Chapter 5: Tables & Figures(CH5FOD_Figures_Nov23 rev.1_Th.doc)

Table 5.1. 2000 World Transport Energy Use, by mode (exajoules)

LDVs	34.20	
2-wheelers	1.20	
Heavy freight trucks	12.48	
Medium freight trucks	6.77	
Buses	4.76	
Rail	1.19	
Air	8.95	
Shipping	7.32	
Total	76.87	Source: IEA/SMP Model

Table 5.2.Overview of impacts of present-day transportation sectors on climate change through radiative forcing (RF) and potential mitigation measures

	Surface transportation (vehicular)		**Shipping**		**Aviation**	
Forcing (derivative)	Forcing (+/-) mW m^{-2}	Technological mitigation measures	Forcing (+/-) mW m^{-2}	Technological mitigation measures	Forcing (+/-)[1] mW m^{-2}	Technological mitigation measures
CO_2	+ve	fuel efficiency	34.3[2]	fuel efficiency, ship modifications	25.3	fuel efficiency
NO_x (O_3)	51[3]	combustion technology, catalysts	29[4]	combustion technology, catalysts	23	combustion technology
SO_4 particles (direct effect)	-ve	fuel S content	-20[5]	fuel S content	-3.5	fuel S content
Black Carbon particles	64 - 160[6]	combustion technology, particle traps	+ve	combustion technology	2.5	combustion technology
Water vapour	negligible	–	negligible	–	2.0 (but potentially larger for supersonics)	fuel efficiency
Linear contrails	–	–	–	–	10	operational measures
Enhanced cloudiness	unknown	combustion technology, particle traps	-110[7]	combustion technology, fuel S content	30[8] 0 - 26[9]	operational measures
CH_4[10]	-ve (indirect)	combustion technology, catalysts	-20 (indirect)[11]	combustion technology, catalysts	-10.4 (indirect)	–
VOCs (O_3)	+ve (indirect)	combustion technology, catalysts	+ve (indirect)	combustion technology, catalysts	+ve (indirect) but negligible	combustion technology
CO (O_3)	+ve (indirect)	combustion technology, catalysts	+ve (indirect)	combustion technology, catalysts	+ve (indirect) but negligible	combustion technology

[1] Aviation RFs taken from recent reanalysis of Sausen et al. (2005), excepting enhanced cloudiness
[2] Eyring et al. (2005 in prep.)
[3] Niemeyer et al. (2005?)
[4] Calculated from 0.7 DU tropospheric czone column chnage from Endresesen et al. (2003) and 0.042 W/m^{-2}/DU (IPCC, 2001)
[5] Endresen et al. (2003)
[6] Schultz et al. (2004)
[7] Capaldo et al. (1999)
[8] Stordal et al. (2005)
[9] Minnis et al. (2004)
[10] CH_4 has complex impacts: it is a direct GHG (+ve RF); ambient CH_4 is destroyed by tropospheric chemistry and NO_x emissions (indirect –ve RF); it contributes through tropospheric chemistry to O_3 formation
[11] Endresen et al. (2003)

Table5. 3 Summary of shipping technology scenarios of Eyring et al.(2005b)

Technology scenario 1 (TS1) – 'Clean scenario'	Technology scenario 2 (TS2) – 'Medium scenario'	Technology scenario 3 (TS3) – 'IMO compliant scenario'	Technology scenario 4 (TS4) – 'BAU'
Low S content fuel (1%/0.5%‡), aggressive NO_x reductions	Relatively low S content fuel (1.8%/1.2%), moderate NO_x reduction	High S content fuel (2%/2%), NO_x reductions according to IMO stringency only	High S content fuel (2%/2%), NO_x reductions according to IMO stringency only
Fleet = 75% diesel, 25% alternative plant	Fleet = 75% diesel, 25% alternative plant	Fleet = 75% diesel, 25% alternative plant	Fleet = 100% diesel

‡Note that the fuel S percentages refer to values assumed in (2020/2050)

Table 5.4

Table 1

Energy and GHG Impacts of Ethanol:
Estimates from Corn- and Wheat-to-Ethanol Studies

	Feedstock	**Ethanol production efficiency (litres/tonne feedstock)**	**Fuel process energy efficiency (energy in/out)**	**Well-to-wheels GHG emissions: compared to base (gasoline) vehicle (per km travelled)**	
				Fraction of base vehicle	Percent reduction
GM/ANL, 2001	corn-*a*	372.8	0.50	n/a	n/a
GM/ANL, 2001	corn-*b*	417.6	0.55	n/a	n/a
Pimentel, 2001/91	corn	384.8	1.65	1.30	-30%[c]
Levelton, 2000	corn	470.0	0.67	0.62	38%
Wang, 2001a	corn-dry mill	387.7	0.54	0.68	32%
Wang, 2001a	corn-wet mill	372.8	0.57	0.75	25%
Levy, 1993	corn-*a*	367.1	0.85	0.67	33%
Levy, 1993	corn-*b*	366.4	0.95	0.70	30%
Marland, 1991	corn	372.8	0.78	0.79	21%
Levington, 2000	wheat	348.9	0.90	0.71	29%
ETSU, 1996	wheat	346.5	0.98	0.53	47%
European Commission, 1994	wheat	385.4	1.03	0.81	19%
Levy, 1993	wheat-*a*	349.0	0.81	0.68	32%
Levy, 1993	wheat-*b*	348.8	0.81	0.65	35%

Note: Where a range of estimates is reported by a paper, "*a*" and "*b*" are shown in the feedstock column to reflect this.
[c] Negative greenhouse gas reduction estimate connotes an increase. n/a: not available.
Sources: Except for Levelton, 2000, Wang 2001a and GM/ANL 2001, data presented here for these studies are taken from the comparison conducted by CONCAWE, 2002.

Table 5.5

Country	Vehicles*	Refuelling Stations	VRA**	Last Updated
Argentina	1,413,664	1,342		Jan 05
Brazil	1,000,000	1000		Apr 05
Pakistan	800,000	740		Jul 05
Italy	420,000	504		Mar 05
India	204,000	198		Apr 04
USA	130,000	1,300	3,271	May 03
China	69,300	270		Apr 03
Egypt	52,000	79		Apr 04
Venezuela	50,000	140		Jan 04
Ukraine	45,000	130		Dec 03
Colombia	43,380	78		Sep 04
Russia	36,000	218	2	Dec 03
Bangladesh	31,988	79		Dec 04
Iran	22,058	40		Dec 04
Japan	24,000	288	658	Mar 05
Canada	20,505	222	3,208	Aug 01
Germany	27,175	539	450	Mar 05
Bolivia	28,790	59	46	May 05
Malaysia	14,700	39		May 05
Ireland	9,780	10	6	Jul 04
France	7,100	102	100	Dec 03
South Korea	5,585	158		Oct 04
Bielorussia	5,500	24		Dec 01
Chile	5500	13		Mar 05
Indonesia	4,660	28		Dec 01
Thailand	4,905	31		May 05
Sweden	4,260	44		Oct 03
Trinidad & Tobago	3,812	13		Nov 03
Australia	2,104	127	55	Aug 01
Mexico	2,000	4		Apr 03
New Zealand	1,555	30		Sep 03
Great Britain	875	34	40	Jul 03

Source: IANGV,2005

Table5. 6

1. Configuration	Empty Tonne	Payload Tonne	Fuel Tonne	Max TOW Tonne
Baseline	236	86	178	500
BWB	207	86	137	430
Laminar Flying Wing	226	86	83	395
LFW with UDF	219	86	72	377

Table 5.7: taxes and pricing in the transport sector in developing and developed countries

Instrument	Developing Countries/EIT	Developed countries
Tax incentives to promote use of Natural gas	Pakistan, Argentina, Colombia, Russia	Italy, Germany, Australia, Ireland, Canada, UK
Incentives to promote natural gas vehicles	Malaysia, Egypt	Belgium, UK, USA, Australia, Ireland
Annual Road tax differentiated by vintage	Singapore and India (fixed span and scrapping)	Germany
Emission Trading	Chile	
Congestion Pricing including Area Licensing Scheme	Chile; Singapore	Norway
Vehicle Taxes based on emissions-tax deductions on cleaner cars e.g. battery operated or alternative fuel vehicles	South Korea	Austria, Britain, Belgium, Germany, Japan, The Netherlands, Sweden
Carbon tax by size of engine	Zimbabwe	
Cross subsidization of cleaner fuels (ethanol blending by gasoline tax-through imposition of lower surcharge or excise duty exemption	India	

Adapted from Pandey abd Bhardway (2000), Gupta (1999) and European Natural Gas Vehicle Asociation (2002)

Table 5.8 Impact of a permanent increase in real fuel prices by 10%

	Short run (within 1 year)	Long run (5 years)
Traffic volume	-1%	-3%
Fuel consumption	-2.5%	-6%
Vehicle fuel efficiency	-1.5%	-4%
Vehicle ownership	Less than -1%	-2.5%

Source: Goodwin et al. (2004)

Table5.9

Tax/Pricing Measure	Potential Energy/ GHG Savings or transport improvements)	Reference
Optimal Road Pricing based on congestion charging (London UK)	37% CO2	Maddison et al 1996
Congestion Pricing of the Namsan Tunnels (Seoul S Korea)	34% reduction of peak passenger traffic volume Traffic flow from 20 to 30km/hr	World bank 2002b
Fuel Pricing and Taxation	15-20% for vehicle operators	Martin et al (1995)
Area Licensing Scheme (Singapore)	1.043GJ/day energy savings Vehicular traffic reduced by 50% Private traffic reduced by 75% Travel speed increased 20 to 33 km/hr	FWA, 2002
Urban Gasoline tax (Canada)	1.4 Megatonnes by 2010 2.6 megatonnes by 2020	In the case of Canada (Transportation in Canada, 1999- www.tc.gc.ca/pol/en/Report/anre1999/tc9905be.htm

Table 5.10. Marginal CO2 abatement cost at selected emission reduction targets in selected cities, US$/tonne CO2*

City	Total Comulative CO2 Emission (10^6 tonnes)	Marginal Abatement Cost						
		5%	10%	15%	20%	25%	30%	40%
Bandung	19	121	204	412	132503	NA	NA	NA
Beijing	105	29	33	NA	37	NA	39	253
Delhi	30	35	44	49	66	115	NA	NA
Hangzhou	6	76	89	NA	100	962	NA	NA
Jakarta	200	NA	112	NA	156	NA	269	246215
Manila	182	178	327	528	NA	NA	NA	NA
Mumbai	12	17	NA	19	21	24	47	NA

* the figure for HCMC are 0.1, 0.5, 1.3 and 2.1 US$/tonne of CO2 at 3%, 6%, % and 12% reduction targets respectively.
NA – not available

Table 5.11 Composite Fuel Economy Results for Best-Estimate, Best-Case, and Worst-Case Scenarios

Propulsion System	Fuel Economy, mpg gasoline-equivalent		
	Worst Case	Best Estimate	Best Case
Gasoline DOD SI CD Baseline	20.2[a]	21.3	22.4
Gasoline DI SI CD	23.2	24.2	25.4
Diesel DI CI CD	25.2	25.8	27.1
E85 DOD SI CD	20.2[a]	21.3	22.4
CNG DOD SI CD	19.9[a]	21.0	22.1
H_2 DOD SI CD	24.3[a]	25.6	26.9
Gasoline DOD SI HEV	24.5	26.5	34.0
Gasoline DI SI HEV	27.0	29.2	33.6
Diesel DI CI HEV	28.5	30.8	39.4
E85 DOD SI HEV	24.5	26.5	34.0
CNG DOD SI HEV	23.5	25.4	32.5
H_2 DOD SI HEV	29.2	31.6	40.5
Gasoline/naphtha FP FCV	25.7	32.2	36.3
Gasoline/naphtha FP FC HEV	29.5	37.5	42.2
MeOH FP FCV	28.1	35.2	39.6
MeOH FP FC HEV	32.7	40.8	45.9
EtOH FP FCV	25.7	32.2	36.3
EtOH FP FC HEV	29.5	37.5	42.2
H_2 FCV	47.6	50.8	54.5
H_2 FC HEV	52.6	56.1	59.8

[a] Engine modeled without DOD for the worst-case scenario.

Source: General Motors, 2005

Abbreviations

DOD	Displacement on demand
SI	Spark ignited
CD	Conventional drivetrain
DI	Direct injection
CI	Compression ignition
E85	85% ethanol/15% gasoline (by volume) fuel
CNG	Compressed natural gas
H_2	Hydrogen
HEV	Hybrid electric vehicle
FP	Fuel processor
FCV	Fuel cell vehicle
MeOH	Methanol
EtOH	Ethanol

Table 5.12 .Tank to Wheels and Well to Wheels CO_2 Emissions from Compact Cars With Four Different Powertrains (Owen and Gordon, 2003)

Technology	**Year**	**CO_2 Tank to Wheels**	**CO_2 Well to Wheels**
Baseline diesel	2004	149 g/km	167 g/km
Mild hybrid	2010	114 g/km	123 g/km
Parallel hybrid (Prius-type)	2012	92 g/km	103 g/km

Hydrogen series hybrid FCV	2030	0 (0.89-1.43 kg/100km H_2)	74-119 g/km

Table 5.13 GHG Emissions from Vehicles and Transportation Modes in Developing Countries (Source: Sperling and Salon, 2002)

	Load Factor (average occupancy)	CO2-Equivalent Emissions Per Passenger-Km (full energy cycle)
Car (gasoline)	2.5	130-170
Car (diesel)	2.5	85-120
Car (natural gas)	2.5	100-135
Car (electric)*	2.0	30-100
Scooter (two-stroke)	1.5	60-90
Scooter (four-stroke)	1.5	40-60
Minibus (gasoline)	12.0	50-70
Minibus (diesel)	12.0	40-60
Bus (diesel)	40.0	20-30
Bus (natural gas)	40.0	25-35
Bus (hydrogen fuel cell)**	40.0	15-25
Rail Transit***	75 percent full	20-50

Note: All numbers in this table are estimates and approximations, and are best treated as illustrative.
*Ranges are due largely to varying mixes of carbon and non-carbon energy sources (ranging from about 20-80 percent coal), and also the assumption
that the battery electric vehicle will tend to be somewhat smaller than conventional cars.
**Hydrogen is assumed to be made from natural gas.
***Assumes heavy urban rail technology ("Metro") powered by electricity generated from a mix of coal, natural gas, and hydropower, with high passenger use (75 percent of seats filled on average).

Table 5.14

Study	Mitigation Measure/Policy	Region	CO2 reduction(%)				CO2 reduction (Mt)				mitigation cost ($/t-CO2)	comments
			2010	2020	2030	2050	2010	2020	2030	2050		
IEA2004	Alternative scenario	World	2.2	6.8	11.4		133	505	997			
		OECD	2	6.9	11.5		77	308	557			
		Developing	2.8	6.8	11.4		49	170	381			
		TransitionE	2.3	6.2	11.2		8	27	59			
IEA2001	Improving Tech for Fuel Economy	OECD		30%	40%							
	Diesel				5-15%							timeframe not clear
	Policy Packages		16%									including transit improvements, parking restrictions and increased prices, and promotion of walking and bicycling
	Policy Packages		>30%									adds significant amounts of low greenhouse-gas alternative fuel (such as cellulosic ethanol) to

												the fuel economy improvement measures
IEA2002	All scenario included	NA	6.6	14.4			148	358				
	All scenario included	W.Europe	6.6	15.6			76	209				
	All scenario included	JA	8.3	16.1			28	61				
IEA2004	Improving Fuel Economy	World			18%							
	Biofuels				12%							
	FCV with Hydrogen Refuelling				7%							
	COMBINING THESE THREE				30%							
IEA2004	Reduction in fuel use per km	World		15%	25%	35%						Reduction in fuel use per kilometre, gasoline/diesel vehicles (compared with a reference case)
	Blend of biofuels			5%	8%	13%						Blend share in gasoline and diesel fuel of biofuels having 50% lower well-to-wheels GHG emissions per kilometre than gasoline
	Reduction in growth of LDV travel			5%	10%	20%						Reduction in growth of light-duty-vehicle travel(compared with a reference case)

	using hydrogen in vehicle			0%	3%	75%						using hydrogen in vehicle–reduction in well-to-wheels GHG emissions
ECMT												
	Driving training + technical aids(shift indicators, fuel use indicators etc)	EU	5-10%								(-49)-54.5	timeframe not clear
	low rolling-resistance tyres		1-2%								(-327)-(-108)	timeframe not clear
	idle stop/start:Gasoline (dense traffic)		4-8%								(-50)-176	timeframe not clear
	idle stop/start:Diesel (dense traffic)		2-4%								(-18)-474	timeframe not clear
	adaptive cruise control :diesel(light traffic)		15%								(-42)	timeframe not clear
	adaptive cruise control:gasoline(light traffic)		10%								369	timeframe not clear
	All technologies to reduce on-road fuel consumption		>10%									timeframe not clear
EC	voluntary agreement	EU	7.6				75					
	add other operational measures		10.6				105					
	Rolling Resistance (Freight)						10.9				-90	1.25Euro=$
	Variable Valve Lift Timing + Cylinder Deactivation						22.8				23.75	

	(Passenger carsPetrol)											
	Driver Training - (Freight-HDV)						10.9				23.75	
	Petrol to Diesel shift Passenger carsPetrol						7.8				102.5	
	Advanced Gasoline Direct Injection (advanced: "DISC") Passenger carsPetrol						19				115	
	Lightweight structure - Petrol cars Passenger carsPetrol						9.9				271.25	
ACEEE	A scenario	US	9.9	26.3			132	418			(-33.5)-(-27)	moderate tech+2%HEV
	B scenario		11.8	30.6			158	488			(-24)	moderate tech 47%+adv tech 47%+ 6%HEV
	C scenario		13.2	33.4			176	532			(-25)	adv tech +2%HEV
					2035							
MIT2004	baseline	US		3.4	16.8							increase in fuel economy
	medium HEV			5.2	29.9							HEV sale share of 50% in 2035
	composite			14.9	44.4							HEV+VMT constant beyond 2008
	combined policies		2.9-6.2	13.7-23.8	31.9-50.4							Policy measures include CAFÉ, gasoline tax and ethanol (from cellulose) content increase.
PEW2003	Efficiency Standards	US		2015								potential in whole transport sector

	Light-duty vehicles			6(9)	18(31)							
	Heavy Trucks			2(9)	3(20)							
	Commercial Aircraft			1(9)	2(22)							
	Replacement & Alternative Fuels											
	Low-Carbon Replacement Fuels			2(30)	7(100)							
	Hydrogen Fuel (All LDV fuel)			1(1)	4(6)							
	Pricing Policies											
	Low-carbon fuel subsidy			2(30)	6(100)							
	Carbon pricing			3(3)	6(6)							
	Variabilization			6(8)	9(12)							
	Behavioral											
	Land Use & Infra-structure			3(5)	5(10)							
	System Efficiency			0(2)	1(5)							
	Climate Change Education			1(1)	2(2)							
	Fuel Economy Information			1(1)	1(2)							
	Total			22	48							
WEC	energy saving due to new technologies	WR		30%		45.55 %						
WBCSD	Road transport	WR										
	WEDGE 1 - Diesels (LDVs)			0.9	2.1	1.8		61	160	181		

	WEDGE 2 - Hybrids (LDVs and MDTs)			2.4	6.1	6.1		161	474	623		
	WEDGE 3 - Biofuels - 80% low GHG sources by 2050			5.7	15.6	29.5		386	1207	3030		
	WEDGE 4 - Fuel Cells - fossil hydrogen			5.9	16.7	32.7		400	1293	3364		
	WEDGE 5 - Fuel Cells - 80% low-GHG hydrogen in 2050			5.9	17.2	45.3		400	1333	4650		
	WEDGE 6 - Mix Shifting 10% FE Improvement			6.7	18.8	47.3		451	1455	4864		
	WEDGE 7 - 10% vehicle travel reduction - all road vehicles			9.4	22.8	51.9		639	1765	5335		

Fig 5.1 Vehicle Ownership as a Function of Per Capita Income (GDP/person)

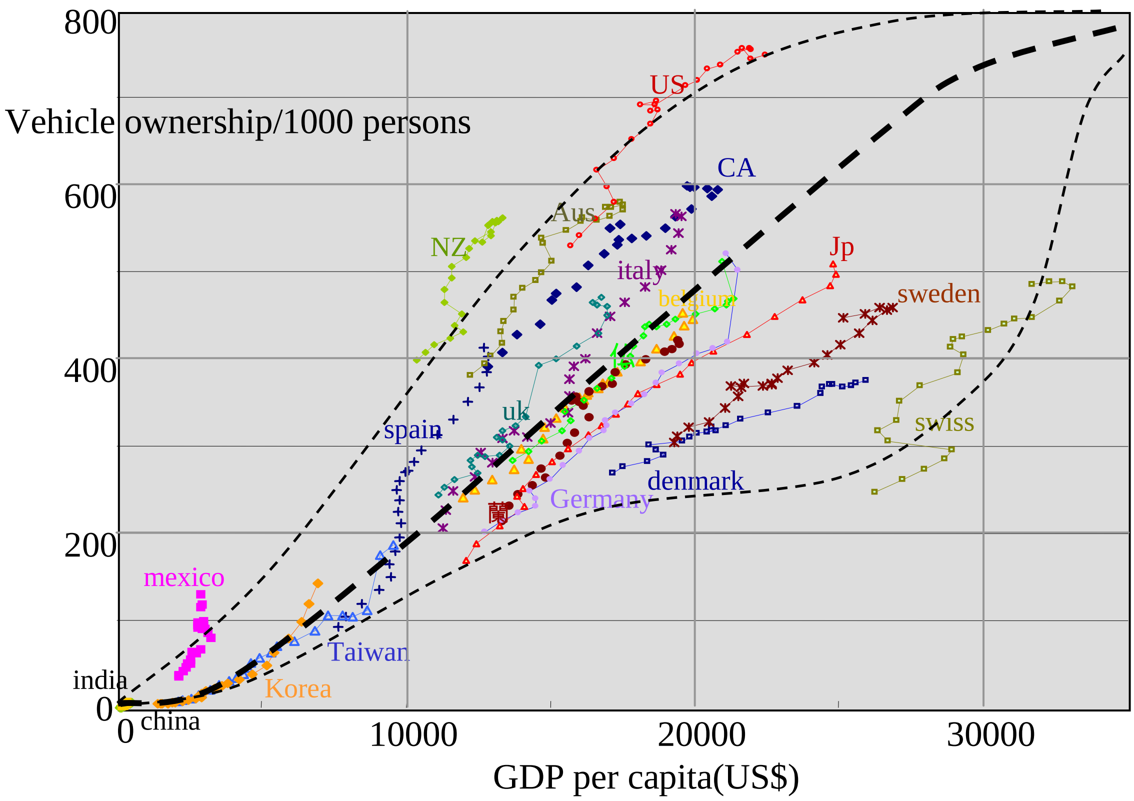


Fig 5.2

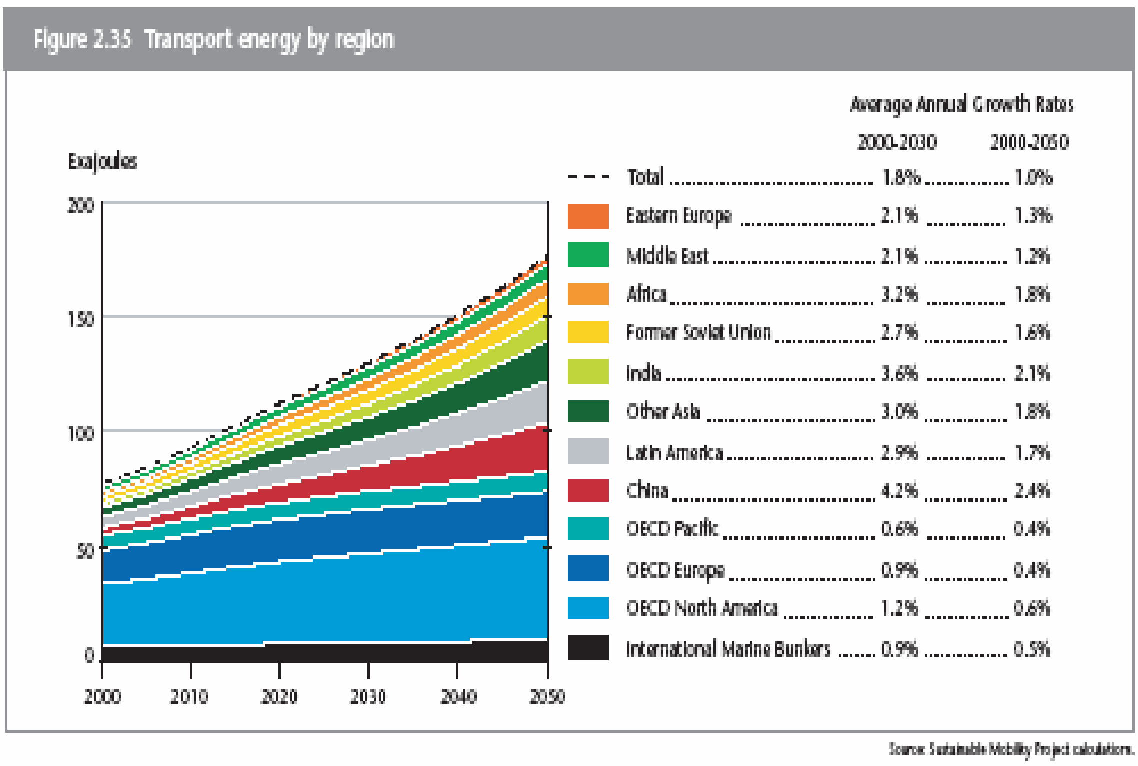


Figure 5.3: Comparison of calculated global emissions of total aviation CO_2 emissions, 1990 to 2050 with other estimates for 2050

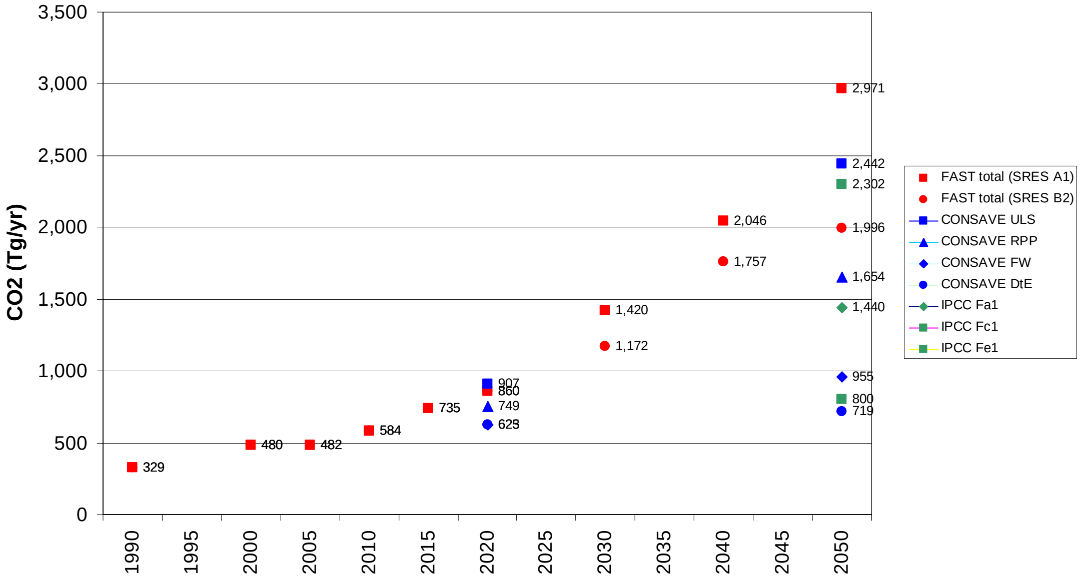


Figure 5.4 Historical and projected emissions of seagoing shipping, 1990 to 2050 (Tg C yr^{-1}) adapted from Eyring et al. (2005a, b)

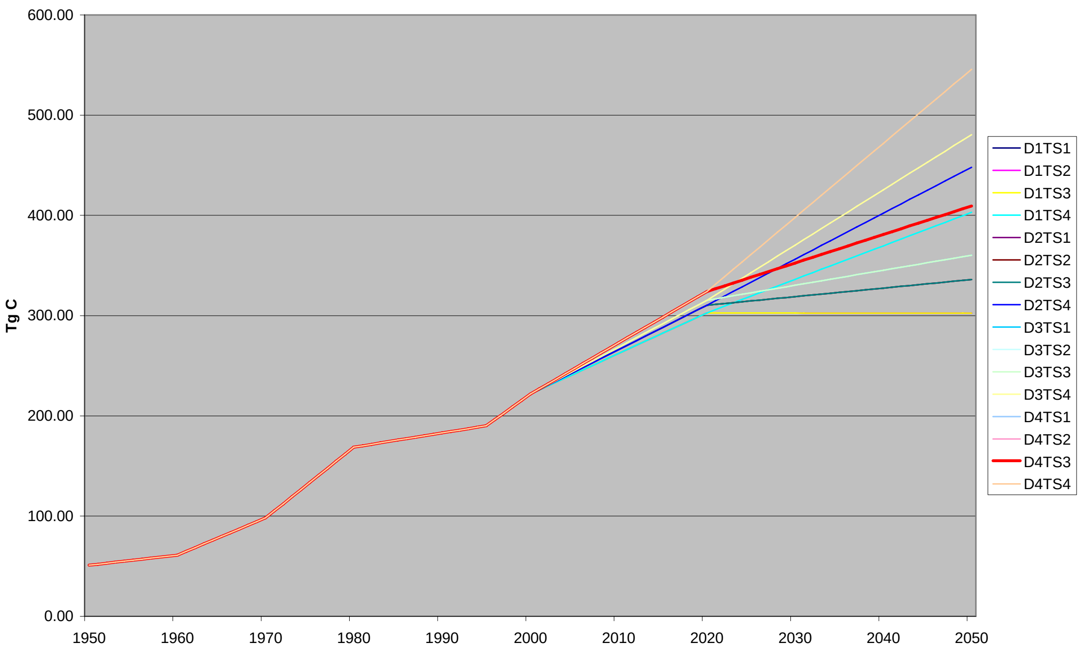


Figure 5.5. Schematic picture of various scenarios.

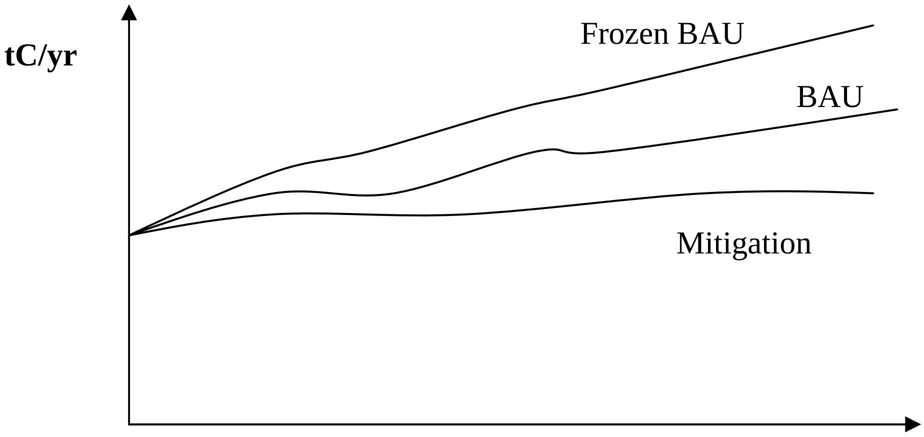


Figure 5.6

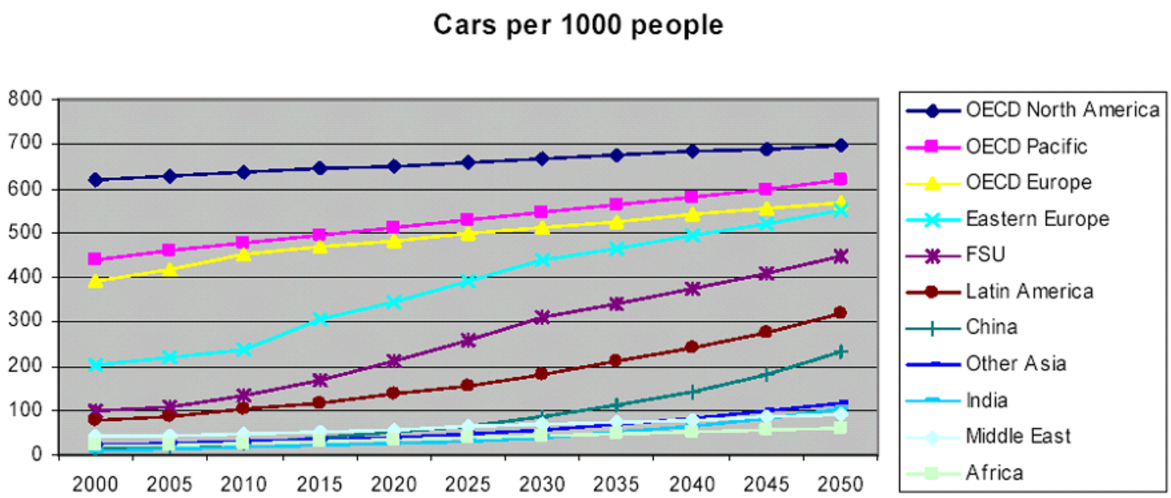


Figure 5.7

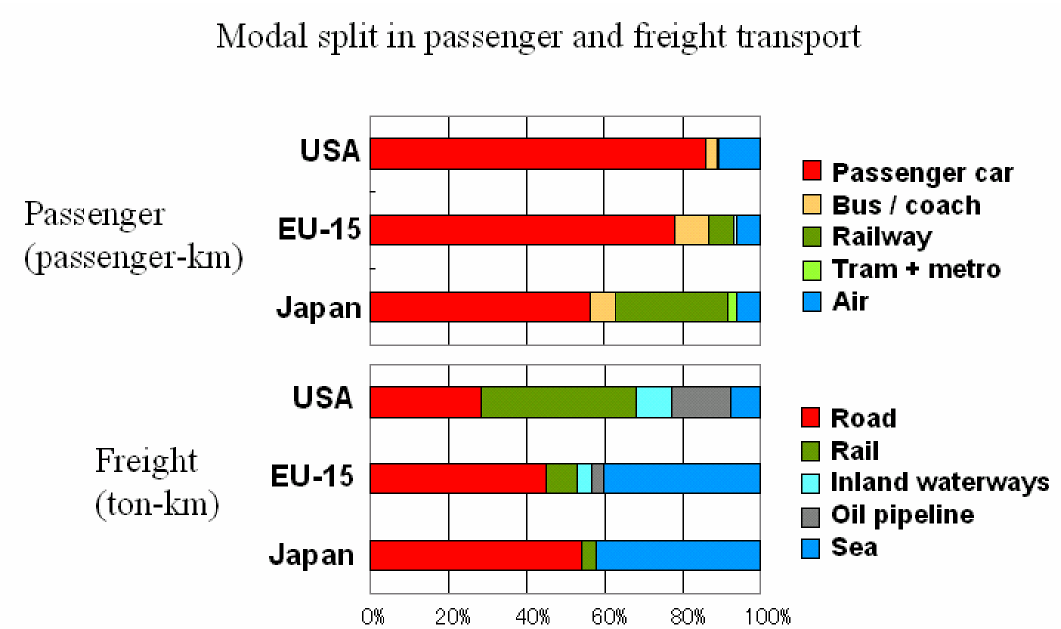


Figure 5.8

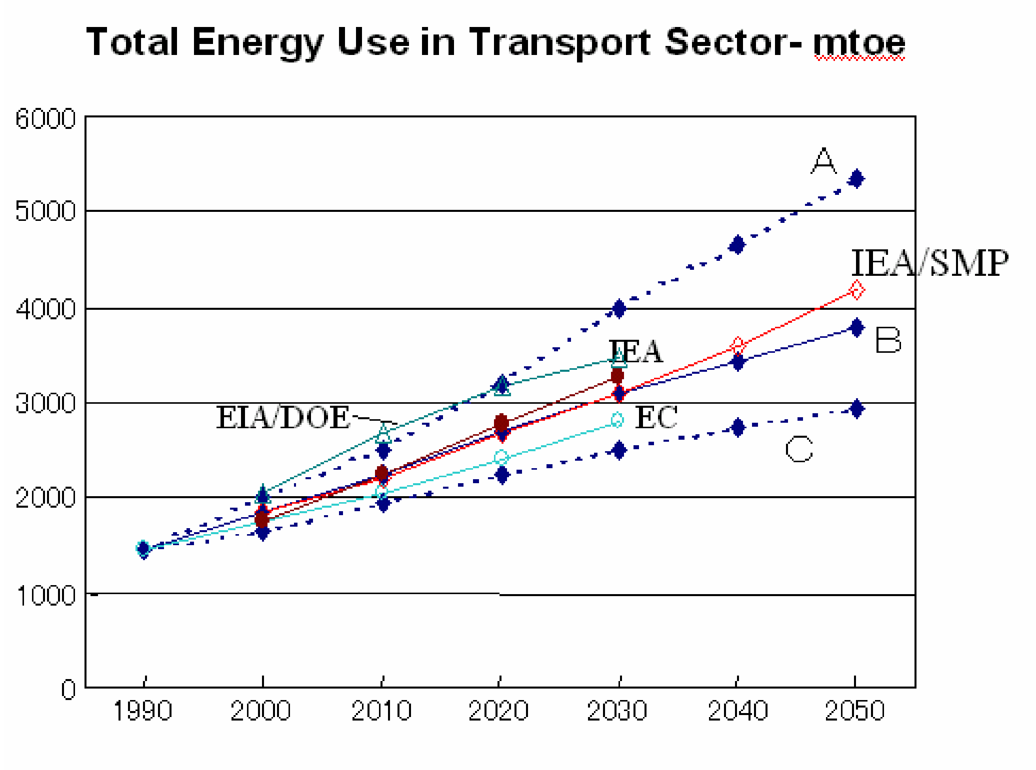


Figure 5.9

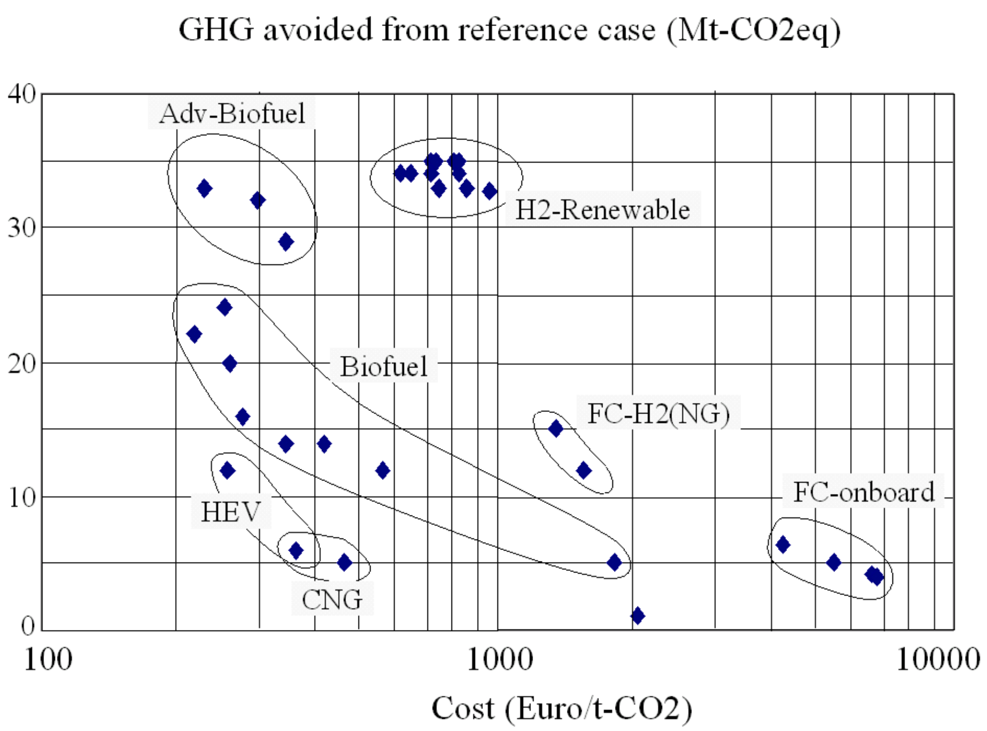


Figure 5.10

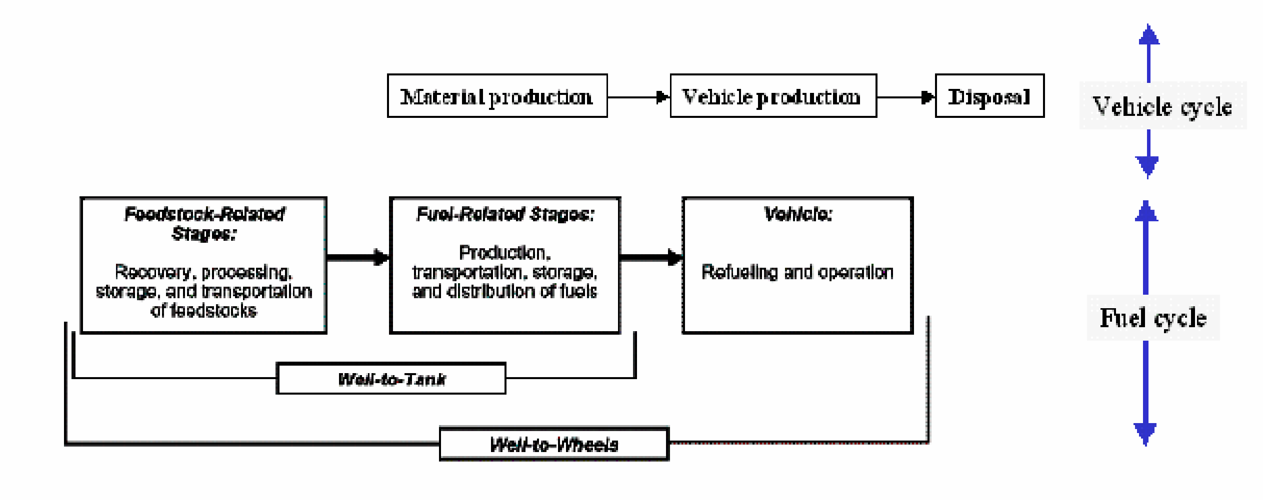


Figure 5.11

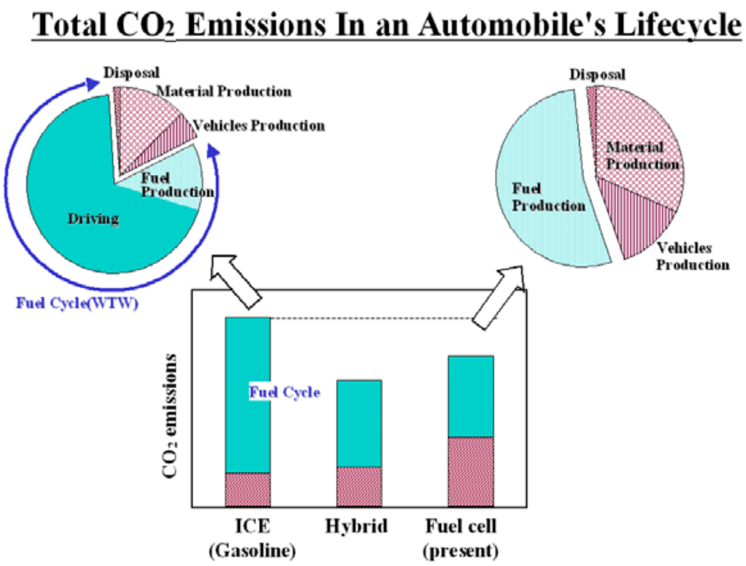


Figure 5.12

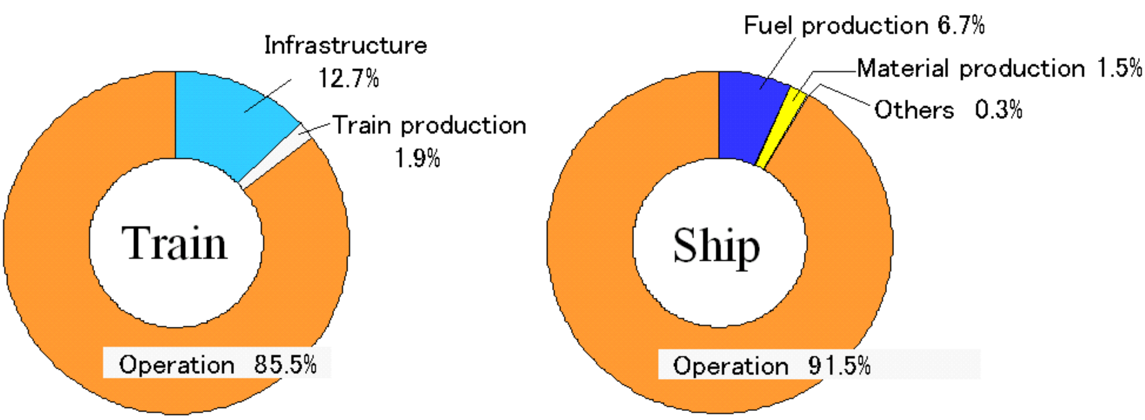


Figure 5.13

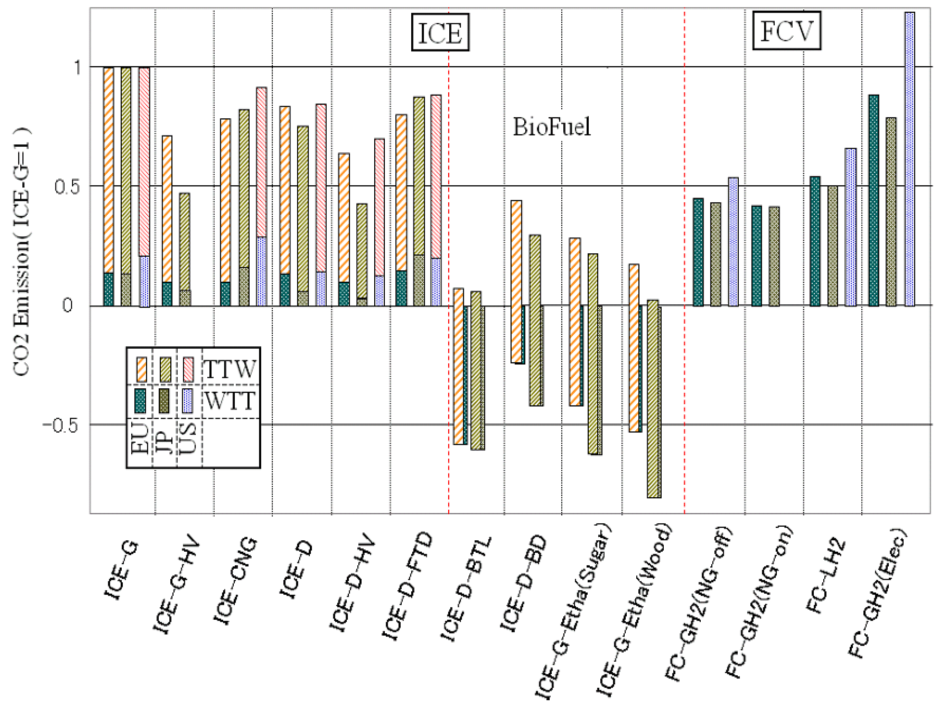


Figure 5.14

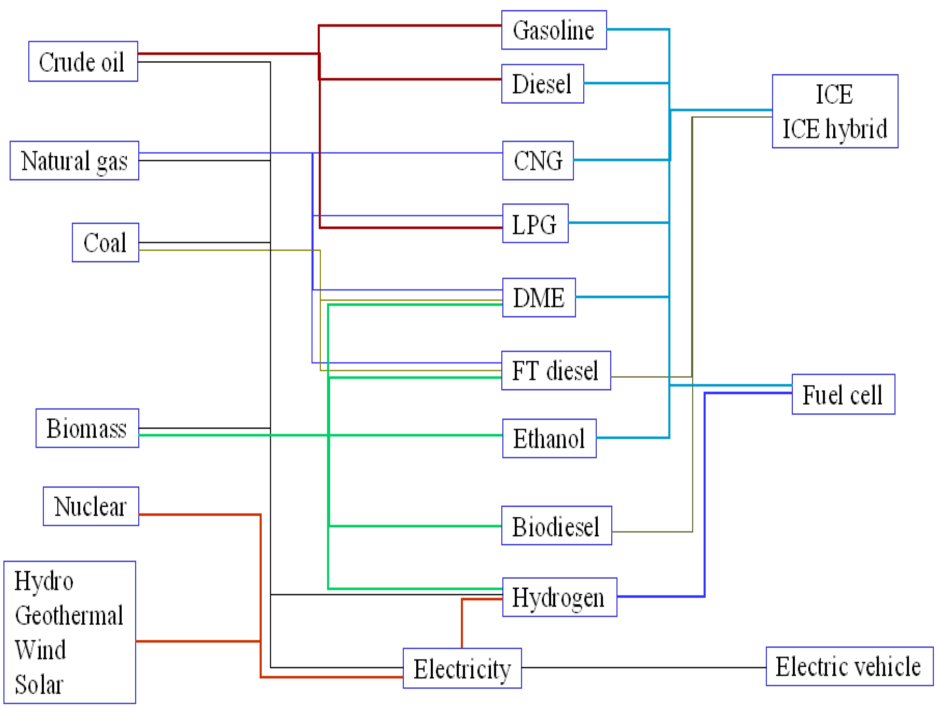


Figure 5.15

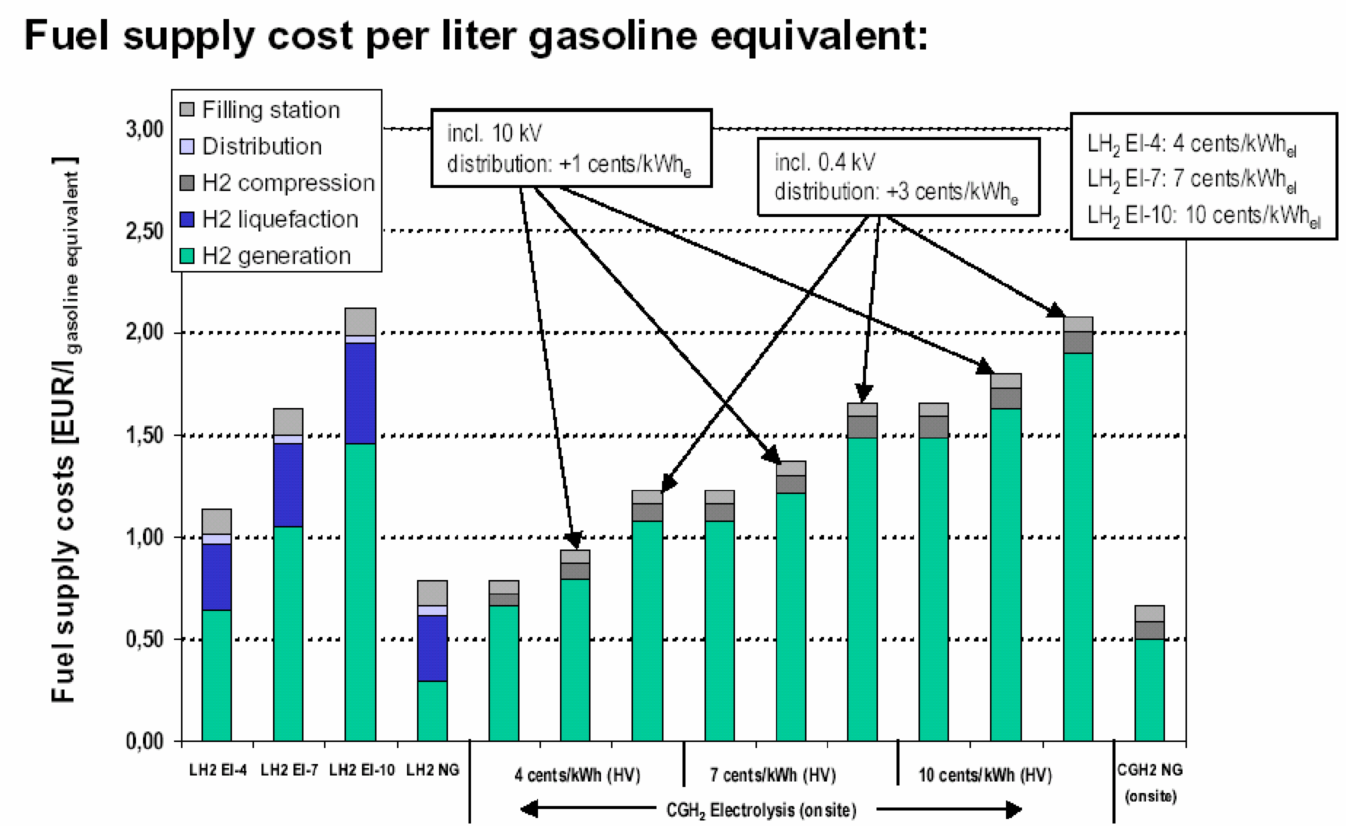
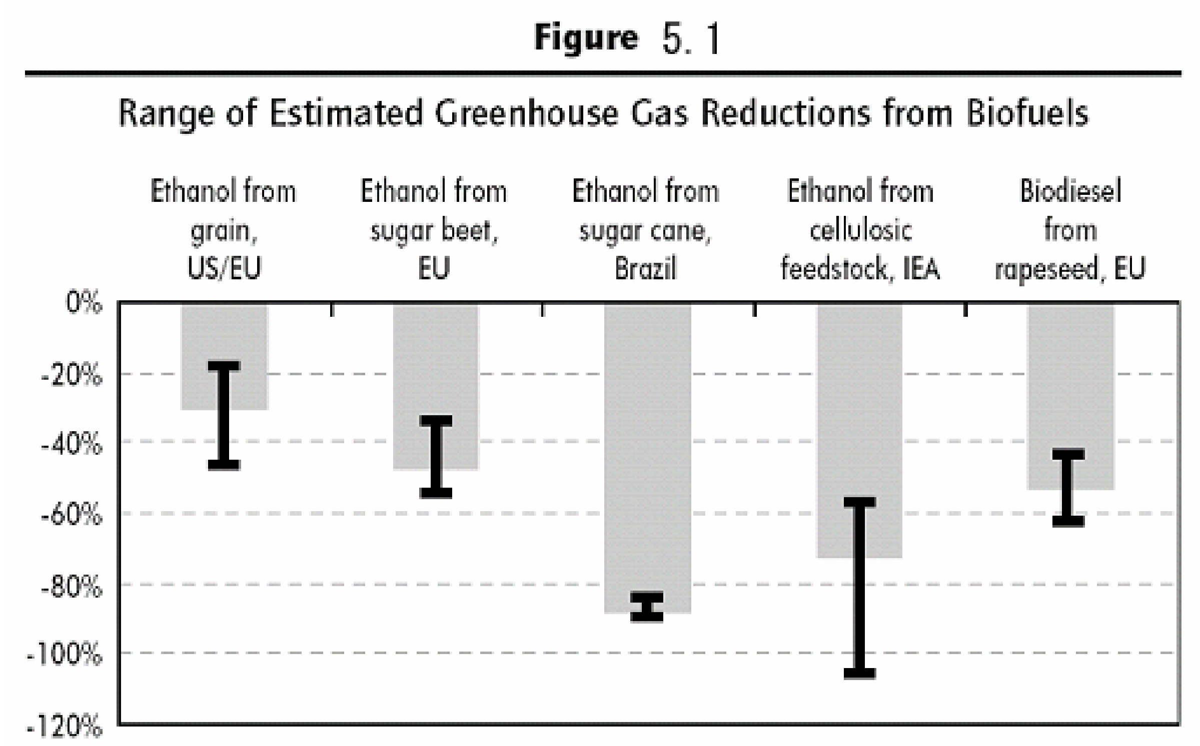


Figure 5.16



Note: This figure shows reductions in well-to-wheels CO_2-equivalent GHG emissions per kilometre from various biofuel/feedstock combinations, compared to conventional-fuelled vehicles. Ethanol is compared to gasoline vehicles and biodiesel to diesel vehicles. Blends provide proportional reductions; e.g. a 10% ethanol blend would provide reductions one-tenth those shown here. Vertical black lines indicate range of estimates; see Chapter 3 for discussion.

Figure 5.17

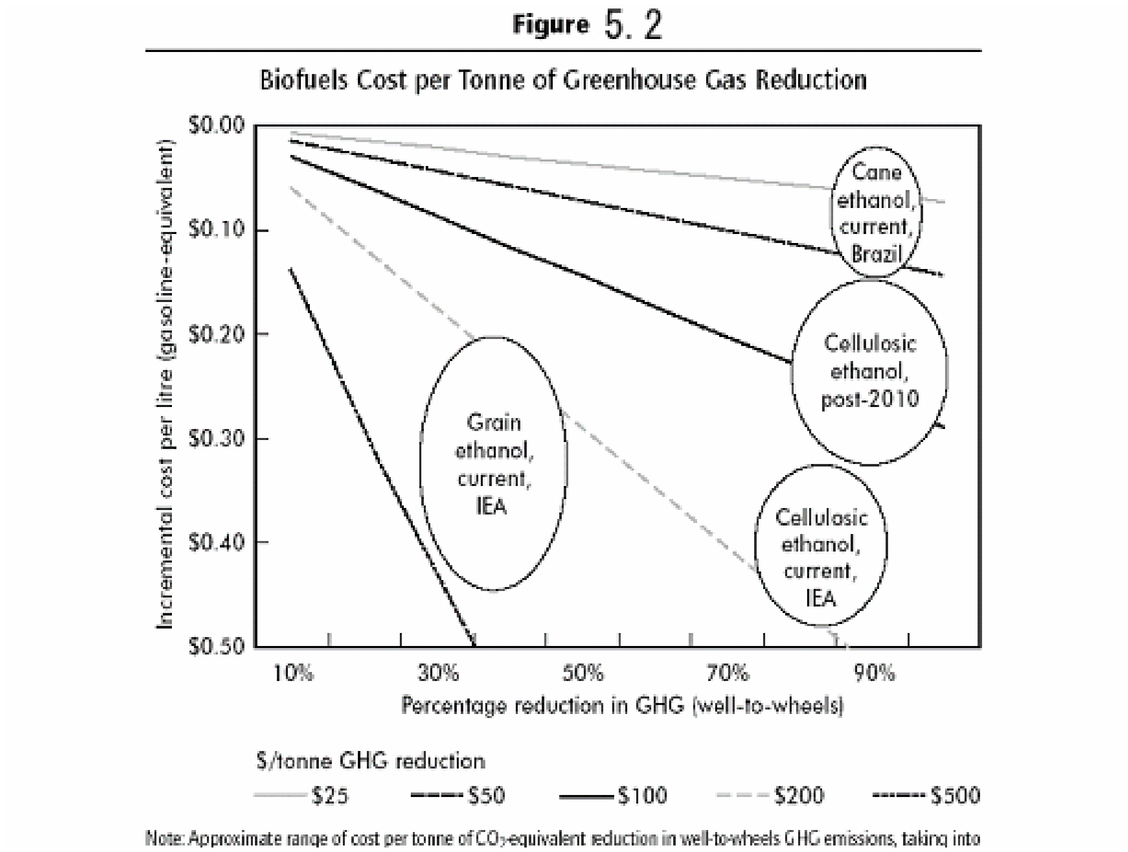


Figure 5.18

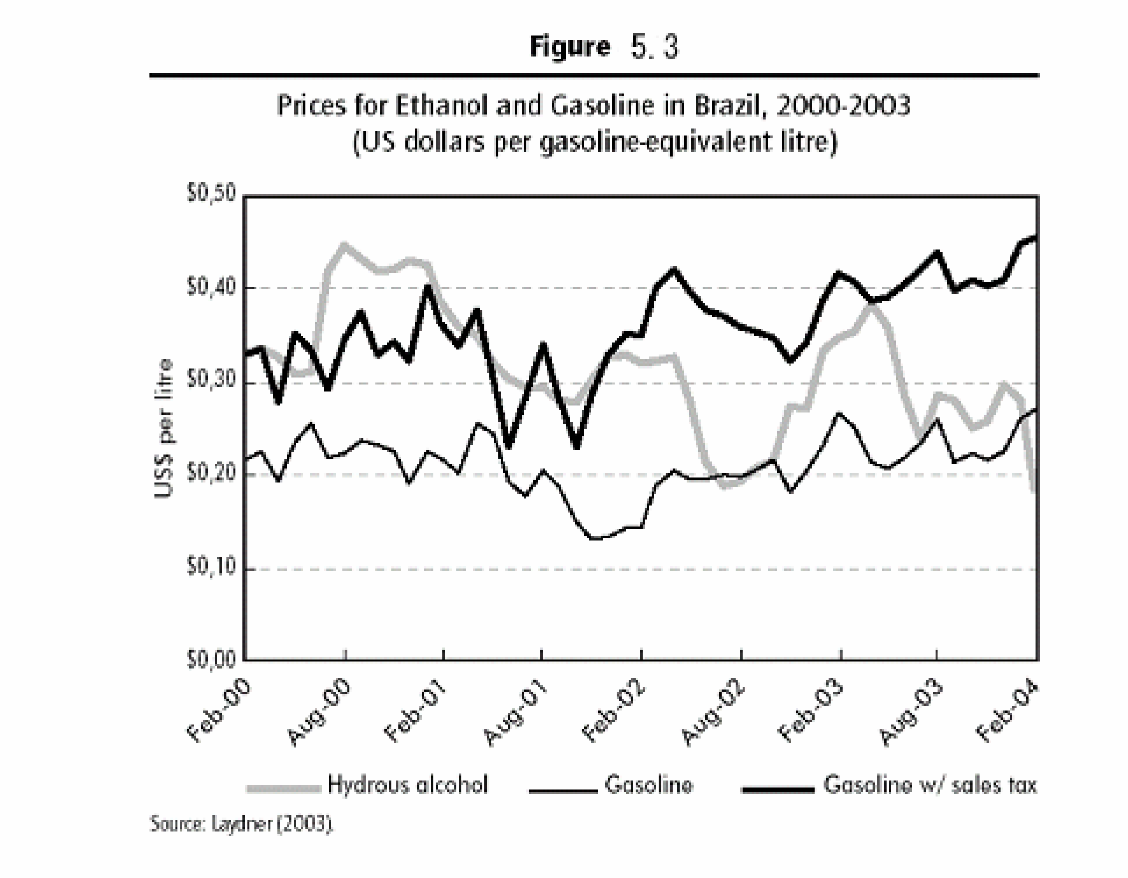


Figure 5.19

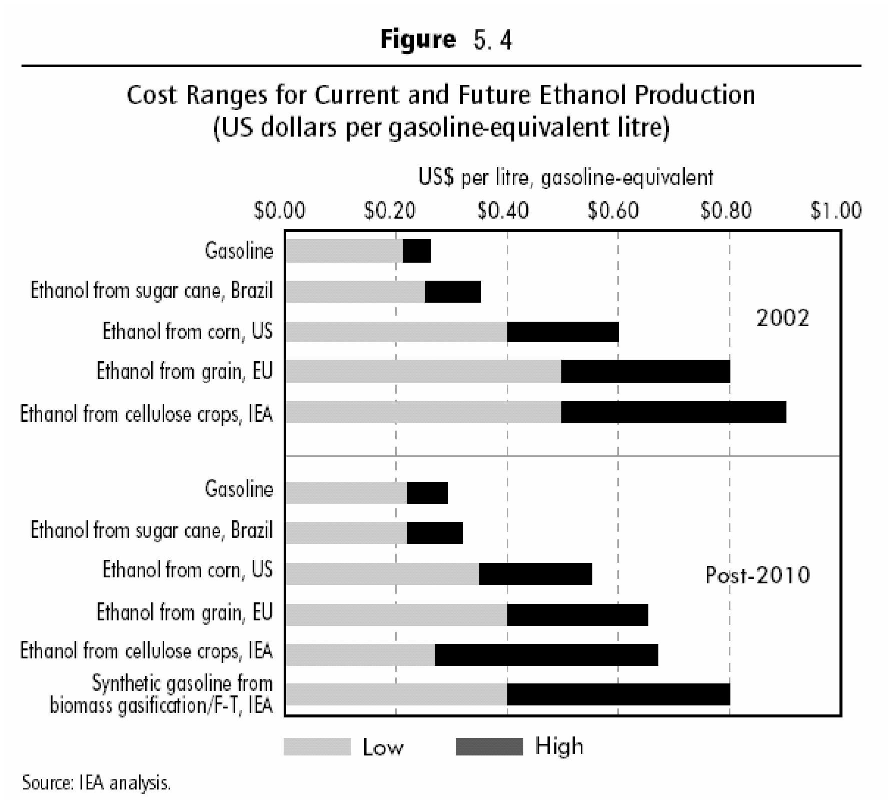
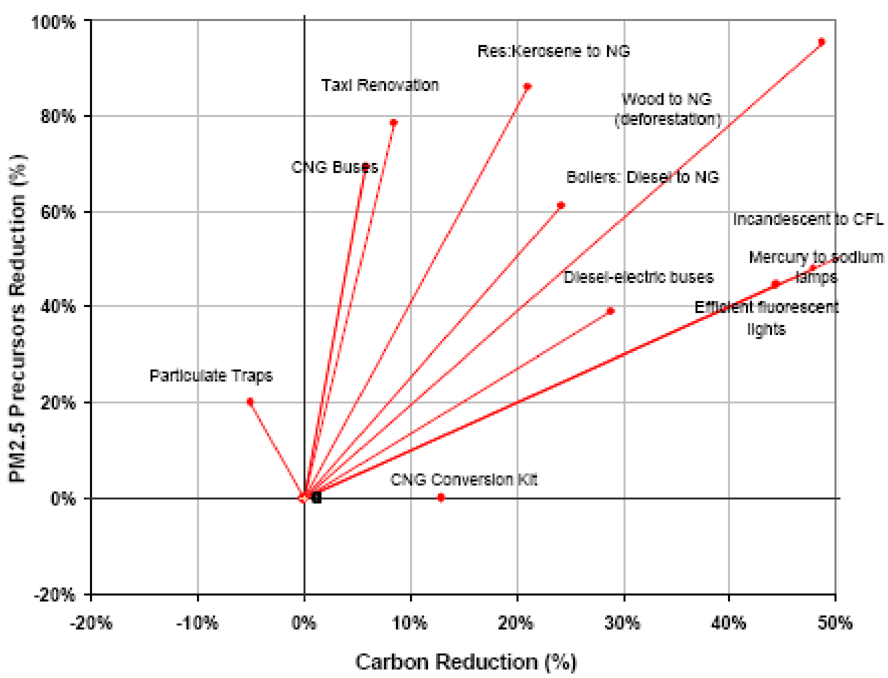


Figure 5.20



Source: Cifuentes et al., 2001
Note: Figure also shows co-benefits from some non-transport policies

Figure 5.21 Two Possible Scenarios for Greenhouse Gas Reductions in Light-Duty Vehicles
Source: IEA, 2004b

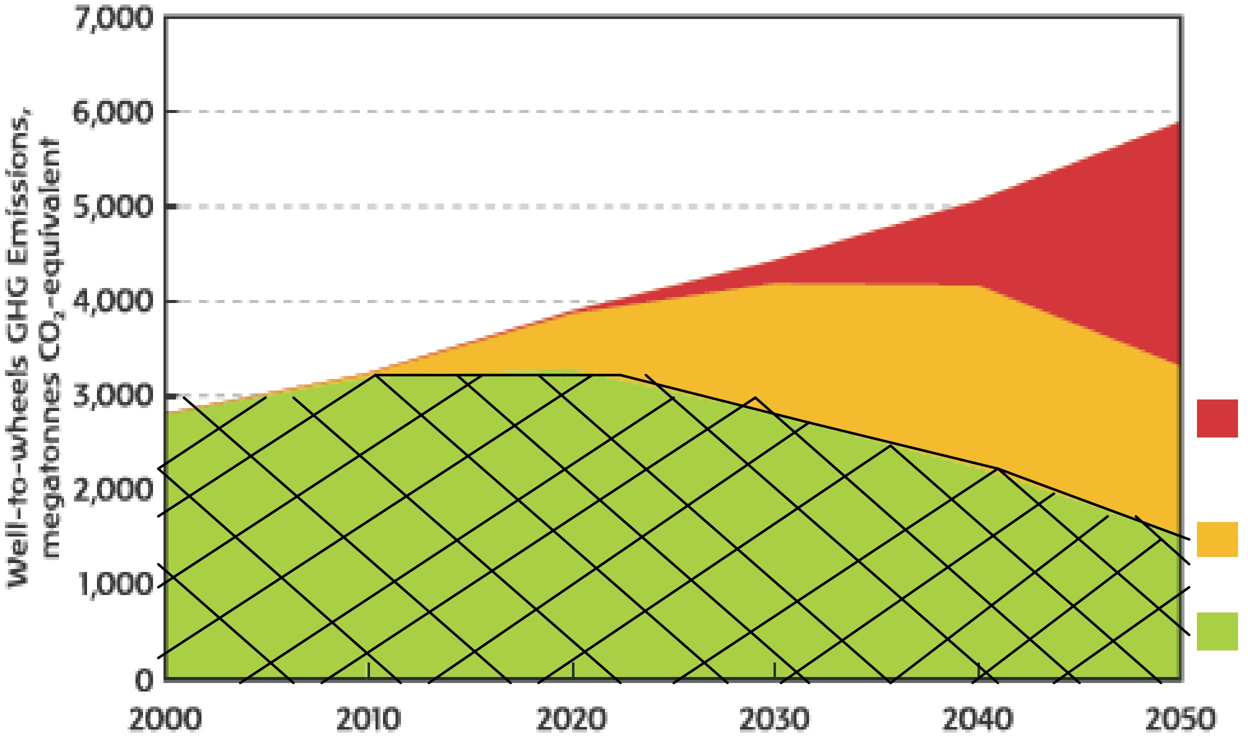


Figure 5.22

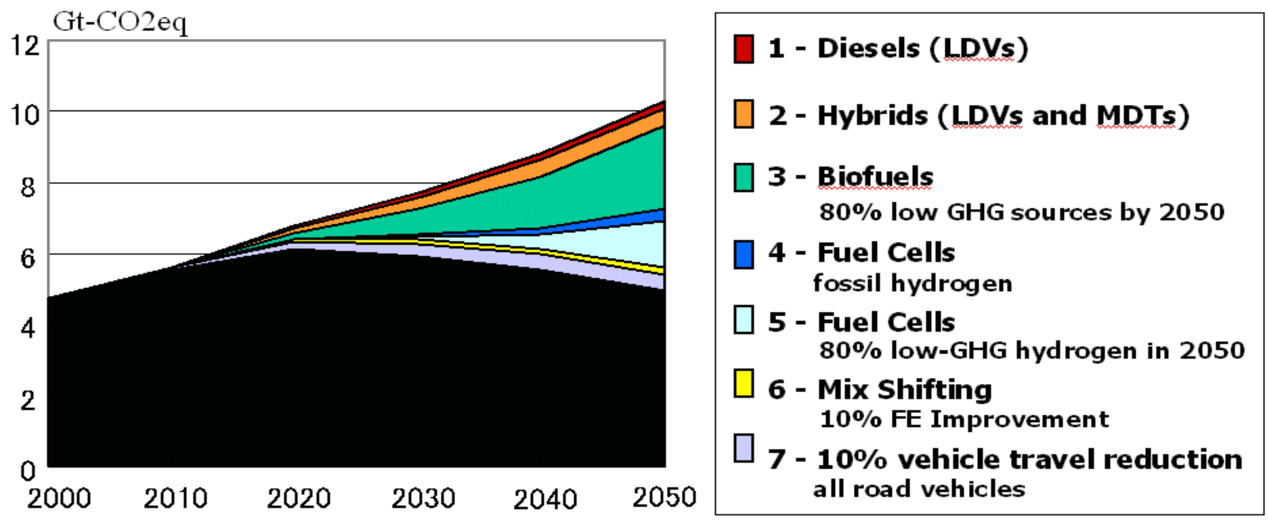


Figure 5.23

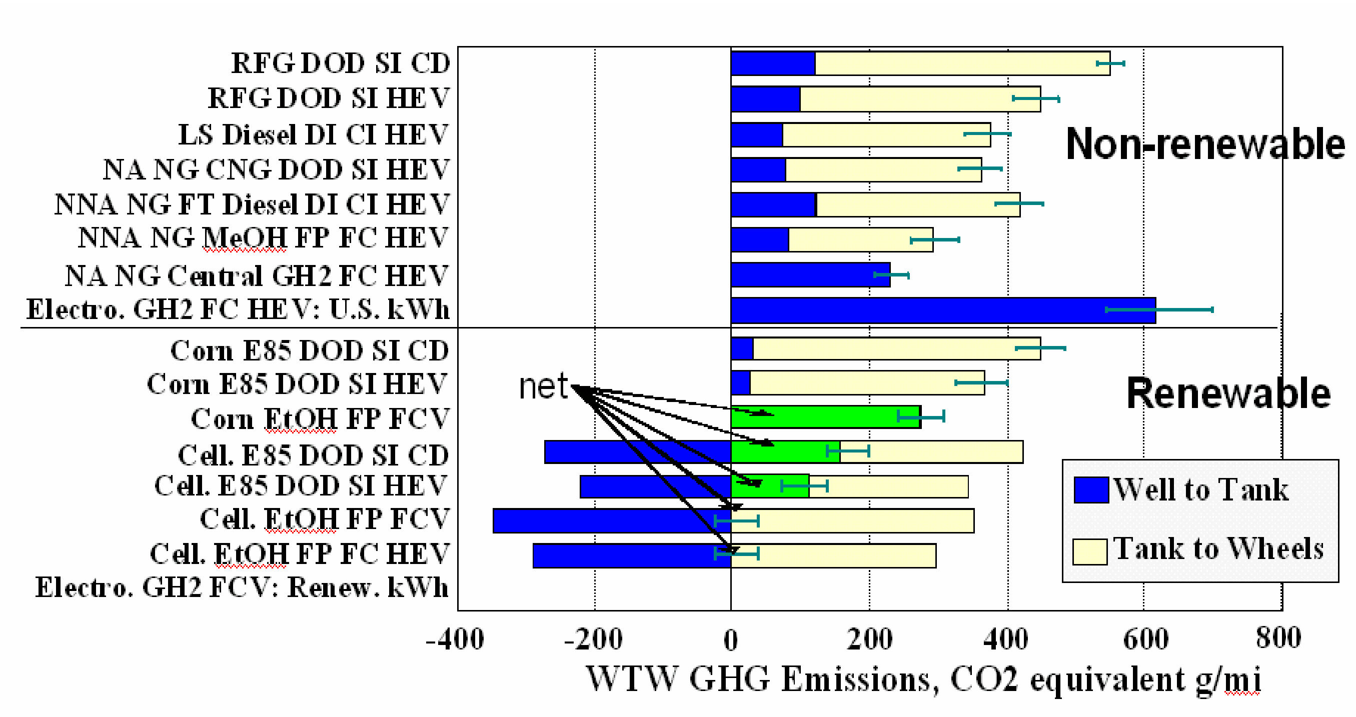


Figure 5.24

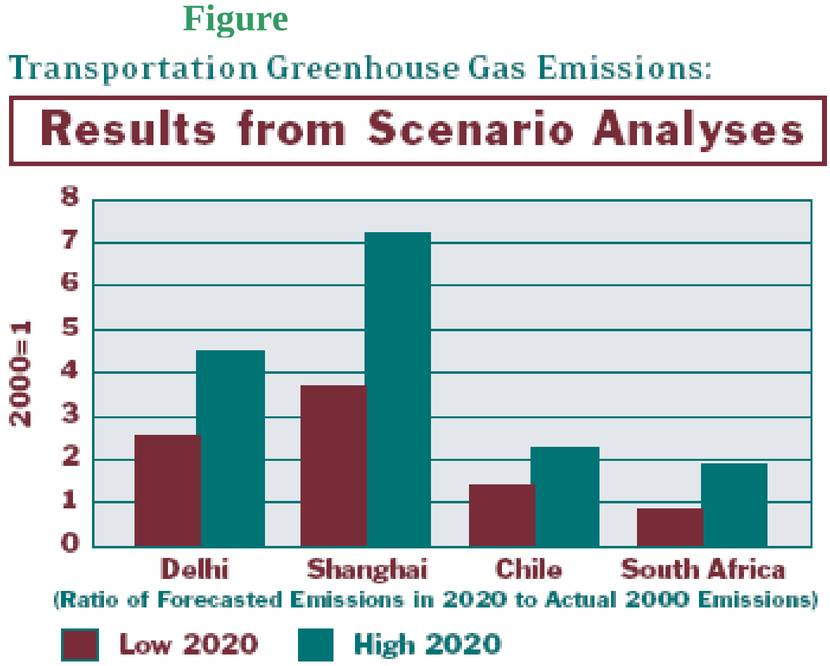


Figure 5.25

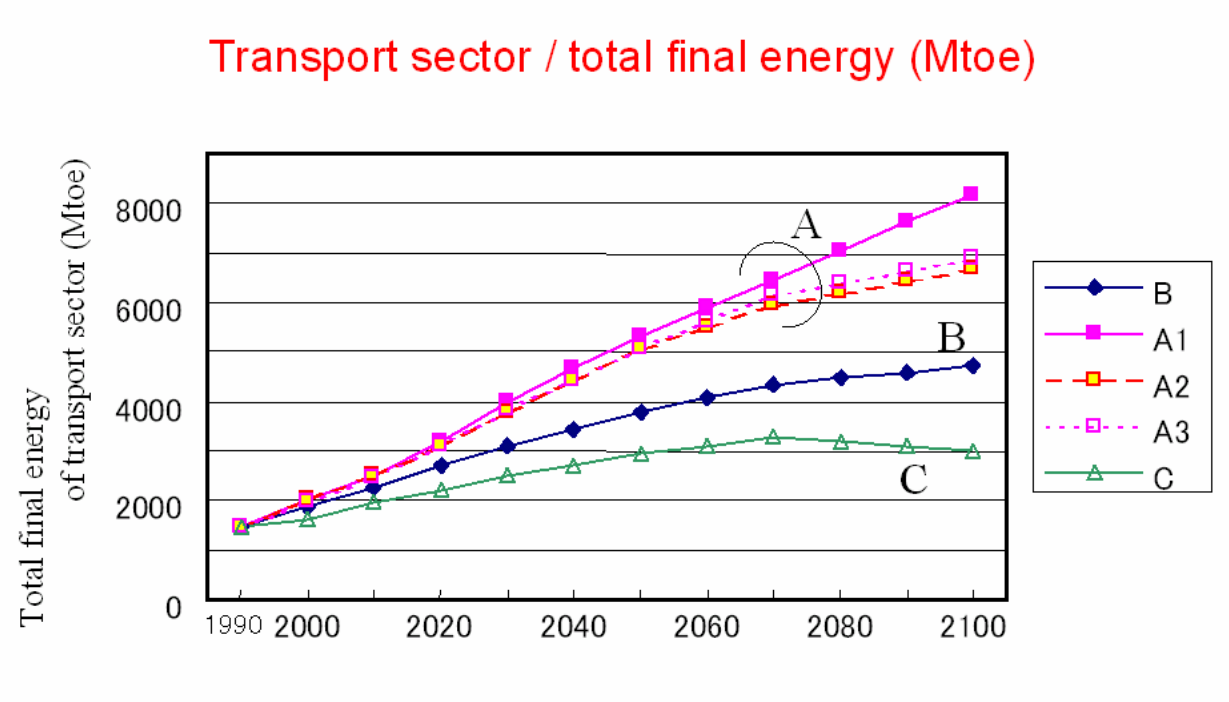


Figure 5.26

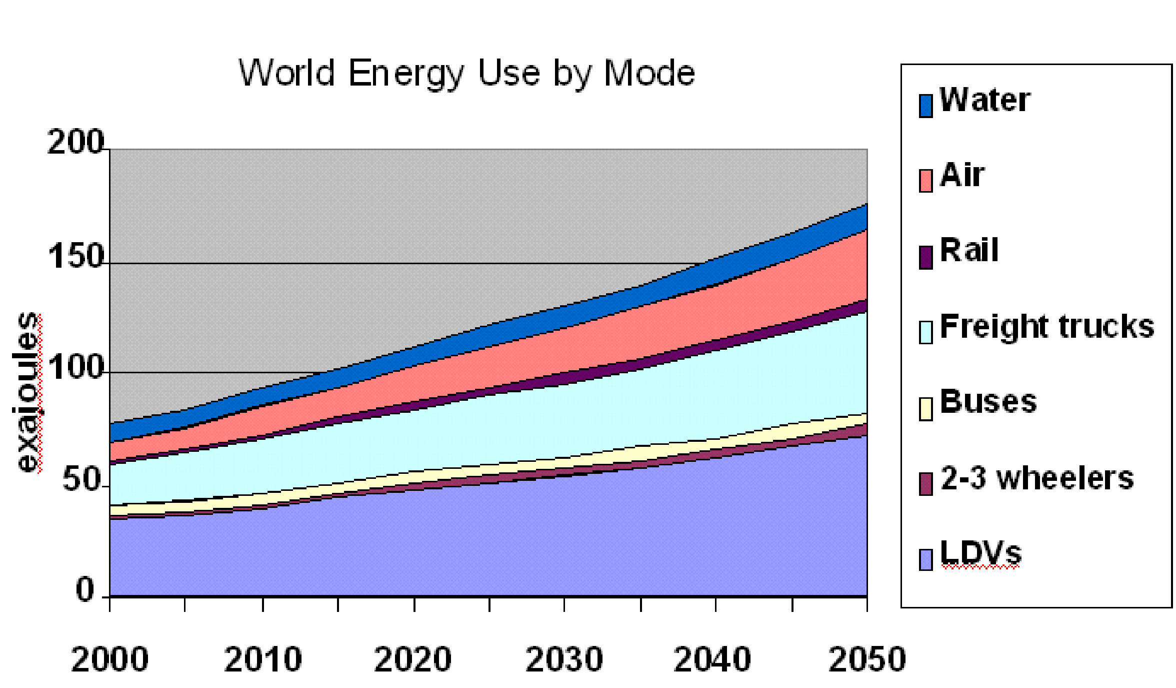


Figure 5.27

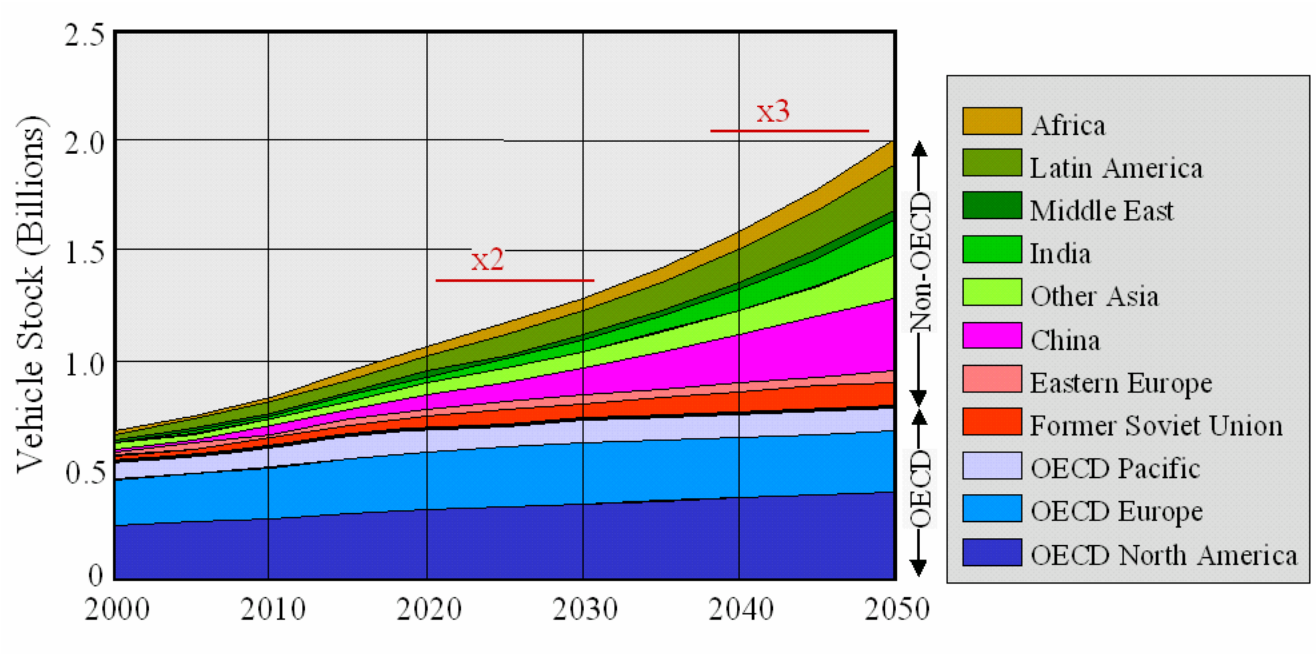


Figure 5.28

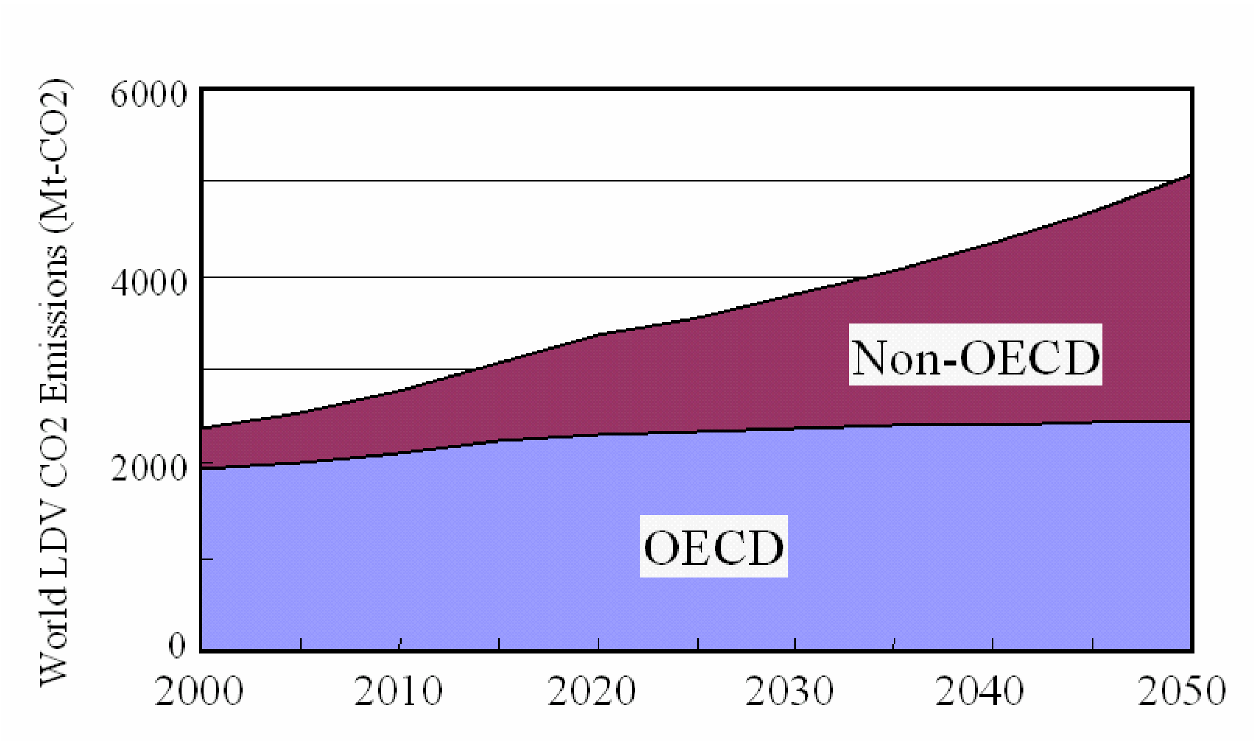


Figure 5.29

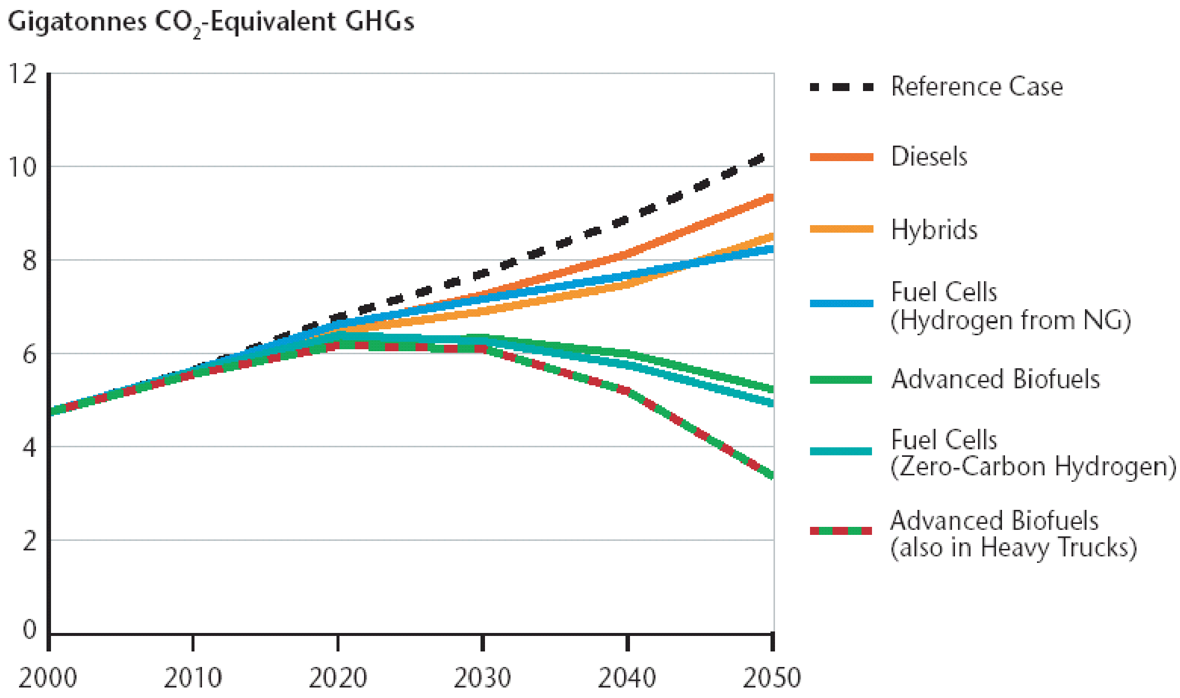
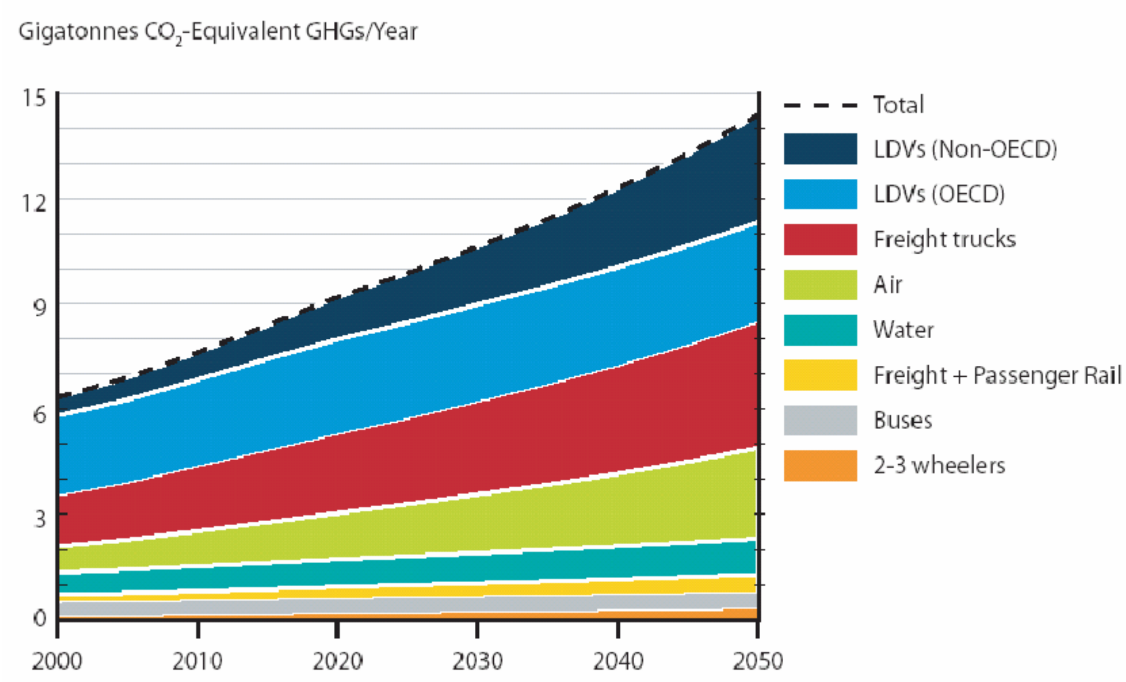

Gigatonnes CO_2-Equivalent GHGs
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050
Reference Case
Diesels
Hybrids
Fuel Cells (Hydrogen from NG)
Advanced Biofuels
Fuel Cells (Zero-Carbon Hydrogen)
Advanced Biofuels (also in Heavy Trucks)

Figure 5.30


Gigatonnes CO_2-Equivalent GHGs/Year
15
12
9
6
3
0
2000
2010
2020
2030
2040
2050
Total
LDVs (Non-OECD)
LDVs (OECD)
Freight trucks
Air
Water
Freight + Passenger Rail
Buses
2-3 wheelers