(Green) gas: an opportunity for the future

Lecture COGEN
August 2023

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Competence center for all aspect upstream and downstream from infeed to client

Gas.be	Cerga	NGVA	Labo
Green gas	New appliances	Green mobility	New appliances
Promote natural gas and renewable gas to the market and policy	Quality label for installers and development of norms	Development of Gas for transport (CNG, bio-CNG, LNG, bio-LNG)	Lab for testing and accredit – appliances on gas, hydrogen, pellets, …

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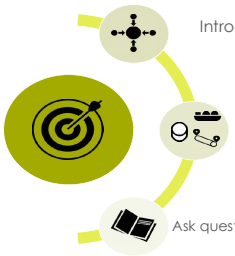
Biogas-3 Green Gas Platform gas.be valbiom

https://greengasplatform.be/

Our objective today



Introduction

Gas market, green gas, Gas quality and certification

Ask question and give us your feed back.

This lecture is informative. Data are mainly public data and not the responsibility of the lecturer of Gas.be and can alter in time. Views expressed during the lecture are those of the lecturer and not a priori of Gas.be members

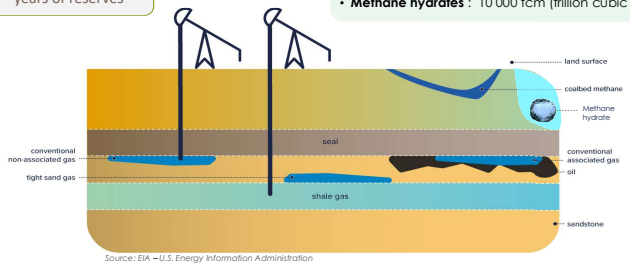
GENERAL

1. GAS production in the world
2. GAS in Europe

Natural gas sources available

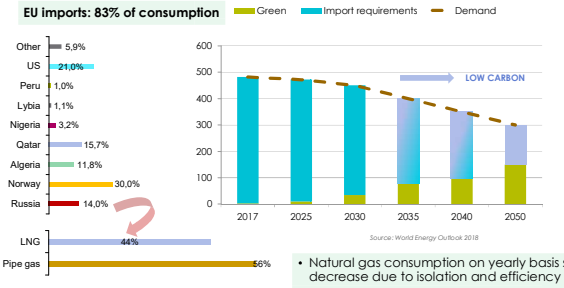
For more than 250 years of reserves

- **Conventional natural gas:** 200 000 bcm
- **Shale gas :** 215 000 bcm
- **Methane hydrates** : 10 000 tcm (trillion cubic meter)



Source: EIA – U.S. Energy Information Administration

EU decreasing gas demand: imports needed (low carbon) + green gas



Source: BP Statistical Study June 2019 – reference year 2018

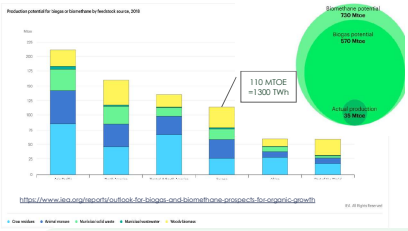
Source: World Energy Outlook 2018

- EU North Sea fields fading out
- Dutch L-gas Groningen field: progressive phase-out of exports and production cap
- Slow increase of biomethane
- Green hydrogen production still very low

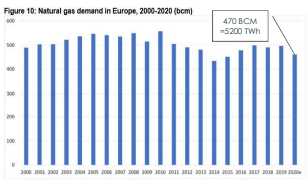
- **Demand destruction due to Ukraine crisis ~ 15%**

- Natural gas consumption on yearly basis should decrease due to isolation and efficiency of appliance
- Peak capacity in winter will most likely remain

Global and European potential of biogas/biomethane



https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth



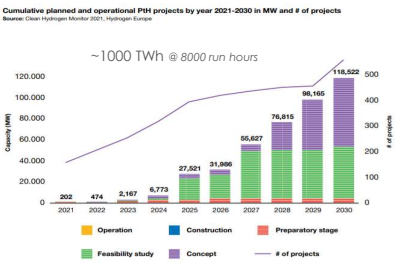
Source: 2000-2019: IEA and Eurostat data, 2020: Author's estimate as of (early) June 2020

https://www.oxfordenergy.org/wpcms/wp-content/uploads/2020/06/Natural-gas-demand-in-Europe-the-impacts-of-COVID-19-and-other-influences-in-2020.pdf

- Biomethane (is upgraded biogas) can reach 8 000 TWh/y, on global scale
- For Europe the potential is 1 300 TWh/y → 25 % of current demand of 5 200 TWh (2020 not → covid)
- This could become 40% when demand decreases to 3 500 TWh (- 30%) by 2040 (expected)
- Current biomethane production is 26 TWh in Europe

1 BCM(billion cubic meter) = 11 TWh Natural gas
1 MTOE (million ton oil equivalent) = 11,63 TWh

European potential of hydrogen



- The produced Hydrogen from electricity *(typically electrolysis)* will strongly depend price signal electricity → 150 €/MWh H2 @ electricity 90€/MWh
- The rules to produce green Hydrogen are very strict *(EU delegated acts proposed)*
- Low carbon Hydrogen produced with Carbon Capture will be more abundant
- Other sources of Hydrogen are chemical processes → this H2 is mostly present in harbors or industrial zoning

- Hydrogen will mainly be bleu (low carbon)
- It can either be transported in dedicated pipe-lines or be injected in the Natural gas grid

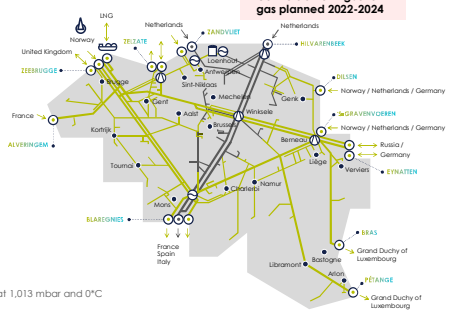
GAS INFRASTRUCTURE BELGIUM

1. Gas grid
2. Gas quality
3. Demand and flexibility
4. Capacities Entry – Exit
5. Gas prices and Hubs

High pressure (15 – 80 bars) transmission infrastructure

- **Conversion of L-gas to H-gas planned 2022-2024**

4,000 km pipelines
- High calorific gas
- Low calorific gas
- Physical interconnection points
- LNG terminal
- Compressor stations
- Blending stations
- Storage



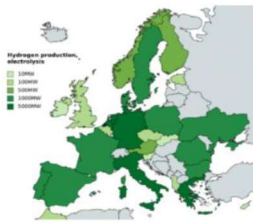
Higher calorific value

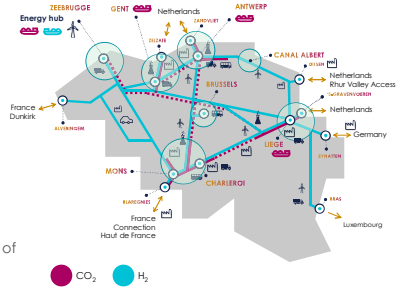
H-gas = 11,3 kWh/m³(n)
L-gas = 9,8 kWh/m³(n)

Normal cubic meter or m³(n) are expressed at 1,013 mbar and 0°C

Fluxys Hydrogen and CO2 backbones planning 2025 - 2030

Initial focus on big industry:
- Capture of CO2 → focus re-utilization
- Conversion to Hydrogen → BE production and import via NH3





Maximum reuse
Minimal cost for society

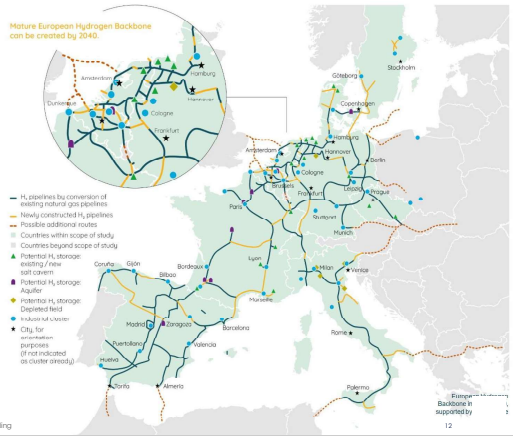
Cost for Reuse of pipeline is max 30% of new pipeline

Integrated into the European hydrogen backbone

- Fluxys together with 10 other European gas infrastructure companies
- Same principle: maximum re-use of the existing infrastructure

Import hydrogen

Offshore wind: sea + inland pipes
Europe: wind + sun regions: pipe + ship
Outside Europe: import terminals + pipes



Average Values of Gas Quality

GAS COMPONENTS	GRONINGEN (NL) %	LNG %	ZEEPIPE (NORWAY) %
Methane (CH4)	82,07	93,88	91,13
Ethane (C2H6)	3,01	4,84	4,8
Propane (C3H8)	0,44	0,06	1,05
Butane (C4H10) (ISO and NORM)	0,16	0,007	0,41
Pentane (C5H12) (ISO and NORM)	0,04	-	0,09
Hexane and superior HC (C6+)	0,05	-	0,08
C. Dioxyde (CO2)	1,11	0,001	1,35
Nitrogen (N2)	13,08	1,20	1,08
Helium (He)	0,05	-	0,01

Source: Fluxys metering

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O + 891\ kJ$$

Gross Calorific Value
→ GCV (gross calorific value)
→ PCS (pouvoir calorifique superieur)
→ BCW (boven calorische waarde)

Lower Calorific Value
→ LCV/GCV = 0,90313 (@25°C)

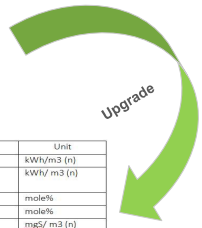
Energy density or Wobbe
→ Wobbe = GCV/ √ (Rel.Dens.)
With *Rel Dens =(Rho$_{gas}$/Rho$_{air\ (1,29)}$)*

Gas specifications		H-cal	L-Cal
Rho	*kg/m³(n)*	0,81	0,79
Dens	*kg/m³(n)*	0,63	0,61
GCV	*kWh/m³(n)*	11,30	9,80
Wobbe	*kWh/m³(n)*	14,26	12,52
GCV	*MJ/m³(n)*	40,68	35,28
Wobbe	*MJ/m³(n)*	51,34	45,08

Biogas and Biomethane

- **BIOGAS** *(average composition)*

Typical Composition of Biogas		
COMPOUND	MOLECULAR FORMULA	PERCENTAGE
Methane	CH_4	50–75
Carbon Dioxide	CO_2	25-50
Nitrogen	N_2	0–10
Hydrogen	H_2	0–1
Hydrogen Sulphide	H_2S	0–3
Oxygen	O_2	0–0

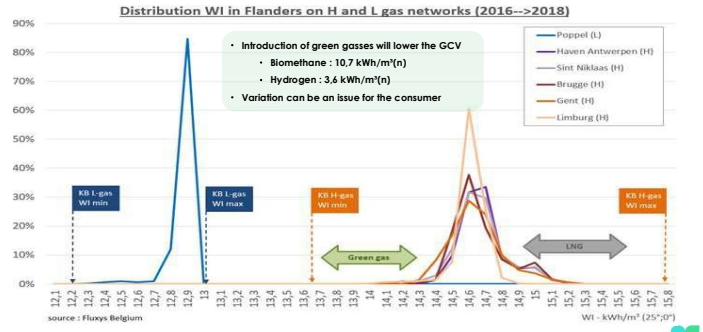


- **BIOMETHANE: (***Synergrid specs)*

	TSO	DSO	Unit
PCS	10,8 – 12,8	10,7 a 12,8	kWh/m3 (n)
Wobbe index	13,6 – 15,66	13,6 – 15,66	kWh/ m3 (n)
O2	< 0,7% mol	< 0,75% mol	mole%
CO2	< 2,5% mol	< 3,5% mol	mole%
H2S	< 5	< 5	mgS/ m3 (n)
NH3	< 3	< 3	mg/ m3 (n)
Siloxanes	na	na	mg/ m3 (n)
H2	< 6% mol	< 6% mol	mole%

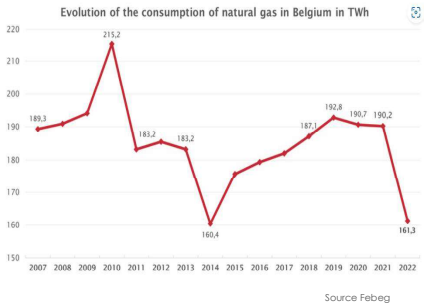
Cost upgrade over 10years → +- 5 €/MWh

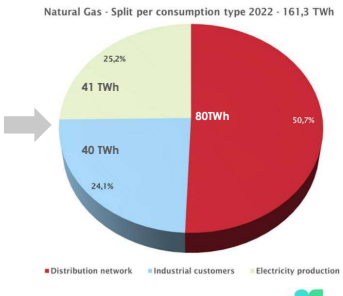
Difference between green gas and natural gas



Gas demand in Belgium

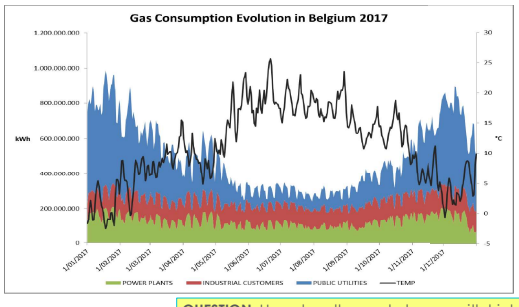
Real-time data on www.fluxys.com → LINK





Source Febeg

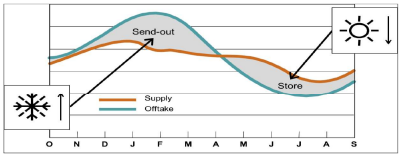
Seasonal demand profile

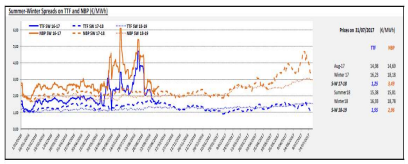


- Gas consumption has a strong seasonal profile
- Household consumption typically stops when temperature above 16°C
- winter demand is typically 2,5 times summer demand, mainly due to domestic consumption
- Industrial consumption and power plants have a very slight seasonal profile

QUESTION: How does the market cope with high offtake difference between summer and winter

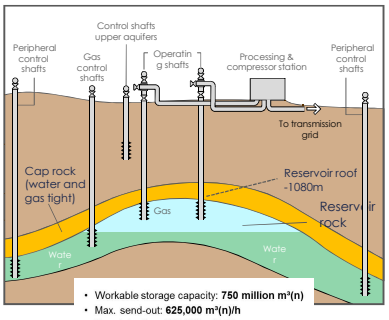
Gas Storage: solution for seasonal flexibility



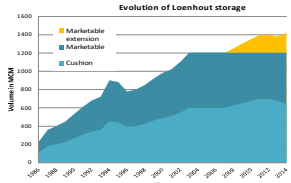


- The physical need to store gas due to **oversupply summer** and to compensate **peak demand in Winter**
- The lower summer prices versus the higher winter prices create a **Summer Winter spread** which can create a profit for supplier
- European storage date on https://agsi.gie.eu/#/graphs/1
- Gas Storage is facilitated in **aquifers or salt caverns** (can also be used for hydrogen)

Underground gas storage in Loenhout

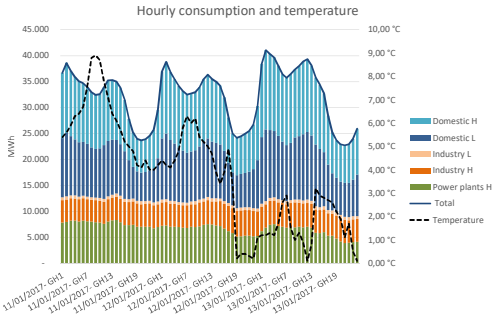


- Workable storage capacity: **750 million m³(n)**
- Max. send-out: **625,000 m³(n)/h**
- Max. injection: **325,000 m³(n)/h**



Could store up to 10% of hydrogen

Hourly demand profile and temperature

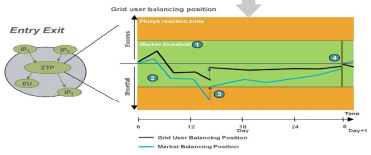


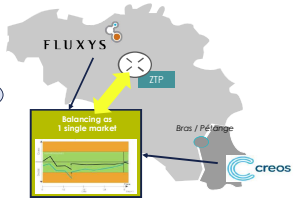
- The first gas hour (GH1)starts at 6h in the morning
- Hourly demand has a morning peak starting at 8h AM and an evening peak around 19h PM
- Peak demand is typically 1,5 times night demand in winter
- Household (domestic) demand is temperature driven
- Powerplants have slight decrease during night hours
- Industry has almost flat offtake

Line-pack, commercial daily flex and balancing

Linepack = p V = (Z n R T)
where:
P = Pressure (Bara); T = Temperature (°K); n number of moles
V = Volume (m³) ; R Gas constant (8.314 J/(K·mol)
Z = compressibility → 0,85 – 0,9 for high pressure gasflows

Gas pipe-line are operated between 50 – 80 bar and have has flexible **linepack**

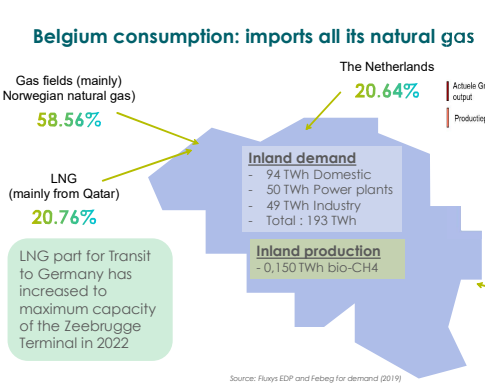




Balancing is managed by a separate company : BALANSYS
(= joint venture Fluxys - Creos)

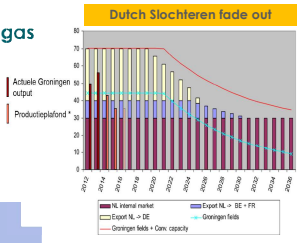
- Linepack flex is translated for into commercial flex for the market. But at the end of the day all gas must be balanced to the initial zero position of the morning (gas-day starts at 6h AM)

Belgium consumption: imports all its natural gas

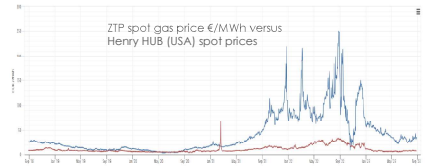


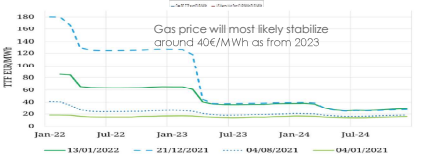
LNG part for Transit to Germany has increased to maximum capacity of the Zeebrugge Terminal in 2022

Import from Germany have stopped and export has increased to maximum



Gas is sold on HUB's which are also used for balancing





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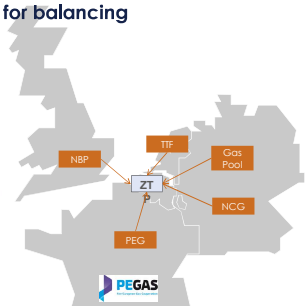
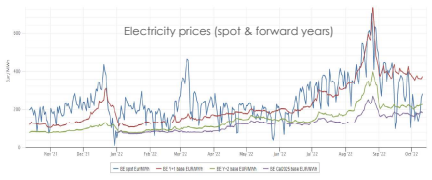


- Fluxys facilitates the ZTP together with PEGAS as the preferred Market Exchange provider

Gas is sold on HUB's that are also used for balancing



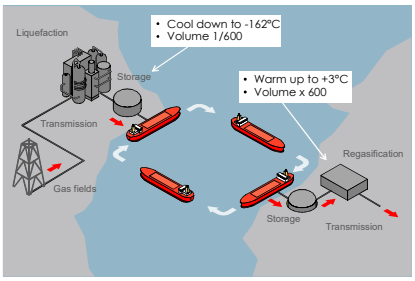
Electricity prices
- Spot prices → high volatility and expected to stabilize around 400€/MWh
- Forwards 2025 evolving towards around 200 €/MWh

Gas Prices
- Spot prices → high volatility and expected to stabilize around 150 €/MWh
- Forwards 2025 evolving towards around 50 €/MWh

Relation prices
- Marginal production unit is CCGT on gas (typical 53% eff.)
- Clean spark spread formula @ 50€/MWh gas and 100 €/MWh CO2 → 190 €/MWh

1. LNG global
2. LNG Europe
3. LNG Belgium

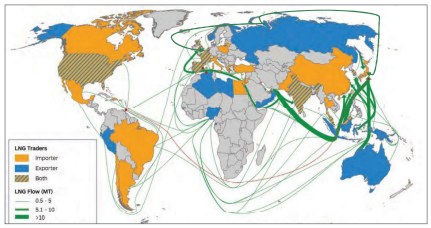
LNG chain (liquefied natural gas)



Why LNG?

- LNG offers competitive advantage over pipe gas for transmission over longer distances
- Easy diversification of sources
- Easy flexibility in destination markets
- Many suppliers (e.g. Qatar) have booked long term capacity in receiving terminals over the world

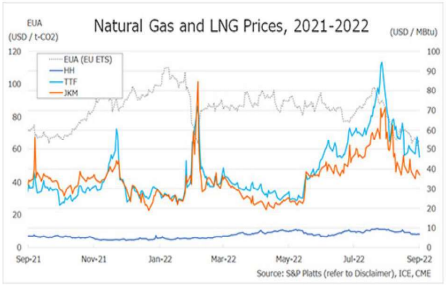
LNG WORLD: shipping routes - 240 million tonnes per year



Ship flows today 2022

- LNG traffic is global and ship can easily change destinations (Europe or China)
- Sea ships however can not run on Heavy Fuel Oil (HFO) due to sulphur limiting legislations (all ships) → many ships switch to LNG as motorfuel.

All cargo's went to Asia in Winter 2020-2021



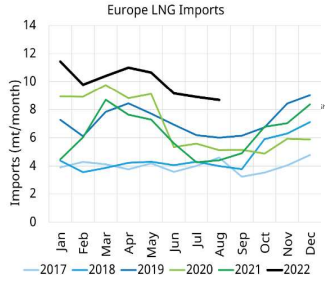
JKM = Asian LNG price
TTF = European gas reference price
1 MWh = 3,44 MMBTU
1$ = 1,03 €

- JKM price in line with TTF as most LNG is going to Europe these days
- LNG from US → high profits

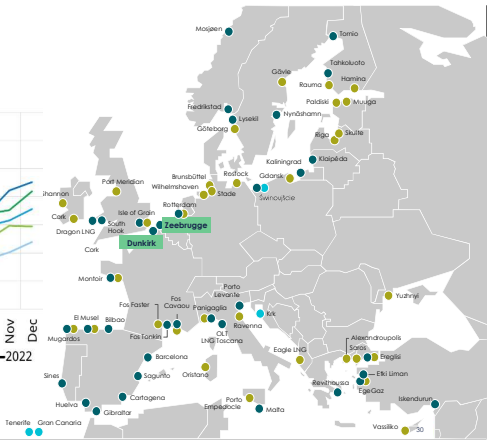
	$/Mbtu	€/MWh
Henry Hub (HH)	10,0	35,4
Liquefaction (US)	2,5	8,9
Shipping to EU	8,0	28,3
US LNG for EU	**20,5**	**72,6**
TTF gas price EU	55,0	194,9

(*) shipping cost today are 4 times more expensive than before the crisis

LNG terminals in Europe

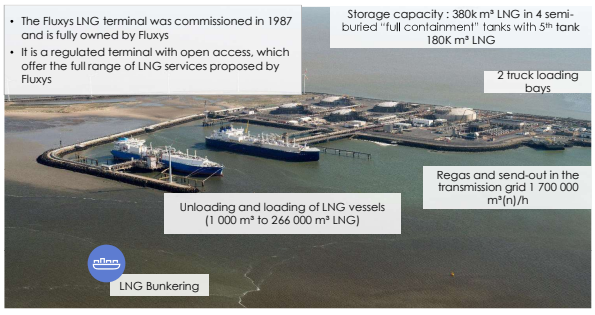


Source: LNG Unlimited, Timera Energy



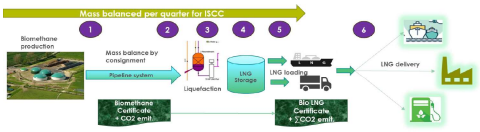
Zeebrugge LNG-Terminal

- The Fluxys LNG terminal was commissioned in 1987 and is fully owned by Fluxys
- It is a regulated terminal with open access, which offer the full range of LNG services proposed by Fluxys



Small scale bio-LNG → a fast growing new market

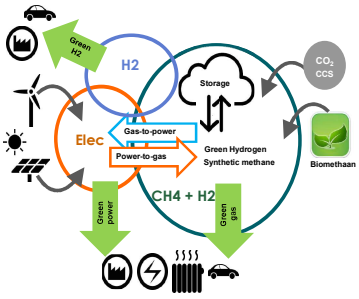
- **Conventional use of LNG**: LNG is delivered on a large scale, stored and regasified for injection into the natural gas grid
- **Small-scale LNG** applications cover the use of LNG
  - as a sustainable alternative fuel for ships and long-haulage trucks
  - as an attractive energy source for industries in areas that are not connected to the natural gas grid
  - **Bio-LNG is available at the Zeebrugge terminal**



GREEN and LOW CARBONS

1. Transition and challenges
2. Biomethane and recycled gas
3. Hydrogen
3. Why Green gas in Belgium

Transition = integrated approach taking into account all key challenges

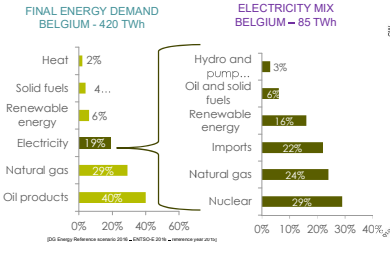


Flexibility
- The Gas grid and H2 grid can be a solution for the flexibility need of the electricity grid in case of positive intermittency *(overproduction Electricity)*
- The power production from the Gas and H2 grid can support negative intermittency *(shortage of electricity production)*

Energy capacity
- The gas grid and H2 grid have "flexible" transport capacity that is 5 times bigger than electricity
- The gas grid and H2 grid (98%) are mainly existing infrastructure (some new build H2) and are cheaper

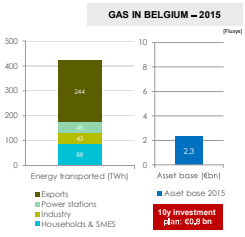
Green character
- Biomethane – Green Hydrogen – Low carbon gasses are available technology

Why green gas in Belgium

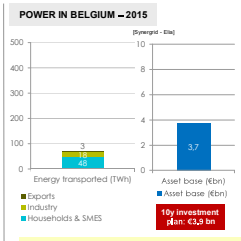


- Seasonal (and daily) need for production flexibility is huge and cannot be delivered by electricity only → **green gas (biomethane and hydrogen) can provide this flexibility**
- Transition wise infrastructure exist and can be easily converted, and production of green gasses are mature technologies

Biomethane uses the gas infrastructure → 8 times cheaper & 5 times bigger



Gas transmission:
- Asset base: **€5.5 mln/TWh** transported
- Allowed revenue: **€1 mln/TWh** transported



Power transmission:
- Asset base: **€54 mln/TWh** transported
- Allowed revenue: **€10 mln/TWh** transported

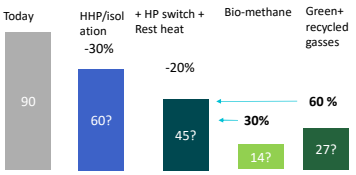
Expected investments for Reinforcements of Electricity grid (2035) **almost 20 Bn€**

7 Bn €	ELIA
5 Bn€	Fluvius
4 Bn€ ?	Wallonia
2 Bn€ ?	Brussels

The potential of green gas for the domestic renewable share

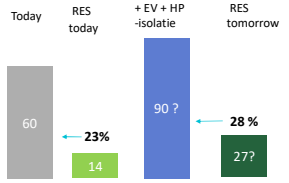
Note that figures (in TWh) shown are only qualitative (not quantitative) only in order to show possible future impacts.

Gas infrastructure (Domestic only)



- *Peak is less impacted (on -20%)*
- *No additional infrastructure cost for domestic grid*

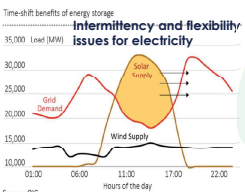
Electricity infrastructure (Domestic only)

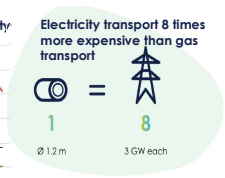


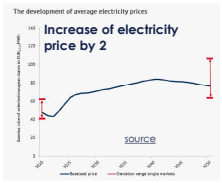
Additional infrastructure cost in Flanders only estimated at 5 bn€

Assuming all green gasses and all renewable production is used in the domestic consumption market only the renewable part for gasses could be significantly higher.

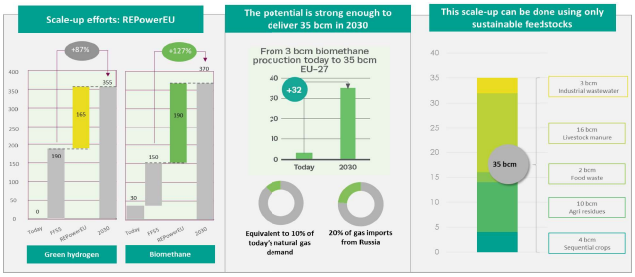
New challenges that come with-coal nuclear fade out







Repower EU: biomethane & hydrogen



To reach the EU target in 2030 we need to multiply by 10 the current green gas production
Europe is evaluating what member state targets could be by 2030

Expected targets – obligation in RED III

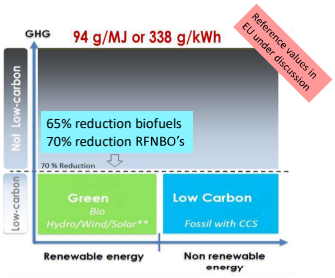
NEW

Target	Expected outcome of RED III (to be confirmed in final proposal)
RES Target	42.5% + 2.5% aspirational
Transport GHG	2030 binding target of: Memberstate can decide and go further - 14.5% GHG reduction OR - 29% 'energy intensity' (i.e. renewable energy share)
Transport 2030 target for advanced biofuels/biogas and RFNBO	- 5.5%
RFNBO 2030 sub-target in transport	- 1%
Article 27.3 – Additionality	Cfr. Current DA applicable RED II
Fossil fuel comparator	94 g CO2/MJ reduction biofuels 65% , reduction RFNBO's 70%
Industry – RES	Annual increase of RES of 1.6%
Industry – RFNBO target Art. 22b	- 42% hydrogen used in industry from RFNBO in 2030, 60% in 2035 (with a possibility to decrease the targets) - Possibility to reduce by 20%: o If a MS contribution to the overall EU target meet expectation o The share of hydrogen from fossil fuels is not more 23% in 2030 and 20% in 2035 - Recitals from the room document REV3 - Deletion unabated
Building, heating and cooling (NEW ETS @ max 45 €/ton CO2)	Indicative renewable energy share in buildings of 49% in 2030 Binding annual increase of 0.8% of renewable for heating and cooling until 2021-2025, and 1.1% from 2026 to 2030

What are the main criteria for EU compliant green gasses

NEW

1. GHG reduction must be sufficient



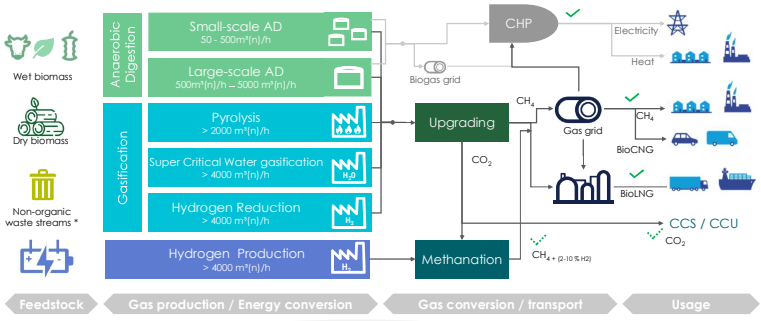
2. For RFNBO's additional criteria

1. **Additionality**
   - RES must be online within 36 months of H2 production
   - RES may not recieve support
2. **Geograhical correlation**
   - RES must be in bidding zone (Belgium)
   - Neighboring bidding zones only under specific congestion rules
3. **Temporal correlation**
   - RES must produces in same hour as hydrogen
   - Exception for plants build before 2028

Very stringent rulings for NW-EU H2 production

Import NH3 from outside EU must also comply

Biomethane and recycled methane



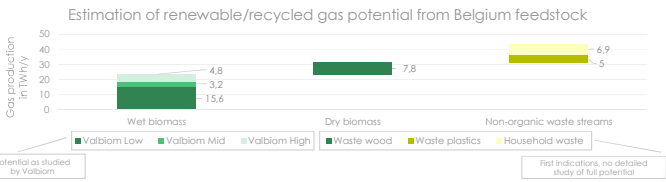
Biomethane (98% CH4) we consider as upgraded biogas (60% CH4; 40% CO2)

Feedstock: Belgian production potential not limited to biomass

Wet biomass
- Side products from industry & agriculture
- GFT, manure, sludge, ...

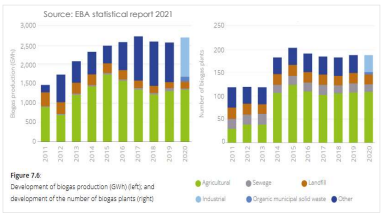
Dry biomass
- Wood, pellets, waste wood ...
  - input quality important for most conversion techniques

Non-organic waste streams
- Plastics, tires, ...
  - Focus on energy dense streams
- Other residual waste (industrial, chemical, household)



Current situation in Belgium → biomethane = opportunity

Biogas 2020



New installations

Shift from biogas to biomethane

Fade out biogas Flanders towards 2025 expected around 1,4 TWh

Maximum BE
Valbiom – gas.be 2019

15,6 TWh injectable biomethane (Valbiom 2019)

Expect BE 2030
Guidehouse –2022

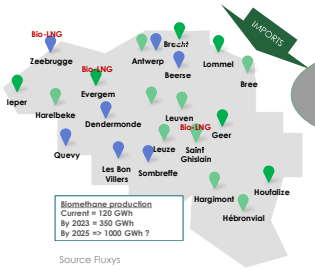
6,3 TWh
Other
Industry
Agro
Manure

- Today 2,6 TWh of production is biogas for local CHP = (i) 2 TWh Flanders and (ii) 0,6 TWh Wallonia → 1,4 TWh could be switched in Flanders
- The feedstock potential for biomethane determined by Valbiom (2018 – 2021) is 15,6 TWh
- Current realistic objective for BE towards 2030 would be around 6,3 TWh (Guidehouse)

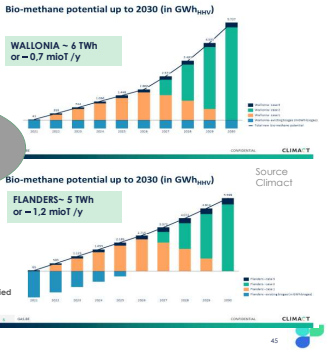
Biomethane today in Belgium and what could be

Feedstock potential is **~ 15 TWh** *(Studies Gas.be, Valbiom, Guid*

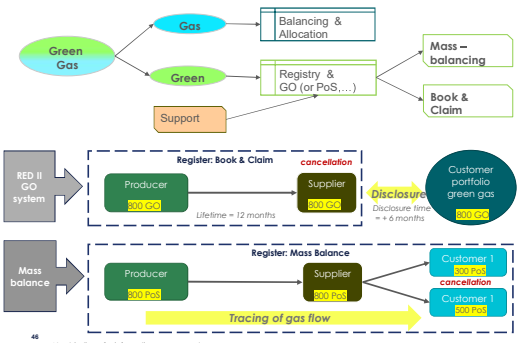
Realistic potential for coming 10 years **~ 10 TWh**



Activation supported by regions is key



Buying / Selling green gas (Mass balance versus Book & Claim)

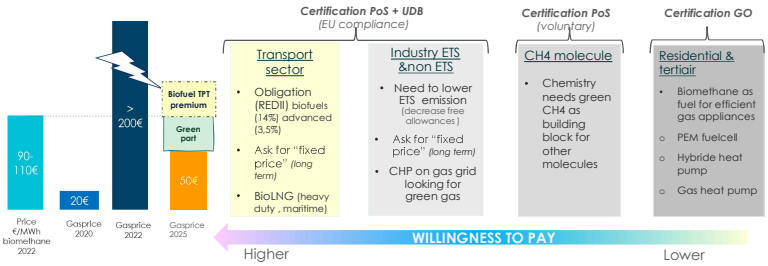


- Gas is sold at the gas price (via existing natural gas market) to a supplier (levies are applicable)
- Green part (GO or certificate) is sold separately to a green trader(no levies)
- Mass Balance (synchronicity between gas & green sales) is required for Biofuel and ETS consumption (with proof of sustainability "PoS" and "GHG calculation")

The PoS includes PoO, GHG calcul and mass balance

- In book & claim the GO can be sold to any consumer but disclosure will be required (to avoid fraud)

Who is looking for biomethane



- Not all consumers have the possibility (technically or financially) to switch to electricity
- Biomethane is considered the 'first green alternative' for natural gas
- Consumers expect to reduce exposure to high volatile gas prices via long term engagements
- Producers need to engage in long term contracts to receive a bank loan

Biomethane producer need long term contracts over min 5 years

2

Transport: transposition of RED II in Belgium

RED II obligations on % : "NECP BE 2019"

Biobrandstoffen (%)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Reële waarde	8,95	8,95	9,25	9,55	9,8	10	10,2	10,45	10,45	10,45	10,45
1G	7	7	7	7	??????						
2G Deel A	0,1	0,1	0,1	0,1	0,1	0,5	0,5	1	1,5	1,75	1,75
2G Deel B	1,85	1,85	2,15	2,45	2,7	2,5	2,7	2,45	1,95	1,7	1,7
dubbeltelling2G	0,6	0,6	0,95	0,95	0,95	2,2	2,2	2,7	3,2	3,45	3,45
Nominale waarde	9,55	9,55	10,2	10,5	10,75	12,2	12,4	13,15	13,65	13,9	13,9

RED II obligations on sutainability and GHG reduction obligation (FQD) :

- BioCNG and bioLNG must be reported as from 2022 by fuel suppliers and accounts for their mandatory objective of **6% GHG decrease** (related to the EU reference of 94 gCO2 eq./ MJ) in BE biofuel register → future registration in UDB

Possible introduction of Bio-tickets

"Brandstofwet" (Min. Vanderstraete)

expected to be published 2023 and applicable 2024 ?.

"decreet duurzaamheid" (Min. Katthabi)

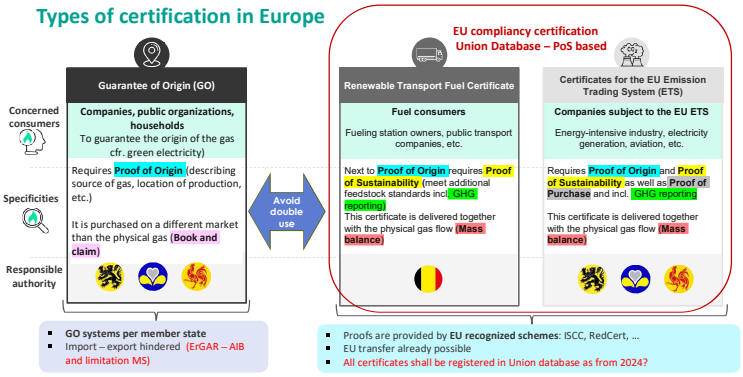
published 14 feb 2022 applicable 2022.

CERTIFICATIONS

1. Legislation
2. Certification

3

Types of certification in Europe

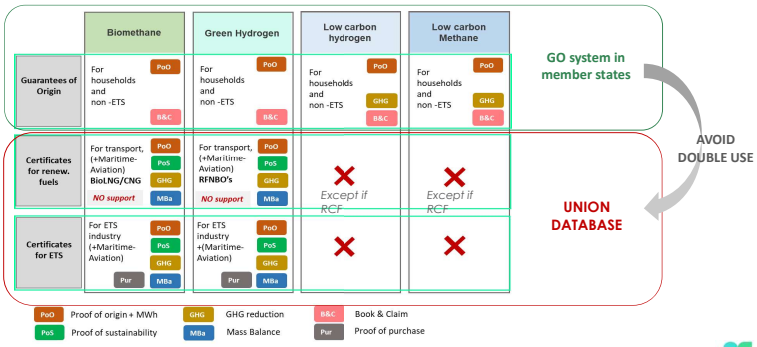


- GO systems per member state
- Import – export hindered (ErGAR – AIB and limitation MS)

- Proofs are provided by **EU recognized schemes**: ISCC, RedCert, ...
- EU transfer already possible
- All certificates shall be registered in Union database as from 2024?

3

Expected landscape of certification in Europe

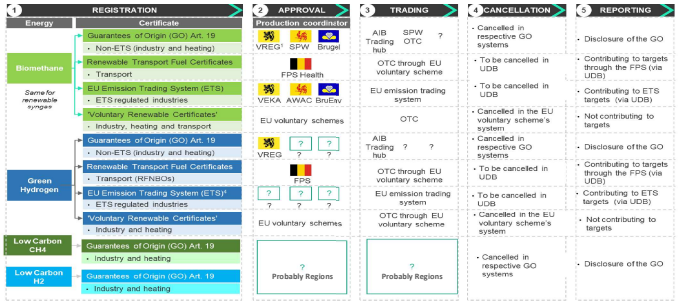


3

Fragmentation of competencies in BE is a fact:

need to create consistency and where possible system centralization ?

Source: SIA partner study for Gas.Be

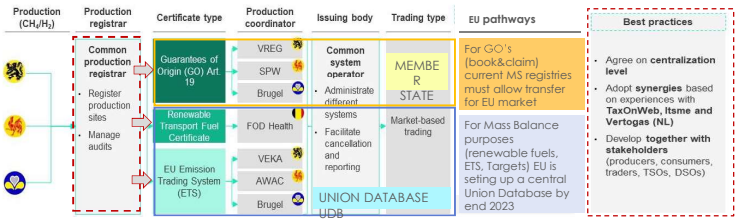


Improved pathway → partial centralization

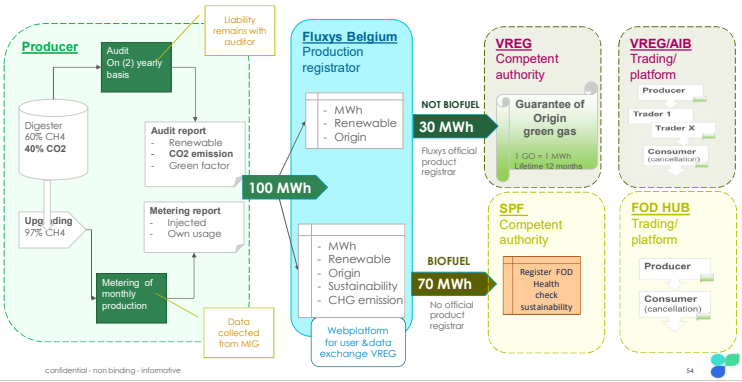
Long-term and system-wide development provides a coordinated green gas certification framework that removes barriers to market development

In the longer term, a more fundamental development of the green gas certification system should be considered, based on a holistic view of the different systems. **Centralization** where possible alleviates pain points for producers and consumers and **maximizes the potential of green gas** contribution to renewable and GHG reduction targets.

Systems (GO and UDB) must be linked to insure **"single use"**



Process for GO's in Flanders (could also be applied for biofuels/ETS)



No compliant biomethane without adequate certification

	Type of use	Competency	RED II compliant law	Certification framework status
	Biofuel, RFNBO certificates	economie	✓ **Royal Decrees (2014, 2018, etc.).** In revision. Sustainability Ministry Health ✗ **"Brandstofwet", FPS Economy (2013).** In revision. Ministry Energy (economie)	Introduction of a registration system and linked data base for biofuels from biomass
	GO **ETS**	VREG VEKA	✓ **Energy decree (2019),** takes into account **all renewable gasses** ✓ **Specific transposition of MRR by EKA**	**Registration** started in 01/20 and GOs are tradable as from 05/20 managed by VREG & AIB (CT. illustration slide 6 for further explanation)
	GO **ETS**	Wallonie service public SPW Wallonie environnement Awac	✗ **"Arrêté du Gouvernement Wallon relative to certificates and labels of guarantee of origin for gases from renewable sources (2018).** Only refers to **biomethane**, not yet fully compliant.	**"Label de Garantie d'Origine"** in place but targeted to support Wallonian **combined heat and power (CHP) plants only**
	GO **ETS**	brugel No clarity yet (Brugel?)	✗ **"Ordonnance gaz" (2004), relative to the gas market organization in the Brussels-Capital Region.** Still need to be adapted.	**No system yet** as there is not green gas production in Brussels today

Source Sia-partners

- Certification is different for ETS and biofuels than for GO's
- Belgium has a very fragmented certification landscape

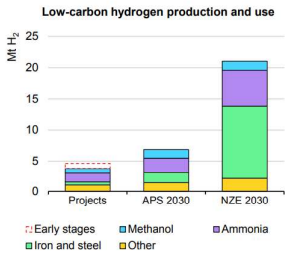
→ **Single use is difficult to prove**

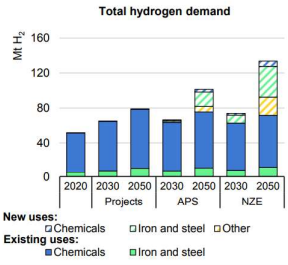
Import is difficult

THANK YOU FOR ATTENTION

QUESTION TIME

Global production of low carbon hydrogen versus demand

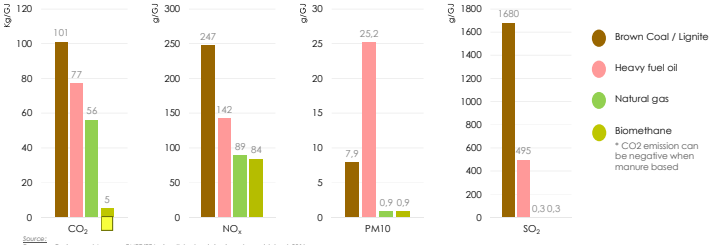




- Production of low carbon (including renewable) hydrogen is much lower than hydrogen demand
- Renewable hydrogen will be difficult to get in Europe due to stringent ruling

Advantage of natural gas and biomethane

TAIL – PIPE versus WELL to PIPE



Source:
European Environment Agency - EMEP/EEA air pollutant emission inventory guidebook 2016
Public electricity and heat production - dry bottom boiler @ high calorific value

Higher carbon/hydrogen ratio's mean less CO2 emissions

Natural gas $\frac{H}{C} = \frac{4}{1} = 4$

Oil $\frac{H}{C} = \frac{22}{10} = 2.2$

Coal $\frac{H}{C} = \frac{12}{24} = 0.5$