Well-to-Wheels analysis of future fuels and associated automotive powertrains in the European context

A joint initiative of **EUCAR/JRC/CONCAWE**

Preliminary Results for CNG

Summary of Material Presented to the EC Contact Group on Alternative Fuels in March 2003

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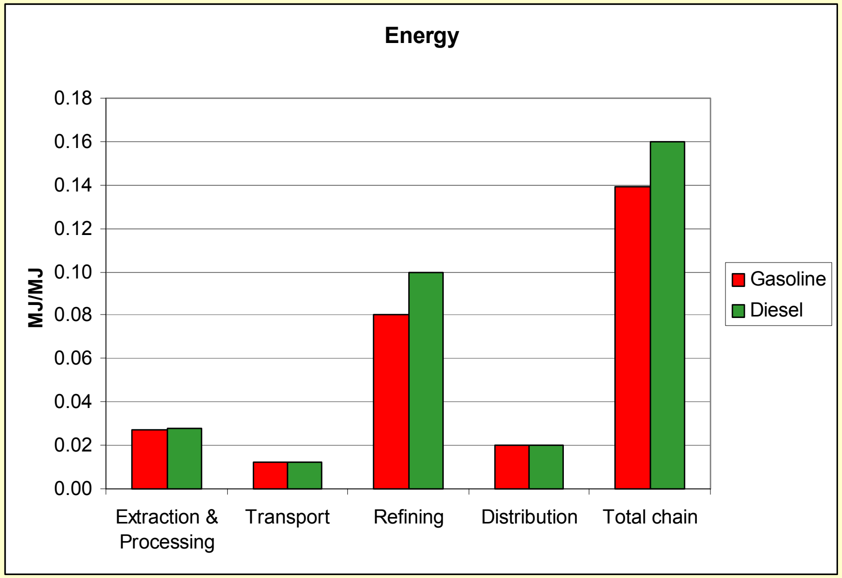
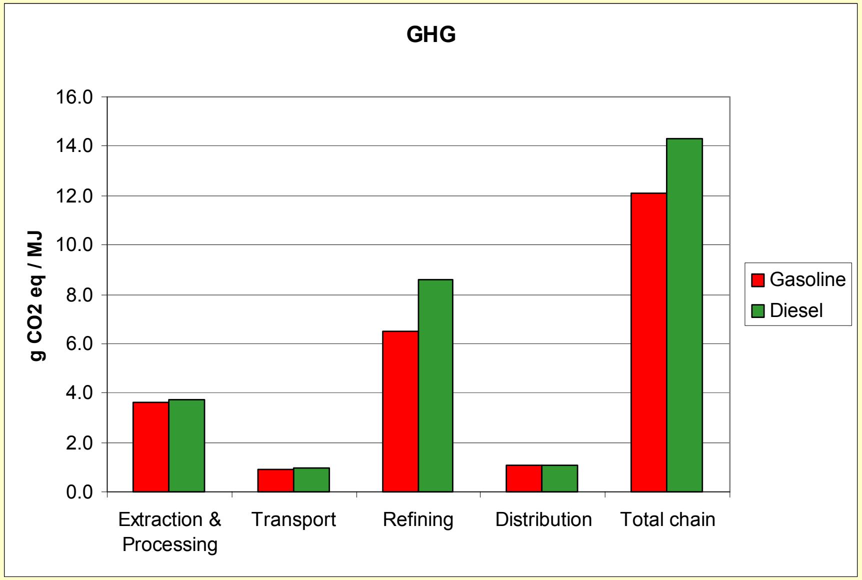
WELL-TO-TANK
(CNG-2002)

Well-to-Tank analysis
Conventional oil pathways

- At the 2010-2020 horizon, alternative fuels will replace some fraction of the current conventional fuels market
  - The energy that can be saved and the GHG emissions that can be avoided therefore pertain to the MARGINAL production of conventional fuels
- Europe is short in diesel and long in gasoline: the “natural” balance between gasoline and middle distillates is stretched
  - **As a result, refinery production of *marginal* diesel is more energy-intensive than that of *marginal* gasoline**





CO2 emitted on combustion is about 73g/MJ

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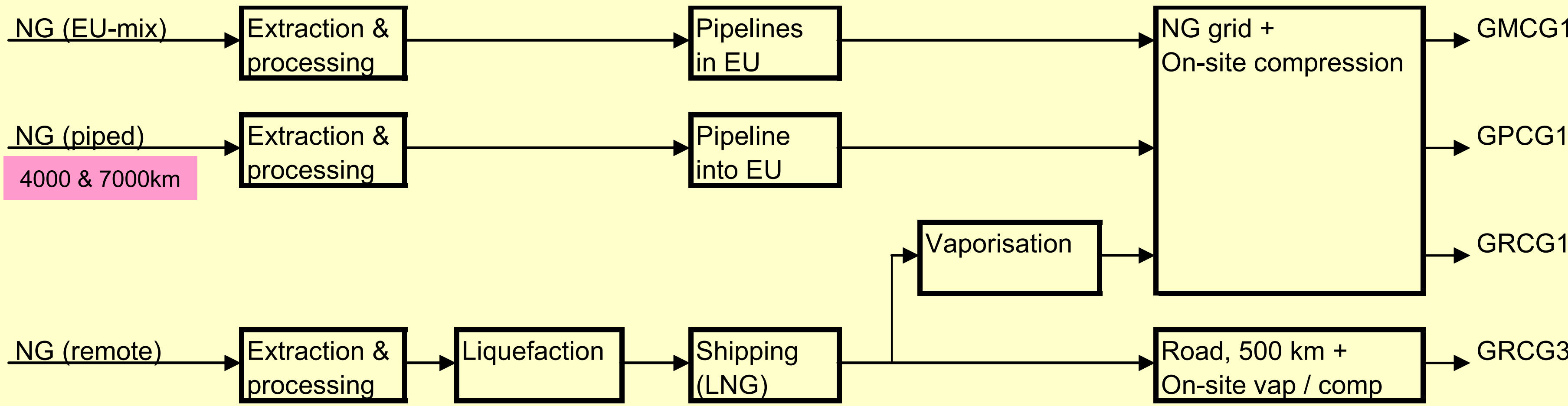
Well-to-Tank study: CNG pathways

Pathways considered



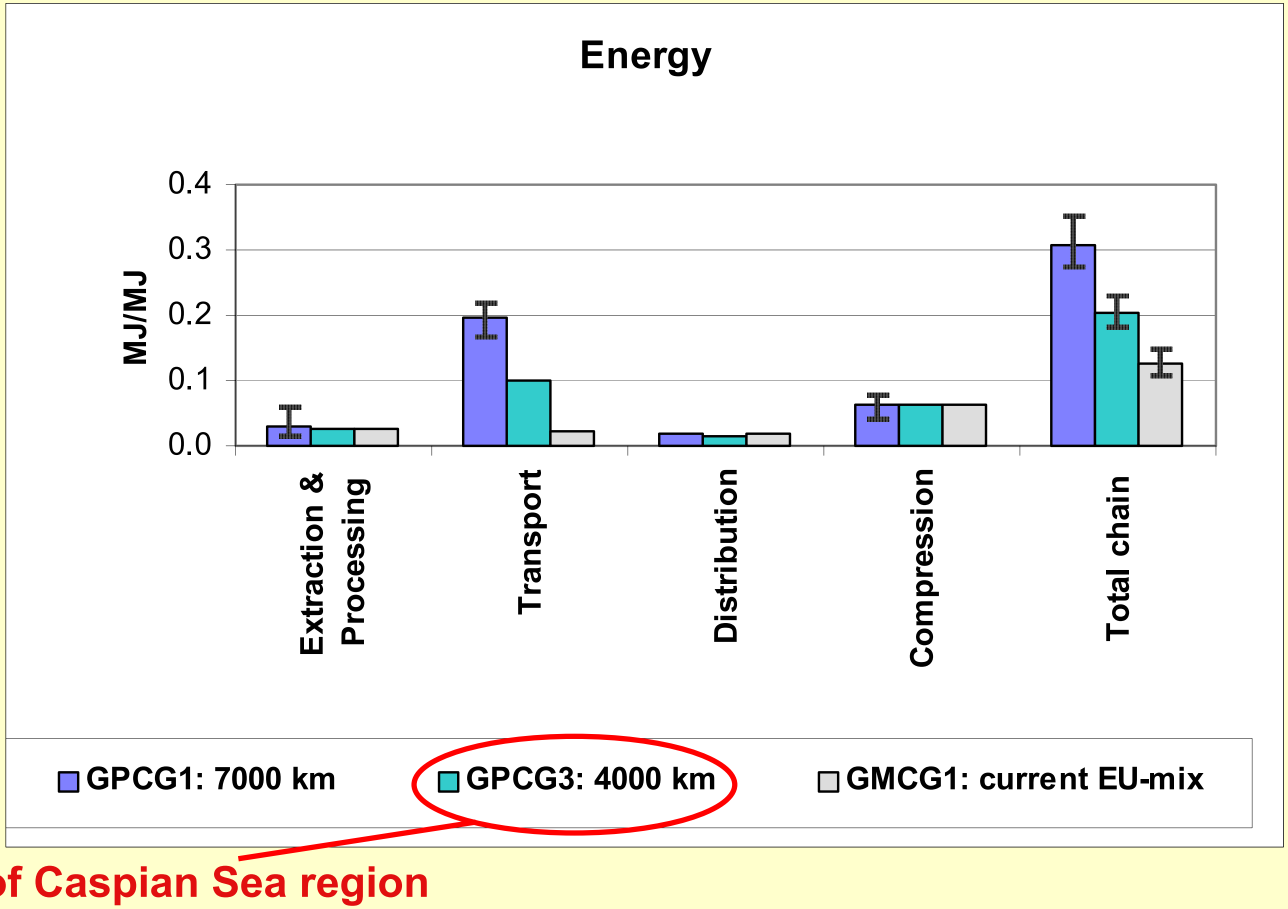
The EUmix case is included for reference only - marginal cases are more relevant

Natural gas grid pressures

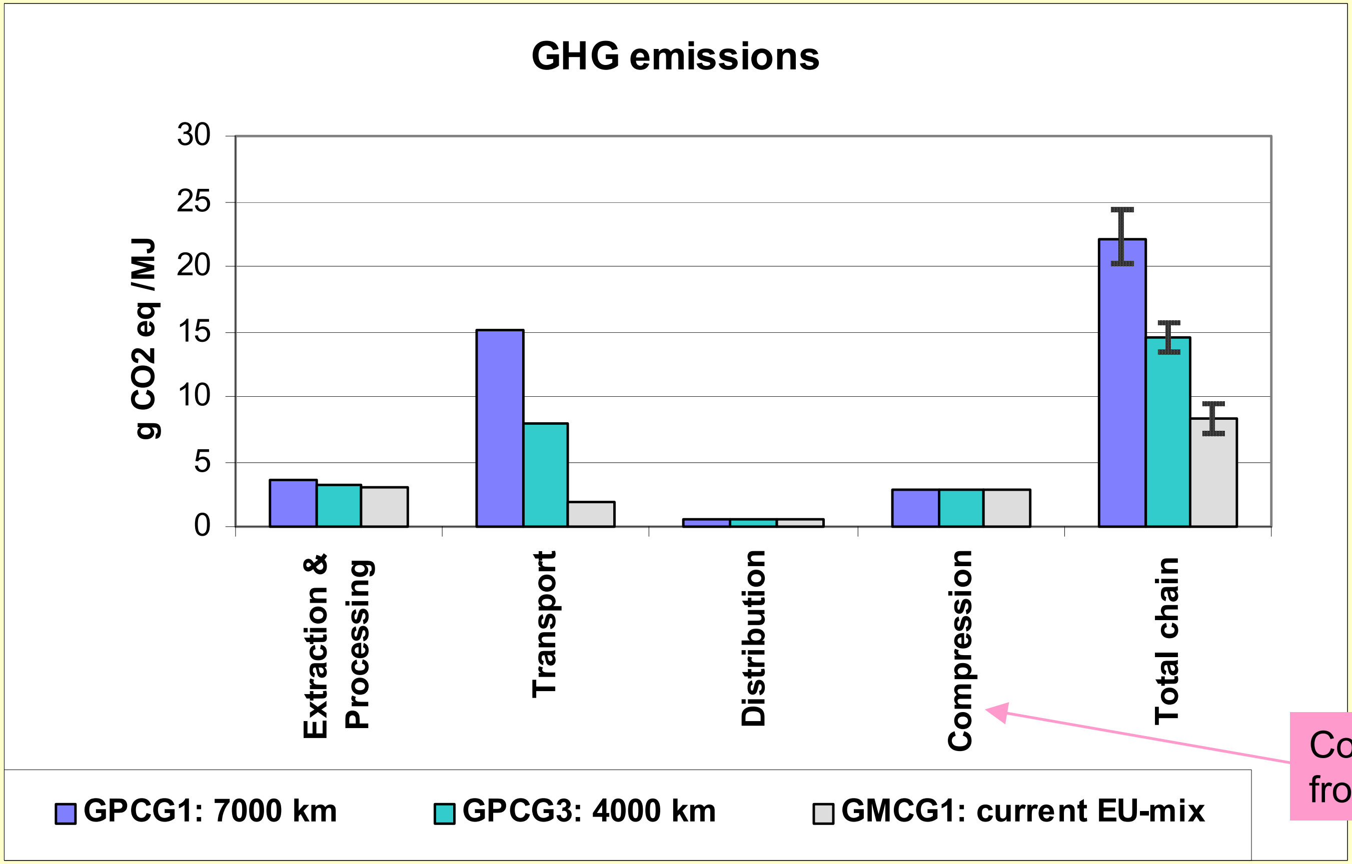
- Main trunk lines (HP) are typically between 40 and 60 bar
- Modern local distribution networks are at 4 bar_{gauge} (base case)
- Actual available pressures can vary between 1 and 20 bar_{gauge}

Well-to-Tank study: CNG from piped gas

- Typical distances are 7000 m for Western Siberia and around 4000 km for South West Asia and about 1000 km for European sources
- Up to 35% of the delivered energy can be used in the chain



Well-to-Tank study: CNG from piped gas



Compression from 4 bar_{gauge}

The transport distance considered and the distribution pressure are crucial to the overall result

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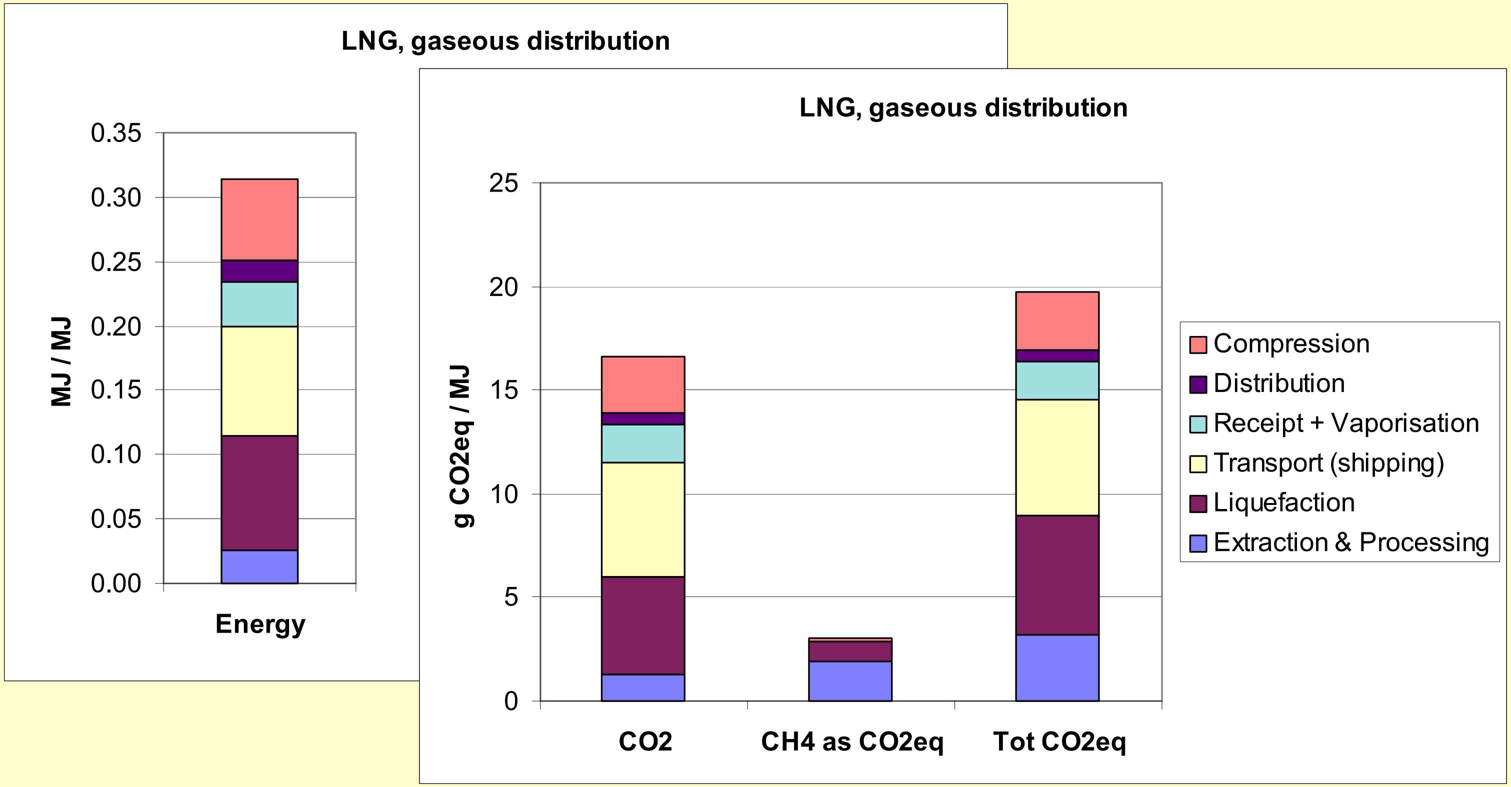
Well-to-Tank study: CNG from LNG

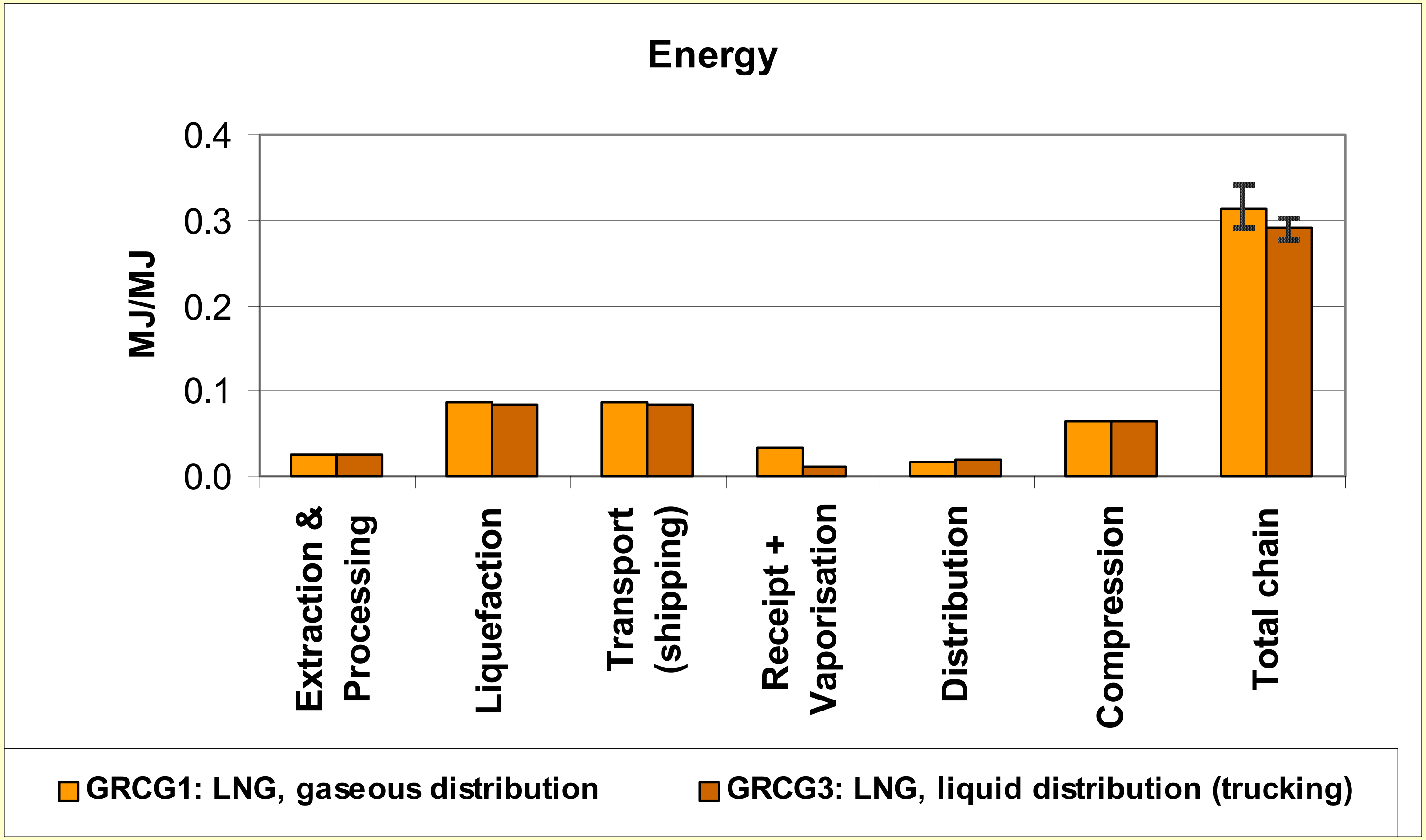
- Liquefaction, long-distance transport and compression are the main energy factors for LNG
- Methane losses influence the total GHG pattern



LNG transport distance: 5500 nautical miles

Well-to-Tank study: CNG from LNG

- Liquid distribution (trucking) and on-site vaporisation/compression of LNG would have a slight advantage in energy terms…



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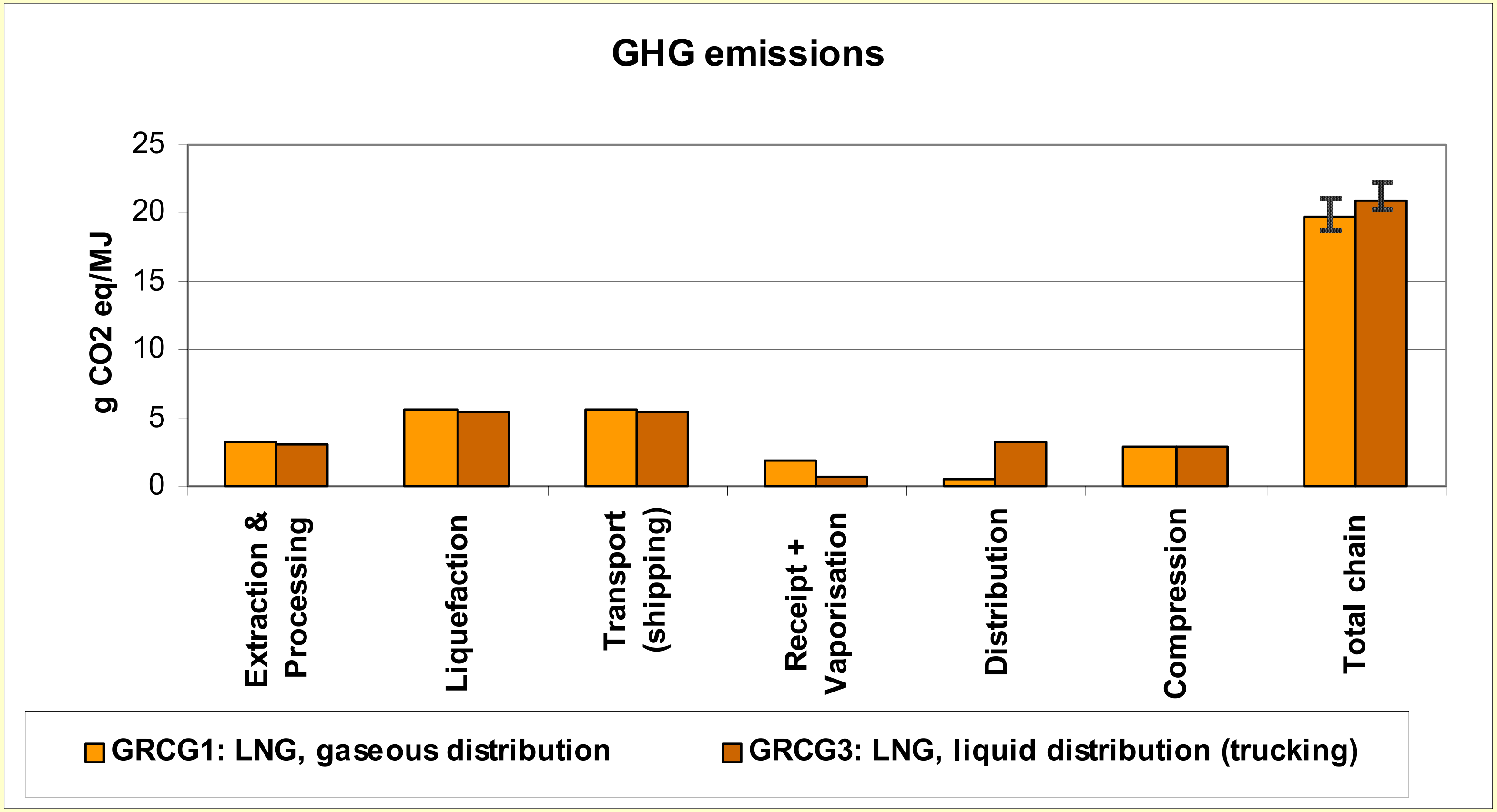
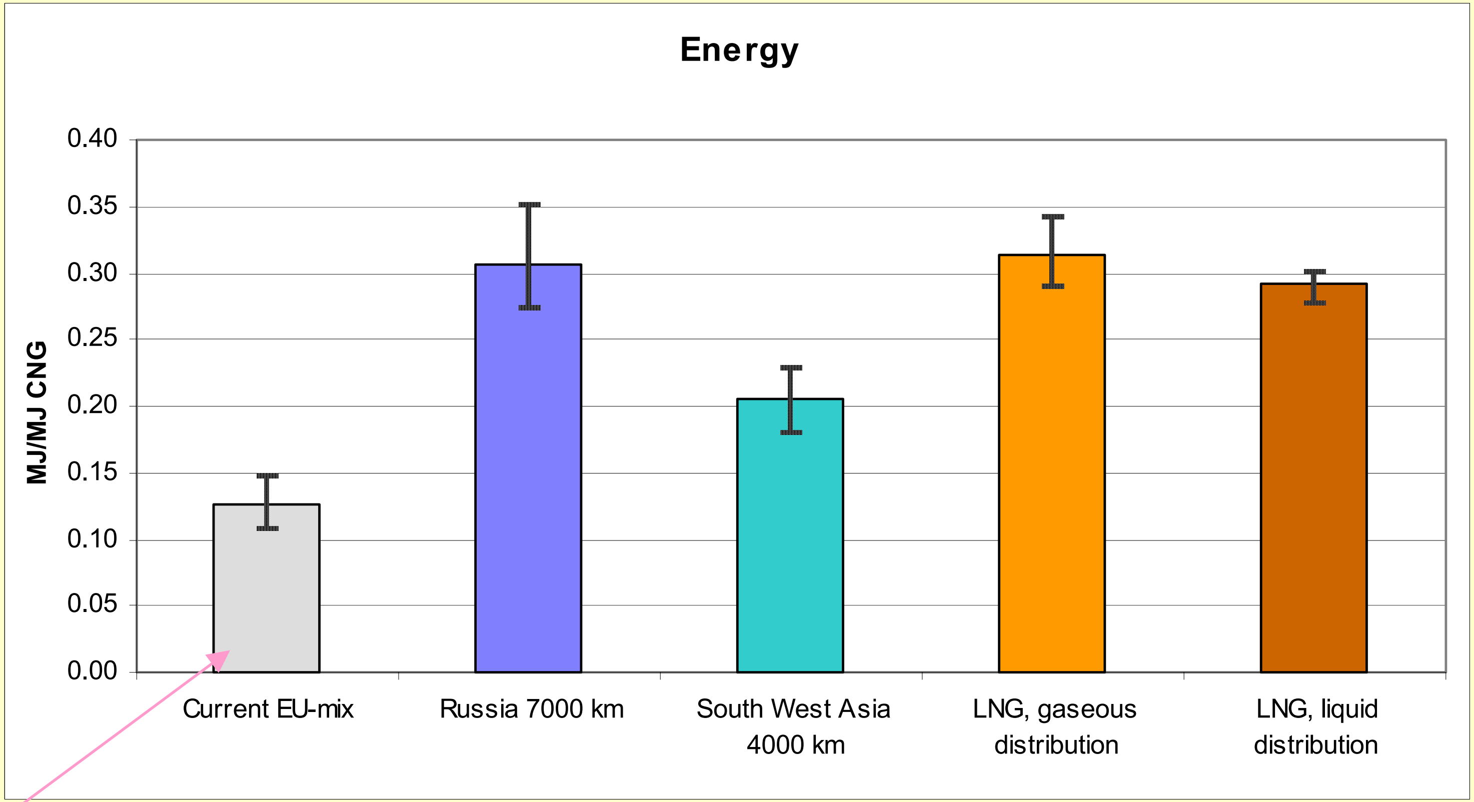
Well-to-Tank study: CNG from LNG

- …but not for GHG emissions



Well-to-Tank study: CNG Pathways

- LNG does not offer significant energy benefits over piped gas
- The current EU-mix is energy efficient because of the short transport distances involved



The EUmix case is included for reference only

TANK-TO-WHEELS (CNG-2002)

Tank-to-Wheels study: first phase

- For the purpose of this study, **a "virtual" vehicle** has been selected based on the VW Golf 1.6 l gasoline (most popular segment of the market)
- The results **do not** represent a fleet average
- The engine technologies considered here are essentially typical of 2002 for this first phase
- 2010 technologies will be considered in phase 2
- The engine technologies and fuels investigated do not imply any assumptions with regard to their potential market share

NOT

SEE HYDROGEN SLIDES

Engine Type	PISI	SIDI	CIDI
Gasoline	1.6 lit.	1.6 lit.	
Diesel			1.9 lit.
CNG (Bi Fuels)	1.6 lit.*		
CNG (dedicated)	2.0 lit.		

* Reduced performance

- Fuels & adapted technologies for comparable performance

Preliminary

Tank-to-Wheels study: first phase
Compared CO_2 emissions

	gasoline		diesel	CNG bi-fuel	CNG dedicated
Cold start	PISI 1.6	SIDI 1.6	DIESEL1.9	CNGBF** 1.6	CNG2.0
CO_2 emissions on the NEDC (g/km)	166.2	155	135	129	129.5
Consumption NEDC (MJ/100km)	224	207	183	229	230
Consumption NEDC (kg/100km)	5.21	4.87	4.25	5.08	5.1
Consumption NEDC (l/100km)	6.95	6.49	5.09	7.12	7.15
CO_2 benefit compared to PISI gasoline	Ref.	-7%	-19%	-22%	-22%
Euro III HC g/km	0.2	0.2	0.06	0.20	0.20
CH4	0.04	0.04	0.012	0.16	0.16
CO_2 equivalent	0.84	0.84	0.25	3.36	3.36
NOx g/km	0.15	0.15	0.5	0.15	0.15
N2O	0.003	0.003	0.01	0.003	0.003
CO_2 equivalent	0.93	0.93	3.1	0.93	0.93
GHG global g/km	168.0	157	138.3	133.4	133.9
GHG benefit / PISI gasoline (CO_2 equiv.)	Ref.	-6.5 %	-17.7 %	-20.6 %	-20.3 %

CNGBF** 1.6 Performance limited (12% reduction) by the cylinder volume occupancy

NEDC = New European Driving Cycle

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Tank-to-Wheels study: first phase
Unexpected results for CNG engines?

- Bi-Fuel (gasoline adapted) engine, even accepting the 12% reduction in performance, suffer an inertia class jump (1 step) due the tank weight:
  - This results in a CO_2 benefit reduced from 24% (chemistry) to 22%

- Dedicated engine need to be upsized to 2.0 l to match performance criteria:
  - Compression ratio increase (3 pts) brings +9% fuel efficiency
  - Under low load operation (least efficiency on the NEDC cycle) the upsized engine consumes 9 % more fuel
  - Overall CO_2 benefit remains at 22%

- Impact of CH_4 and N_2O emissions reduces the benefit by 1% to 21%
- Compared to Diesel the benefit is only 3%

- Comparison for Heavy Duty engines is under documentation

Tank-to-Wheels study: first phase
Comparison with earlier studies

- For bi-fuel engines our results are similar to the GM US study
- The GM EU study was more favourable for dedicated engines:

Global G.H.G.	PISI 1,8 lit.	SIDI 1,8 lit.	DIESEL 2,0 lit.	CNG D.S.T.C.
Gasoline	Reference	-14%		
Diesel			-20%	
Natural gas				-29%

As :

- It assumed a turbo-charged downsized engine for CNG…
  - …But not for gasoline
  - ...Gasoline engine can also benefit from t/c and downsize
- This study compares vehicles at the same level of technology

WELL-TO-WHEELS (CNG-2002)

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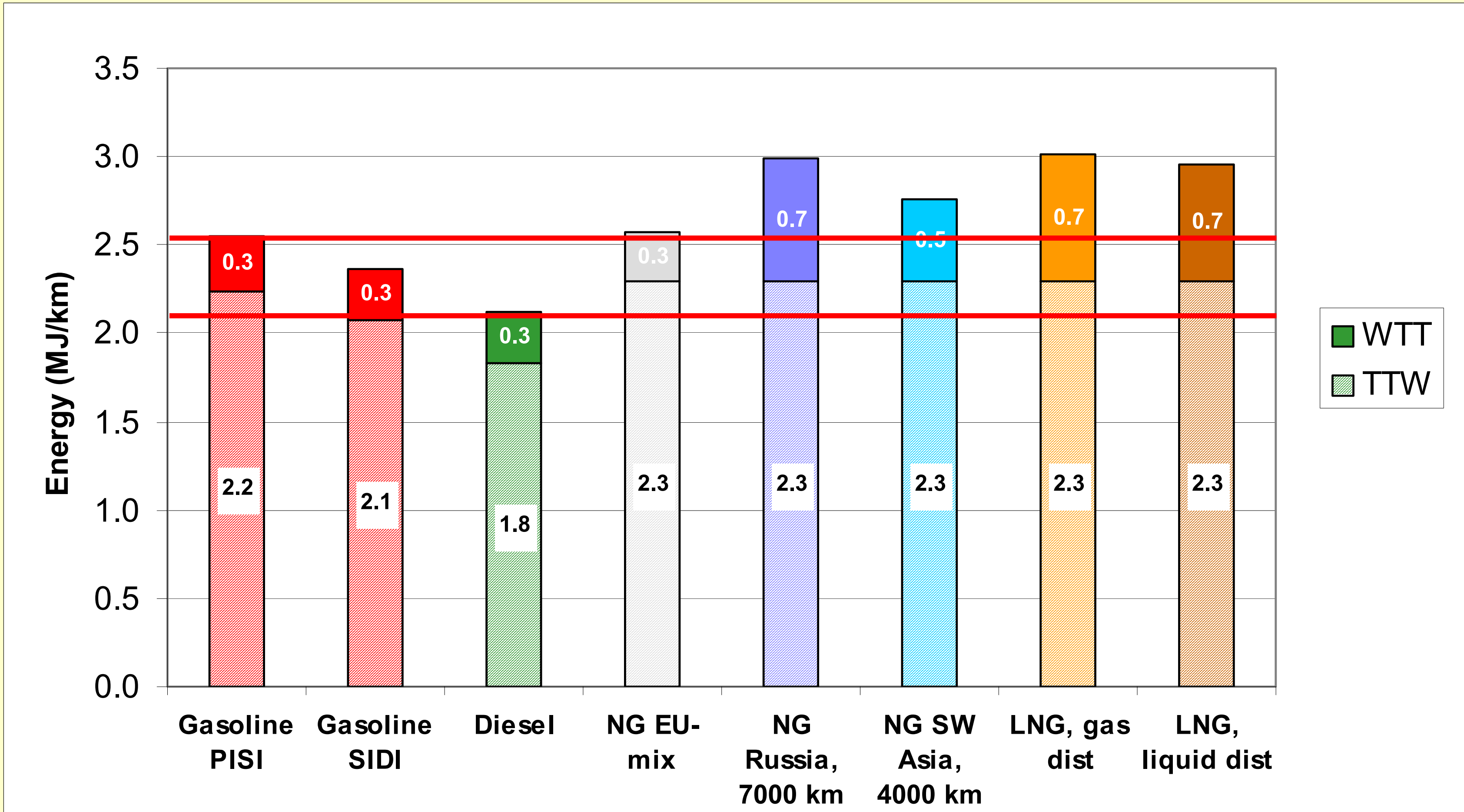
Well-to-Wheels analysis
CNG vs conventional pathways

- CNG pathways are more energy-intensive than those based on marginal conventional fuels



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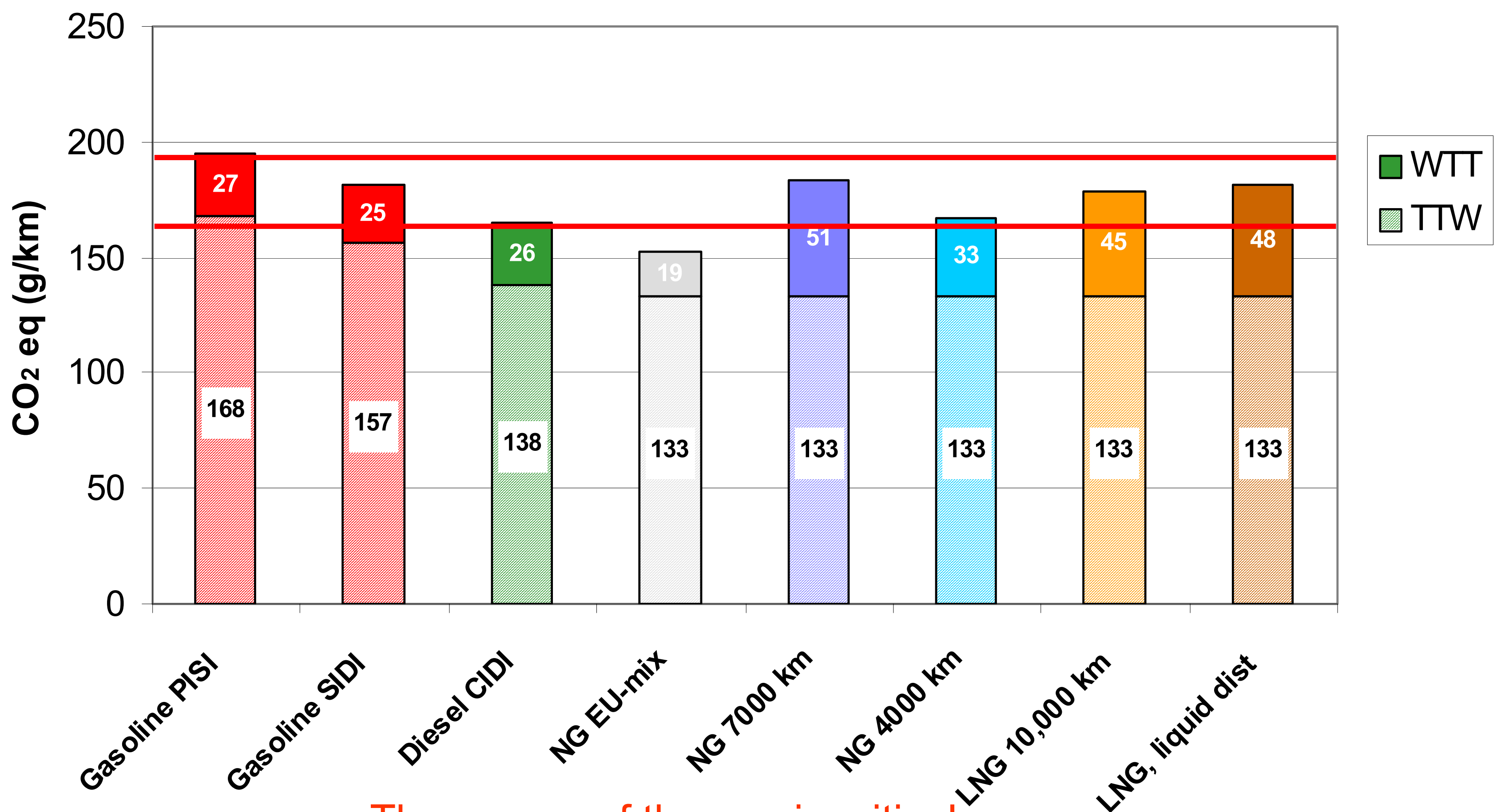
Well-to-Wheels analysis
CNG vs conventional pathways

- GHG emissions: a mixed result



The source of the gas is critical

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Well-to-Wheels analysis
CNG vs conventional pathways
CONCLUSIONS

- CNG for 2002-technology passenger vehicles
  - would be more energy intensive than conventional fuels
  - Would allow a small GHG saving compared to gasoline, but not compared to diesel
  - The supply route would be critical to the actual GHG savings

- Factors that could make CNG more effective in the future are
  - Use by vehicle fleets to maximise fuel usage relative to infrastructure cost
  - Use of the highest available grid pressure to improve energy efficiency and GHG emissions
  - Spark-ignition engines, including CNG, have more remaining potential for improvement than diesel engines

SEE HYDROGEN SLIDES FOR PRELIMINARY EXTRAPOLATION TO 2010 TECHNOLOGY