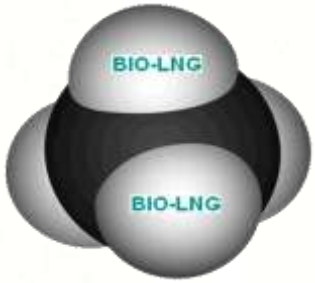
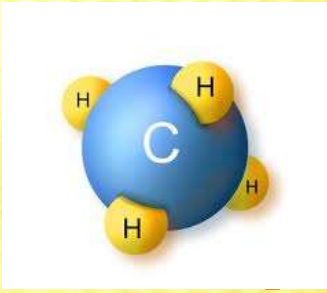


Analysing Challenges of Producing Bio-LNG and building the infra for it

Peter van der Gaag
www.hollandinnovationteam.nl

Content of the presentation

- Introduction :LNG and bio-LNG
- Standard and premium quality: oil companies policy
- Bio-LNG can be used to combat methane slip and improving methane number
- Comparing small scale LNG and bio-LNG with other fuels: advantages and disadvantages
- How much bio-LNG is there? What would be the price? What are the outlooks for small and large LNG and can fit bio-LNG in there?
- Why is blending of bio-LNG not obliged to for fill RED?
- The advantages of bio-LCNG fuelling stations
- Holland Innovation Team and Chive Fuels are setting up the bio-LNG chain : Anglo Dutch liquid methane and current projects
- Conclusions and recommendations



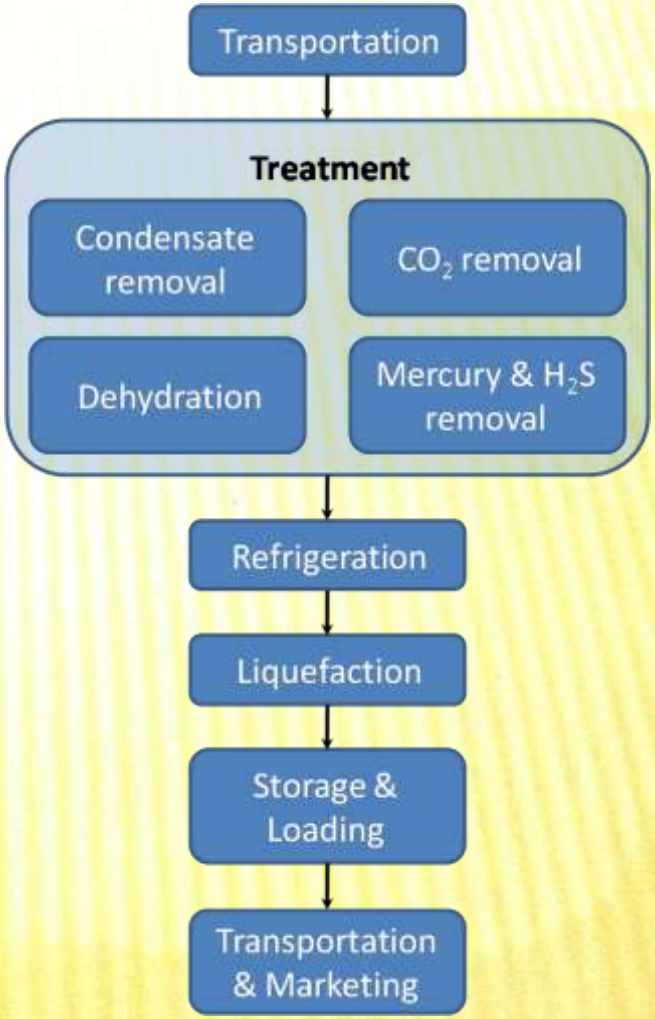
LNG accepted worldwide

LNG, liquid natural gas, consists for the largest part of methane, which is liquid at a temperature of minus 162 degrees Celsius.

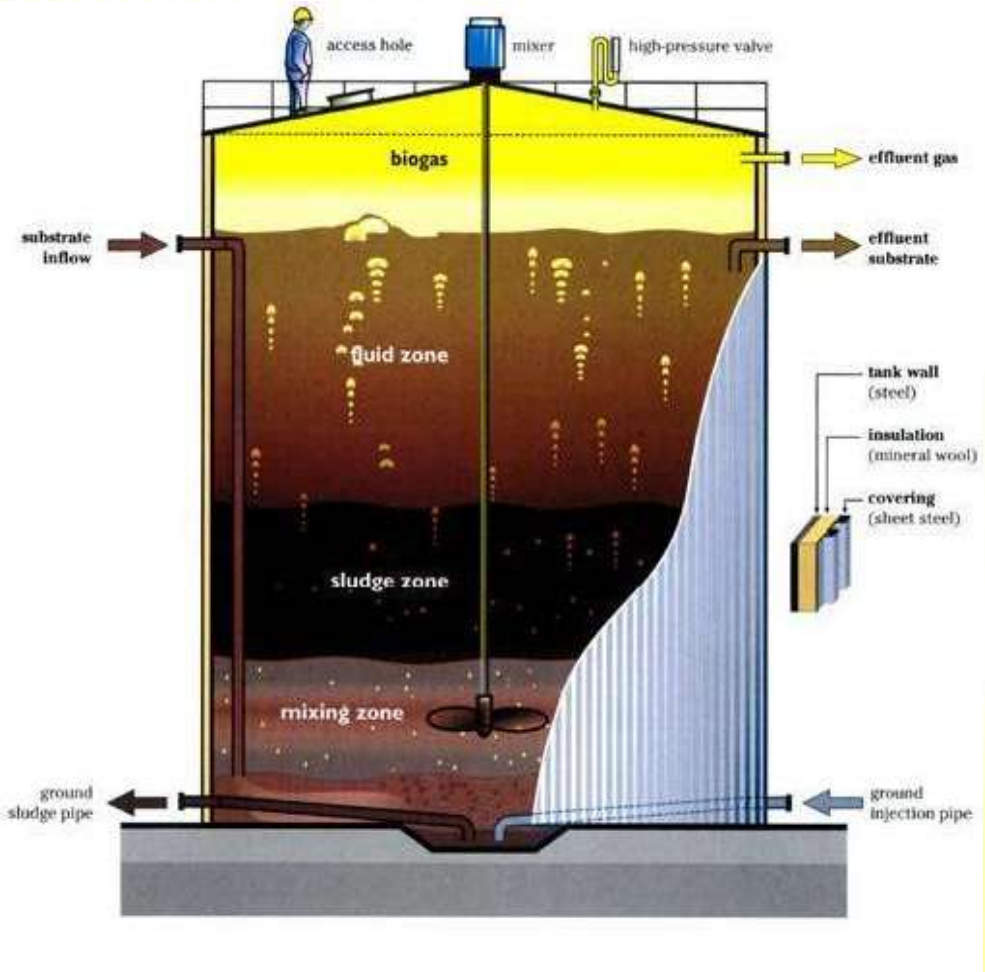
LNG is made from natural gas all over the world. All CO2, H2S, particles, mercury have to be removed. Water freezes out.

Depending on the source, the composition of LNG still varies. Methane content is between 80% and 99.9%.

Essentially we consider two types of LNG:
- Rich LNG contains a relative large quantity of heavy hydrocarbons
- Lean LNG contains few (no) heavy hydrocarbons.



The lesser known Bio-LNG: what is it?



Bio-LNG is produced from biogas. Biogas is produced by anaerobic digestion.

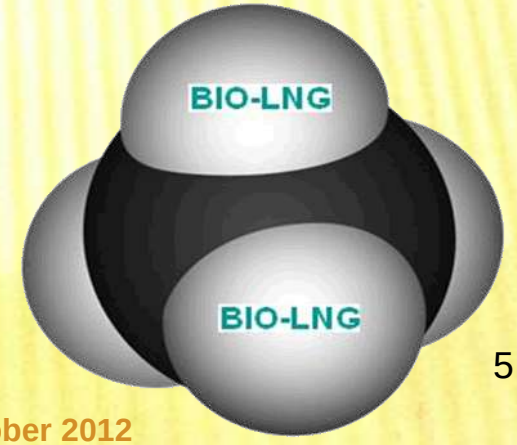
All organic waste can rot and can produce biogas, the bacteria do the work. Therefore biogas is the cheapest and cleanest biofuel without competition with food or land use.

Bio-LNG (LBM) = liquid bio-methane. For the first time there is a biofuel which has always a better quality than its fossil counterpart LNG, so:

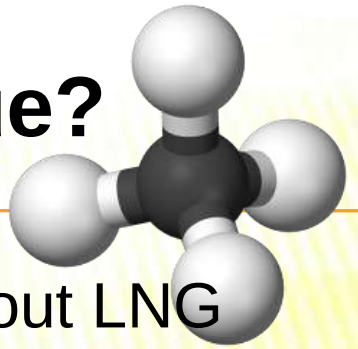
besides fossil LNG there is the premium Bio-LNG

Advantages of bio-LNG versus fossil LNG

- Bio-LNG is of better quality than fossil LNG. This is the first time that a bio fuel is better than its fossil counterpart
- While bio-LNG can be used without blending, it can also be used to improve the quality of fossil LNG
- Bio-LNG can replace 20% of our fossil transportation fuels by 2020 in inland navigation, heavy duty trucks and cold ironing in ports
- Bio-LNG can be used to produce bio-CNG for private cars with minor additional costs (this also combats boil off at the fuelling stations)
- Bio-LNG emits negligible NOx or PM when burnt
- Bio-LNG has a much lower carbon footprint than other fossil fuels or bio fuels: Bio-LNG can even be carbon negative
- Bio-LNG is cheapest bio fuel per energy unit



What about the LNG quality issue?

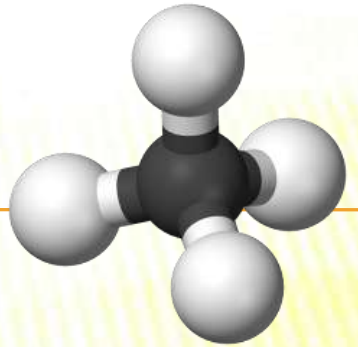


Holland Innovation Team wrote a position paper about LNG quality after consultation of experts and gas engine manufactures. http://tinyurl.com/biolngpp

There are engines which can run on almost anything but this will temper the achievements (especially of next generation high performing gas engines. Many heavy LNG qualities will not be good enough for direct use in engines, so should be improved at the terminal site. Prominent institutions like OEM and IAEA want standardization of LNG quality

Bio-LNG will always full fill minimum demands and will improve LNG quality, so future bio-LNG producers are happy with worldwide LNG developments

We can use the strategy of the majors to promote bio-LNG



Only recently the CEO of Shell Netherlands BV (Mr Dick Benschop):

GTL is a premium fuel according to our standards. Therefore GTL can cost more than normal diesel because it is cleaner and it cost more money to produce!!!!!

SO why not paying more for cleaner bio-LNG from European soil than for fossil LNG from far away with lower quality!

Well to wheel CO2 emissions : After Air-LNG

FUEL COMBUSTION "from-tank-to-wheel"		Diesel/Kero.	Gasoline	LNG	Bio-LNG	bio-diesel	Hy.BTL	FT.BTL	bio-ethanol
Fuel Density	Kg/lt	0,81	0,72	0,45	0,40	0,88	0,78	0,78	0,78
Fuel LHV	MJ/Kg fuel	43,0	44,0	49,00	50,0	37,5	43,2	43,2	27,0
	MJ/lt fuel	34,8	31,7	22,1	21,5	33,0	33,7	33,7	21,1
	Kwh(th)/Kg fuel	11,9	12,2	13,6	13,9	10,4	12,0	12,0	7,5
CO2 Emissions	KgCO2/Kg-fuel	3,18	3,11	2,75	2,75	2,73	3,12	3,12	1,91
	grCO2/MJ	74	71	56	55	73	72	72	71
	grCO2/Kwh(th)	266	254	202	198	262	260	260	255
Engine type	technology	diesel	Otto	diesel DF	diesel DF	diesel	diesel	diesel	Otto
	performance	42%	32%	42%	42%	42%	42%	42%	32%
Fuel Consumpt.	gr Fuel/kwh(mech)	199	256	175	171	229	198	198	417
CO2 Emissions	gr CO2/Kwh(mech)	634	795	481	471	624	619	619	797

FUEL - PREPARATION "from-field-to-tank"			Diesel/Kero.	Gasoline	LNG	bio-LNG	bio-diesel	Hy.BTL	FT.BTL	bio-ethanol
Energy	field extraction	%	3,00%	3,00%	2,50%	7,50%	25,20%	22,07%	6,25%	20,00%
consumption	ship./transports	%	1,50%	1,50%	4,50%	13,50%	19,98%	17,50%	9,38%	15,00%
(% of specific energy	process energy	%	10,00%	10,00%	10,00%	22,00%	15,00%	16,00%	38,00%	30,00%
of fuel)	distribution	%	0,50%	0,50%	1,00%	0,98%	0,51%	0,50%	0,50%	0,75%
TOTAL ENERGY RECOVERY		%	85,0%	85,0%	82,0%	56,0%	39,3%	43,9%	45,9%	34,5%
USED ENERGY	MJ/Kg fuel		6,5	6,6	8,8	22,0	22,8	25,1	23,4	17,8
NET ENERGY	MJ/Kg fuel		36,6	37,4	40,2	28,0	14,7	18,1	19,8	9,2
CO2 emissions for fuel preparation										
energy consumption	KgCO2/Kg-fuel		0,48	0,47	0,50	1,21	1,66	1,81	1,69	1,26
chemical process	KgCO2/Kg-fuel		0,00	0,00	0,00	2,75	0,00	0,55	3,14	0,96
combustion process	KgCO2/Kg-fuel		3,18	3,11	2,75	2,75	2,73	3,12	3,12	1,91

TOTAL PREPARATION+COMBUSTION "from-field-to-wheel"		Diesel/Kero.	Gasoline	LNG	bio-LNG	bio-diesel	Hy.BTL	FT.BTL	bio-ethanol
CO2 Emissions	KgCO2/Kg-fuel	3,66	3,58	3,25	6,71	4,39	5,48	7,95	4,13
CO2 Emissions	grCO2/NET-kwh(mech)	858	1.076	692	2.056	2.552	2.593	5.438	5.021

CO2 CAPTURE & RECYCLE /STORE "from-air-to-field"		Diesel/Kero.	Gasoline	LNG	bio-LNG	bio-diesel	Hy.BTL	FT.BTL	bio-ethanol
Energy Crop	type				any crop	rapeseed	rapeseed	dry crop	wheat
specific acreage	m2/kg fuel	-	-	-	2,9	10,0	8,8	3,1	5,0
	m2/kwh(mech)	-	-	-	0,5	2,3	2,0	0,6	2,1
CO2 capture ability	gr CO2/m2 of crop	-	-	-	4.200	1.000	876	4.200	2.000
CO2 capture ability	gr CO2/kwh (mech)	-	-	-	2.057	2.286	1.753	2.604	4.167
					0%	-10%	-32%	-24%	-17%

CO2 LIFE CYCLE BALANCE	Diesel/Kero.	Gasoline	LNG	Bio-LNG	bio-diesel	Hy.BTL	FT.BTL	bio-ethanol
CO2 NET BALANCE grCO2/kwh(mech)	858	1.076	692	-1	266	839	834	854

The issue of Methane slip: LNG/bio-LNG

If gas is burnt in gas engines some of the methane is emitted unburnt. Research shows that methane slip is higher for dual fuel engines than for lean burning gas engines, especially for retrofit (refurbishing).

Modern four stroke gas engines can emit 4-8 gr of CH4 per KWh or 5,5-11% (Tanker shipping and trade April/May 2012)

Methane slip gives sceptism an argument to decrease the benefits of use of LNG. But what about bio-LNG made from waste? Bio-LNG is made from methane slip!!!!!

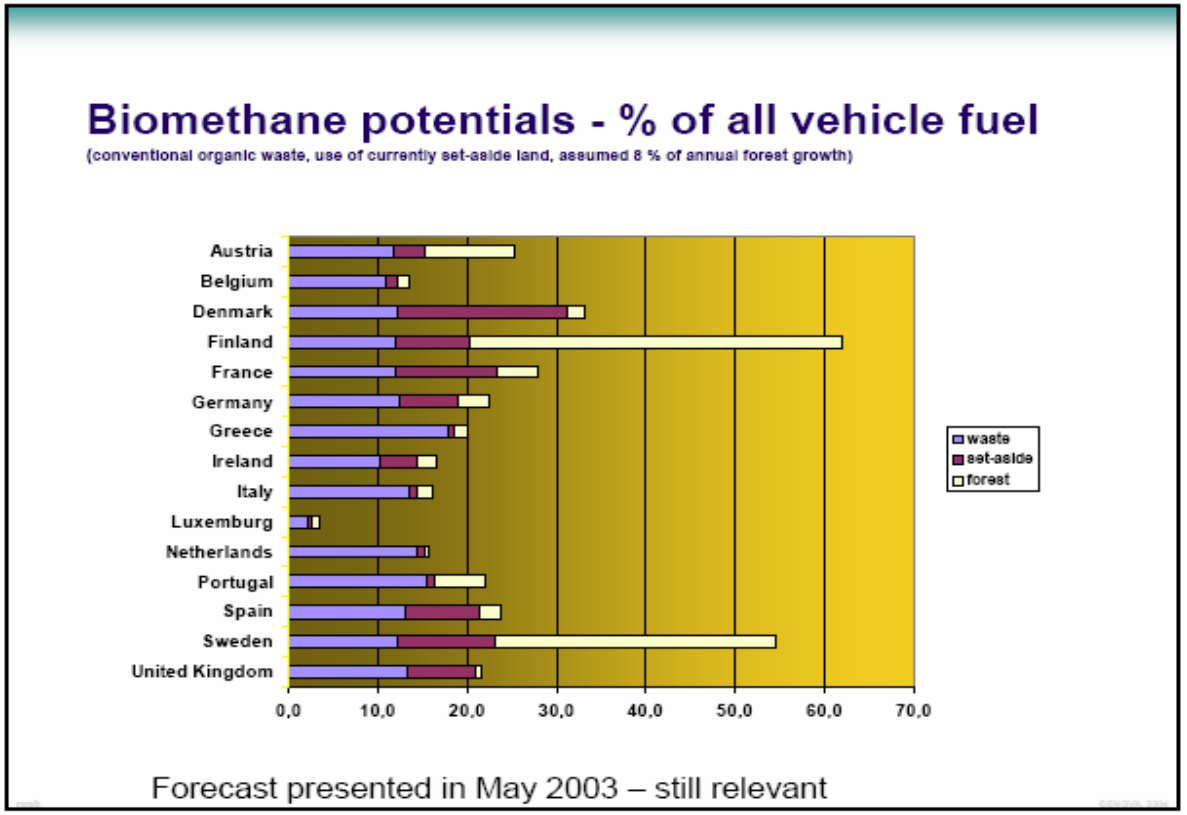
Bio-LNG is made of methane slip, so

On the 5th of June 2012 : Holland Innovation Team advised at the bio-energy conference of the EU in Brussels to support bio-LNG and to use - according to RED - the same obligation for LNG (blending with bio-LNG) as for diesel and gasoline

Why not the obligation to blend LNG with bio-LNG in the same way as biodiesel in diesel and bioethanol in gasoline, it is highly recommended to do so, because:

Bio-LNG improves quality of LNG, is not made of food, has the best CO2 reduction, no NOx/PM and avoids methane slip!

How much bio-LNG can be made? Enough!



Source:http://ecocomplex.rutgers.edu/PeterBoisen.pdf

Dutch government agency forecasts that 3 billion cbm of so-called ‘green gas’ can be produced from anaerobic digestion (NL) and gassification of biomass i.e. equivalent >>> 1 million ton of bio-LNG.

Landfills in Europe, huge potential

There are many tens of thousands of landfills in Europe
Estimates say about 150.000 in European countries

If these landfills produce 500 Nm3 biogas/hour for 5 years:
then we can produce 3 trillion NM3 of biogas or
3 * 1 million * 1 million in the next 5 years!!!

So let us improve liquid biofuel production from landfills.

Generating electricity without use of heat is a waste,

So develop cheap upgrading and liquefaction installations (containerized)
:

The infra : advantages of (bio) LCNG stations

We think bio-CNG is not an option for inland navigation and heavy duty trucks.
Bio-LNG can used to serve both private cars and heavy transportation.

Advantages: LCNG stations are cheaper to operate, bio-CNG from bio-LNG can set the standard for biomethane in Europe, because bio-CNG from bio-LNG always>98%CH4. So called Groen Gas in the Netherlands has almost a quarter of inert gasses by weight which is expensive to compress and limits driving distances drastically!!!

You can put LCNG refuelling stations everywhere without being limited to gas grid connections

We see a great future for bio-LNG

Using bio-LNG for bringing heavy LNG into necessary specs – small scale (bio) LNG carriers to LNG terminals?

Using bio-LNG for implementation of the EU directive for biofuels (5% now – 10% in 2020)

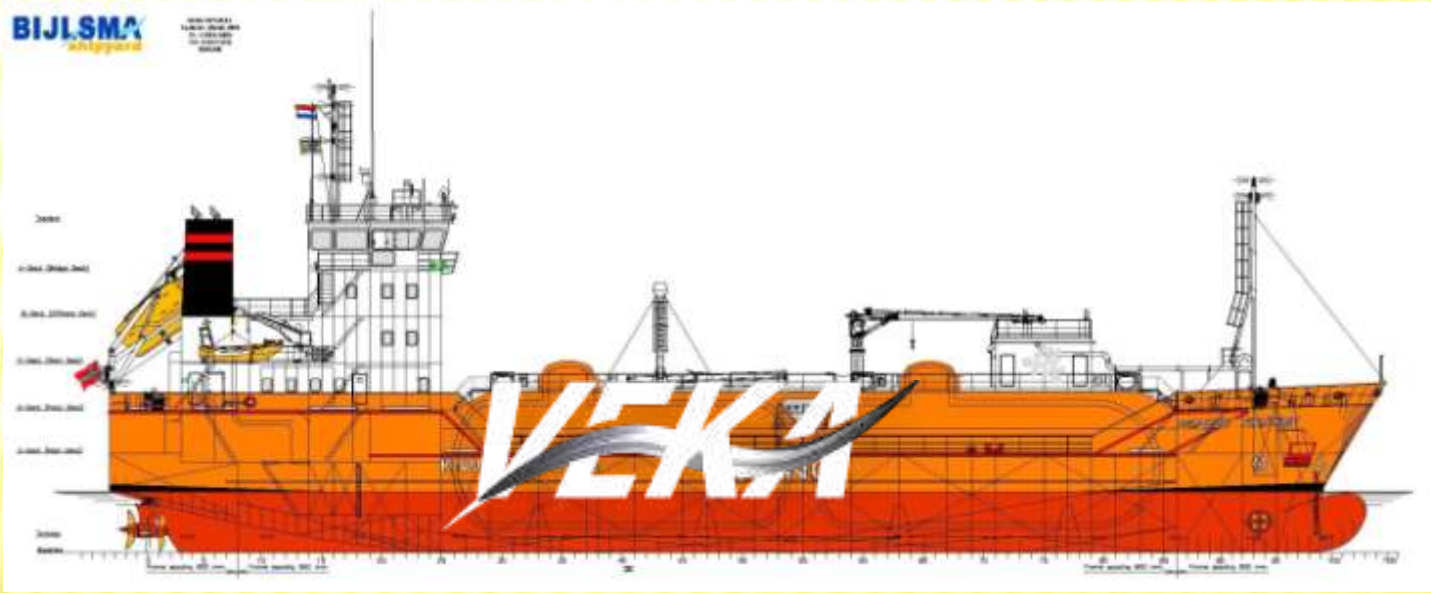
Using bio-LNG as a premium fuel, which means enormous publicity for companies which will produce bio-LNG from their own waste and drive on bio-LNG.

That is way we are starting the bio-LNG chain with partners and founded Anglo Dutch Liquid Methane with Chive Fuels:

projects are:

Inland and short sea shipping becomes "green" by Bio-LNG

Holland Innovation Team wants to build a bunkering bio-LNG terminal in Zwijndrecht together with Nobel close to Rotterdam. "The bio-LNG must be transported to this to other terminals and distribution centers," Van der Gaag. "We are creating a whole chain. This vessel is indispensable. A bio-LNG plant would produce between 40-150 tons of bio-LNG daily. Distribution can be done by bio-LNG tankers of 1100-4000 cbm." **E-Energy Market** by Erik Groen



Development of bunkering and distribution vessels

Sponsored by EU

For transporting fossil LNG from small scale plants and for transport of bio-lng to bunkering stations and large terminals for improving LNG quality, there will be a new market for (bio) LNG bunkering vessels and carriers – for bio-LNG to 4000cbm and for small scale LNG to? .

Global Biomethane Congress Brussels 10th of October 2012

We need (bio-)LNG bunkerterminals

Bunkerworld News - Latest News -

A. Nobel & Zn Bunkerservice

22 November 2011 -
'First movers' integral in LNG **bunkering** future **...** part of trials to acquire permit for construction of **bio-LNG bunkering** terminal
A grant of the ministry of infrastructure and environment was awarded in November – the ministry gave additional scores to bio-LNG bunkering above LNG bunkering
See movie of test bunkering at youtube:
http://tinyurl.com/testbunker

(Bio)LNG bunker terminal

Initial bunkering from tank trucks

A. Nobel & Zn Bunkerservice

Then starting with 500 m3 LNG storage tank, later expanded to 2000 m3 (modular layout)

The bunkering station is already heated and cooled by water of Oude Maas river (heat exchanger)

Boil-off of bio-LNG will generate electricity, creating the first bunkering terminal of the post-fossil fuels era

Permits application are submitted this month.

A new LNG container vessel: Rotterdam - Duisburg

A grant for development of this first inland navigation container vessel on LNG - Stevas shipping and VEKA has been awarded by a fund of the Port of Rotterdam (September 2012)

Why not use bio-LNG for cold ironing?

Because a large number of power stations are coal-fired, running ships on shore electricity when alongside could result in greater levels of atmospheric pollution than the traditional practice of using ship fuel. Furthermore, installing the necessary berthside connection points in EU ports could cost EUR 675 million in aggregate and, thereafter, EUR 50 million a year to maintain. https://www.bimco.org/en/News/2009/11/11_Feature_Week_46.aspx

Holland Innovation Team is preparing a bio-LNG cold ironing test , investments costs are considerably lower – next to that: Bio-LNG is renewable!

Fuelling stations in the Netherlands

fryslân fernijt

First (bio)LNG fuelling station of **Anglo Dutch Liquid Methane to** be placed in Heerenveen, more to come Using Chive Fuels' proven design and logistics

Building the chain: SS (bio-)LNG production

Regional bio-LNG production is also the goal in the aforementioned Fryslan project.
Partner: waste disposal company Omrin

Feasibility study for conversion of Dutch biogas plants (now struggling to produce electricity) to supply bio-LNG for use as fuel in agriculture and construction industry

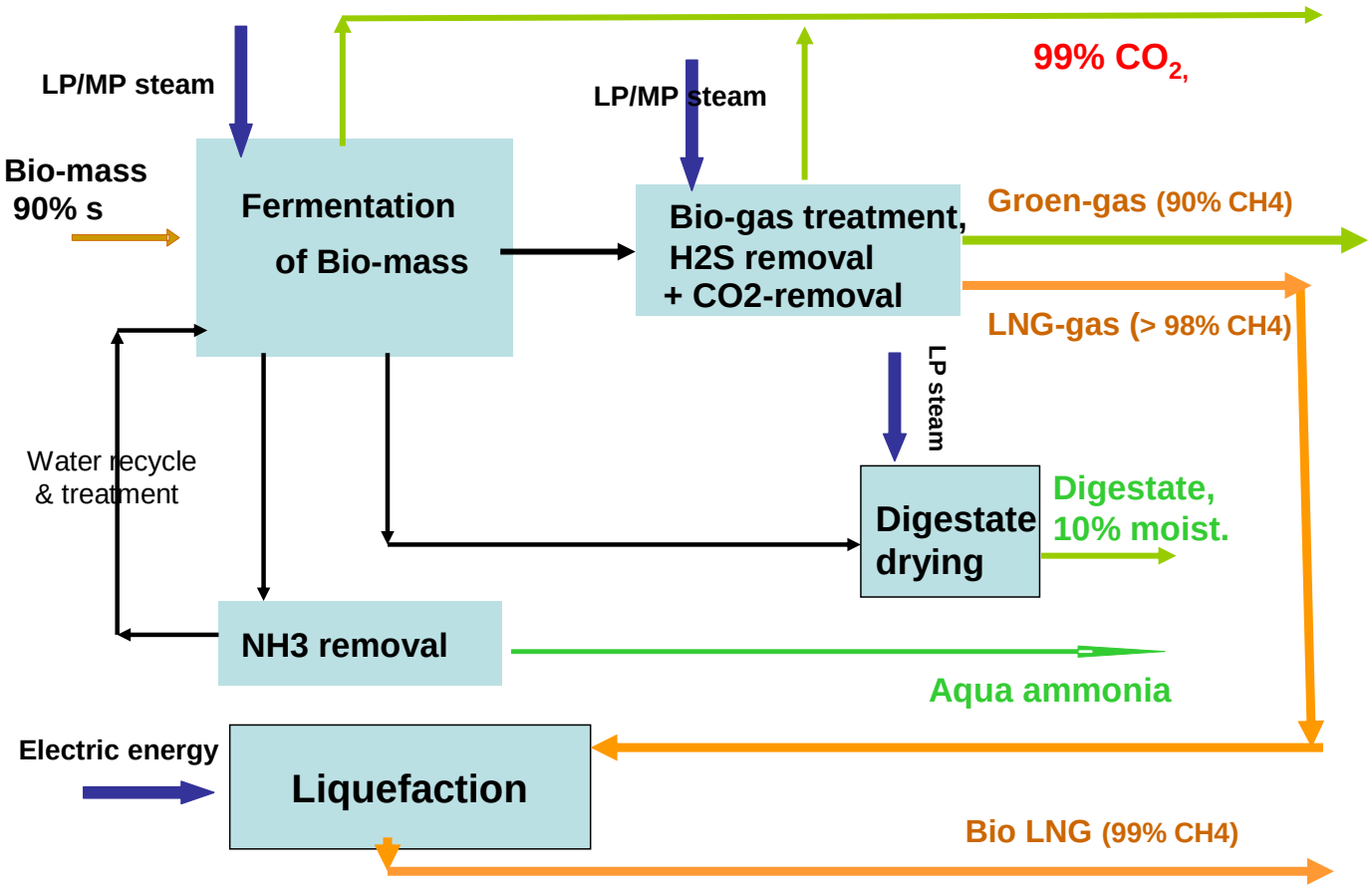
Partner: Prima Energy / SHV Energy
(a leading propane supplier in 25 countries)

fryslân fernijt

Bio-LNG example of a 100 t/day plant

Production of bio-gas, upgrading and liquefaction to LNG

Cambi fermentation unit, Cirmac upgrading, Cryonorm liquefaction)



Price of bio-LNG from a 100 tons per day plant would be less than 900 Euro per ton
But with 4 times biotickets it is cheaper than fossil LNG!

Conclusions and recommendations

Though some engines can cope with almost any quality, LNG with high methane number has more energy per ton and has higher efficiency in modern gas engines than heavy LNG

Oil and gas companies always are keen upon superior quality of fuel, so following their strategy:we will sell premium quality bio-LNG

Bio-LNG is the best example of a premium fuel which is renewable and made from our own waste. Bio-LNG can be used to upgrade quality of fossil LNG in Europe

Bio-LNG can deliver premium quality bio-CNG via L-CNG refuelling stations **2 in one!!!!**

It is advised by Holland Innovation Team to make blending of Bio-LNG in LNG in Europe obligatory (RED). With bio-LNG 10% biofuels will be easy without competition with food/landuse.

So keep thinking out of the box!

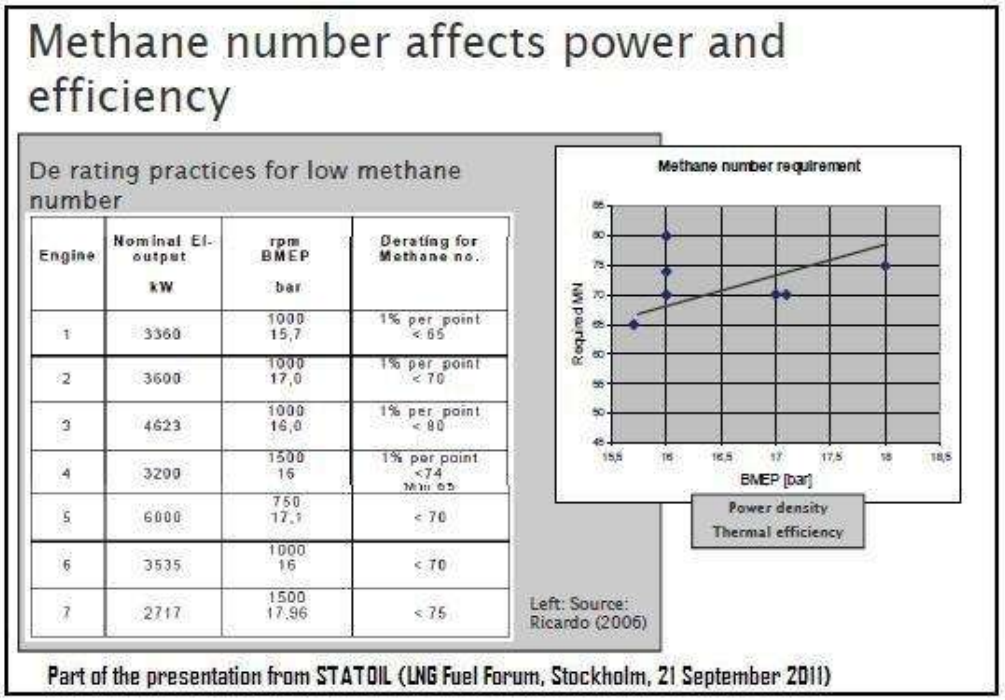
And we see a great future for bio-LNG

Thank you for your attention

Peter van der Gaag Holland Innovation Team

www.hollandinnovationteam.nl
www.bio-lng.info

Why we use the methane number for engines - opinions which matter



Euromot, 5 December 2011, advises minimum methane number of 80 for gas engines

For dual fuel engines:Ideally, the LNG will have a MN >90 and will have a low percentage of heavier hydrocarbons such as ethane, propane and butane."

http://www.cleanairpower.com

Volvo Netherlands advises MN of 90 (CARB) for their dual fuel vehicles Pers COM April 2012,

"Lower methane number increases NOx emission and methane slip for lean burning gas engines": Feist, M., Landau, M., and Harte, E., The Effect of Fuel Composition on Performance and Emissions of a Variety of Natural Gas Engines, SAE Int. J. Fuels Lubr.

But there is more BIO-LNG is premium :

Boil-off at LNG storage changes composition, Bio-LNG not

Storage of 50.000 liters LNG with 8 % C2/C3.

Boil-off 0,1% /day, storage empty after 10 days.
250 liters of methane lost.

Boil-off 0,1%/day, after 10 days, storage half empty. 375 liters of methane lost. Composition of remaining LNG increased in C2/C3