Blue INNOship projekt:
Reduction of methane from LNG in diesel engines

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Innovationsfonden

FORSKNING, TEKNOLOGI & VÆKST I DANMARK

Spørgsmål:

Hvorfor skal vi anvende naturgas?

Hvorfor skal vi bekymre os om methan slip?

Hvad er problemet i motorerne?

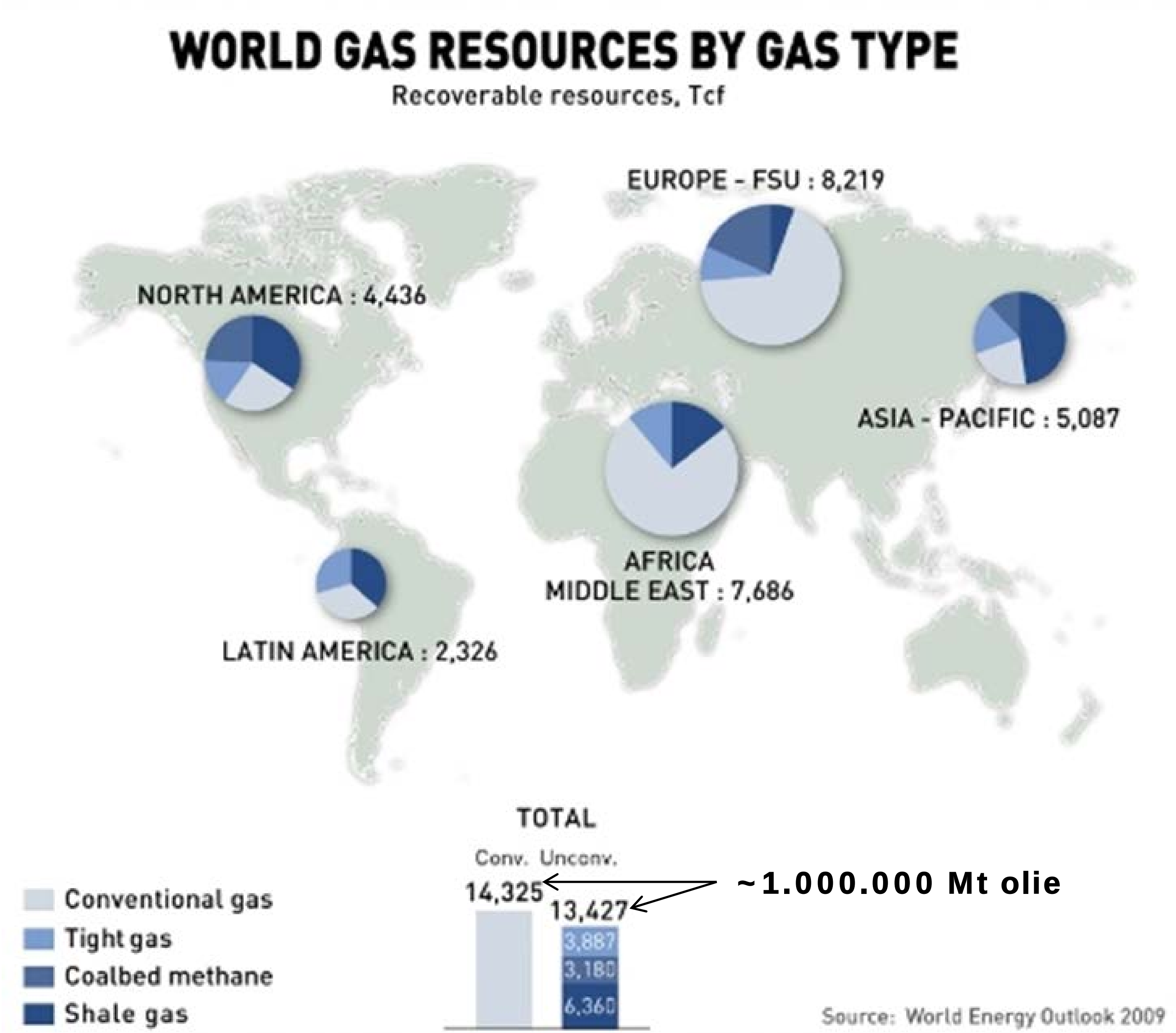
Katalysatoren?

Hvad er løsningen?

Hvorfor skal vi anvende naturgas?

Crude oil reserves: top 5 countries

	Reserves (Mt)		Production (Mt)		R/P
Country	2011	1993	2011	1993	years
Venezuela	40 450	9 842	155	129	> 100
Saudi Arabia	36 500	35 620	526	422	69
Canada	23 598	758	170	91	> 100
Iran	21 359	12 700	222	171	96
Iraq	19 300	13 417	134	29	> 100
Rest of World	82 247	68 339	2 766	2 338	30
World total	**223 454**	**140 676**	**3 973**	**3 179**	**56**

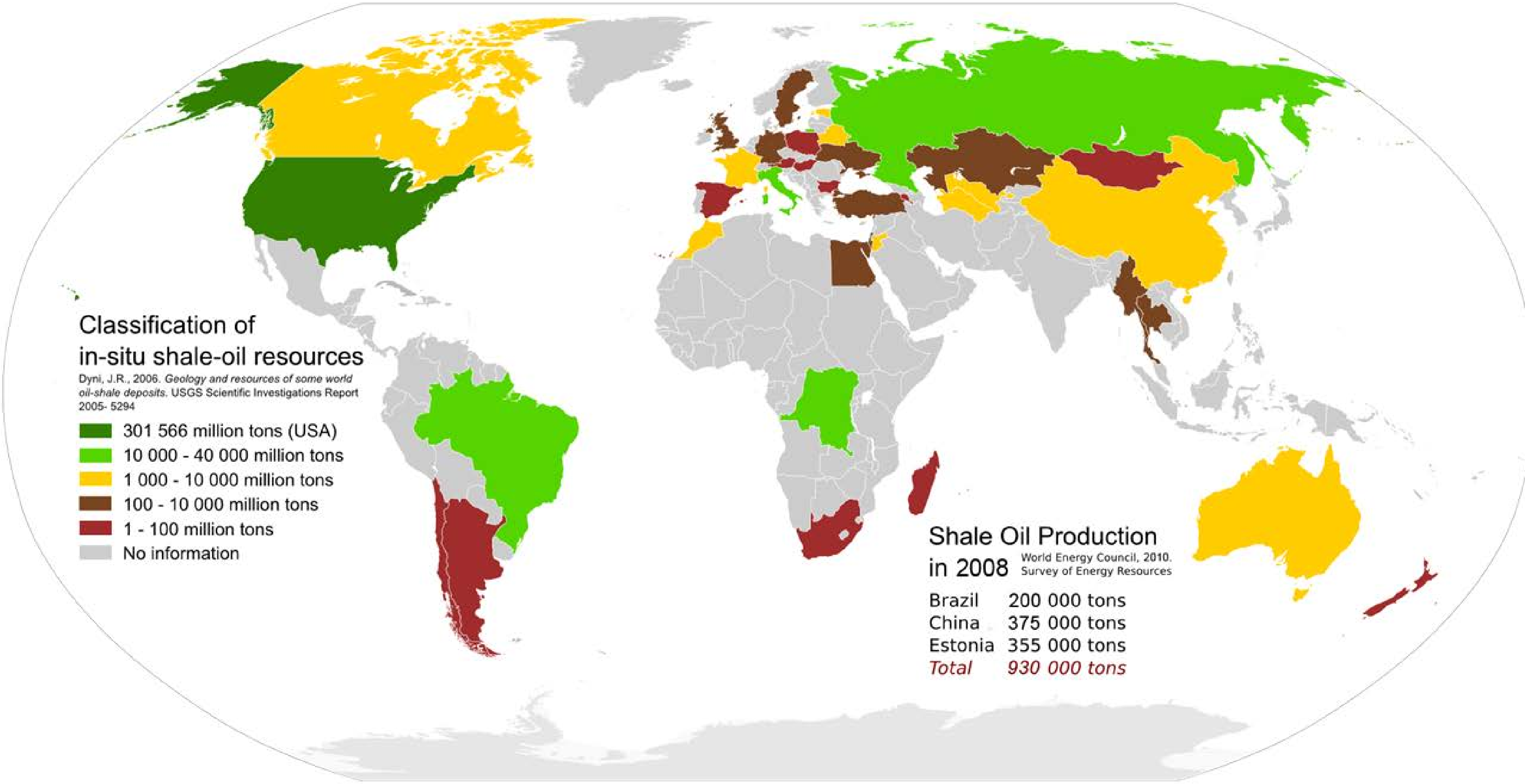


~1.000.000 Mt olie

Skifergas

Cretaceous-Tertiary Shale Gas Play
Jurassic Shale Gas Play
Upper Paleozoic Shale Gas Play
Lower Paleozoic Shale Gas Play

Skiferolie



Classification of
in-situ shale-oil resources
Dyni, J.R., 2006. Geology and resources of some world oil-shale deposits. USGS Scientific Investigations Report 2005- 5294
301 566 million tons (USA)
10 000 - 40 000 million tons
1 000 - 10 000 million tons
100 - 10 000 million tons
1 - 100 million tons
No information
Shale Oil Production
in 2008
World Energy Council, 2010. Survey of Energy Resources
Brazil 200 000 tons
China 375 000 tons
Estonia 355 000 tons
Total 930 000 tons

MARPOL Annex VI Marine SOx Emission Reduction Areas with Fuel Sulfur Limits

European SECAs	Year	Fuel Sulfur (ppm)	Fuel Sulfur (%)
North Sea, English Channel	Current Limits	10,000	1
	2015	1,000	0.1
Baltic Sea	Current Limits	10,000	1
	2015	1,000	0.1
North American ECAs			
United States, Canada	2012	10,000	1
	2015	1,000	0.1
Global	2012	35,000	3.5
	2020*	5,000	.5

* Alternative date is 2025, to be decided by a review in 2018

ECAs – Present and Future

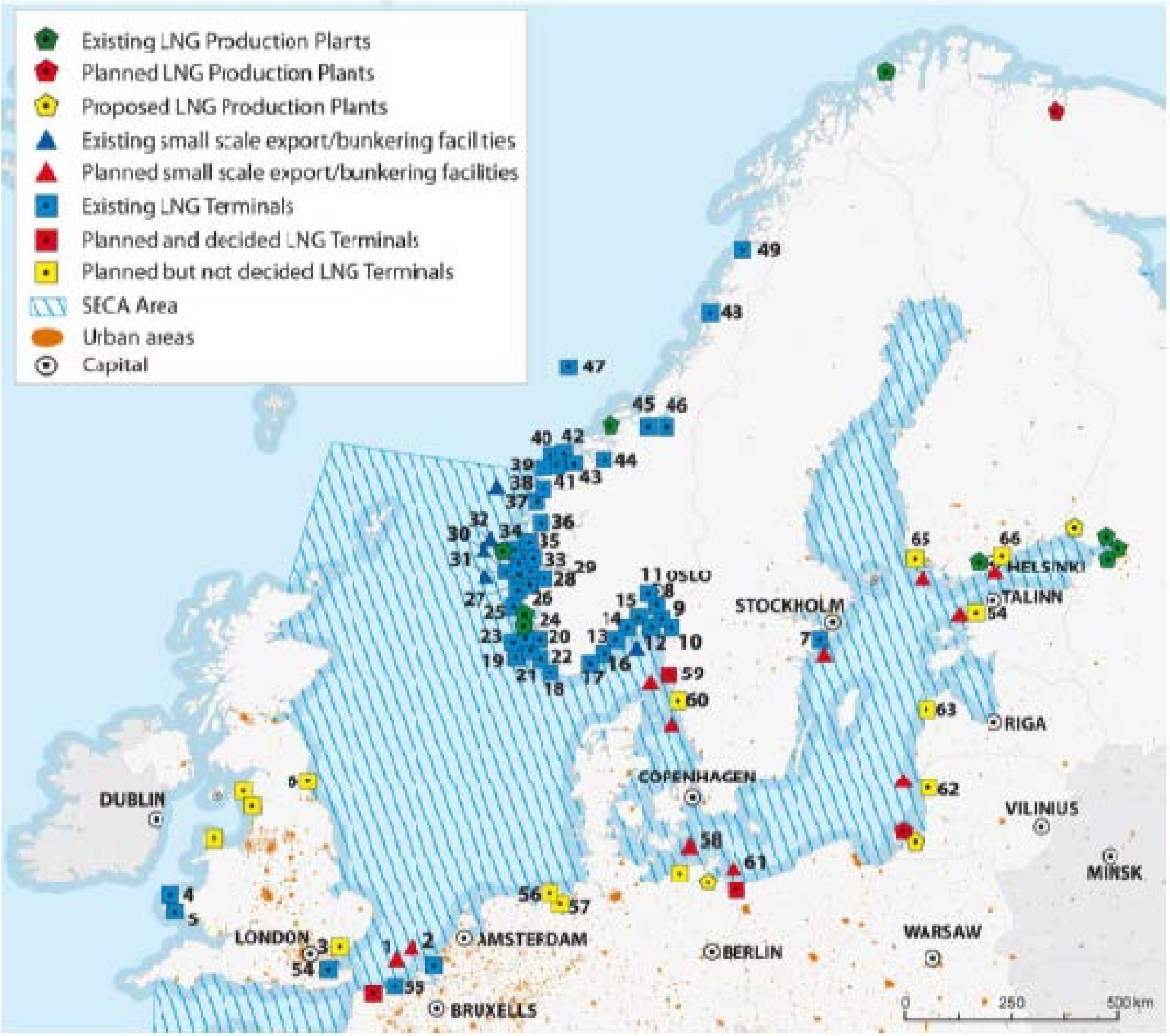
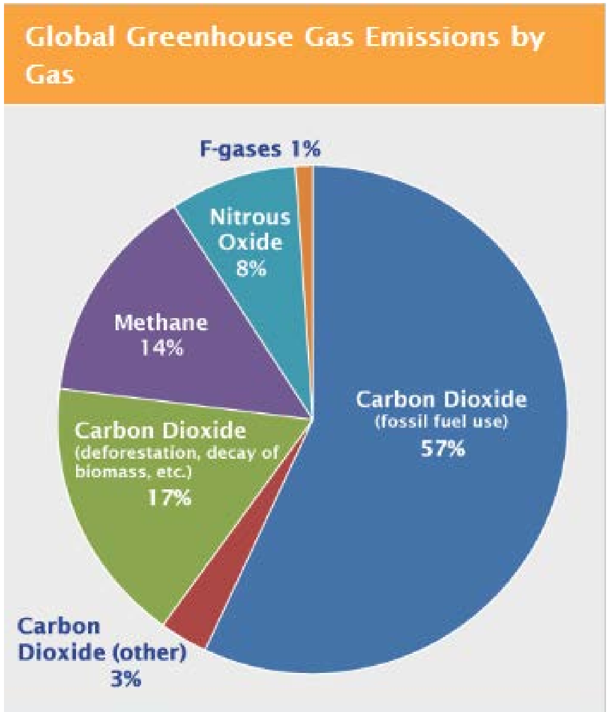
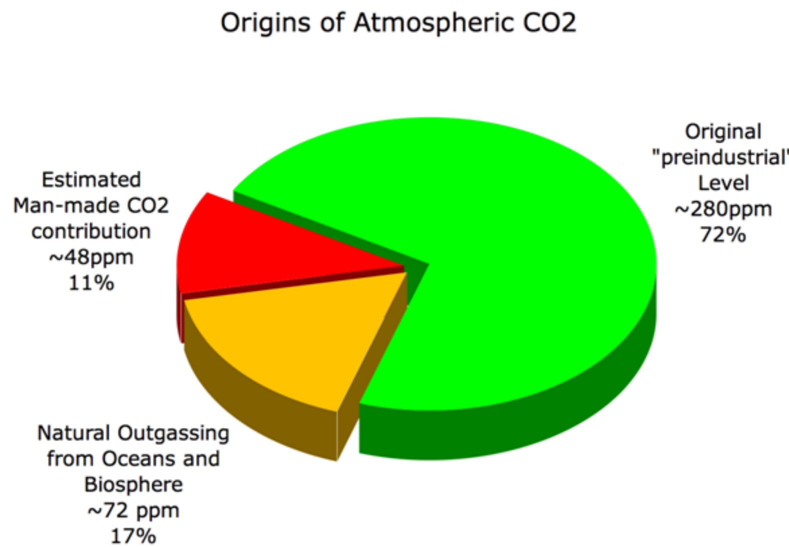
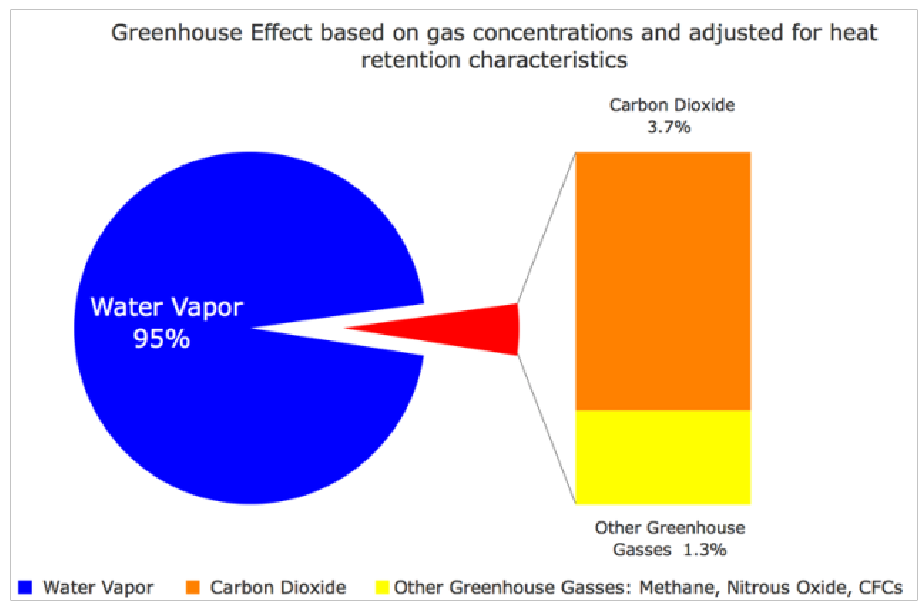


Figure 18. Existing and Planned Production Plants and LNG Terminals in the SECA (Ref. 26)

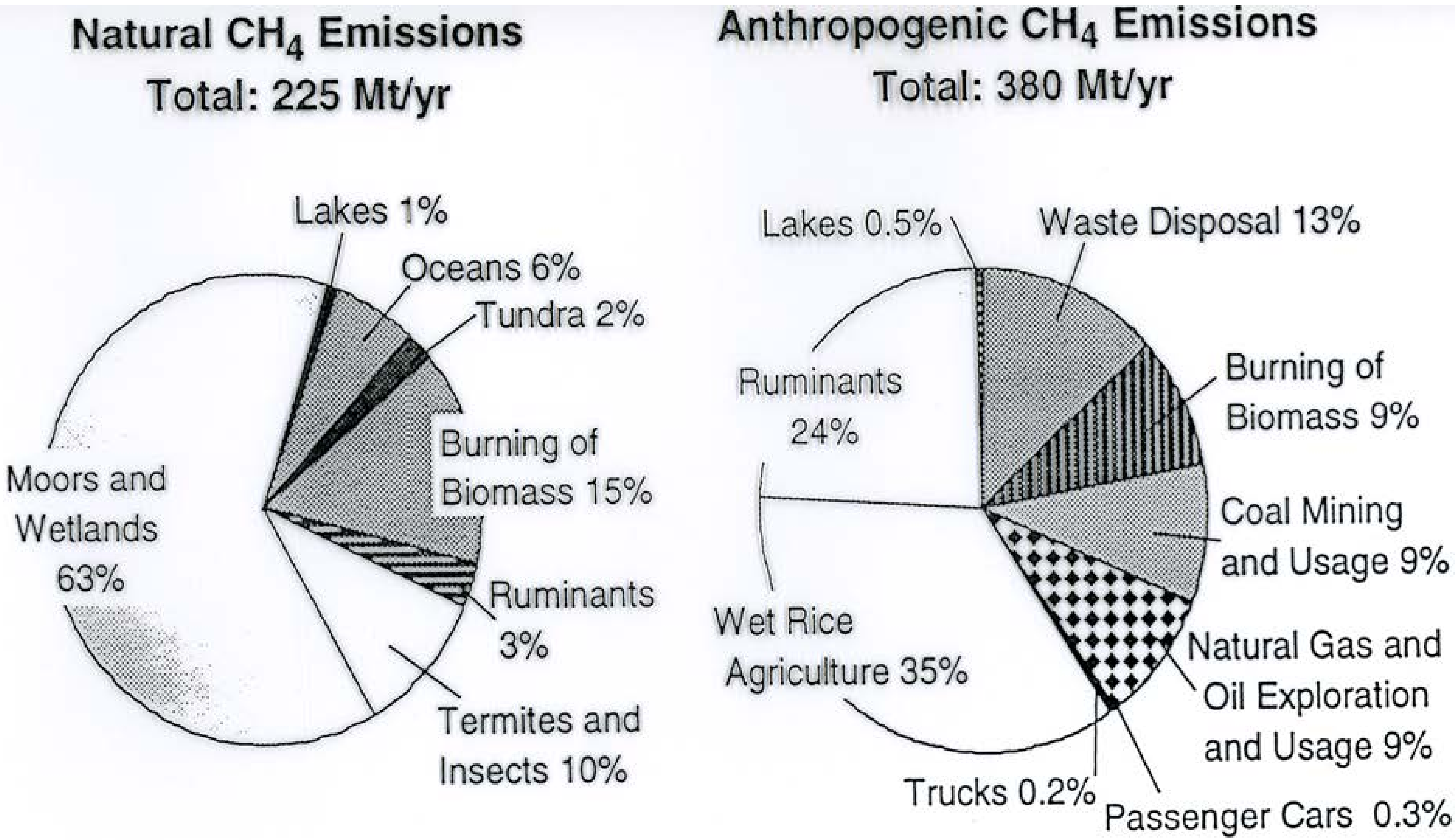
Hvorfor skal vi bekymre os om methan slip?



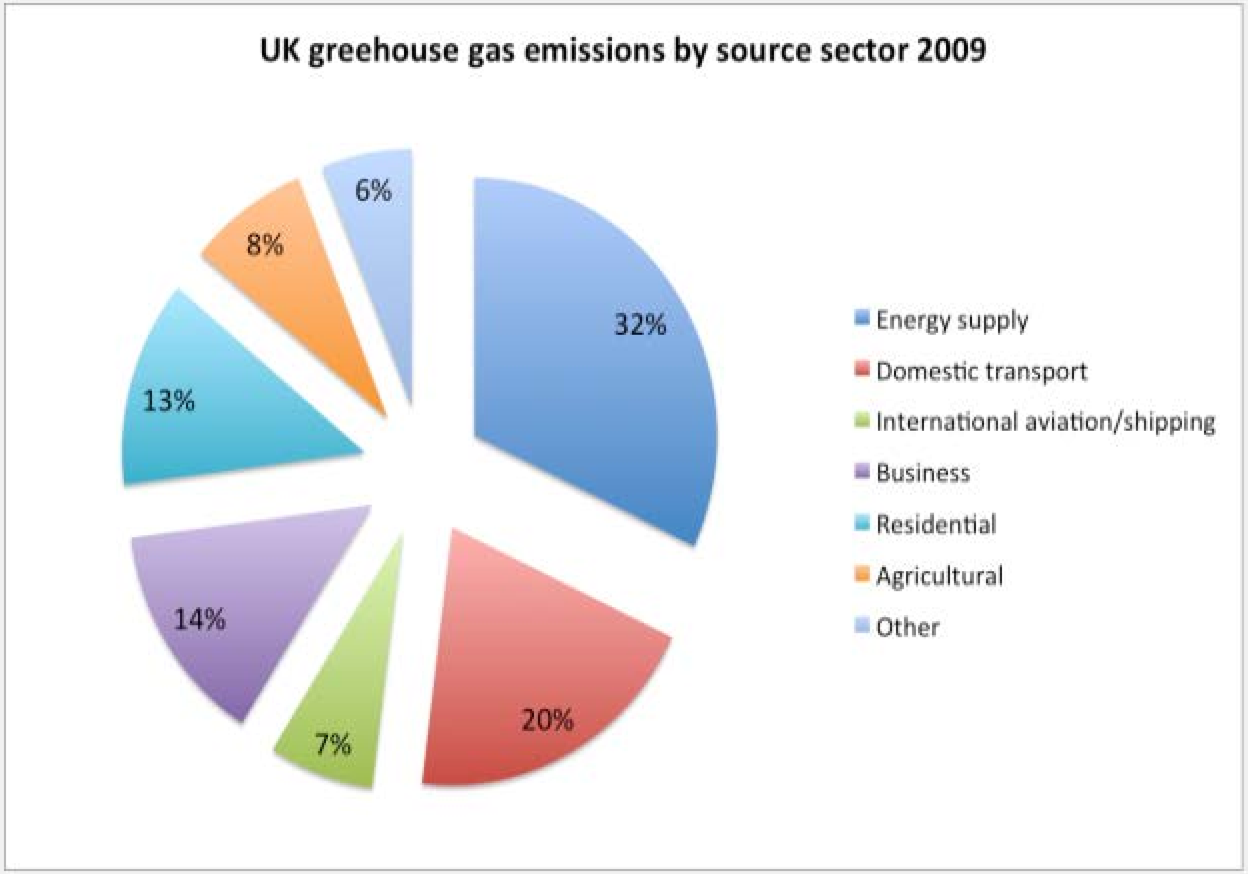




https://digginginthеclay.wordpress.com/2011/02/24/the-futility-of-trying-to-limit-co2-emissions/



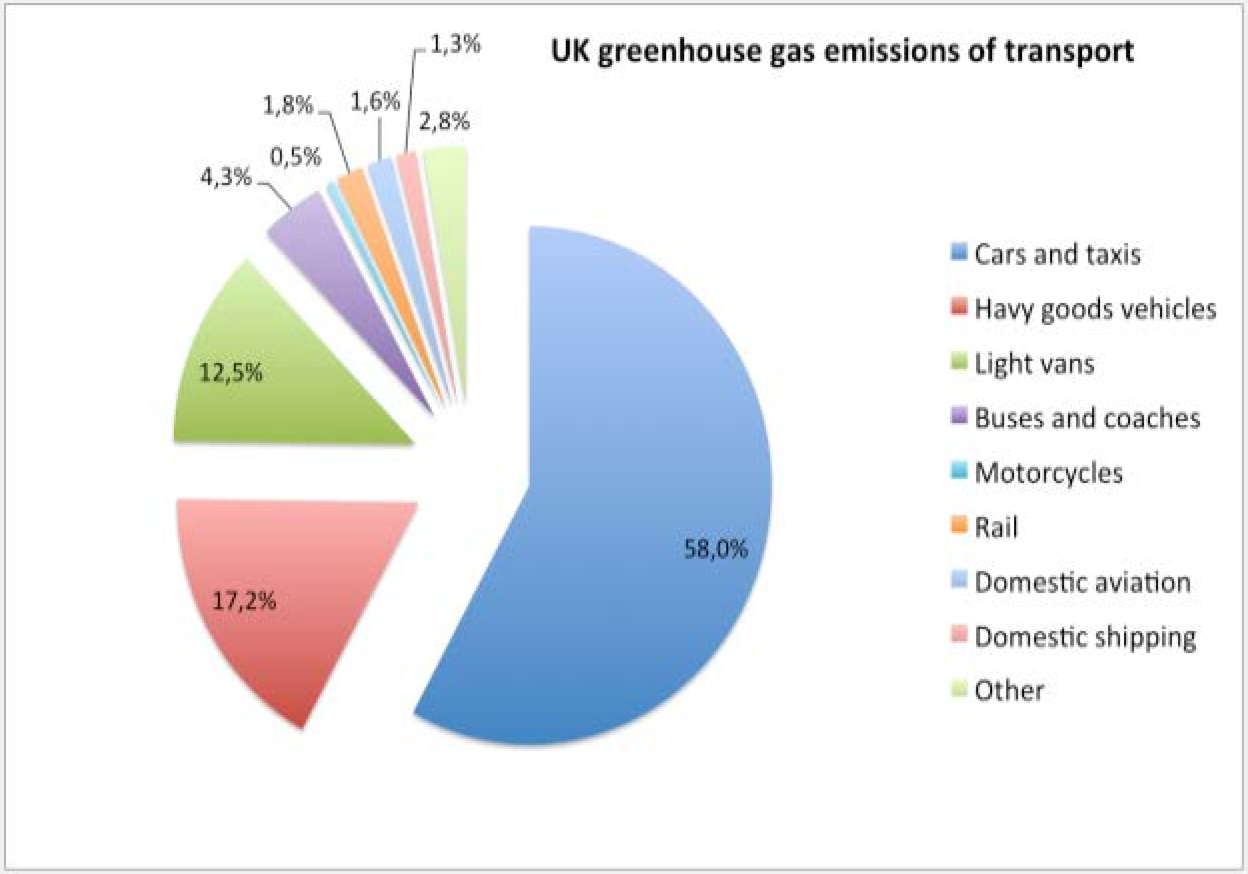
Contribution of various sources to global yearly methane (CH_4) emissions (reference year 1996).



Total UK GHG emissions in 2009 = 607.2 MtCO2e

Other: Public, Industrial processes, Waste management and Land Use and land use change and forestry

Source: National Atmospheric Emissions Inventory (NAEI) [Personal re-elaboration]



Total UK domestic transport GHG emissions in 2009 = 122.2 $MtCO_2e$
Other' is mostly 'military aircraft and shipping', and also includes emissions from 'aircraft support vehicles' and from road vehicles running on liquefied petroleum gas (LPG).
Source: National Atmospheric Emissions Inventory (NAEI) [Personale re-elaboration]

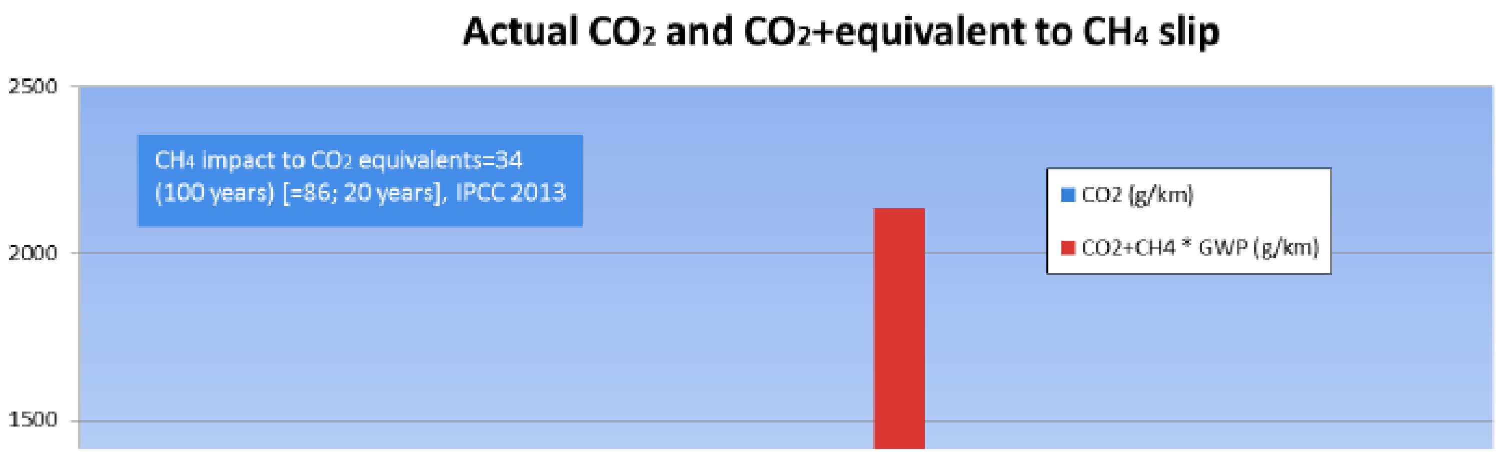
Environmental issues

Wikipedia

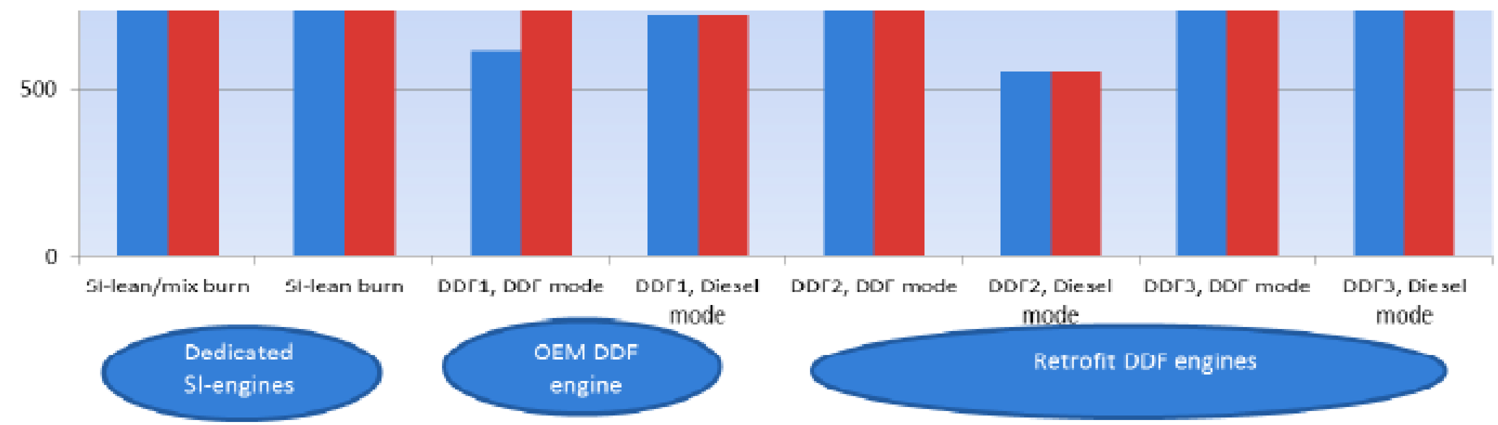
Natural gas does have challenges. For example, there is an issue called methane slip. Methane slip is when gas leaks unburned through the engine. Methane has a GWP100 (100-year global warming potential), which is 25x higher than CO2. If the methane slip isn't controlled, environmental benefits to using natural gas are reduced.

IEA ”Alcohol as a Diesel Engine Fuel ” meeting in Copenhagen, February 2015:

”There might be an even more important market for methanol in marine engines if the methane slip problem of LNG engines is not solved”

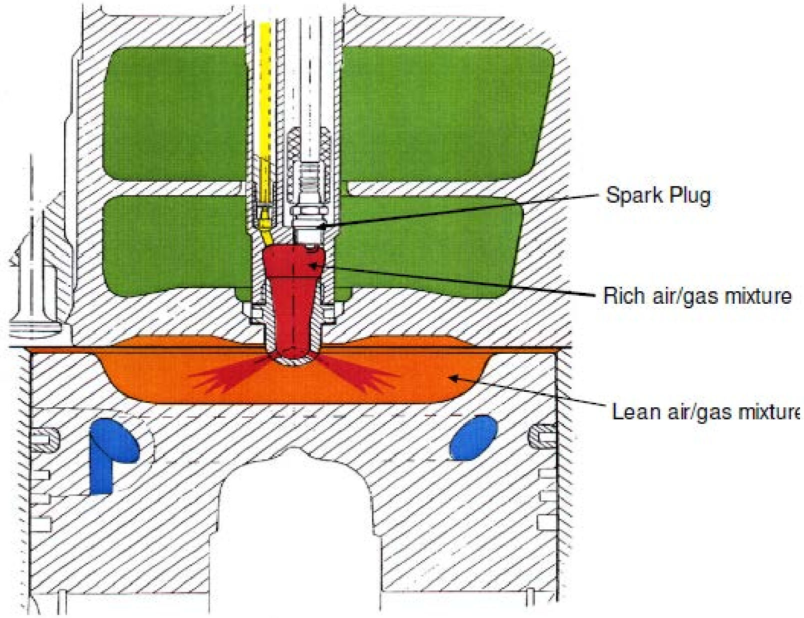


The overall experience from the test program is that emissions of CH_4 will increase when the diesel replacement is increased. In reality, higher rate of diesel replacement with gas will result in higher total greenhouse gas emissions of. This is in fact a serious dilemma for technology of today.

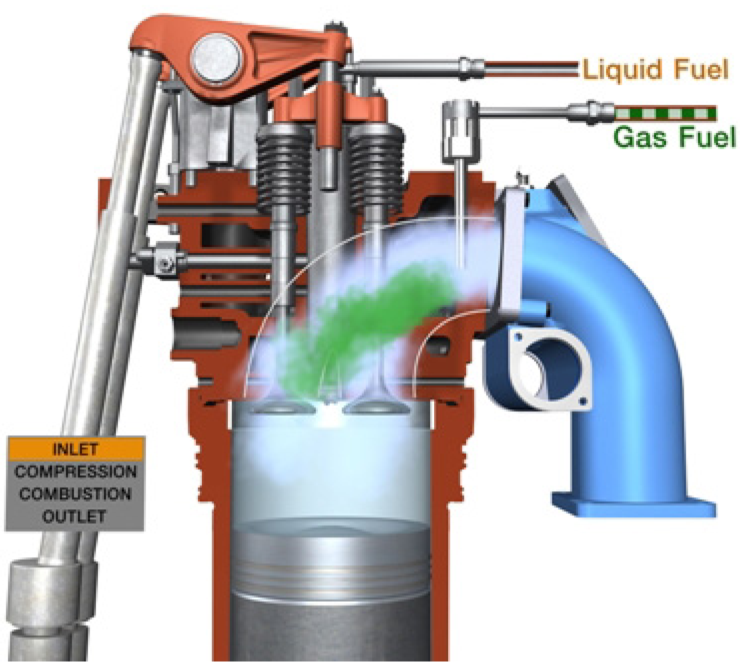


Hvad er problemet i motorerne?

4-stroke:



LEAN-BURN COMBUSTION SYSTEM



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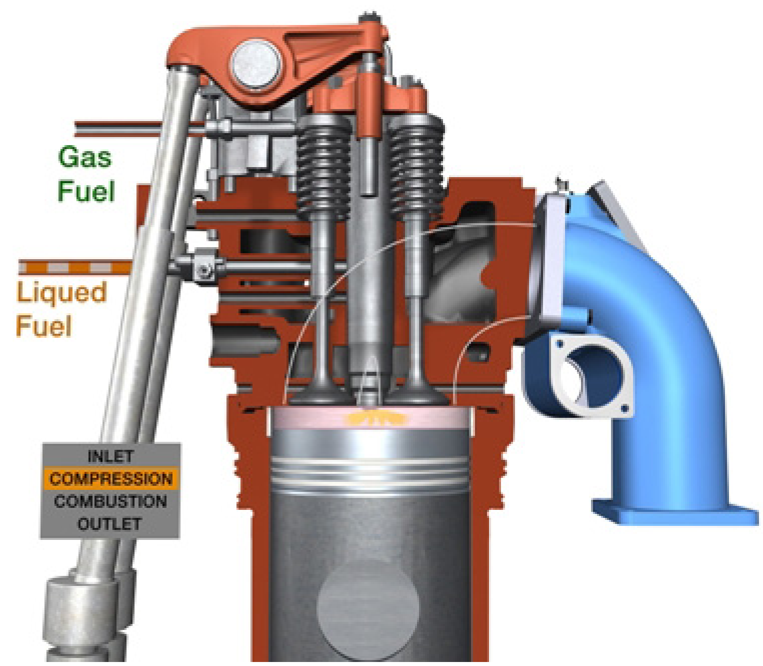
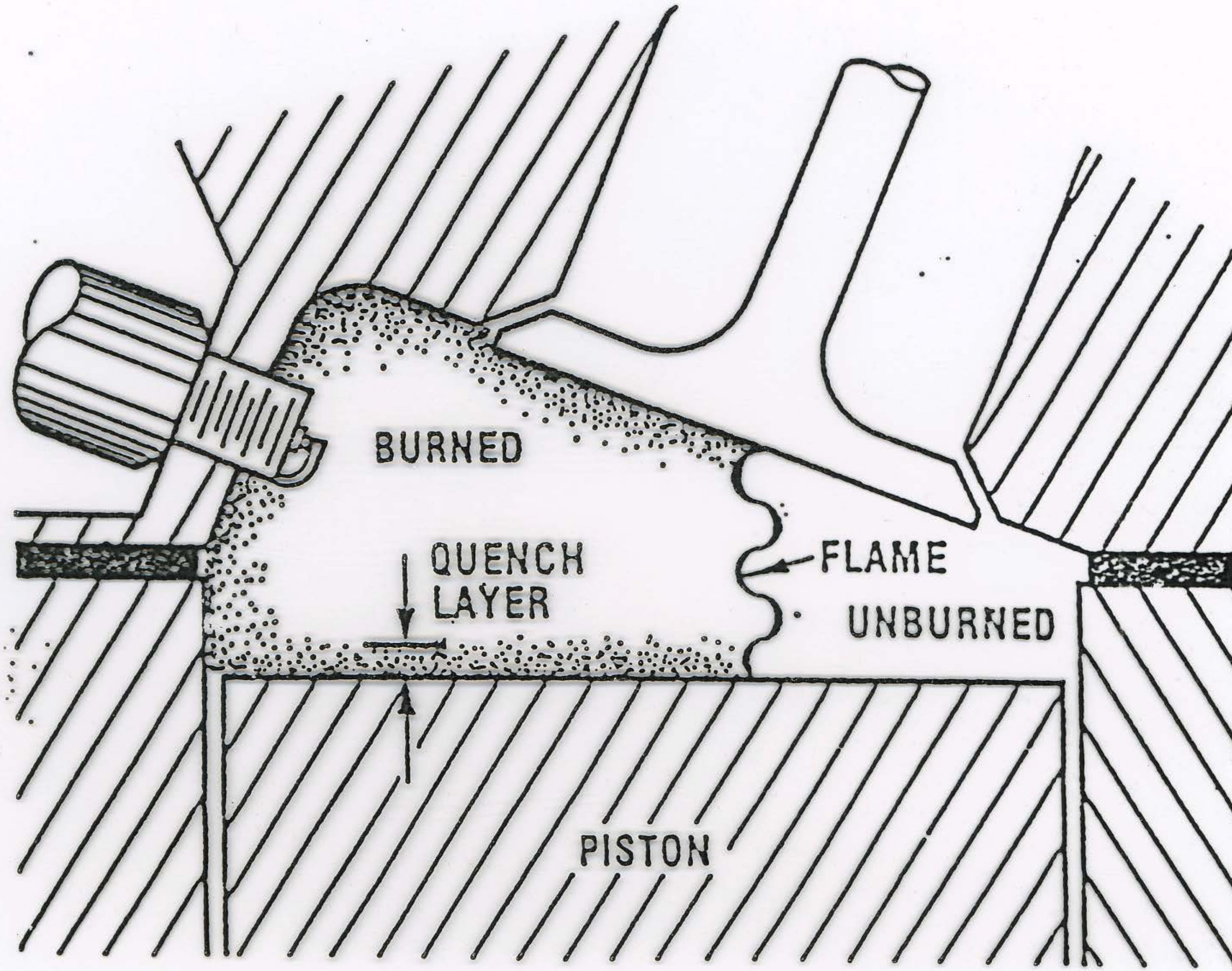
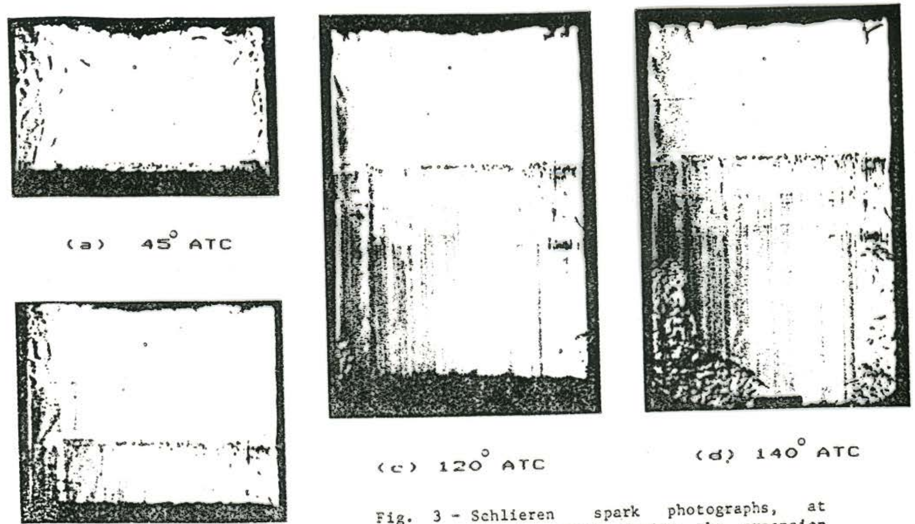
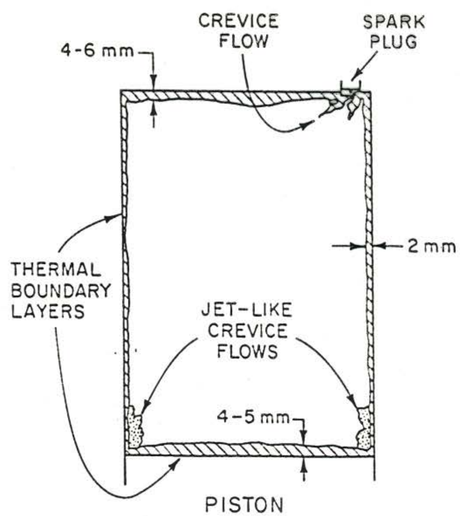



BURNED
QUENCH
LAYER
FLAME
UNBURNED
PISTON



(b) 65° ATC

Fig. 3 - Schlieren spark photographs, at different crank angles during the expansion stroke, which show crevice flow phenomena. See Fig. 4 for a schematic interpretation



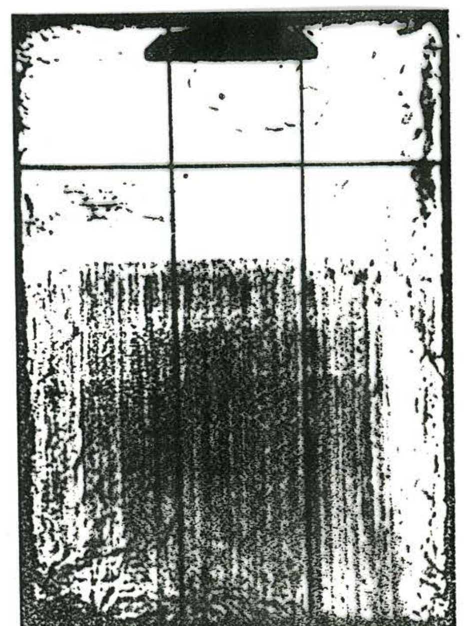
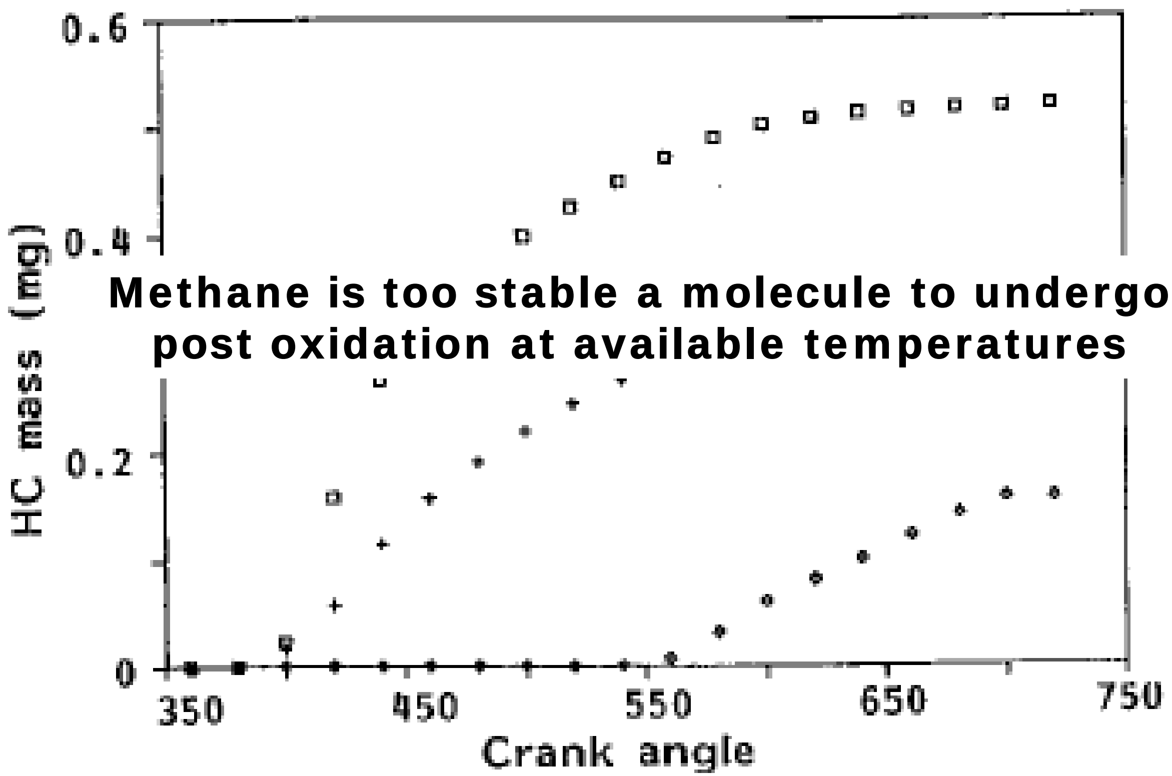


Fig. 4 - Schematic at 120°ATC illustrating the flow out of the spark plug crevice, and the jet flow at the piston crown corners from the crevice regions behind and between the rings. These jets then spread along the walls: See

HC oxidation after flame quench
(SI Engine operating on gasoline)

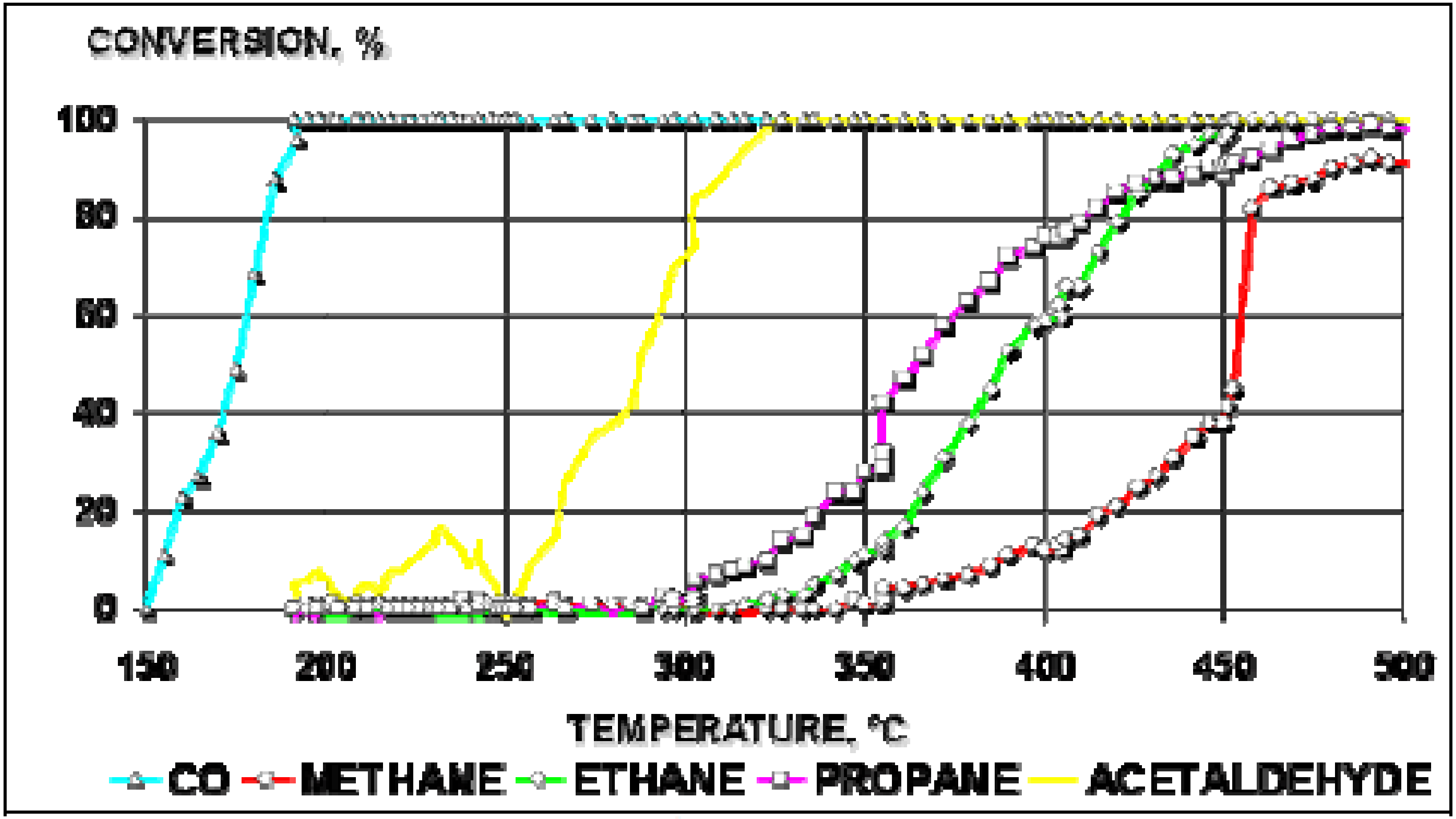


Methane is too stable a molecule to undergo post oxidation at available temperatures

The total desorption from crevices and oil film (□). Left after in-cylinder oxidation (+). Left unburned after exhaust port oxidation (♦).

Katalysatoren?

Hydrocarbons behaves differently



Hvad er løsningen?

Methane Project

DTU Mechanical Engineering
Responsible for engine experiments in laboratory and modelling of physical/chemical processes in engines

DTU Chemical Engineering
Responsible for design of catalyst and modelling of physical/chemical processes

MAN Diesel & Turbo, Holeby
Responsible for the design and experimental work on the MAN L28/32DF engine

Technological Institute, Aarhus
Responsible for measurements on ships in operation

IEA Advanced Motor Fuels IA

Input from other transport sectors

Experimental data on engines

Experimental data on catalysts

Germany, Canada, Sweden, Finland, Japan, Korea and Denmark

Tak for opmærksomheden!