TECHNOLOGIES AND INCENTIVES TO REDUCE CO_2 EMISSIONS FROM PASSENGER CARS

Berlin Seminar in Energy and Climate (BSEC) –
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Agenda

- Introduction / context of research
- Estimation of technological CO_2 reduction potentials
- Overview on technological potentials
- Incentives and policy options
- Impact Assessment with the ASTRA model
- Potentials of incentives
- Conclusion

GHG-TransPoRD (Reducing Greenhouse Gas Emissions Of Transport Beyond 2020)

FP7 RTD project (2009-2011) coordinated by ISI with partners: TRT, TML, ITS, IPTS

Objectives:

- To support the EU in defining a feasible **research** and **policy strategy for GHG reductions of transport** that fits and contributes to the overall GHG reduction targets of the EU.
- To propose **GHG reduction targets for transport** as a whole as well as for each transport mode.
- **Identification** of promising and feasible measures
- **Techno-economic analysis** of details of promising measures to estimate effectiveness of GHG reductions as well as technical feasibility and economic cost and affordability.
- **Formulation of scenarios** consisting of both selected technology pathways and transport policies that would achieve GHG reduction targets for 2020 and 2050
- Linking the promising scenarios with a **suggestion for an EU research strategy**.
- **Communicate with stakeholders** about project findings and most recent advancements to have a platform of mutual understanding.

Estimation CO_2 reduction potentials

Step 1 ▪ Extraction of relevant CO_2 reduction technologies from literature research, technology journal review and expert interviews

→ long list of technologies with min/max reduction potential

Step 2 ▪ Estimation of feasible CO_2 reduction potential for each technology based on 2nd review if possible (otherwise medium potential is taken)

Step 3 ▪ Allocation of technologies to 12 categories (e.g. car body, injection, etc.)

Step 4 ▪ Final choice of technology packages with highest CO_2 reduction potential under consideration of technical compatibility

Step 5 ▪ Calculation of relative CO_2 emission reduction potentials for each technology cluster *i*:

$$POT(i) = 1 - (\prod_{j=1}^{n} 1 - POT_j(i))$$

with: j = technologies

Step 6 ▪ Calculation of absolute CO_2 emission savings based on common energy framework in EU27 (derived from iTREN-2030 and ADAM)

Long list of technologies with range of CO_2 emission reduction potential

Nr.	Measures / Technologies	CO2 Reduction	
		Min	Max
1	Reduced mechanical friction components	0.4%	5.0%
2	Low viscosity lubricants	0.5%	4.0%
3	Low rolling resistance tires	2.0%	2.0%
4	Improved aerodynamics	1.5%	1.8%
5	Tire-pressure monitoring system	1.0%	1.0%
6	Substitution of fossil fuel by battery electric vehicles	7.8%	7.8%
7	Control mechanism for servo-steering	3.1%	5.0%
8	Electric power steering (EPS)	2.0%	3.0%
9	LED headlights		2.5%
10	Pneumatic brake booster	1.6%	2.5%
11	Intelligent fuel pumps	0.3%	0.3%
12	Solar panels on roofs	17.0%	29.0%
13	High efficiency alternators	0.5%	2.0%
14	Intelligent battery sensor	1.5%	1.5%
15	CNG	16.7%	16.7%
16	LPG		9.0%
17	Electrohydraulic valve gear		10.0%
18	Variable compression ratio	5.0%	10.0%
19	Cylinder deactivation	2.1%	8.0%
20	Variable valve actuation	3.0%	7.0%
21	Start-stop system	3.0%	4.0%
22	Variable valve timing	1.0%	3.0%
23	Fuel quality sensor	1.2%	1.2%

Nr.	Measures / Technologies	CO2 Reduction	
		Min	Max
24	Latent-heat storage	8.1%	8.1%
25	Intercooling	2.5%	2.5%
26	Dual cooling circuits	0.5%	2.0%
27	Exhaust heat recuperation	1.5%	1.5%
28	Cooling fluid shutdown system	1.0%	1.0%
29	Hybridtype: full	18.0%	22.0%
30	Hybridtype: mild	10.0%	11.0%
31	Brake energy recuperation	3.0%	3.0%
32	Hybridtype: plug-in		
33	Homogeneous Charge Compression Ignition	11.0%	25.0%
34	GDI with stratified charge (stoichiometric)	8.0%	14.0%
35	GDI with stratified charge (lean burn)	4.3%	6.4%
36	GDI with homogenous charge (stoichiometric)	0.7%	5.0%
37	Piezo injectors	3.0%	3.0%
38	Further penetration of gasoline direct injection		
39	Utilisation of lightweight design and materials	0.9%	20.0%
40	Weight reduction by minimising convenience features	4.9%	4.9%
41	Smaller capacity fuel tanks	2.0%	3.0%
42	Continuouse variable transmission	2.1%	9.0%
43	6-speed manual/automatic gearbox	2.5%	5.0%
44	Dual clutch transmission	4.0%	5.0%
45	Piloted gearbox	4.0%	4.0%
46	Optimisation of gear boxes	1.0%	2.0%

Source: GHG-TransPoRD

Fact sheet – „aerodynamics and resistance“

“Aerodynamics and resistance” summary			
Description			The group of measures assigned to “aerodynamics and resistance” contains measures that aim at reducing the aerodynamic resistance, the mechanical resistance of tires and the friction within engines in passenger cars.
Measures included			Aerodynamics and resistance consists of a combination of five measures: • improved aerodynamics (e.g. via smooth under flow or lower car bodies), • reduced engine friction losses, • low resistance tires (reducing energy wasted as heat), • tire-pressure monitoring system (controlling if the tire pressure is efficient), • low viscosity lubricants (decreasing the mechanical friction in engines)
Field of influence			Energy intensity
Earliest implementation date			Partially already implemented
Relative CO_2 reduction	**2020**	**EU27**	7% for all passenger cars
	2050	**EU27**	9% for all passenger cars
Applicability			Measure is applicable on all new passenger cars.
Absolute CO_2 reduction potential	**2020**	**EU15**	50.4 Mt CO_2
		EU12	10.1 Mt CO_2
		EU27	60.5 Mt CO_2
	2050	**EU15**	66.2 Mt CO_2
		EU12	16.4 Mt CO_2
		EU27	82.6 Mt CO_2
Feasibility			High
Maturity			In process
Cost			1,059 €/Ton CO_2 saved

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CO_2 emission reduction potential per technology group in EU27 (2020 and 2050)

Measure/Technology Group	Earliest Introduction	Feasibility	2020		2050	
			rel.	abs (Mt)	rel.	abs (Mt)
Injection Technology	2018	High	10%	92	24%	211
Electrical System - Energy Supply	2010	Medium	10%	89	20%	178
Heat/Cooling Management	2010	Medium	10%	89	14%	122
Lightweight Construction	2020	Medium	8%	72	17%	152
Engine Control System	2012	Medium	7%	65	12%	112
Hybrid Vehicles	2010	Medium	7%	61	18%	159
Aerodynamics/Resistance	2010	High	7%	60	9%	83
CNG/LPG	2010	Medium	6%	54	8%	75
Battery Electric Vehicles	2010	Medium	6%	54	77%	689
Electrical System - Energy Demand	2010	High	5%	47	7%	64
Drive and Transmission	2010	Medium	3%	29	6%	50
Hydrogen Fuel Cell Vehicles	2025	Medium	0%	0	8%	70

Source: GHG-TransPoRD

Incentives and policy options

- CO_2 labelling of cars
  - Rising awareness of purchasers for energy efficient cars
  - Impact: -3% less CO_2 emissions for newly registered cars
- Feebates on new cars
  - Rebates for low emission vehicles / fees for inefficient cars
  - Limit: 100 g CO_2 / vkm ; rebate/fee: 50 € per g CO_2
  - Revenues / additional costs considered
- Subsidies for enhancing filling station infrastructure for alternative fuel cars
  - Based on revenues from CO_2 pricing
- Mandatory CO_2 emission limits for cars
  - 2015: 130 g CO_2 / vkm ; 2020: 105 g CO_2 / vkm; 2030: 80 g CO_2 / vkm
- Inclusion of road transport into EU-ETS
  - Starting in 2020; upstream-approach on fuels (via fuel tax)

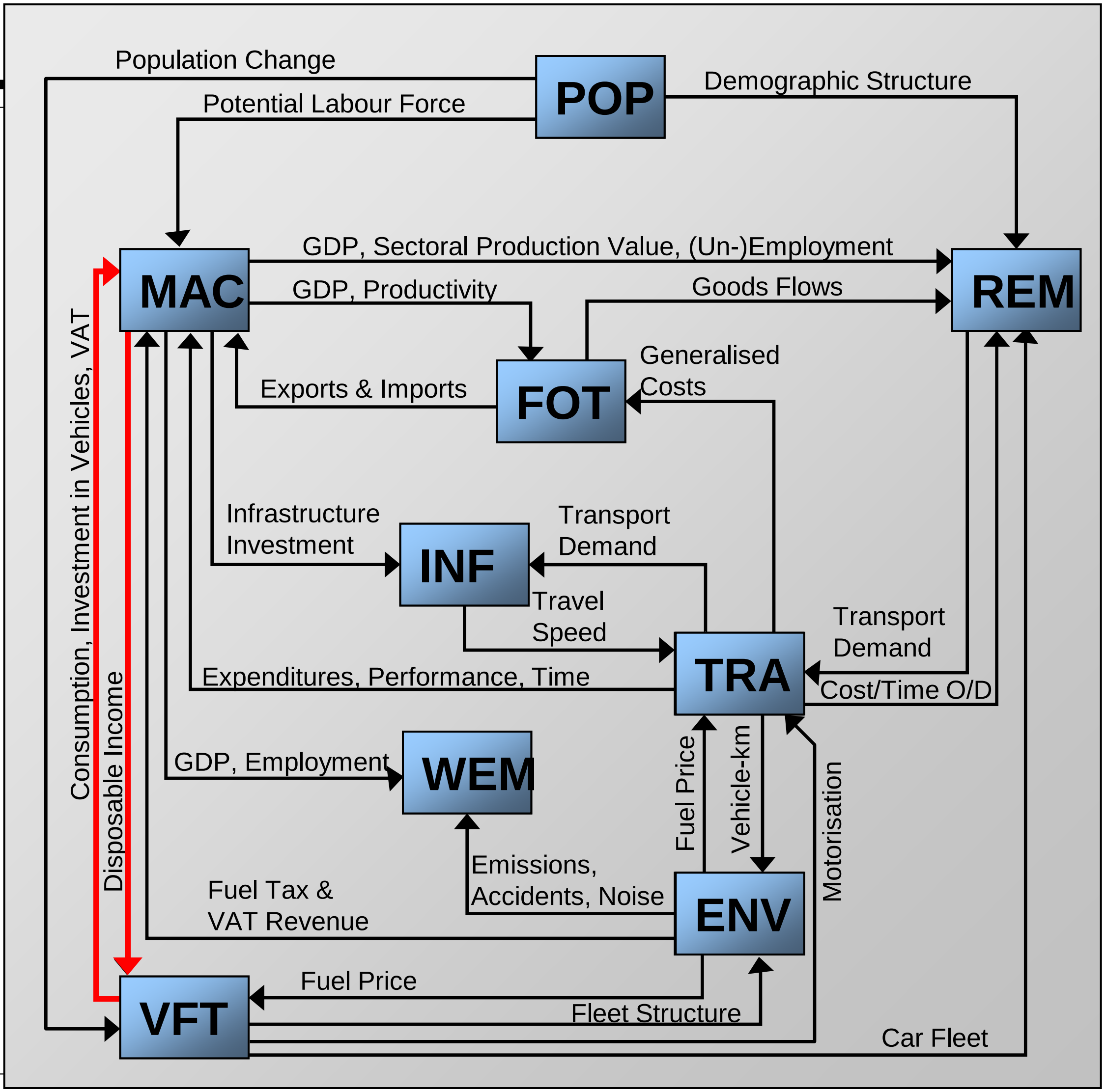
Impact assessment of scenarios with the ASTRA Model

Characteristics

- Vensim® software
- 1990 to 2050 (dt = ¼ a)
- ~ 29 million equations
- Modular structure
- EU27 + CHE/NOR
- 25 economic sectors

Abbreviation of 9 Modules:

POP = Population Module
MAC = Macroeconomics Module
REM = Regional Economics Module
FOT = Foreign Trade Module
TRA = Transport Module
VFT = Vehicle Fleet Module
ENV = Environment Module
INF = Infrastructure Module
WEM = Welfare Measurement Module



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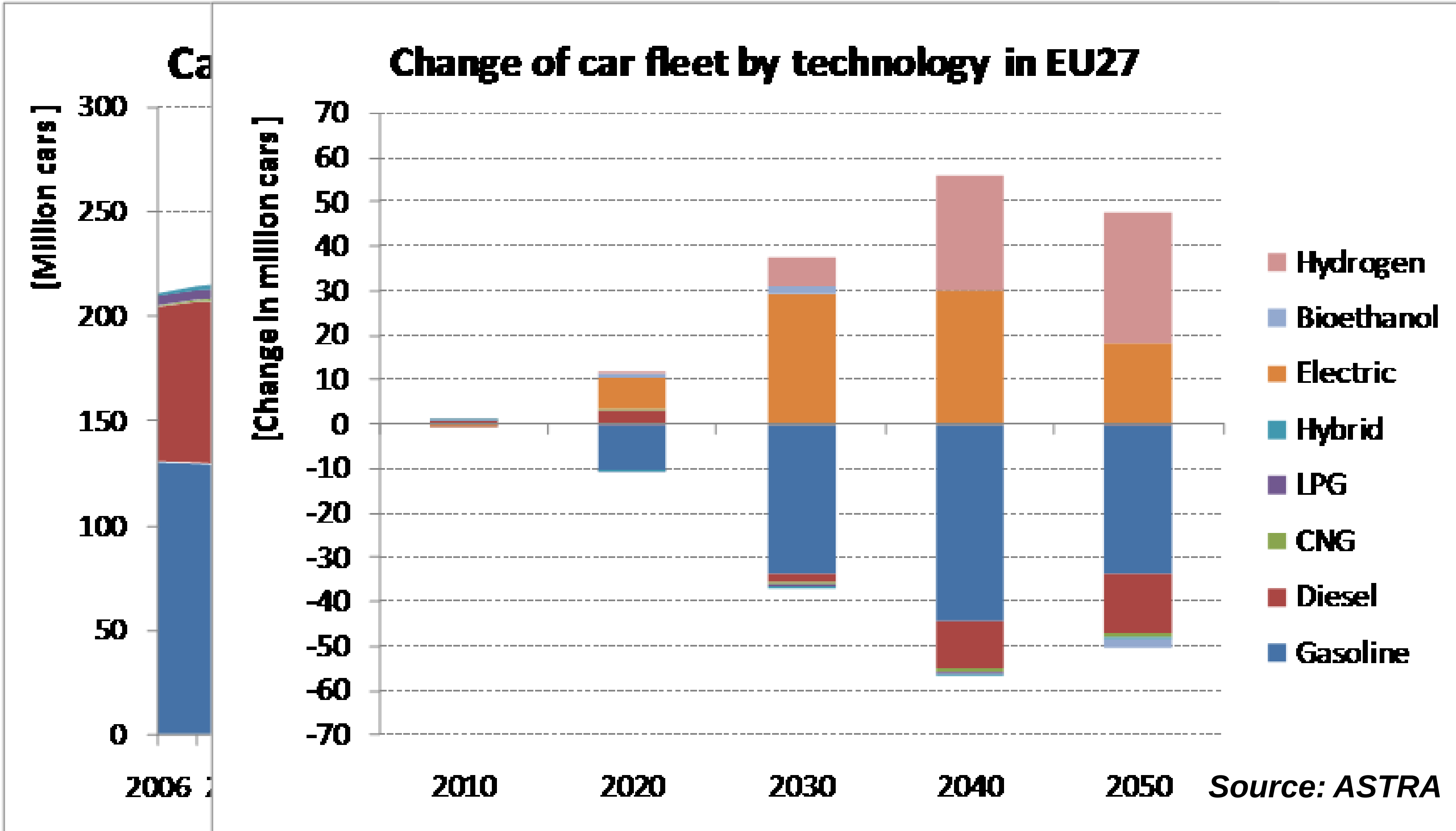
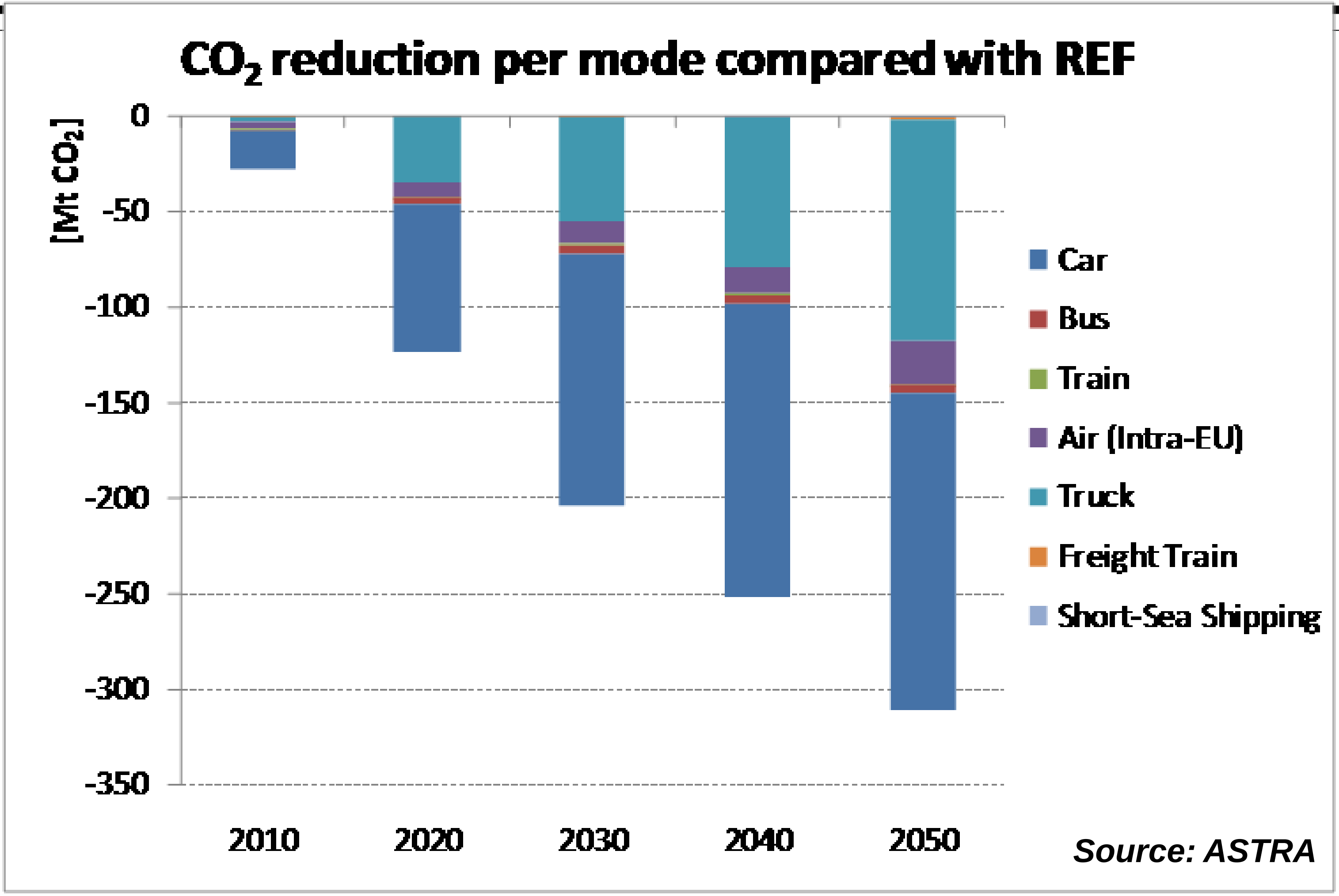
Impacts on the diffusion of alternative fuel cars



Source: ASTRA

CO_2 emission saving potential per mode



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Conclusions – technology

- CO_2 emission reduction potential (only fossil fuel technologies):
  - until 2020: ~40% (to be treated carefully due to optimistic assumptions)
  - until 2050: ~60% - 68% realistic
- Most effective technologies:
  - injection technology
  - electrical system (energy supply) → potential 2020: ~ 10%
  - heat/cooling management
- Battery electric vehicles could in theory contribute by about 77% CO_2 emission reduction until 2050 (carbon intensity assumptions derived from POLES model)

Conclusions – incentives

- 165 Mt. of CO_2 less emitted by cars compared to REF until 2050
  - -21% less CO_2 emissions in 2050 (compared with 1990)
  - Targets clearly failed (2020: -20% ; 2050: -80%)
- Only small economic losses (-1.5% compared to REF in 2050)
  - Loss induced by decreasing government revenues from taxes
- Car technologies: 23 Mio. BEV and 29 Mio. Hydrogen-FCV in 2050
- 78% of all passenger cars in 2050 still depend on fossil fuels
- Most powerful policy instruments: feebates and mandatory CO_2 limits
- Moderate assumptions on fossil fuel price development (90 USD_{2005} in 2030)
- Level of incentives have to be fostered

Thank you for your attention!

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3rd GHG-TransPoRD Workshop
Brussels, December 14th and 15th, 2010

“R&D strategies, innovations, learning and cost of measures to reduce greenhouse-gas emissions of transport”

December 14th: Innovation system and R&D strategies for low carbon transport (09:30 to 17:00)

December 15th: Technological learning and cost development of GHG reduction measures in the transport sector (09:00 to 17:00)

Venue

MCE - Management Center Europe,

Rue de l'Aqueduc 118, 1050 Brussels

Registration details: http://www.ghg-transpord.eu

Literature review – main references

- AEA (2009): Assessment with respect to long term CO_2 emission targets for passenger cars and vans. Deliverable D2 of the Framework contract No. ENV/C.5/FRA/2006/0071. European Commission, Brussels.
- CONCAWE (2006): Well-to-Wheels analysis of future automotive fuels and powertrains in the European context. Concawe/Eucar/JRC, update of the 2003 study.
- EPA (2008): “A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies”. United States Environmental Protection Agency.
- IEA (2005): Making cars more fuel efficient – Technology for real improvements on road. Paris.
- IEEP 2004: Service contract to carry out economic analysis and business impact assessment of CO_2 emissions reduction measures in the automotive sector. Final Report of the project carried out by IEEP, TNO and CAIR on behalf of DG-ENV, 2004. Brussels.
- TNO (2006): Review and analysis of the reduction potential and costs of technological and other measures to reduce CO_2-emissions from passenger cars. Delft.
- TNO (2003): Evaluation of the environmental performance of modern passenger cars running on petrol, diesel, automotive LPG and CNG. TNO-report 03.OR.VM.055.1/ PHE, TNO Automotive, Delft.

Backup Slides

Methodology: analysis of GHG reduction measures in the transport sector

Result

WP2
- Scoping of GHG reduction measures
- Short listing of promising measures
- Estimation of potential CO2 reductions

→ t CO_2 saved by measure

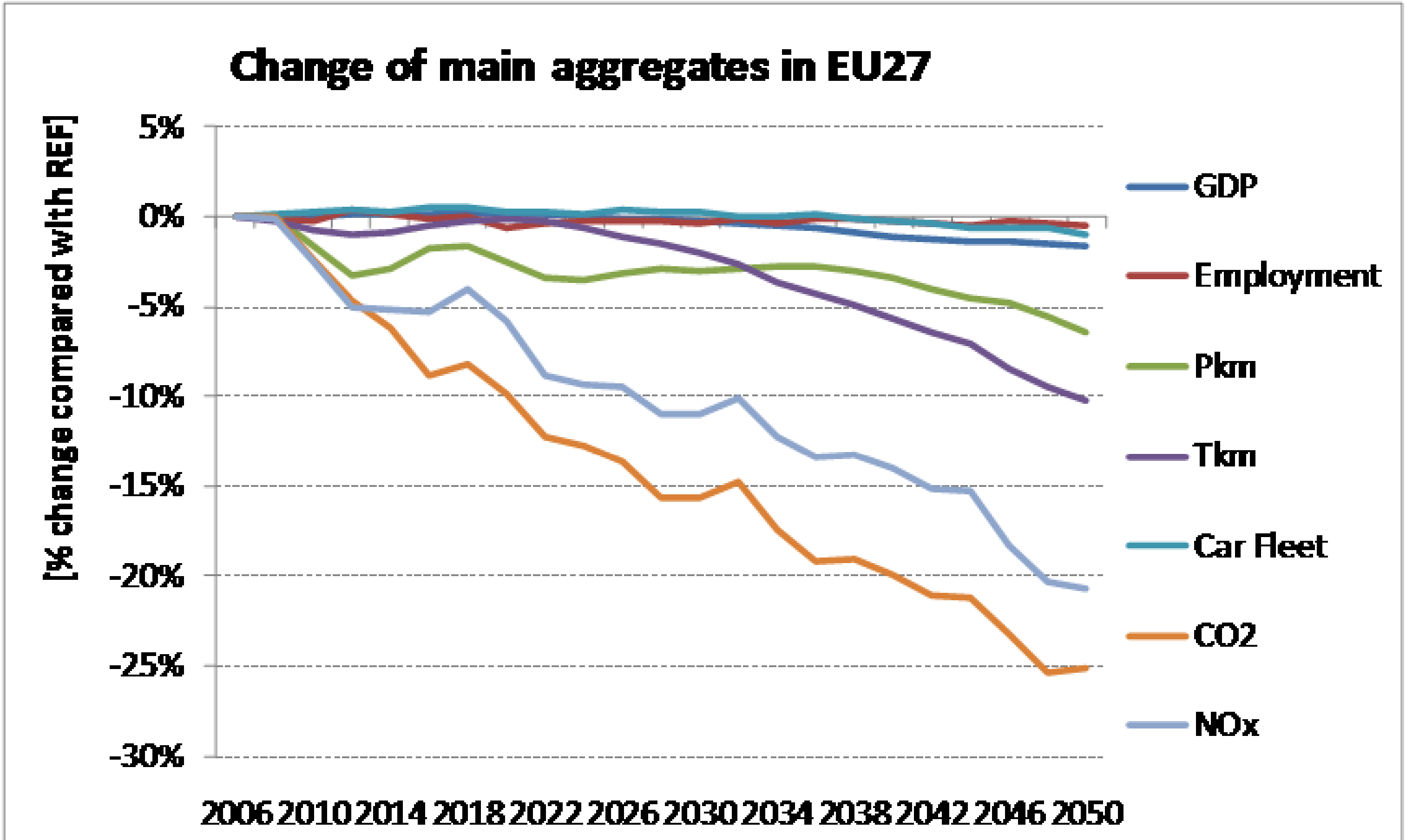
WP3
- Economic impact of GHG reduction measures
- Linking R&D and learning curves to measures
- Estimation of abatement cost of measures

→ €/t CO_2 t_1, t_2, t_3 saved by measure

WP4
- Bundling of measures to scenarios
- Simulation of scenarios with models
- Impact assessment of scenarios

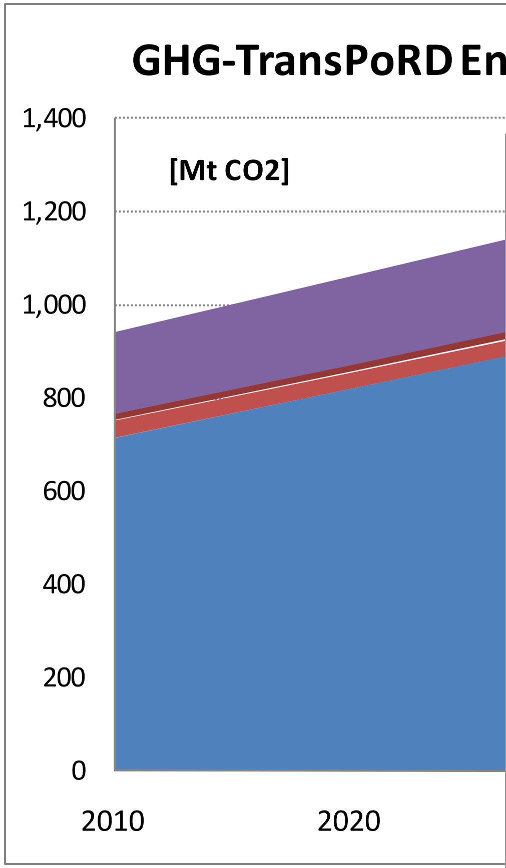
→ ∑t CO_2 saved
∑GDP change
Etc. by EU27

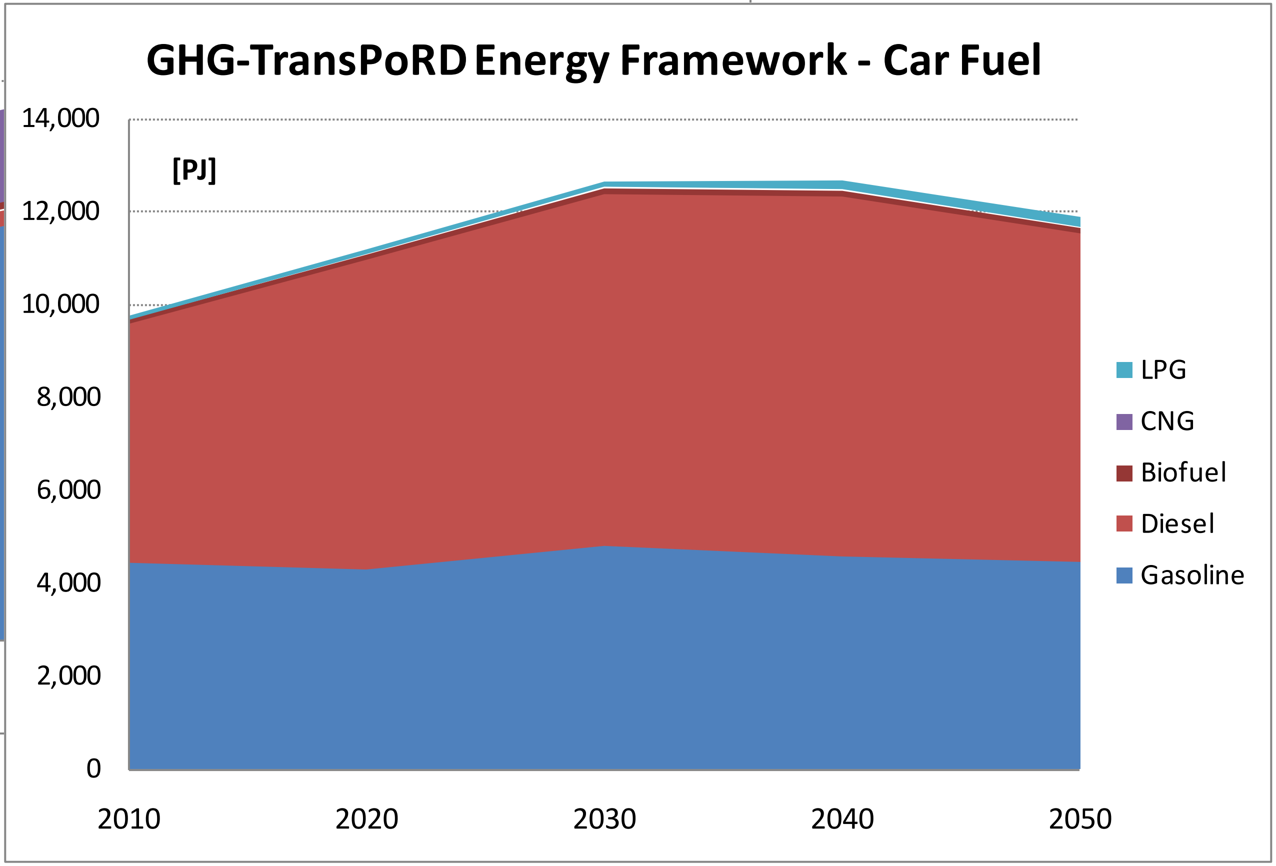
Policy scenario results – main indicators



Source: ASTRA

Common energy framework for road transport and passenger cars in EU27





Source: GHG-TransPoRD

Technologies considered (1/2)

Technology cluster	Technology
Aerodynamics/Resistance	Improved aerodynamics
	Low rolling resistance tyres
	Tyre-pressure monitoring system
	Low viscosity lubricants
	Reduced mechanical friction components
Electrical System - Energy Demand	LED headlights
	Electric power steering (EPS)
	Pneumatic brake booster
	Intelligent fuel pumps
Electrical System - Energy Supply	High efficiency alternators
	Intelligent battery sensor
	Solar panels on roofs
Engine Control System	Start-stop system
	Cylinder deactivation
	Fuel quality sensor
	Variable compression ratio
	Variable valve timing

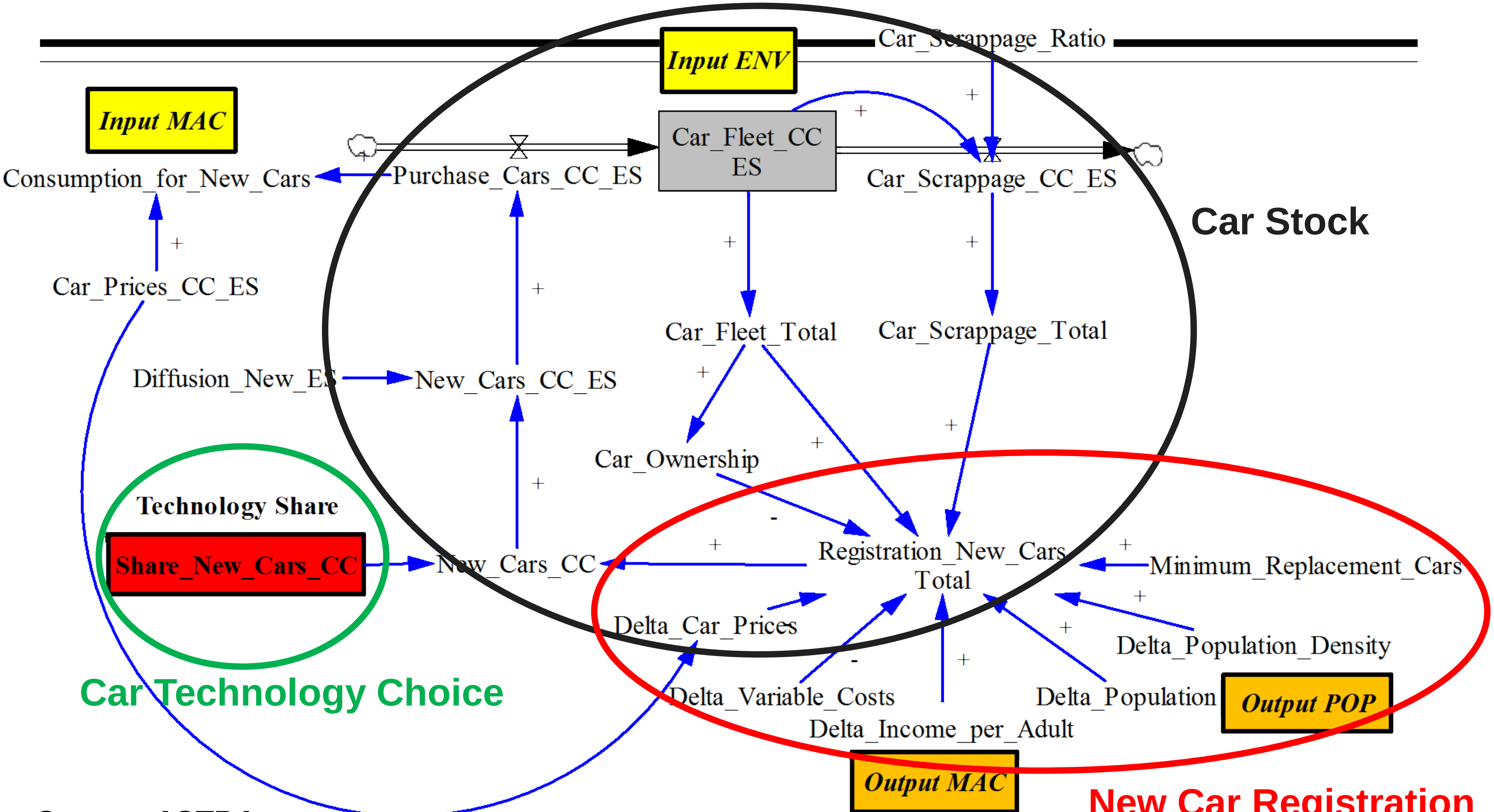
Source: GHG-TransPoRD

Technologies considered (2/2)

Technology cluster	Technology
Heat/Cooling Management	Cooling fluid shutdown system
	Exhaust heat recuperation
	Dual cooling circuits
	Intercooling
	Latent-heat storage
Hybrid Vehicles	Hybridtype: Full
	Hybridtype: Mild
	Hybridtype: Plug-in
Injection Technology	Homogeneous Charge Compression Ignition
Lightweight Construction	Smaller capacity fuel tanks
	Utilisation of lightweight design and materials
	Weight reduction by minimising convenience features
Drive and Transmission	Continuouse Variable Transmission
Hydrogen Fuel Cell	Hydrogen Fuel Cell Vehicles
CNG/LPG	CNG
Battery Electric Vehicles	Battery Electric Vehicles

Source: GHG-TransPoRD

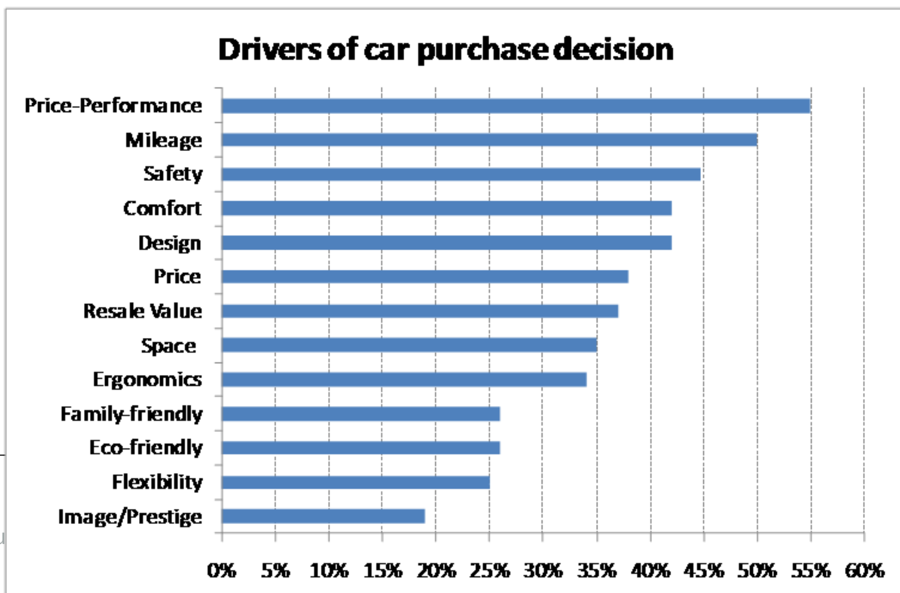
Modelling car fleets



Source: ASTRA

Car technology choice

- Car types: gasoline (< 1.4 l , < 2.0 l and > 2.0 l), diesel (< 2.0 l and > 2.0 l), CNG, LPG, hybrid electric vehicles, battery electric vehicles, bioethanol and hydrogen fuel cell vehicles
- Cost calculation per vhc-km for all technologies covers: fuel, maintenance, taxation and purchase costs
- Integration of filling station density via procurement costs per fuel type
- Technology choice simulated by logit-function:



Qualitative Factors

Costs

$$P_{cc,i} = \frac{\exp(-\lambda_i * pC_{cc,i} + LC_{cc,i})}{\sum_{cc} \exp(-\lambda_i * pC_{cc,i} + LC_{cc,i})}$$

Fact sheets for all technology clusters – „injection technology“

“Injection technology” summary			
Description			Several promising injection technologies have been developed in the past to reduce GHG emissions of ICE. The measure “injection technology” focuses on the most promising technology in terms of GHG emission reduction potential: Homogeneous Charge Compression Ignition (HCCI).
Measures included			HCCI combines homogeneous charge spark ignition (gasoline engines) and stratified charge compression ignition (diesel engines) such that well-mixed fuel and oxidizer are compressed to the point of auto-ignition.
Field of influence			Energy intensity
Earliest implementation date			Partially in 2012 (HCCI operation only in a portion of engine operating range); Advanced in 2018 (full range)
Relative CO_2 reduction	**2020**	**EU27**	10% for all passenger cars (11% before 2018, 25% from 2018 on for conventional passenger cars)
	2050	**EU27**	24% for all passenger cars (25% for conventional passenger cars)
Applicability			Measure is applicable on all conventional passenger cars.
Absolute CO_2 reduction potential	**2020**	**EU15**	76.9 Mt CO_2
		EU12	14.7 Mt CO_2
		EU27	91.6 Mt CO_2
	2050	**EU15**	170.0 Mt CO_2
		EU12	41.5 Mt CO_2
		EU27	211.5 Mt CO_2
Feasibility			High
Maturity			In process
Cost			933 €/Ton CO_2 saved

Source: GHG-TransPoRD

Fact sheet – „electrical system – energy supply“

“Electrical system – energy supply” summary			
Description			The group “electrical system – energy supply” focuses on three technical measures aiming at improving the efficiency of the energy supply side of electrical systems in passenger cars.
Measures included			“Electrical system – energy supply” integrates the following three technical measures: • solar panels on vehicle roofs (providing electrical energy for supporting engines in Hybrid and Battery Electric Vehicles or the electronic applications in fossil fuel cars), • energy efficient alternators (providing steering assist only in case of steering activities), • intelligent battery sensors (controlling the optimal energy flow to electronic devices in cars)
Field of influence			Energy intensity
Earliest implementation date			Already (in the US), 2012 in EU27
Relative CO_2 reduction	**2020**	**EU27**	10% for all passenger cars
	2050	**EU27**	20% for all passenger cars
Applicability			Measure is applicable on all passenger cars (max. potential achieved for HEV and BEV)
Absolute CO_2 reduction potential	**2020**	**EU15**	74.5 Mt CO_2
		EU12	14.8 Mt CO_2
		EU27	89.3 Mt CO_2
	2050	**EU15**	142.6 Mt CO_2
		EU12	35.2 Mt CO_2
		EU27	177.8 Mt CO_2
Feasibility			Medium
Maturity			In process
Cost			2,956 €/Ton CO_2 saved

Source: GHG-TransPoRD

Fact sheet – „heat and cooling management“

“Heat and cooling management” summary			
Description			The group of measures named “heat and cooling management” comprises five measures to reduce GHG emissions from passenger cars. All measures aim at improving fuel efficiency via utilizing heat energy caused by combustion processes or optimizing cooling processes.
Measures included			“Heat and cooling management” consists of the following five technical measures: • latent-heat storage (stores combustion heat to foster warm-up phase in following cold-starts) • exhaust heat recuperation (transferring waste heat to compressed air in order to preheat the air before entering the engine) • intercooling (acting as an air-to-air heat exchange device used on turbocharged ICE), • dual cooling circuits (for turbocharged engines with two cooling circuits in sequence) • cooling fluid shutdown system (stops the circulation of cooling fluids during warm-up)
Field of influence			Energy intensity
Earliest implementation date			Partially already implemented
Relative CO_2 reduction	**2020**	**EU27**	10% for all fossil fuel driven passenger cars
	2050	**EU27**	14% for all fossil fuel driven passenger cars
Applicability			Measure is applicable on all fossil fuel passenger cars (intercooling and dual cooling circuits prerequisite turbocharged engines).
Absolute CO_2 reduction potential	**2020**	**EU15**	74.1 Mt CO_2
		EU12	14.9 Mt CO_2
		EU27	89.0 Mt CO_2
	2050	**EU15**	97.8 Mt CO_2
		EU12	24.2 Mt CO_2
		EU27	122.0 Mt CO_2
Feasibility			Medium
Maturity			In process
Cost			1,022 €/Ton CO_2 saved

Fact sheet – „lightweight construction“

“Lightweight construction” summary			
Description			Three measures are grouped under the name “lightweight construction” aiming at reducing average weight of cars and thus reducing GHG emissions. This is done by substituting heavy by lightweight materials or by resigning on unnecessary convenience features.
Measures included			“Lightweight construction” combines fuel efficiency improvements of the following three measures: • utilization of advanced lightweight design and materials, • weight reduction by minimizing or eliminating unnecessary convenience features, • smaller capacity fuel tanks to avoid additional weight
Field of influence			Energy intensity
Earliest implementation date			Partially already implemented (utilization of advanced lightweight materials not before 2020)
Relative CO_2 reduction	**2020**	**EU27**	8% for all passenger cars
	2050	**EU27**	17% for all passenger cars
Applicability			Measure is applicable on all passenger cars.
Absolute CO_2 reduction potential	**2020**	**EU15**	59.6 Mt CO_2
		EU12	12.0 Mt CO_2
		EU27	71.6 Mt CO_2
	2050	**EU15**	121.6 Mt CO_2
		EU12	30.0 Mt CO_2
		EU27	151.6 Mt CO_2
Feasibility			Medium
Maturity			In process
Cost			7,644 €/Ton CO_2 saved

Source: GHG-TransPoRD

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Fact sheet – „engine control system“

“Engine control system” summary			
Description			Five measures are combined in the group “engine control system”. All measures improve fuel efficiency via control mechanisms for internal combustion engines in cars.
Measures included			“Engine control system” combines fuel efficiency improvements of the following five technical measures: • variable compression ratio (allowing the variation of compression ratios depending on load situation) • cylinder deactivation (applied during light load operation of engines), • start-stop system (automatically shutting down and restarting an internal combustion engines to avoid engine idling) • variable valve timing (enabling the variation of lift, duration or timing of the intake and/or exhaust valves) • fuel quality sensor (controlling the optimum amount of fuel injected during the engine start)
Field of influence			Energy intensity
Earliest implementation date			Partially already implemented
Relative CO_2 reduction	**2020**	**EU27**	7% for all fossil fuel driven passenger cars
	2050	**EU27**	13% for all fossil fuel driven passenger cars
Applicability			Measure is applicable on all fossil fuel passenger cars.
Absolute CO_2 reduction potential	**2020**	**EU15**	52.7 Mt CO_2
		EU12	12.3 Mt CO_2
		EU27	65.0 Mt CO_2
	2050	**EU15**	85.9 Mt CO_2
		EU12	25.6 Mt CO_2
		EU27	111.5 Mt CO_2
Feasibility			Medium
Maturity			In process
Cost			3,335 €/Ton CO_2 saved

Fact sheet – „hybrid vehicles”

“Hybrid vehicles” summary			
Description			For the measure “hybrid vehicles” conventional cars (gasoline and diesel) are substituted step-by step by mild hybrids until 2020 and full respective plug-in hybrids until 2050.
Measures included			Substitution of conventional by hybrid cars (mild and full)
Field of influence			Energy intensity
Earliest implementation date			Mild and full hybrids already implemented, plug-in hybrids in process (2012)
Relative CO_2 reduction	**2020**	**EU27**	7% for all passenger cars
	2050	**EU27**	18% for all passenger cars
Applicability			Measure is applicable on all conventional passenger cars.
Absolute CO_2 reduction potential	**2020**	**EU15**	51.5 Mt CO_2
		EU12	10.0 Mt CO_2
		EU27	61.5 Mt CO_2
	2050	**EU15**	126.7 Mt CO_2
		EU12	32.0 Mt CO_2
		EU27	158.7 Mt CO_2
Feasibility			Medium
Maturity			In process
Cost			5,928 €/Ton CO_2 saved

Source: GHG-TransPoRD

Fact sheet – „battery electric vehicles“

“Battery electric vehicles” summary			
Description			Substitution of fossil fuel driven cars by battery electric vehicles (BEV), assuming a share of 7.8% BEV on total car fleet in EU27 in 2020 and complete substitution of fossil fuel cars until 2050
Measures included			Substitution of internal combustion engines by electric engines
Field of influence			Energy intensity
Earliest implementation date			Already (but with insufficient ranges)
Relative CO_2 reduction	**2020**	**EU27**	6% for all passenger cars
	2050	**EU27**	77% for all passenger cars
Applicability			Measure is applicable on all fossil fuel cars (gasoline, diesel, CNG, LPG and hybrid cars) representing 99.4% of all passenger cars in EU27, but due to lacking ranges only 7.8% (Schade et al. 2009) of fossil fuel cars are assumed to be replaced until 2020.
Absolute CO_2 reduction potential	**2020**	**EU15**	47.3 Mt CO_2
		EU12	6.4 Mt CO_2
		EU27	53.7 Mt CO_2
	2050	**EU15**	565.3 Mt CO_2
		EU12	123.9 Mt CO_2
		EU27	689.2 Mt CO_2
Feasibility			2020 – Low , 2050 – Medium
Maturity			In process
Cost			5,542 €/Ton CO_2 saved

Source: GHG-TransPoRD

Fact sheet – „battery electric vehicles“

“Battery electric vehicles” summary			
Description			Substitution of fossil fuel driven cars by battery electric vehicles (BEV), assuming a share of 7.8% BEV on total car fleet in EU27 in 2020 and complete substitution of fossil fuel cars until 2050
Measures included			Substitution of internal combustion engines by electric engines
Field of influence			Energy intensity
Earliest implementation date			Already (but with insufficient ranges)
Relative CO_2 reduction	**2020**	**EU27**	6% for all passenger cars
	2050	**EU27**	77% for all passenger cars
Applicability			Measure is applicable on all fossil fuel cars (gasoline, diesel, CNG, LPG and hybrid cars) representing 99.4% of all passenger cars in EU27, but due to lacking ranges only 7.8% (Schade et al. 2009) of fossil fuel cars are assumed to be replaced until 2020.
Absolute CO_2 reduction potential	**2020**	**EU15**	47.3 Mt CO_2
		EU12	6.4 Mt CO_2
		EU27	53.7 Mt CO_2
	2050	**EU15**	565.3 Mt CO_2
		EU12	123.9 Mt CO_2
		EU27	689.2 Mt CO_2
Feasibility			2020 – Low , 2050 – Medium
Maturity			In process
Cost			5,542 €/Ton CO_2 saved

Source: GHG-TransPoRD

Fact sheet – „electrical system – energy demand“

“Electrical system – energy demand” summary			
Description			Four technical measures are allocated to the group “electrical system – energy demand”. The objective of these measures is to reduce the energy consumption of electrical devices within passenger cars and, therefore, improve fuel efficiency.
Measures included			“Electrical system – energy demand” consists of a combination of four measures: • LED lights (substituting conventional headlights), • electric power steering (providing steering assist only in case of steering activities), • electric vacuum pumps (replacing motor driven pumps applied e.g. in brake boosters) • intelligent fuel pumps (providing only as much fuel as required)
Field of influence			Energy intensity
Earliest implementation date			Already implemented
Relative CO_2 reduction	**2020**	**EU27**	5% for all passenger cars
	2050	**EU27**	7% for all passenger cars
Applicability			Measure is applicable on all passenger cars.
Absolute CO_2 reduction potential	**2020**	**EU15**	39.0 Mt CO_2
		EU12	7.8 Mt CO_2
		EU27	46.8 Mt CO_2
	2050	**EU15**	51.3 Mt CO_2
		EU12	12.7 Mt CO_2
		EU27	64.0 Mt CO_2
Feasibility			High
Maturity			Ready
Cost			no costs found in literature review

Source: GHG-TransPoRD

Fact sheet – „drive and transmission“

“Drive and transmission” summary			
Description			The measure “drive and transmission” concentrates on the technical measure which optimizes the gear and transmission process the most: continuous variable transmission.
Measures included			Continuous variable transmission allows changing continuously through an infinite number of effective gear ratios between maximum and minimum values. It enables the engine to run at its most efficient revolutions per minute for a range of vehicle speeds
Field of influence			Energy intensity
Earliest implementation date			Already implemented
Relative CO_2 reduction	**2020**	**EU27**	3% for all passenger cars
	2050	**EU27**	6% for all passenger cars
Applicability			Measure is applicable on all fossil fuel passenger cars.
Absolute CO_2 reduction potential	**2020**	**EU15**	24.2 Mt CO_2
		EU12	4.9 Mt CO_2
		EU27	29.1 Mt CO_2
	2050	**EU15**	39.8 Mt CO_2
		EU12	9.8 Mt CO_2
		EU27	49.6 Mt CO_2
Feasibility			Medium
Maturity			Ready
Cost			14,427 €/Ton CO_2 saved

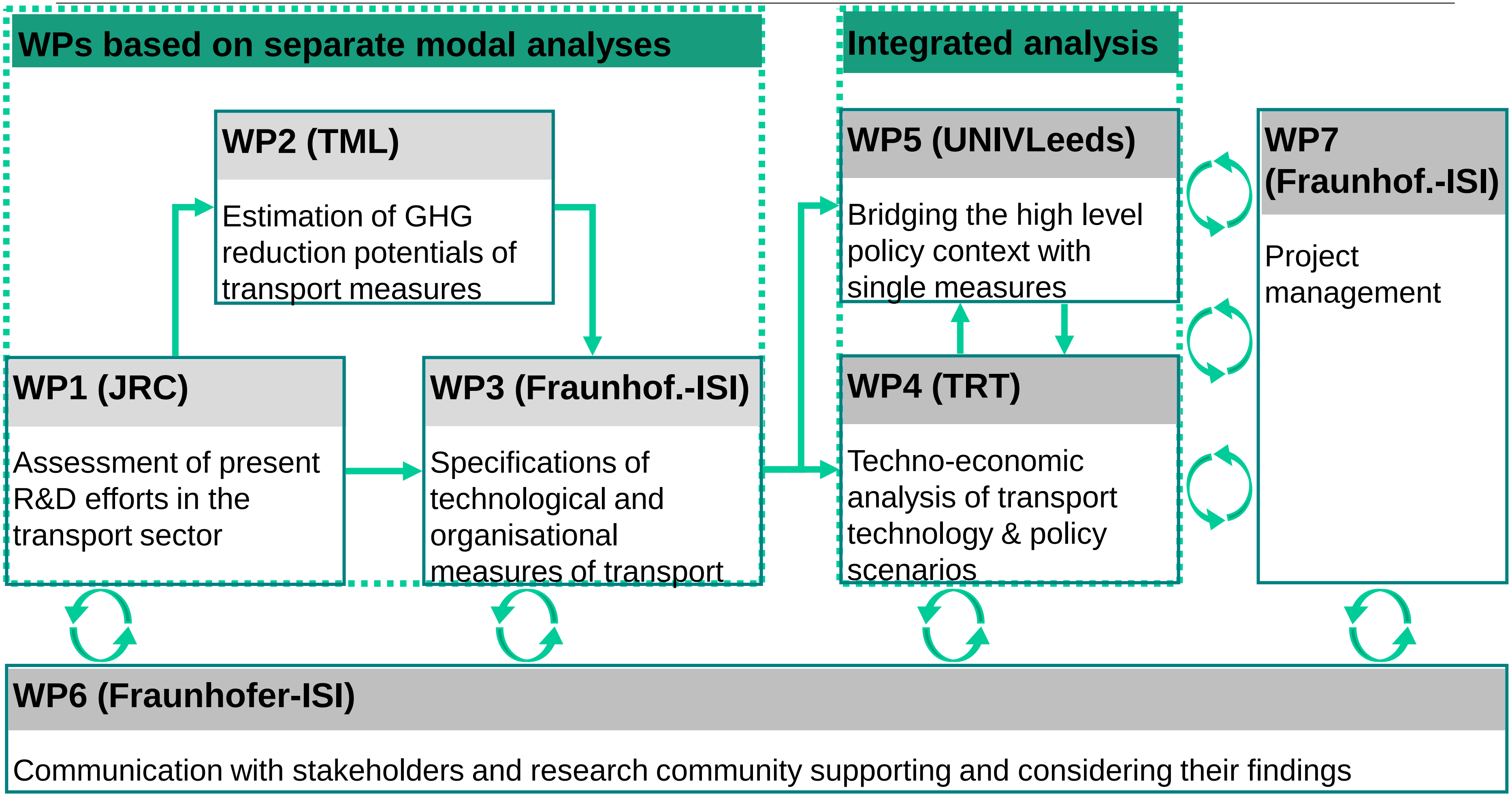
Source: GHG-TransPoRD

Fact sheet – „hydrogen fuel cell vehicles“

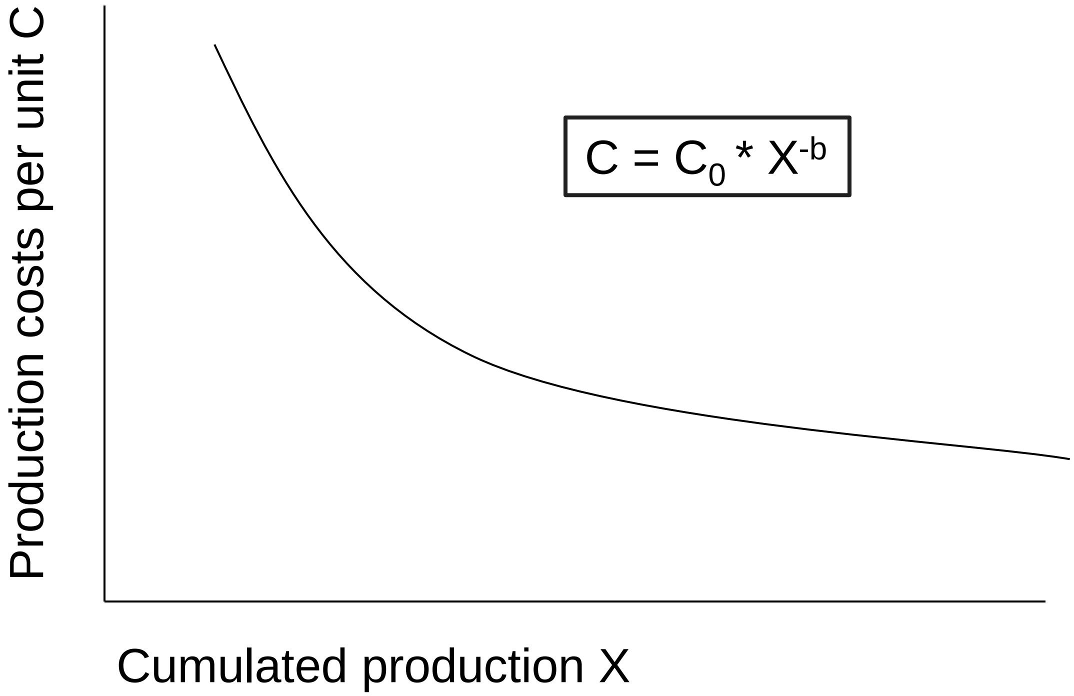
“Hydrogen fuel cell vehicles” summary			
Description			The measure “hydrogen fuel cell vehicles” focuses on the CO_2 reduction potential of an accelerated diffusion of hydrogen fuel cell vehicles replacing fossil fuel vehicles.
Measures included			Replacement of fossil fuel cars by hydrogen fuel cell vehicles according to the ADAM 2 Degree Scenario projections
Field of influence			Energy intensity
Earliest implementation date			2025
Relative CO_2 reduction	**2020**	**EU27**	0% for all passenger cars
	2050	**EU27**	8% for all passenger cars
Applicability			Measure is applicable on all fossil fuel passenger cars.
Absolute CO_2 reduction potential	**2020**	**EU15**	0 Mt CO_2
		EU12	0 Mt CO_2
		EU27	0 Mt CO_2
	2050	**EU15**	56.5 Mt CO_2
		EU12	13.2 Mt CO_2
		EU27	69.7 Mt CO_2
Feasibility			Medium
Maturity			Single field tests
Cost			

Source: GHG-TransPoRD

GHG-TransPoRD: work flow + work packages



Learning/experience curves



Learning/experience curves

$$C(X_{cum}) = C_0 * X^{-b}$$

C production cost per unit

C_0 = cost of first produced unit

X = cumulative production

b = learning parameter

Curve is characterised by:

- unit production cost at a specific cumulated production (C_i, X_i)
- the Learning Rate = $1 - 2^{b}$ → decrease in cost per doubling in production

Learning Curve in the Transport Sector

Technology	Reference	Learning Rate
Road technology		
Hybrid electrical vehicles	AEA Report, 2009	15%
Hybrid electric vehicles	Pill-Soo, 2003	6%
Battery electric vehicles	Pill-Soo, 2003	5%
Fuel cell vehicles	Schwoom, 2008	10-20%
PEM fuel cell	Tsuchiya, Kobayashi, 2004	14-26%
Electrical motors (industry)	Jardot, Eichhammer, Fleiter, 2009	9%
Downsizing (passanger cars and vans)	AEA Report, 2009	10%
Alternative fuels		
Biofuels (1st generation)	Wit, Junginger, 2010	10-20%
Biofuels (2nd generation)	Wit, Junginger, 2010	1-5%
Ethanol (Brazil)	Goldemberg, Coelho, Nastari, Lucon, 2004	29%
Air mode		
Aerospace	Stewart, 1995	15%
Shipping mode		
Shipbuilding	Stewart, 1995	15-20%

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