Biomethane as a vehicle fuel made from upgraded biogas

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Outline

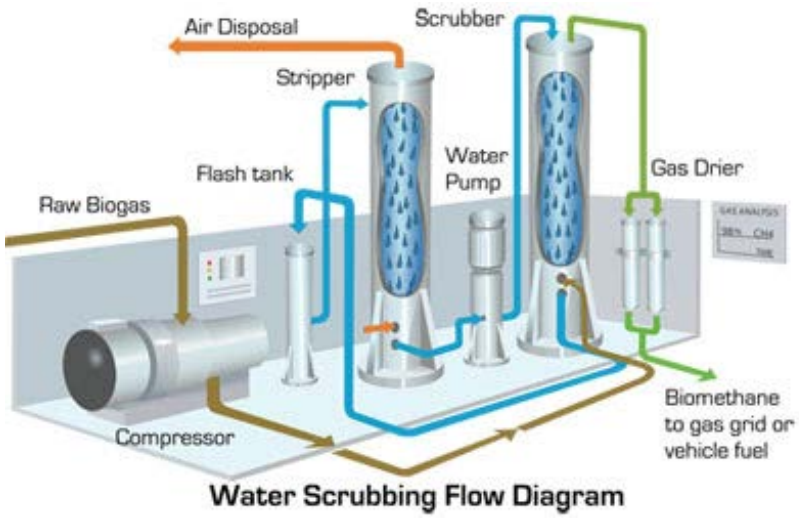
- Utilisation of biomethane as a vehicle fuel today
- Brief overview of biogas upgrading
- Standardisation of vehicle gas (CNG + biomethane)
- The lower emissions of gas vehicles
- Natural gas vehicles of today and tomorrow
- Conclusions

Utilisation of biomethane as vehicle fuel

- Small but growing market
  - Estimation: 1.5-3.0TWh (~2% of European biogas production)
  - Sweden 730GWh, Germany 180GWh, France 21GWh, Switzerland 39GWh, Iceland 7GWh, Norway 4GWh, Finland 1GWh (Data from NGVA Europe)
- Why has Sweden the largest market today
  - Nearly fossil free electricity → subsidy support beneficial for biomethane as a vehicle fuel

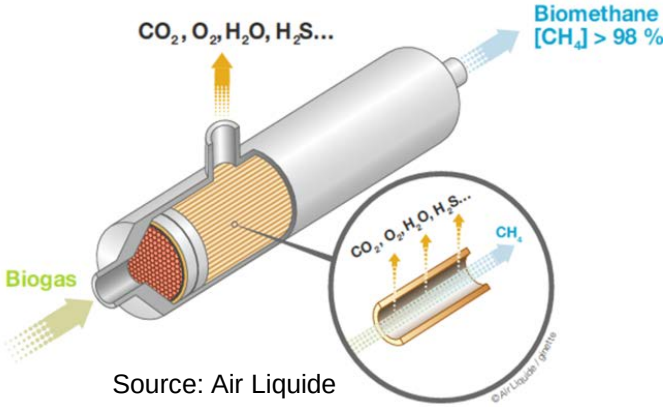
Biogas upgrading technologies

Water/chemical scrubber



Source: Greenlane Biogas

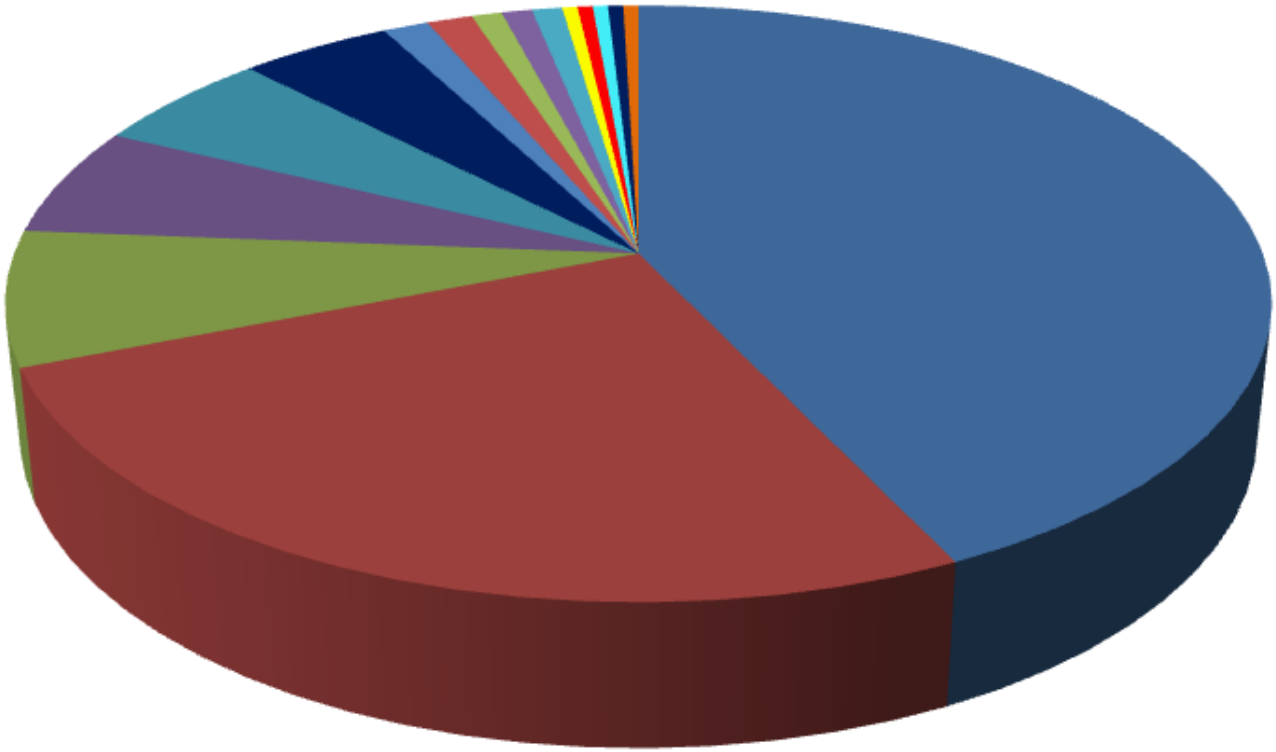
Membrane



Source: Air Liquide

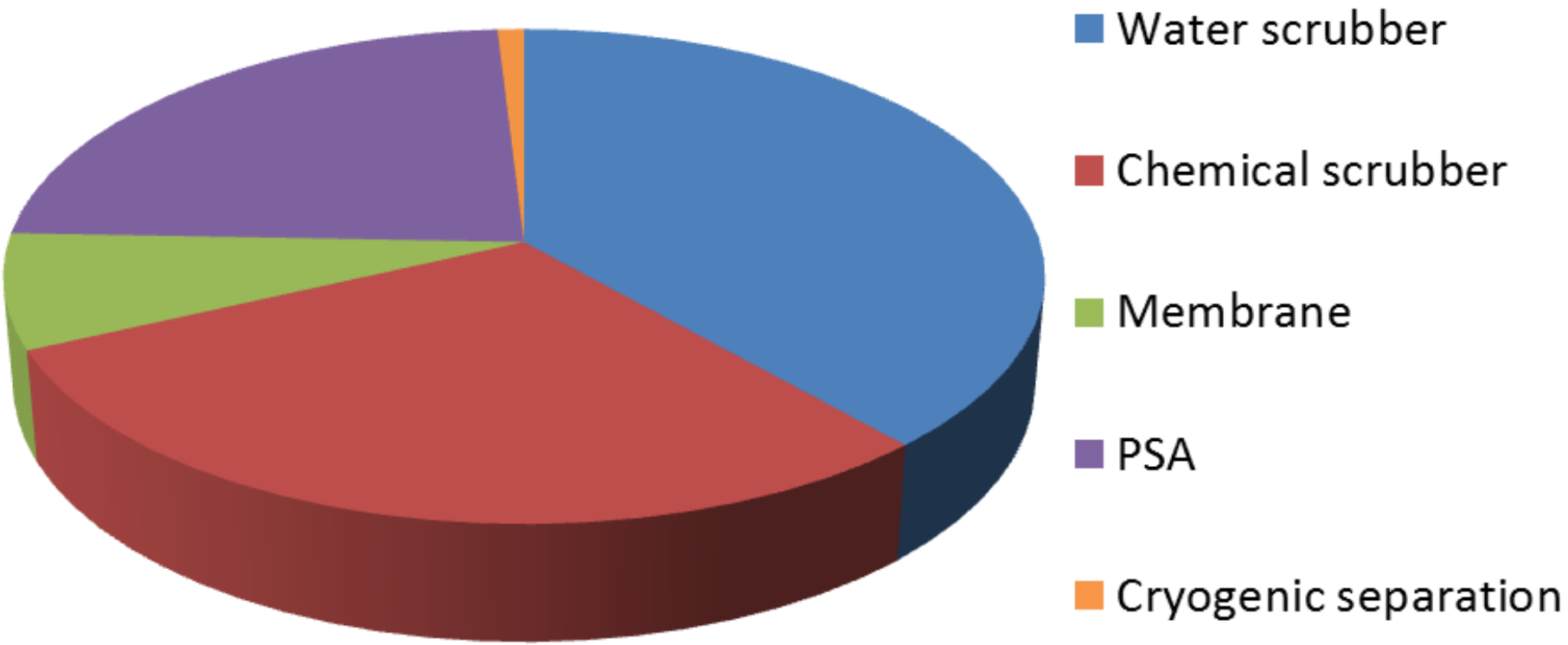
PSA

220 upgrading plants in different countries



Source: IEA Bioenergy Task 37

Upgrading technologies



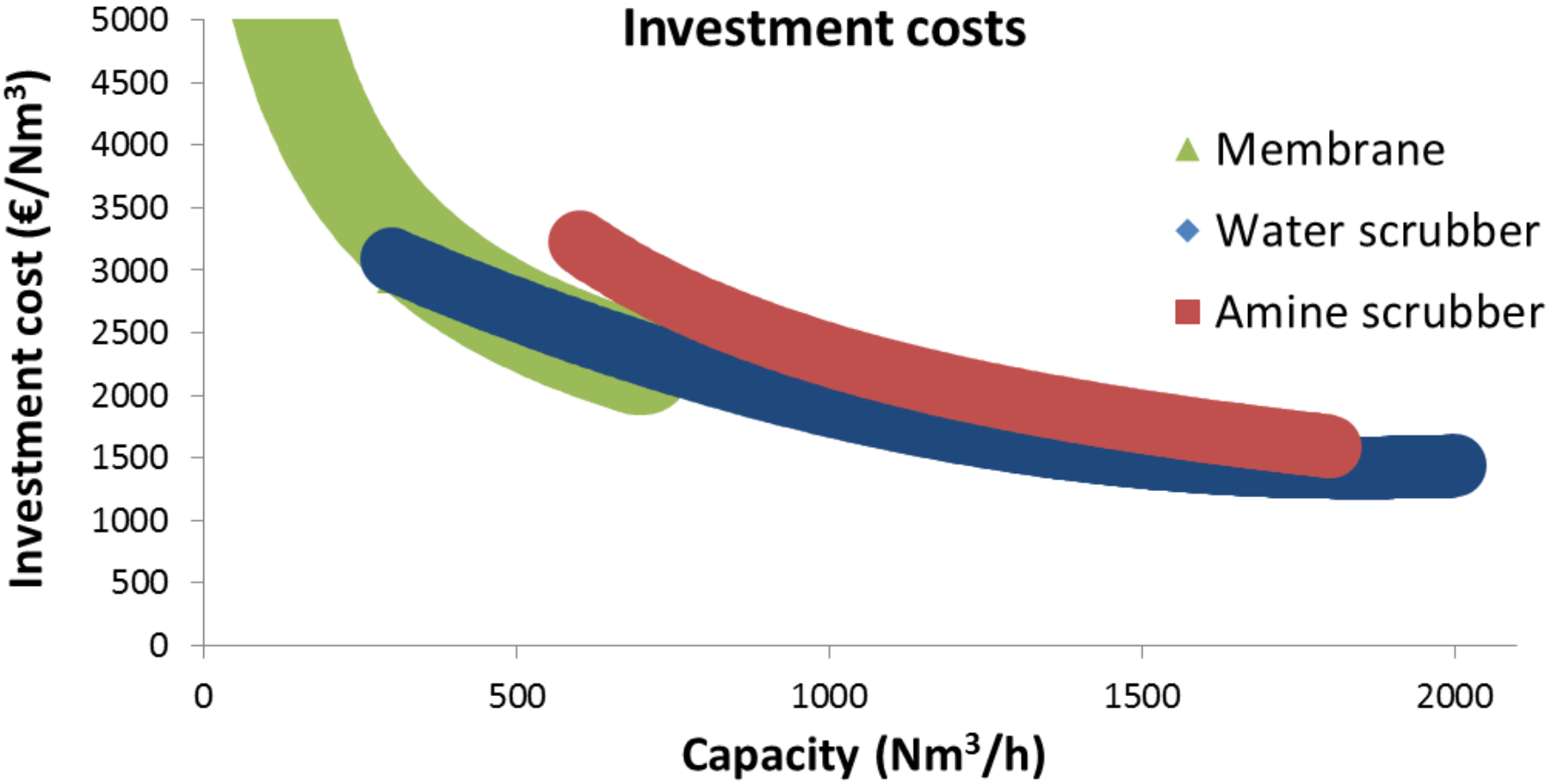
Source: IEA Bioenergy Task 37

Energy consumption

- Amine scrubber: 0.12-0.14 kWh/Nm^3 (+0.55 kWh/Nm^3 heat)
  Pressure: 4 bar(g)
- Membrane: 0.20-0.30 kWh/Nm^3
  Pressure: 5-20 bar(g)
- PSA: 0.20-0.30 kWh/Nm^3
  Pressure: 4-8 bar(g)
- Water scrubber: 0.20-0.30 kWh/Nm^3
  Pressure: 5-9 bar(g)

Source: Data from an SGC project to be published early 2013

Investment cost per Nm^3 raw biogas



Source: Data from an SGC project to be published early 2013

Standardisation of vehicle gas

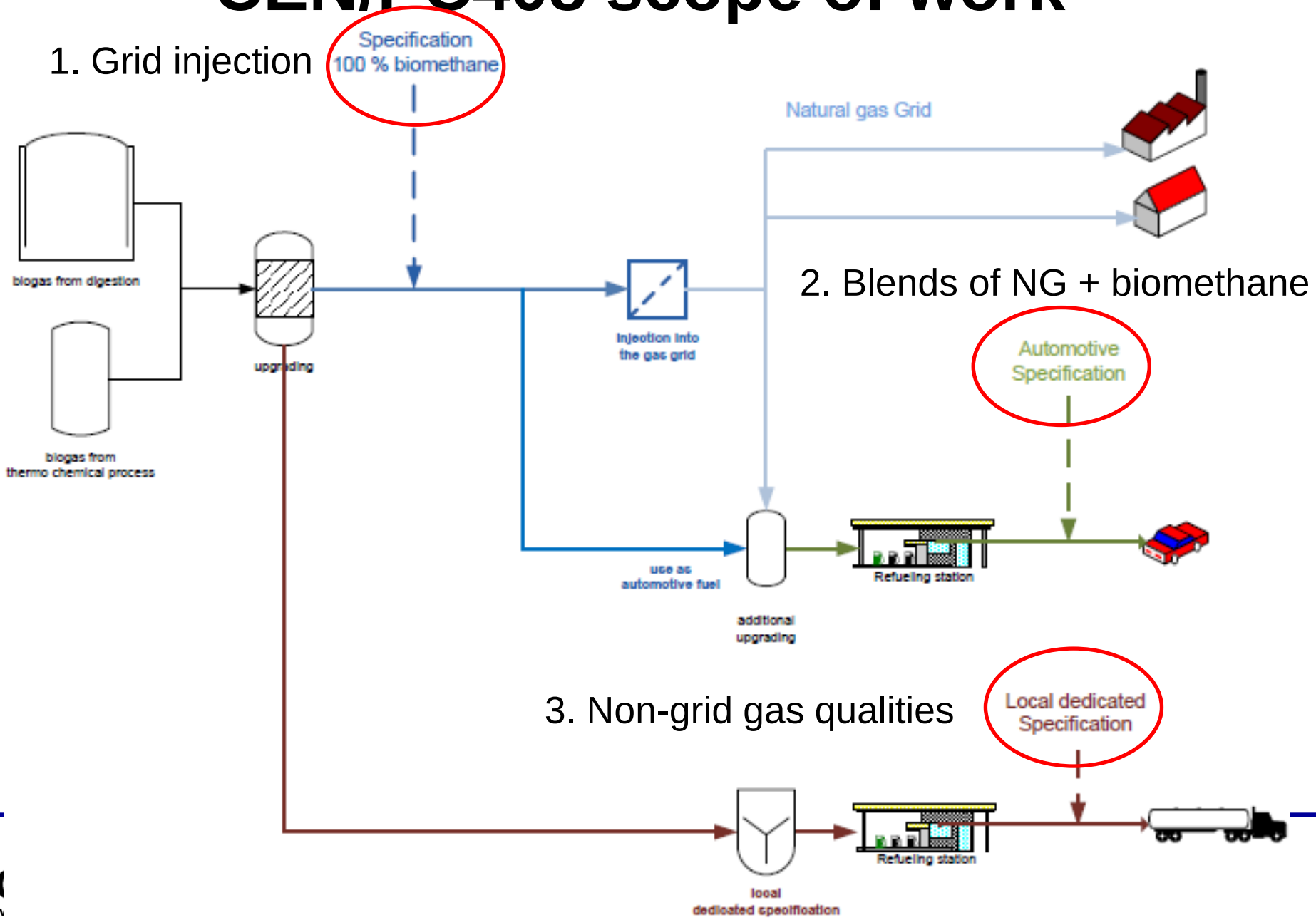
- The barriers of the growth of the NGV* market
  - Infrastructure, Biomethane supply
  - Gas quality standardization
- International std's not yet in place, but EU mandates** to CEN have initiated the process
  - The gas business (CEN/TC234) want wide or no specs
  - OEM's (CEN/TC019) push for tighter specs, needed to attain the full potential of gas engines
  - 2011-2015: Grid owners + OEM's working together in special project committee CEN/PC408!

*Natural Gas vehicles (also Biomethane)

**M/475 08/11/2010, "Mandate to CEN for standards for biomethane for use in transport and injection in natural gas pipelines"; M/400 16/01/2007, "Mandate to CEN for standardisation in the field of gas qualities"

CEN/PC408 scope of work

1. Grid injection



CEN: What limits are discussed?

Have priority lane!

	TC234/WG11	PC408 -grid	PC408-fuel
Sulphur (mg/Nm^3)	5-30, excl. odoriz.	←	7-13, incl. odoriz.
Methane No. (AVL)	65	←	75-90*
O_2 (%)	1 (0.01, storage)	←	-
H_2 (%)	- (0.1-10, no limit better)	←	2
Water (mg/Nm^3)	32 (corrosion)	←	Lower, climate**
Siloxanes (mg Si/Nm^3)	-	1-10	0.5-1***
Compr. oil (mg/Nm^3)	-	-	10-20?#

*Euro6: Emission guarantee not only for reference fuel, but for **all** fuels used

**Driveability issue (methane hydrates). In Sweden as low as 1-5mg/Nm^3

*** abrasive silica sand formation, fouling λ-sensors, faster aging of catalysts

#Pending current validation of new sampling and test method, spring 2013

Microorganisms: Only information, micron filtering. Low hazard assessment

Vinnerås et al 2006 "Identification of the microbiological community in biogas systems and evaluation of microbial risks from gas usage"

Euro6: no problem for NGV's

MAN E2876 LUH03, 320hp engine, launched in 2010 (autoflesz.pl)

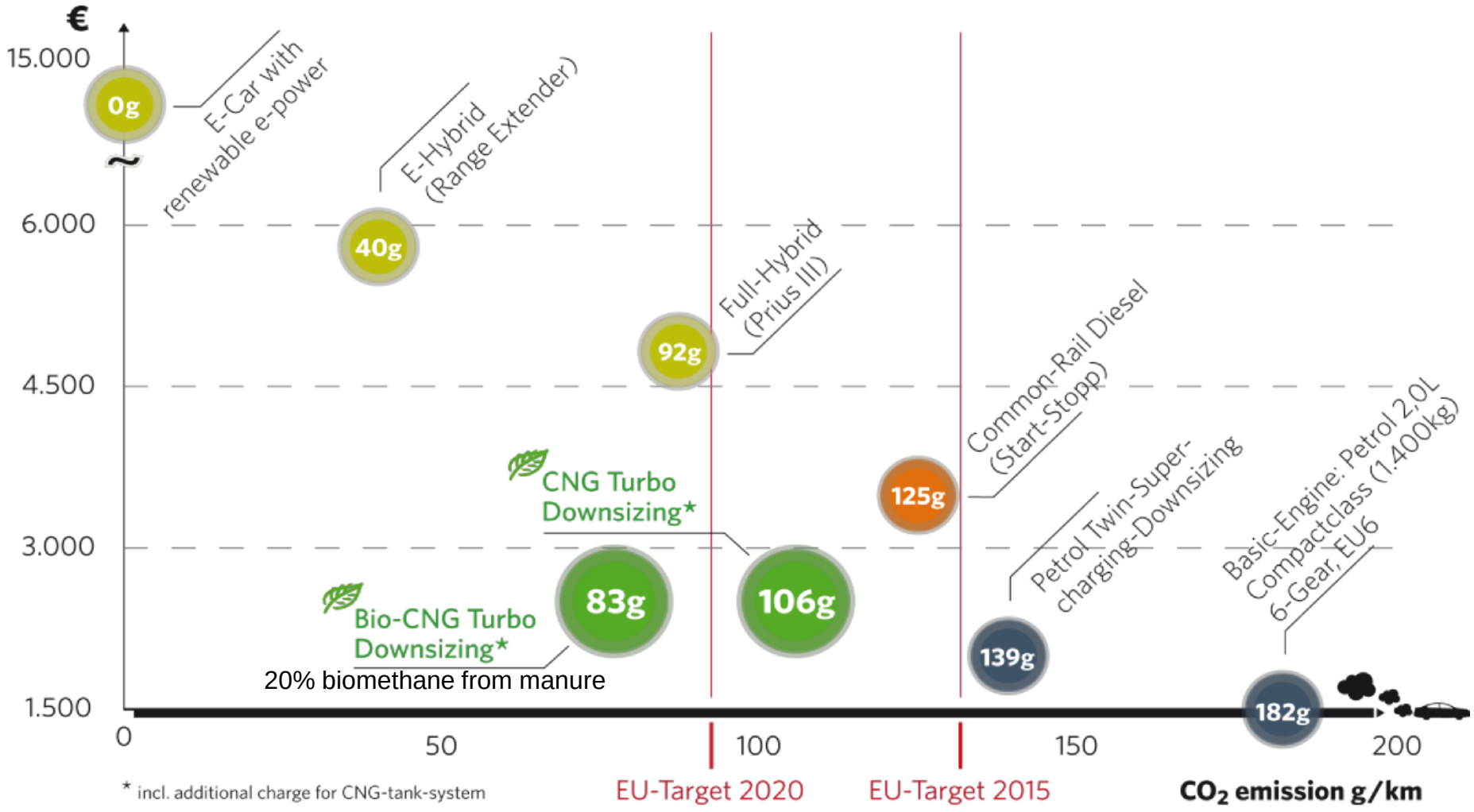
Source: Erdgas Mobil

NGV unregulated emissions: Lower and less harmful

- Regulated emissions (HC, NOx, PM) – total content of different compounds with very different impacts
- NO_X – Nitrogen oxides
  - NO_2: higher tropospheric ozone and photochemical smog forming capacity than NO
  - N_2O: GWP_{100yr}-factor 298 (CH_4, GWP_{100yr} = 25)
- HC – hydrocarbons
  - Harmless ones (methane, ethanol)…
  - Real health hazards such as aldehydes, benzene (aromatic, the B in BTX) and polyaromatics (PAH)
- PM, Particulate Mass
  - Solids with vastly different biogenic impact (reactivity, size)

NGV's: Cost competitive already today

Production-costs per powertrain [EUR] vs CO2 emission [g/km]



Source: Dudenhöffer and Pietron 2010, Center Automotive Research (CAR), Universität Duisburg-Essen : CNG as automotive fuel for Europe

Future: Diesel efficiency in gas engines?

- Short-term: dual-fuel HDV's powered by LNG
  - Fuel efficient methane-diesel tech and space efficient LNG tech gives diesel engine performance with lower fuel costs
  - The challenge: Euro6 possible?

Volvo FM 13-litre MDE Euro5

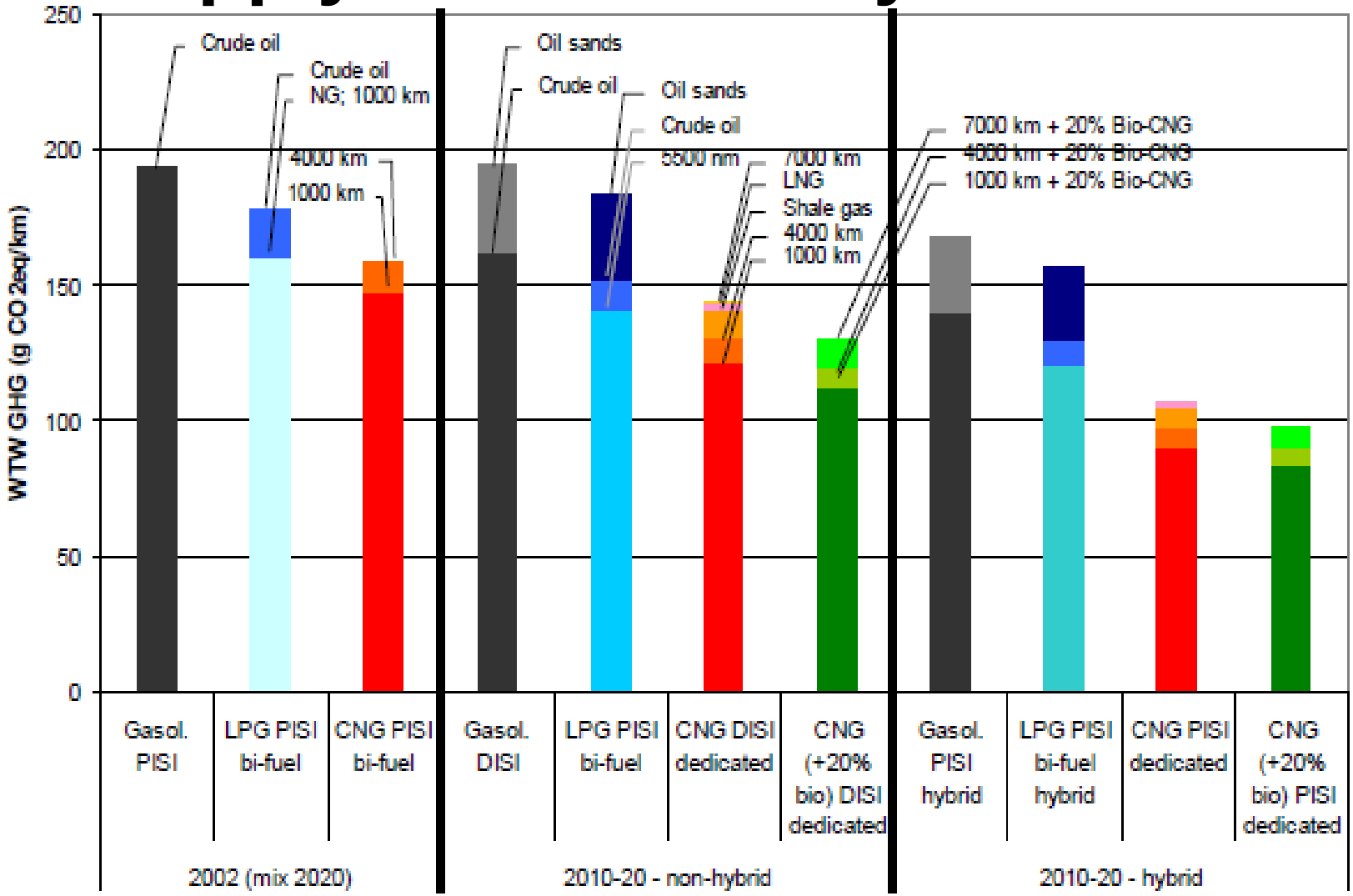
Future: Diesel efficiency in gas engines?

- Medium-term: lots of improvements possible
  - Enhanced engine control
  - New sensors for gas quality detection
  - Increased EGR improves low load performance
  - High energy ignition extends the dilution limit
- High octane fuel → higher compression
  - Higher compression = higher efficiency
  - Best effect with hybridized powertrains
    - High load performance in gas engines already good
    - Decrease in gas cylinder weight possible

The future: The effect of alternative fuel supply chains and hybridization

- Oil sands: The GHG emissions of oil increase significantly
- Shale gas and LNG: relatively small GHG increase
- Unlimited Biomethane blending ↓GHG significantly
- Hybridization in NGV's → relative fuel saving higher than oil

The future: The effect of alternative fuel supply chains and hybridization



Source: P.R. Schmidt 2011, CNG and LPG for Transport in Germany, Ludwig-Bölkow-Systemtechnik (LBST)

Conclusions

- Biogas upgrading: Well established and diversified technology, market is taking off
- Biomethane for NGV's is a small but quickly expanding market within the growing NGV market
- Int'l standardization of biomethane, and also CNG, hopefully by 2015. Non-grid specs possible?
- Euro6 NGV's and beyond: Yet untapped potentials for low cost and fuel efficient propulsion
- Hybridization and biomethane important!