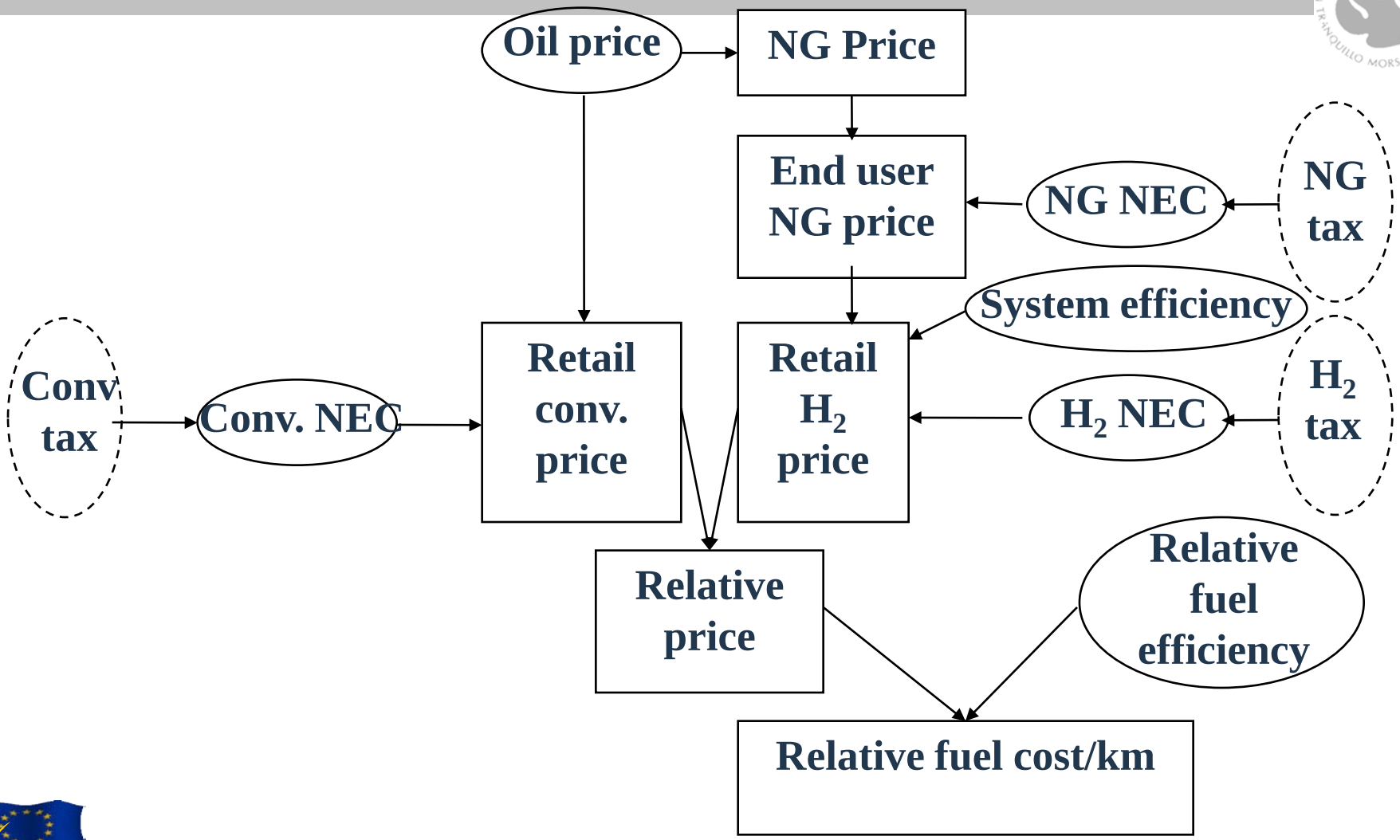
Oil price assumptions 2015-2025

- Some consensus on the model, but not on assumed supply growth

	Accelerated expansion of OPEC oil supply	Moderate expansion of OPEC oil supply	Peak in OPEC oil supply
Annual growth 2005-2030	2.1%	1.0%	0%
Oil price (Brent)	$50-65	$65-85	$85-?

- Research question: “At which oil price is H2 competitive?”
- Rather than “What will H2 cost in 2015-2020?”

Fuel Cost per km Model



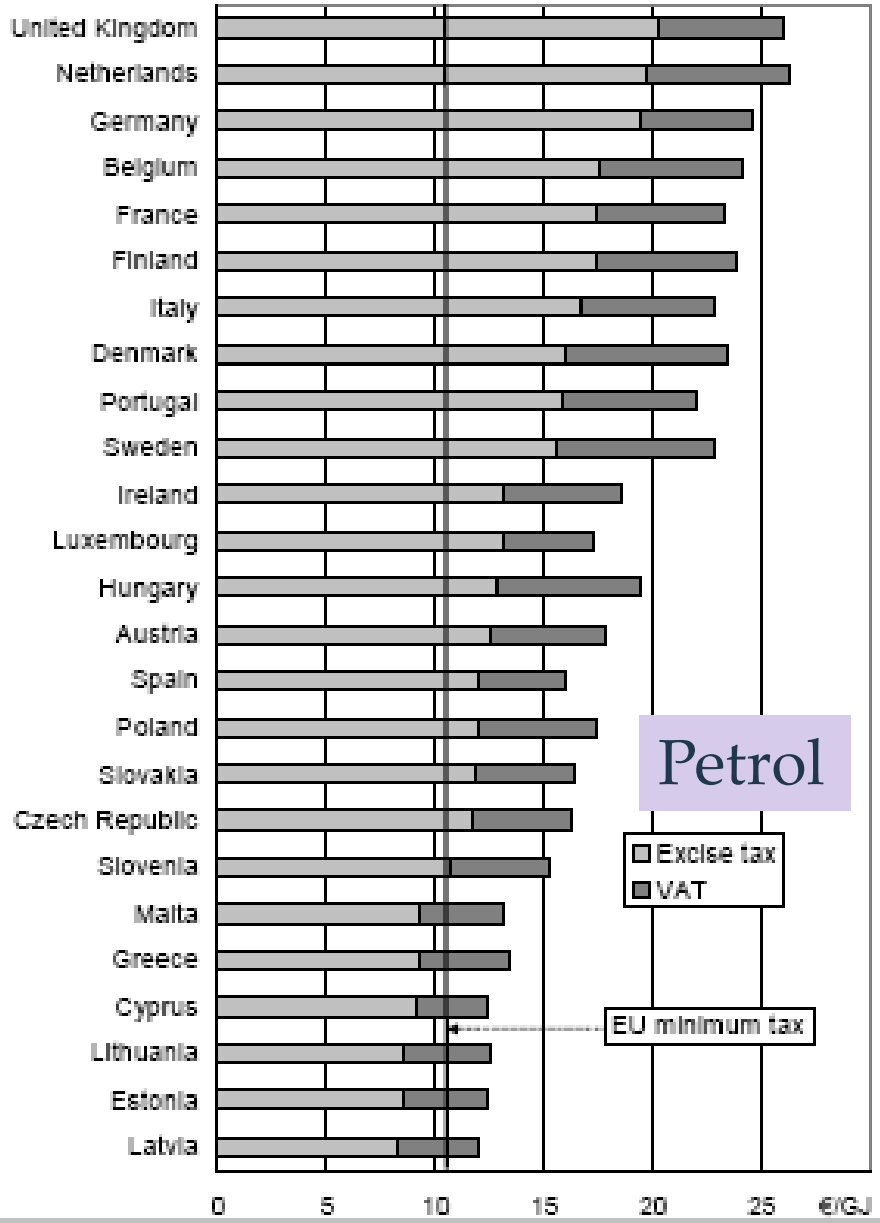
Which competing technology?
TtW energy efficiency advantage

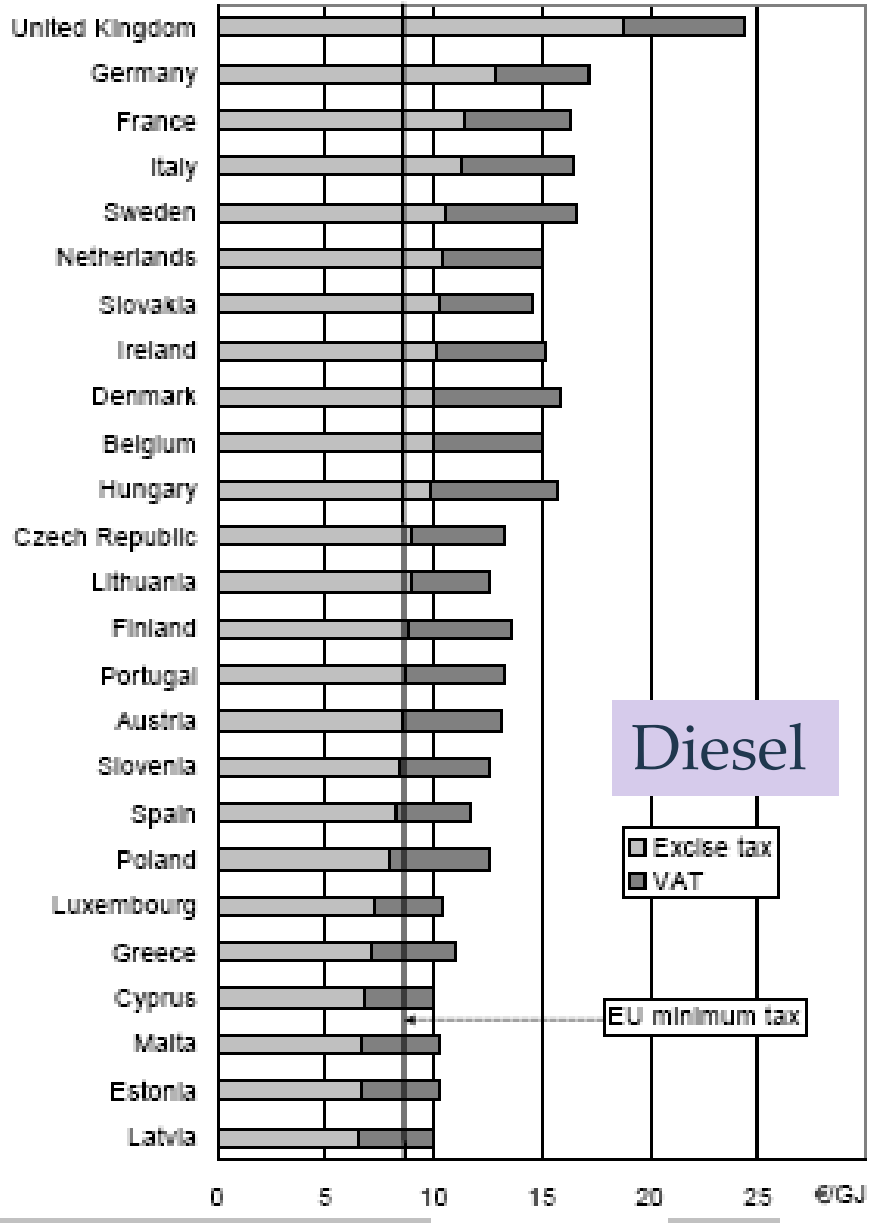
JRC EUCAR and CONCAVE (2006):	
Direct hydrogen	0%
Direct hydrogen hybrid	-11%
Gasoline PISI hybrid	72%
Gasoline/ethanol DISI hybrid	73%
Diesel/biodiesel DICI+DPF hybrid	55%
CNG PISI	48%
LH2 PISI	40%
Argonne National Laboratory (2007):	
CIDI Vehicle (CD, BD, FTD, DME,RFG)	71%
Gasoline etc. hybrids (EtOH, MeOH, NG, RFG)	53%
Diesel etc. hybrids (BD, FTD, or CD)	33%
Hydrogen Fuel-Cell Vehicles	0%
Battery Electric Vehicles	-34%

Eaten up by WtT conversion loss?

	Worst	Best
TtW efficiency advantage	**50%**	**50%**
WtT ("system") efficiency	**62%**	**70%**
WtW efficiency gain	**1%**	**14%**

Fuel taxes 2004 (€/GJ)





Competitiveness threshold for fuel cost per km

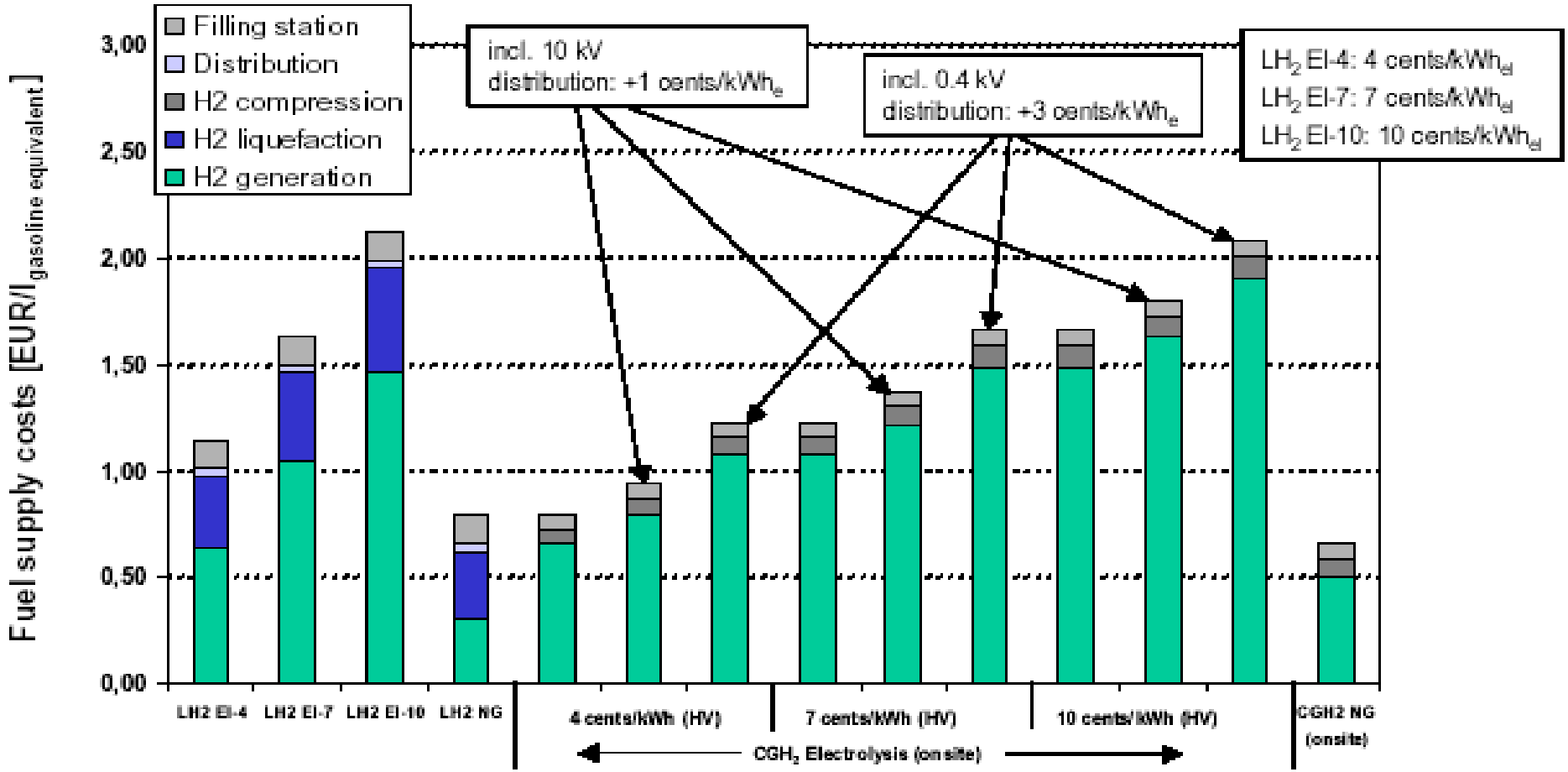
Diesel and petrol (€/ GJ)	0		10		10		10		20	
Hydrogen (€/ GJ)	0		10		0		0		0	
Natural gas (€/ GJ)	0		0		10		8		16	
	NG	Win	NG	Win	NG	Win	NG	Win	NG	Win
Best case ($/ bbl)	188	105	86	85	174	45	115	45	42	-16
Worst case ($/ bbl)	542	170	327	150	590	110	452	110	362	49

Conclusion 1

- Competitiveness depends heavily on the fuel tax level
  - - and at a given tax level natural gas based H2 is not necessarily the cheapest
- Non-GHG based H2 (NG based H2)
- Tax level of €0/GJ
  - $105 ($188)/bbl if fuels are not taxed
- Tax level of €10/GJ
  - $85 ($86)/bbl if hydrogen is taxed equal to petrol and diesel
  - $45 ($115)/bbl if taxed according to primary energy consumption and pollution
- Tax level of €20/GJ
  - $-16 ($42)/bbl if high tax according to primary energy consumption and pollution
- Natural gas based H_2 more expensive in all cases.
- Reconsideration of supply targets is appropriate.

Hydrogen cost comparison based on oil price of $25/bbl

Fuel supply cost per liter gasoline equivalent:



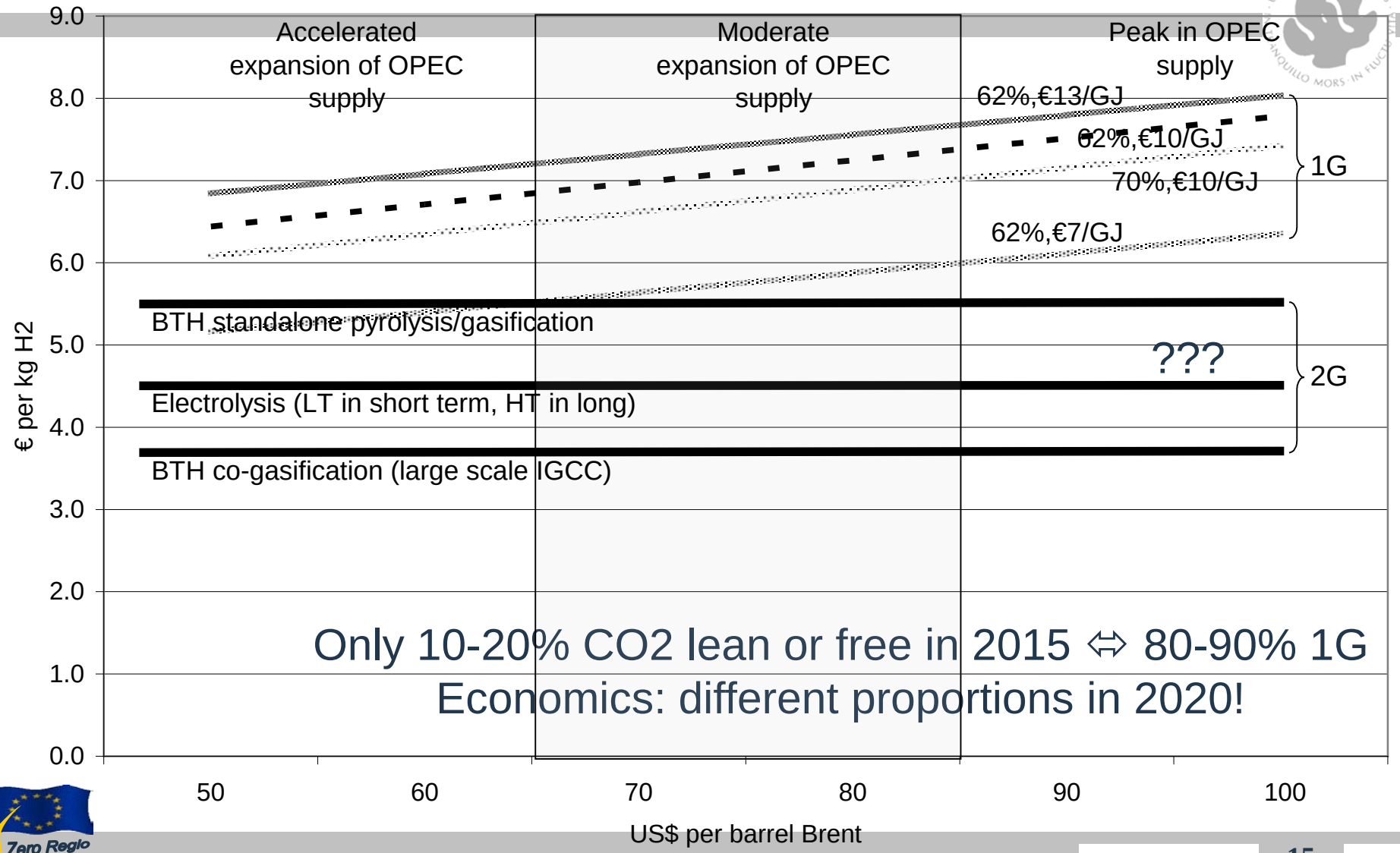
Source: The Alternative Fuels Contact Group (2004)

Europe HFP: “Implementation Plan”

- Natural gas or non-GHG power based hydrogen?
  - Natural Gas based H_2 production technologies
    - fossil without CCS (1. generation H_2)
    - versus
  - Non-GHG H_2 production technologies
    - electrolysis, BTH
    - fossil w. CCS and 4G nuclear (after 2025)
- Europe HFP Implementation plan
    - Focus on Non-GHG technology innovation
    - Production cost targets <€5 per kg
    - Delivery cost target <€2.5 per kg

Costs of NG based H_2 compared to sust. H_2

No taxes



Only 10-20% CO2 lean or free in 2015 ⇔ 80-90% 1G

Economics: different proportions in 2020!

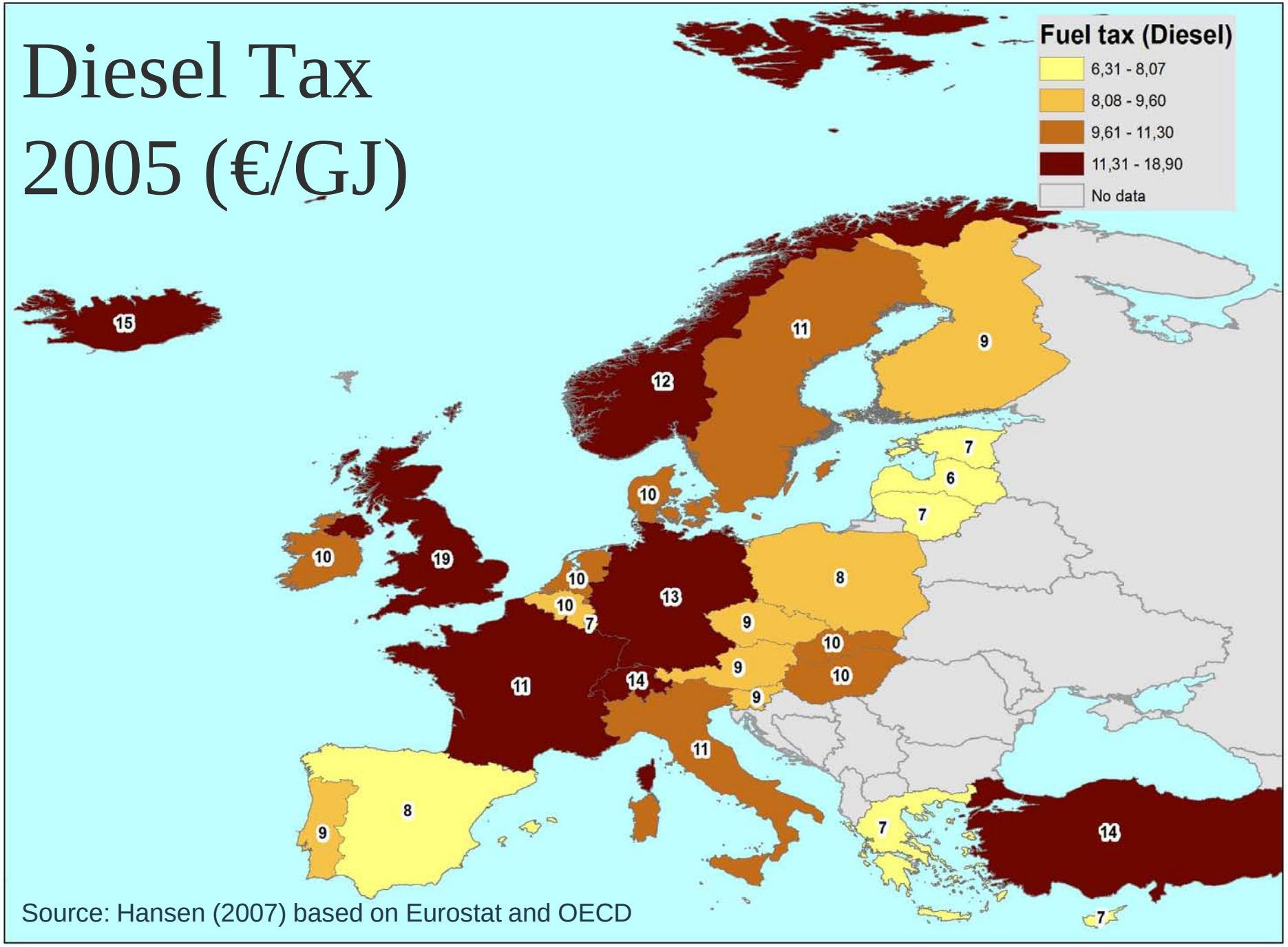
Conclusion 2

- If current fuel tax differences persist…
  - Europe €10-20/GJ
  - Japan €6/GJ
  - US €2/GJ
- … HFC technology for automotive use will become competitive in Europe
- Then in Japan
- Then in the US

Conclusion 3

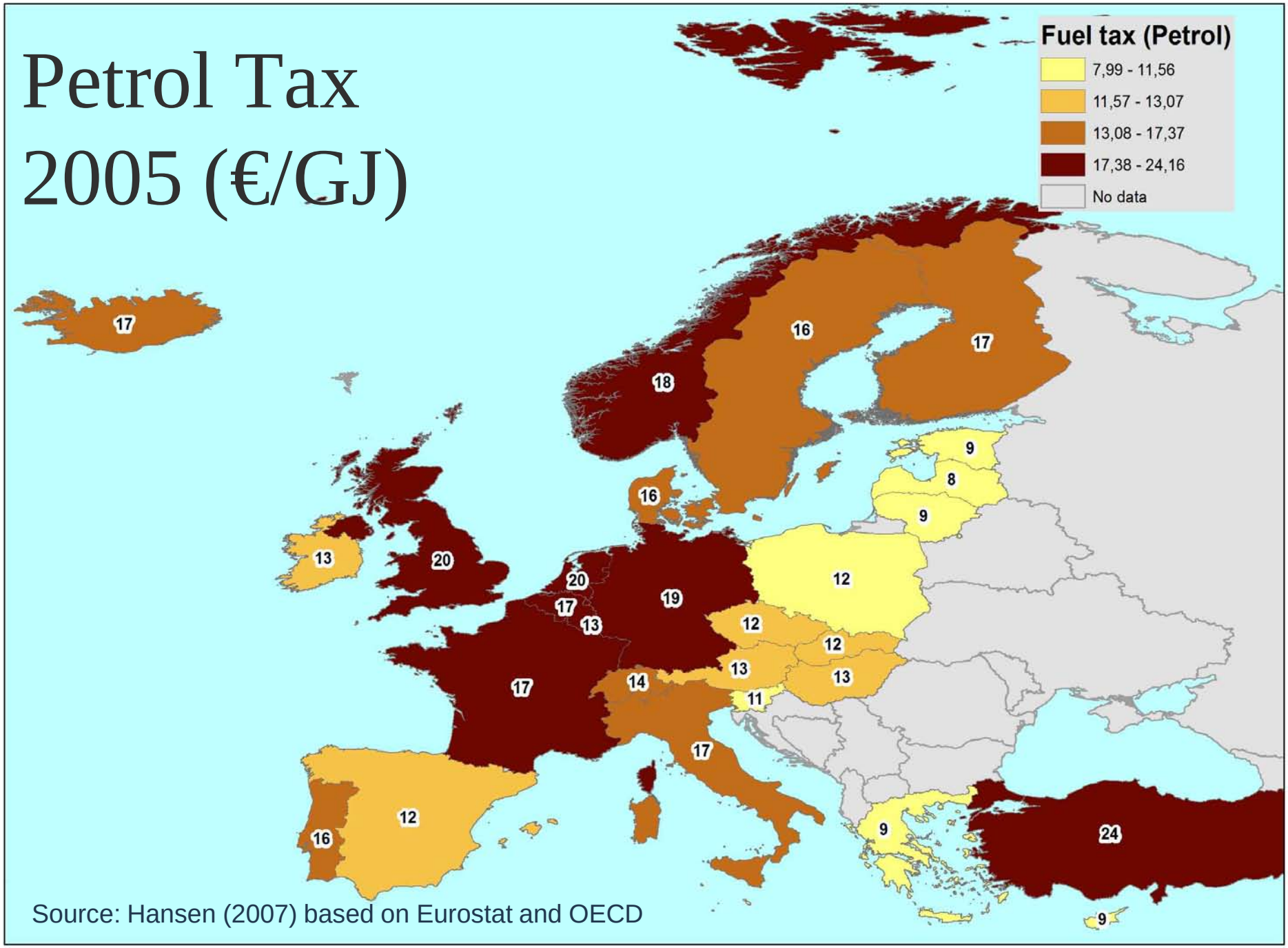
- H2 will become competitive first in the countries/regions with
  - high fuel taxes,
  - relatively lower vehicle taxes for FCVs,
  - high car density,
  - high income level, and
  - environmental and other reasons for promoting electro-motor vehicles (if local environmental impact of power plants is low)
- Which countries and regions are they?

Diesel Tax 2005 (€/GJ)



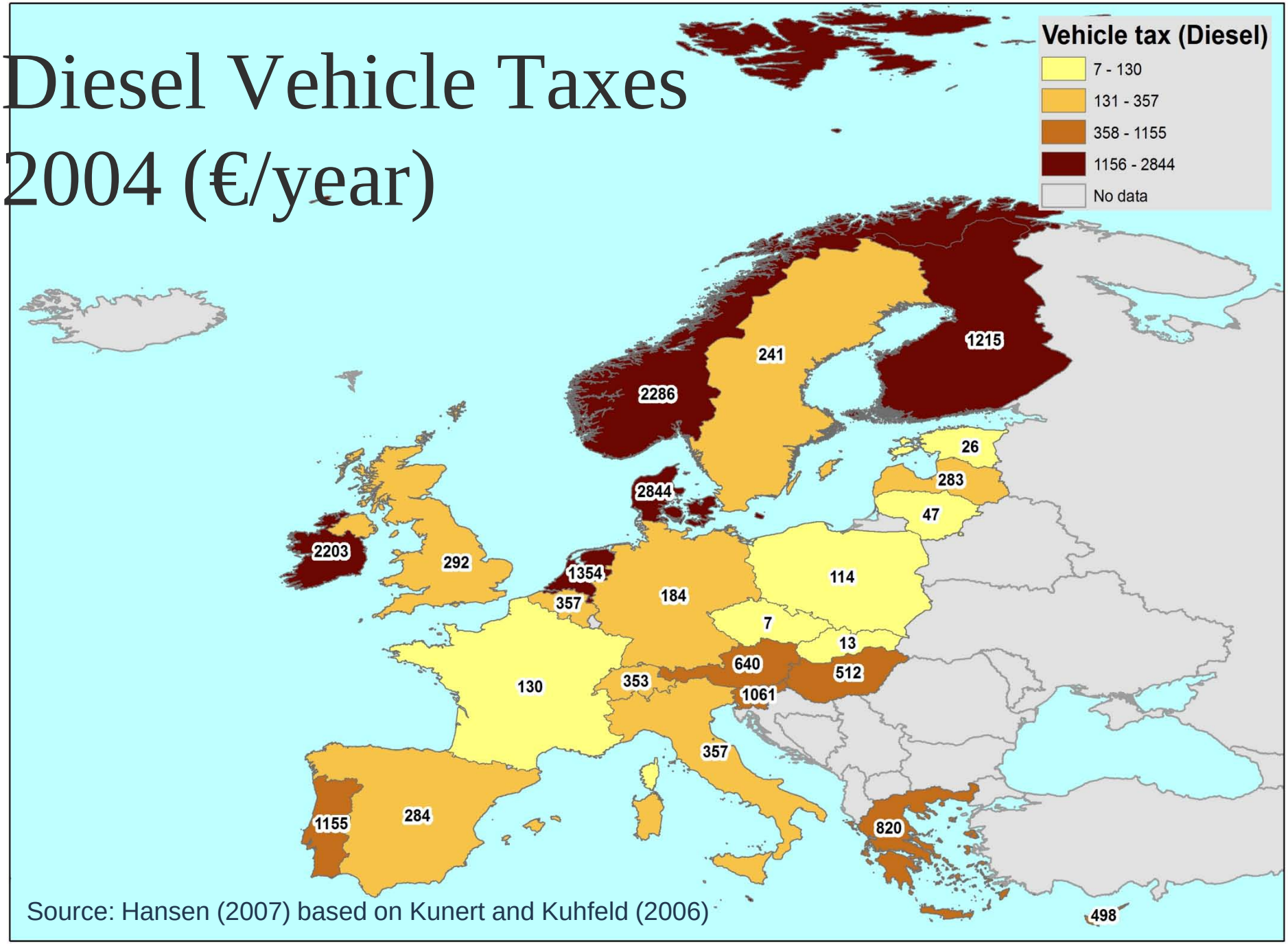
Source: Hansen (2007) based on Eurostat and OECD

Petrol Tax 2005 (€/GJ)



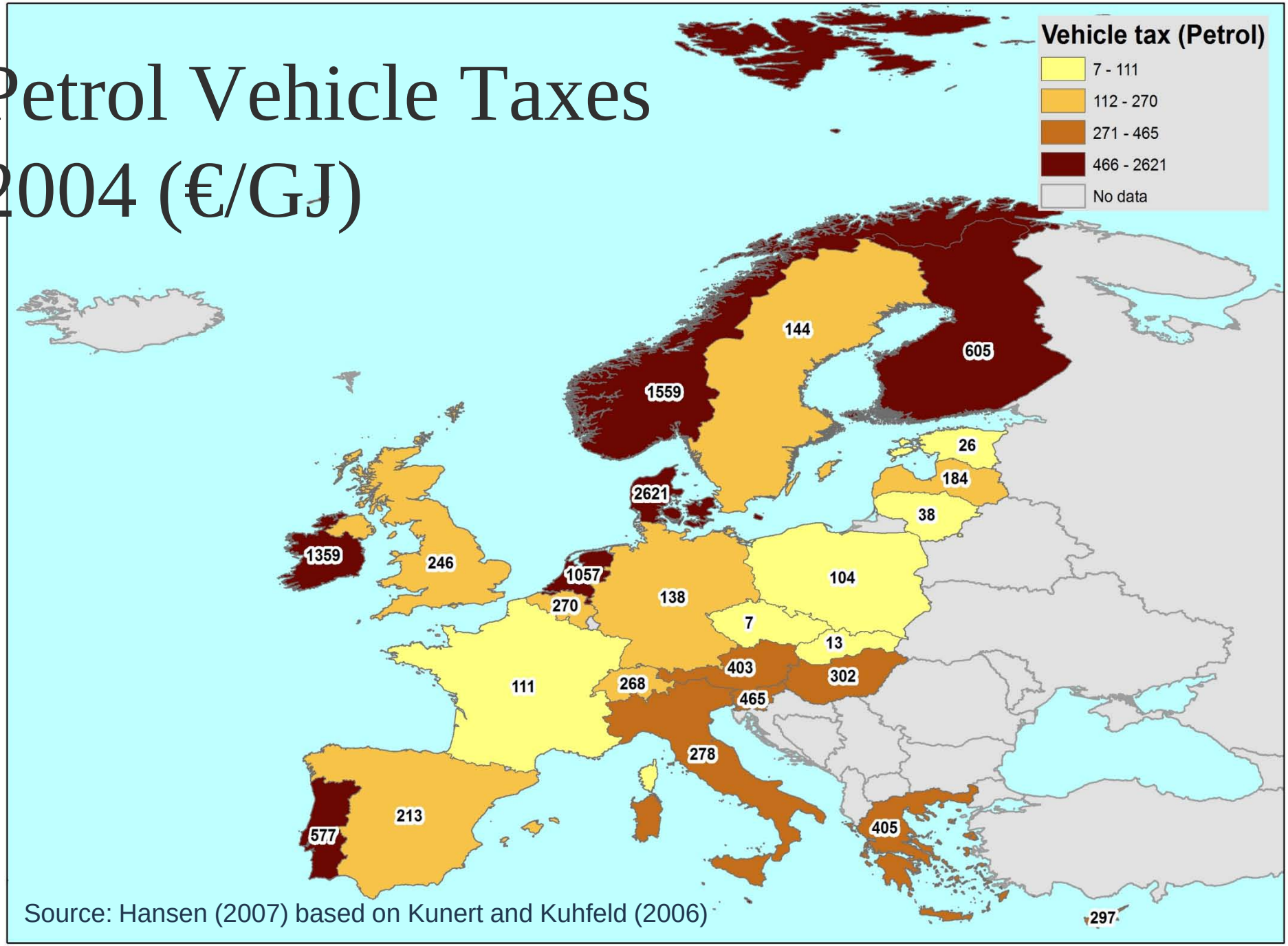
Source: Hansen (2007) based on Eurostat and OECD

Diesel Vehicle Taxes 2004 (€/year)



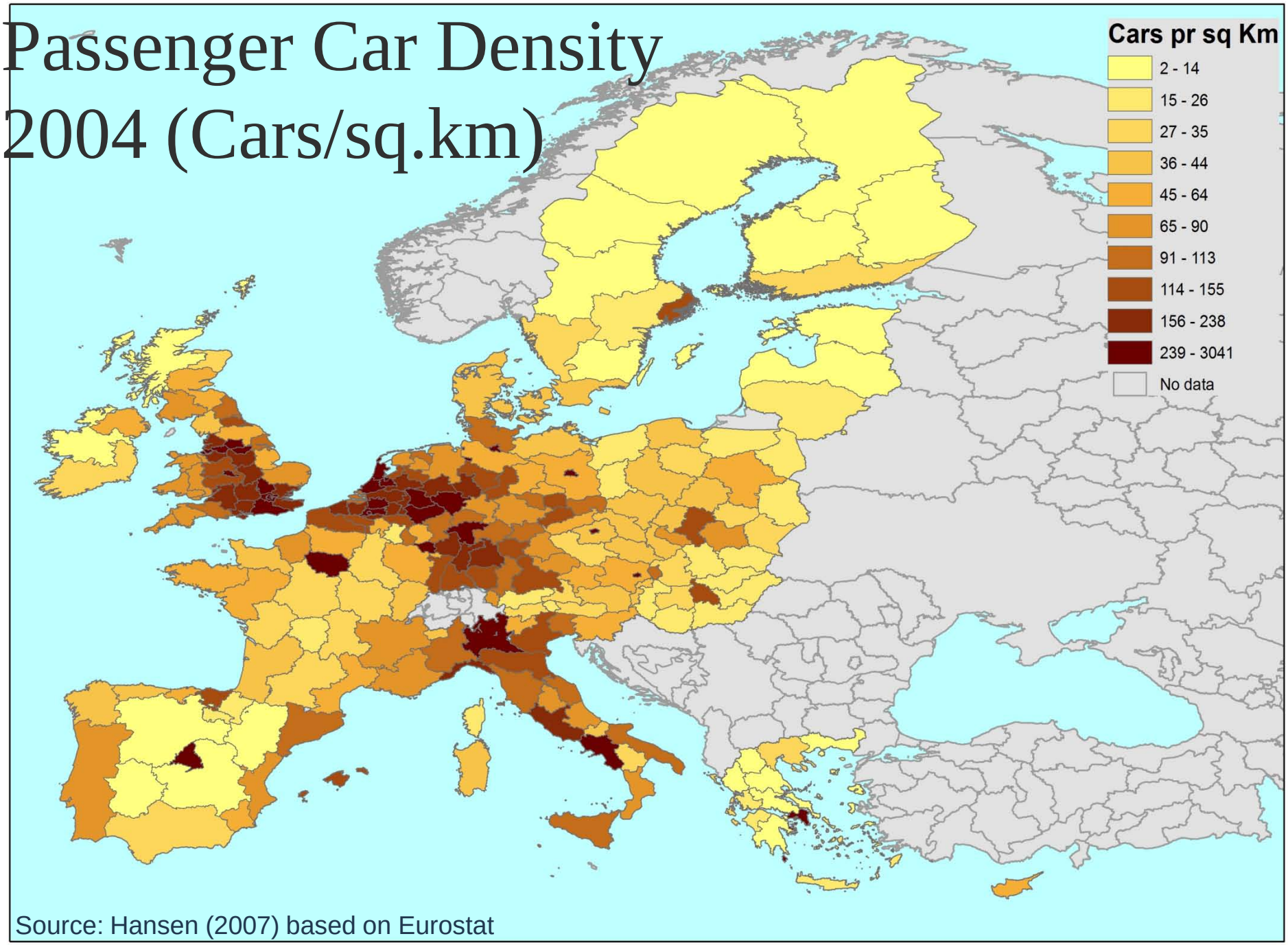
Source: Hansen (2007) based on Kunert and Kuhfeld (2006)

Petrol Vehicle Taxes 2004 (€/GJ)



Source: Hansen (2007) based on Kunert and Kuhfeld (2006)

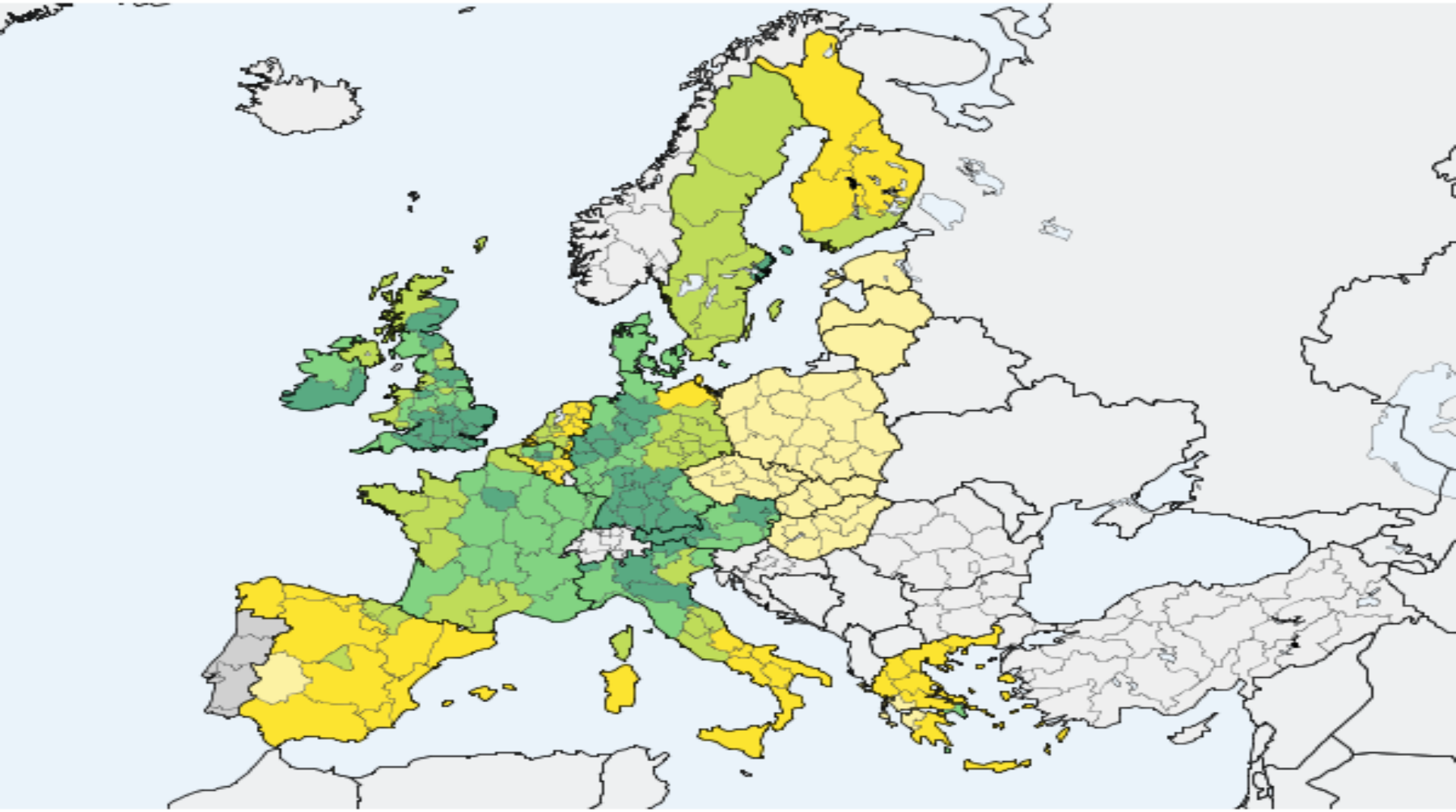
Passenger Car Density 2004 (Cars/sq.km)



Source: Hansen (2007) based on Eurostat

Disposable income

(EUR per inhabitant)



Legend (Data 2004)

1436.3 - 8895.5

8895.5 - 14078.3

14078.3 - 15786.5

15786.5 - 17288.0

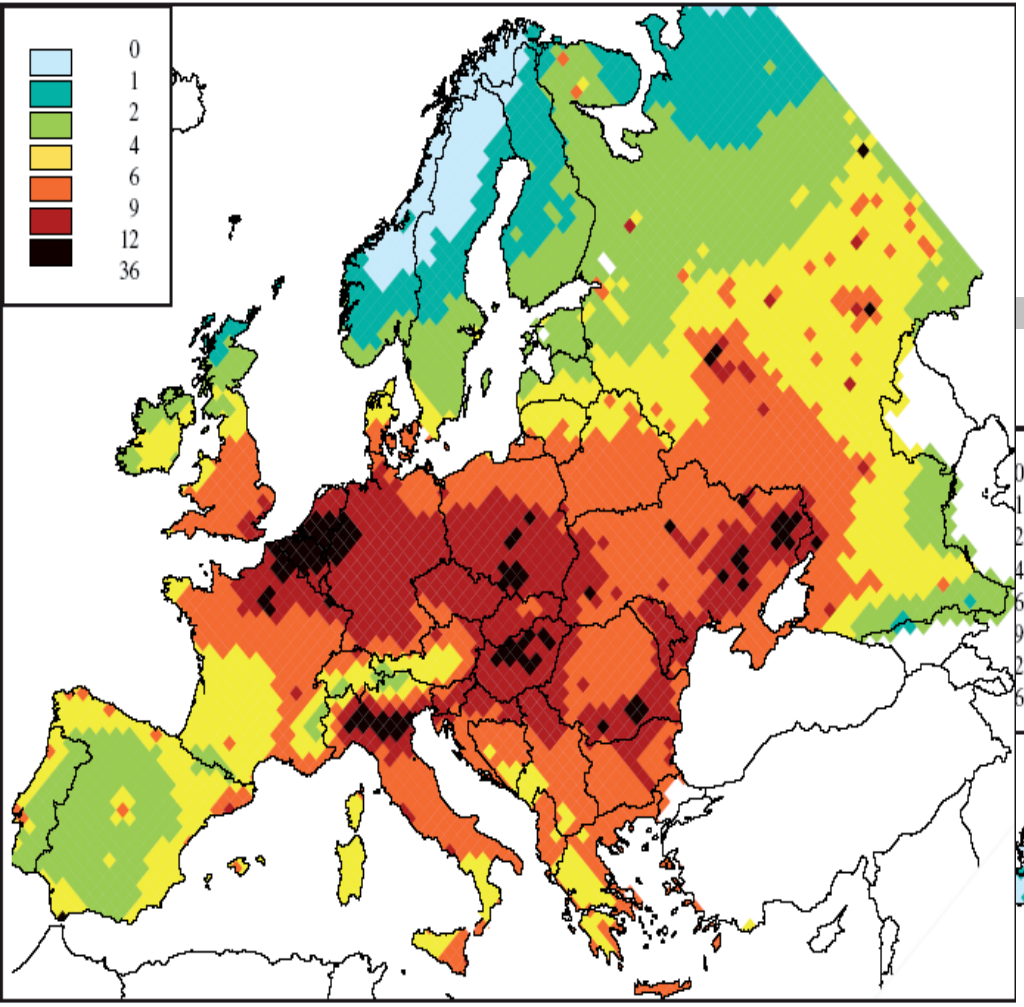
17288.0 - 23382.8

N/A

Minimum value:1436.3 Maximum value:23382.8

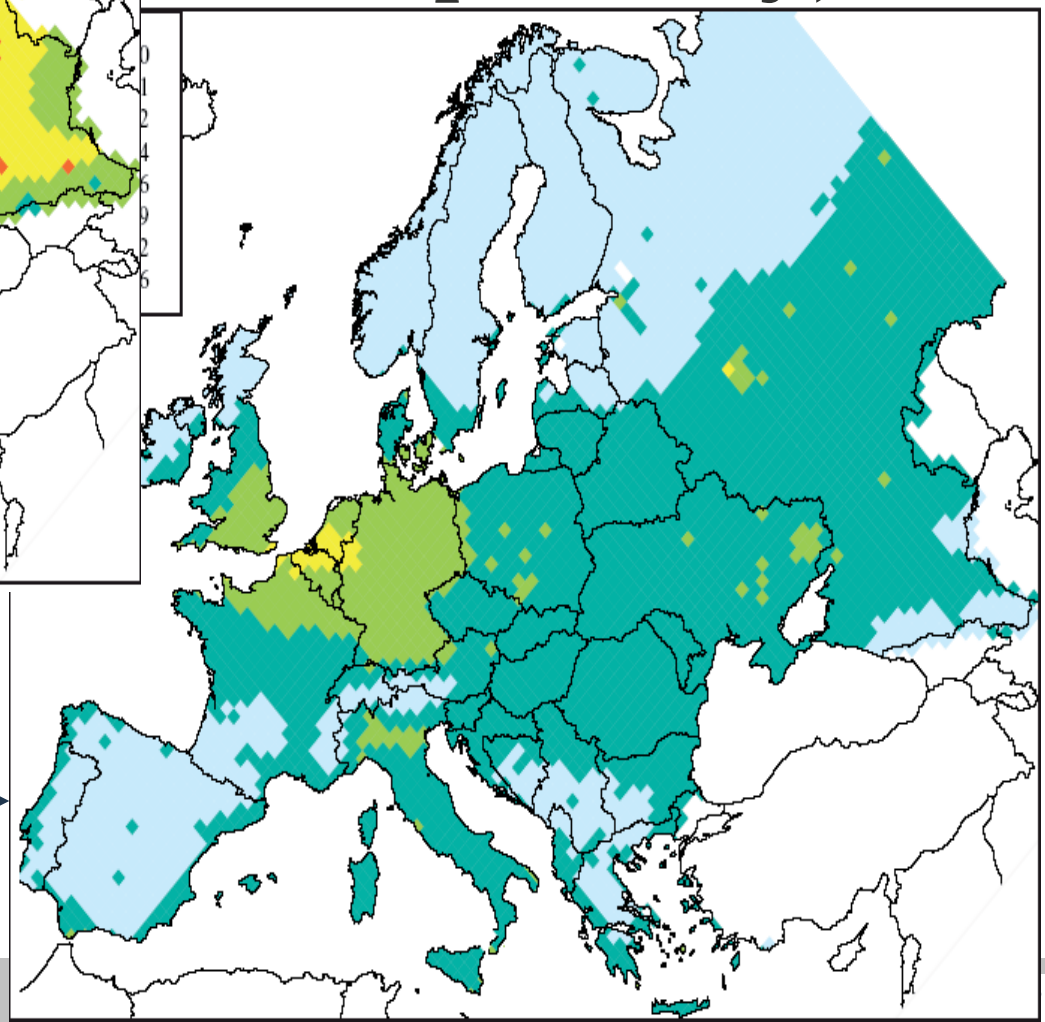
Source: Eurostat (2007)

PM 2.5 deaths (loss of statistical life expectancy)



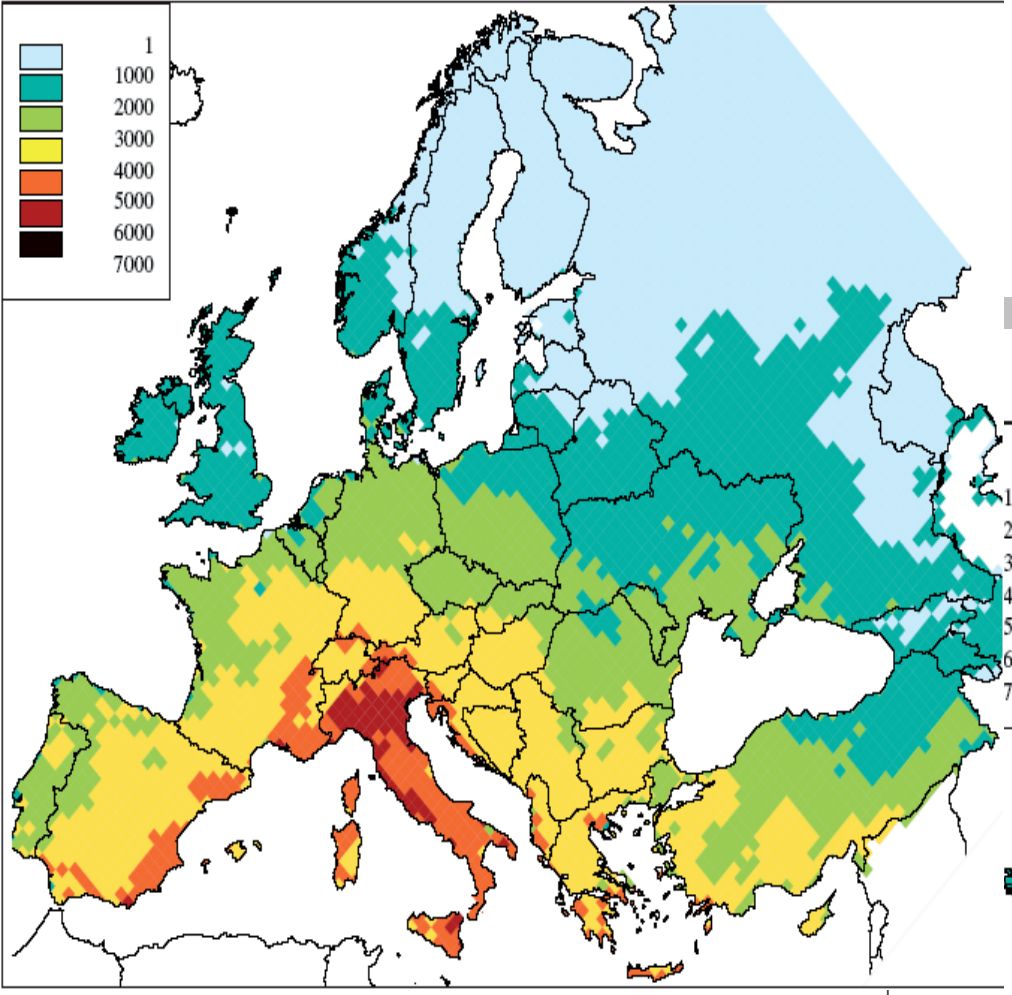
2000

2020 after EU Air Strategy and Maximum Climate Action



Source: EEA (2006)

O_3 concentration (ppb days)



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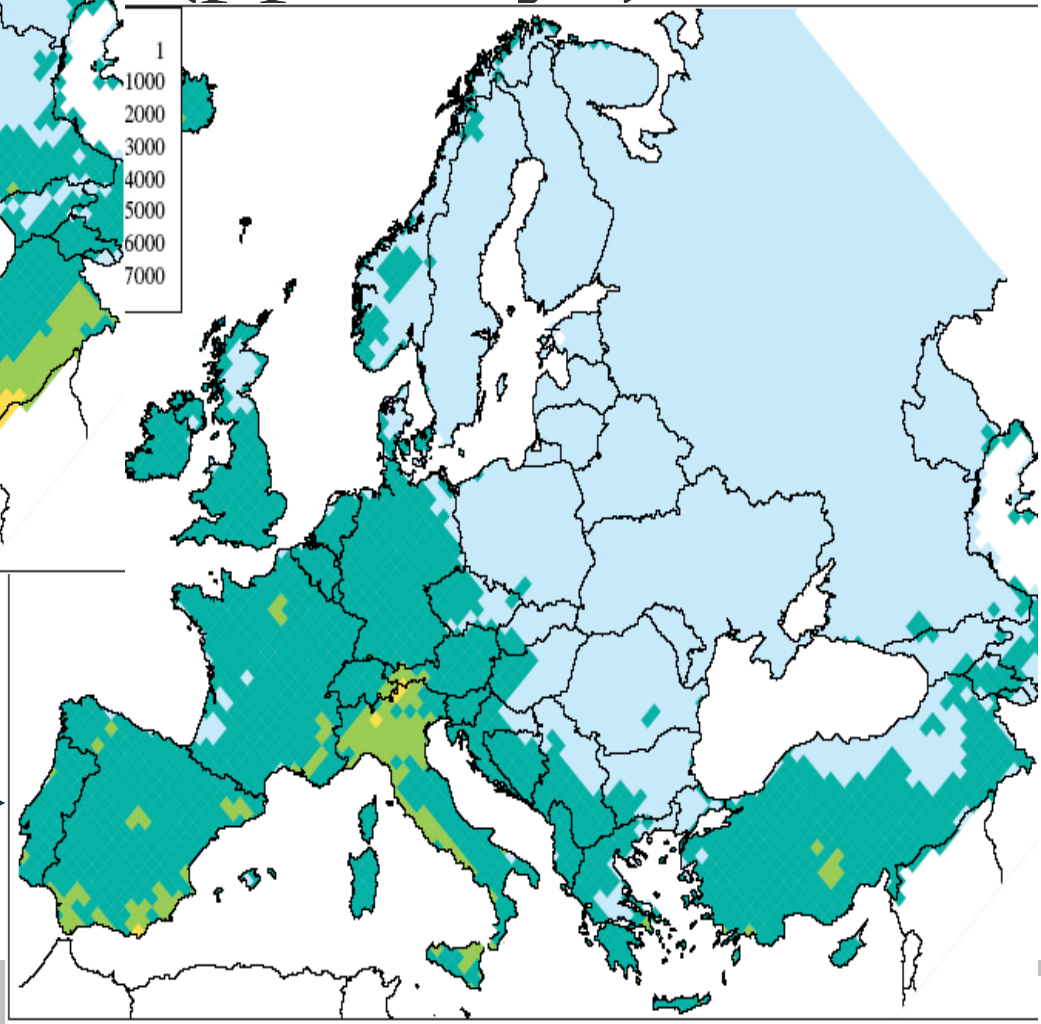

Source: EEA (2006)

Thank you for your attention

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Model with oil price dependent and non-energy costs (NEC)

- P = (a + ak – c – de) / (df – b – bk)
- P = oil price where H2 cost/km = diesoline cost/km
- a = “diesoline” NEC
- b = “diesoline” oil price dependency
- c = hydrogen NEC
- d = hydrogen gas price dependency
- e = natural gas NEC
- f = natural gas oil price dependency
- k = efficiency advantage
  - [(HFC km/GJ)/(ICEkm/GJ)]-1

Recent EECG Research Papers on HFC in automotive use from Department of Environmental, Social and Spatial Change (ENSPAC) at Roskilde University

Hansen, A. C. (2007) Where in Europe Will Hydrogen Become Competitive First? http://hdl.handle.net/1800/3012

Hansen, A. C. (2007) When Will Hydrogen Become a Competitive Transport Fuel? http://hdl.handle.net/1800/3011

Hansen, A. C. (2007) Hydrogen and Fuel Taxation. http://hdl.handle.net/1800/2991

Hansen, A. C. (2007) The Potential Contibution of Hydrogen to Societal Goals. http://hdl.handle.net/1800/2979

Hansen, A. C. (2007) The Supply Security of Hydrogen as Transport Fuel.http://hdl.handle.net/1800/2978

Hansen, A. C. (2007) Hydrogen and Fuel Cell Technology in EU LDV Transport: Potential Contribution to Environmental Goals. http://rudar.ruc.dk/handle/1800/2434

Hansen, A. C. (2007) The International Oil Price and Hydrogen Competitiveness. http://rudar.ruc.dk/handle/1800/2433