# RNG Lessons Learned from Denmark

ABC Sponsored Webinar

August 4, 2022

# Quick Notes

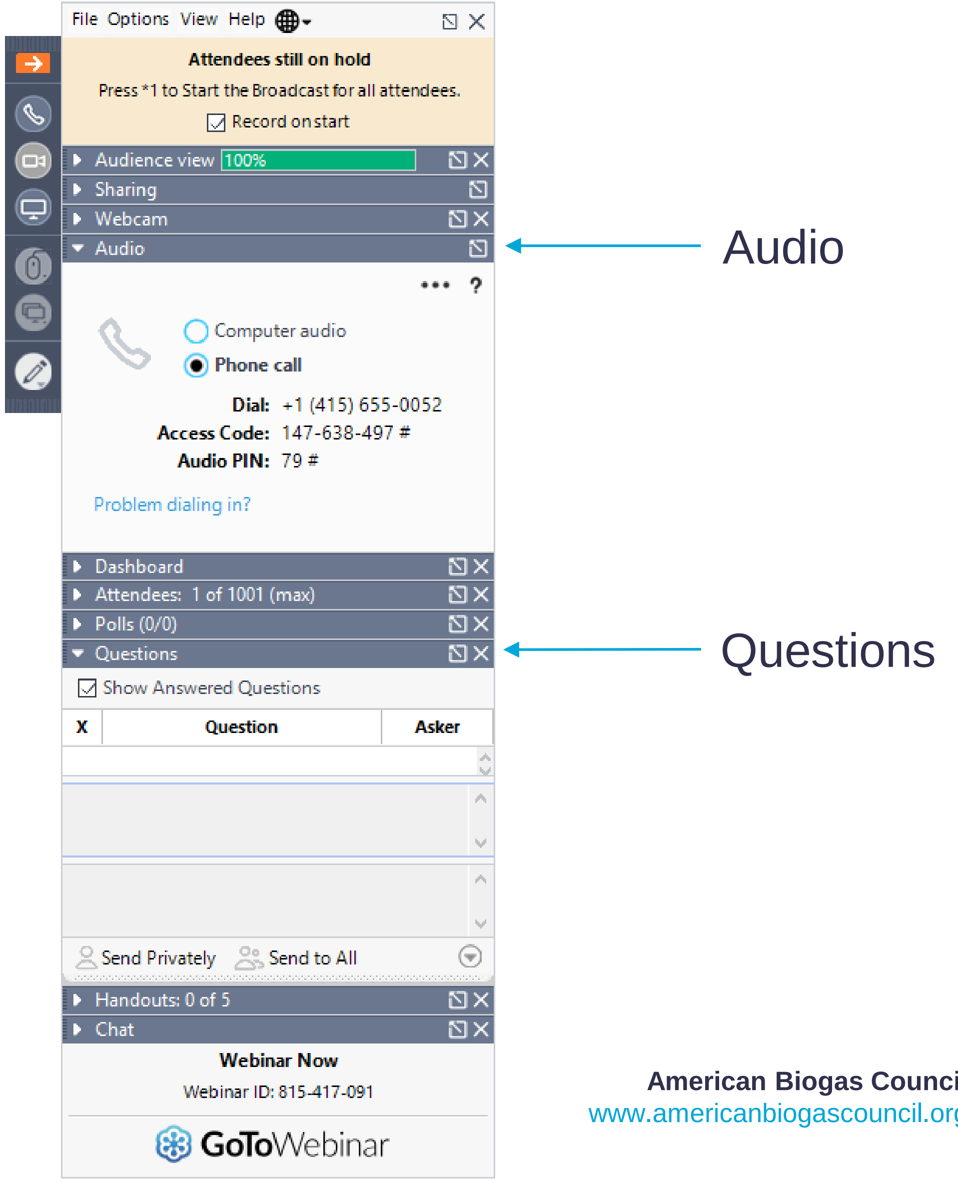
**You should be able to hear me talking now. If you can't, use the questions module to describe your issue.**

**Two Audio Options: Phone or Computer**
**Choose one and connect**

**Pro tip: Don't call in on our phone if your audio is set to "Mic and Speakers"**

**Ask questions using the Questions Panel on the right side of your screen at any time.**

**The recording of the webinar and the slides will be available after the event. We will post them online and send you a link.**




**American Biogas Council**
www.americanbiogascouncil.org

# Who We Are

## The <u>only</u> US organization representing the <u>entire biogas industry</u>

**All sectors represented**

- Project developers/owners
- Equipment retailers and dealers
- Waste management companies
- Waste water companies
- Farms
- Utilities
- Municipalities
- Consultants and EPCs
- Financiers, accountants, lawyers and engineers
- Non-profits, universities and government agencies

**200+**
**organizations**

**2,000+**
**individuals**

# Timothy Robinson

## Clean Methane Systems

# CMS Background & Management

CLEAN METHANE SYSTEMS…
…custom designs, installs, fine-tunes and operates biogas-to-energy systems for manufacturers, consultants, municipalities and energy companies. We are recognized as a worldwide leader in conditioning and recouping waste stream biogas – including chilling; compressing; and removal of sulfur, carbon dioxide and siloxane – with the end goal for our customers of clean power generation and a stronger bottom line. We can help you with straightforward solutions to complex problems, whether you have an existing system with gas purification problems or want to realize the financial and power benefits of a complete biogas conditioning system.

…can direct engineering design, equipment procurement, site selection, injection point hook-up, operations and logistics.

…has been responsible for 200+ global waste-to-energy, water and wastewater and sustainable agriculture projects.

President, CMS

Tim Robinson

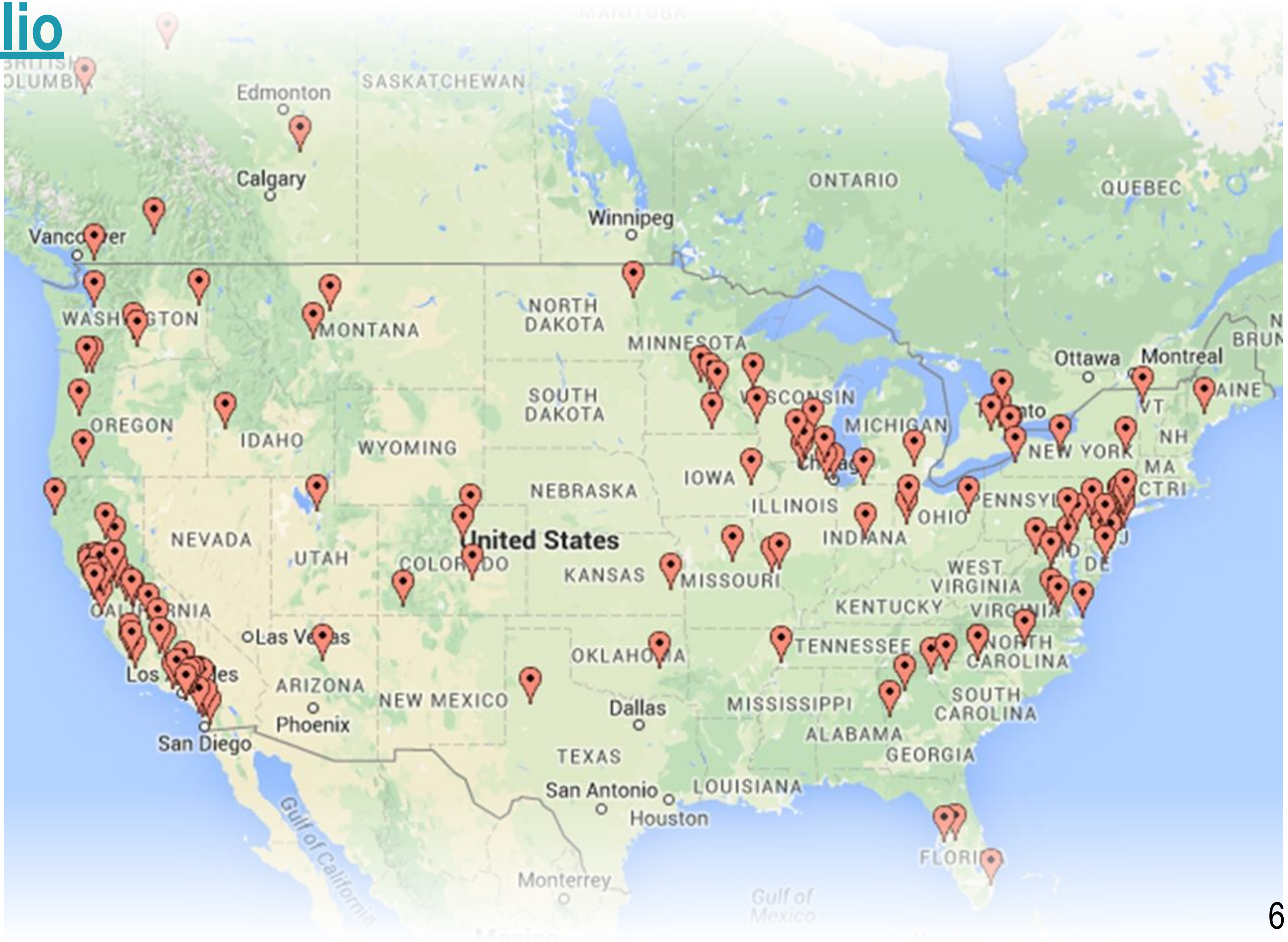
CFO & Operations, CMS

Kit Johnson

Ammongas CLEAN METHANE SYSTEMS

# CMS Project Portfolio

- Over 200 installations worldwide
- International installations in Australia, NZ, South Africa, Brazil & Europe
- First install in 1996 in Sacramento

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# Can the Danish Experience inform North American Oppertunities

How can we use the Danish experience to grow the opportunities in North America.


1) Market Access
2) Project Suitability
3) Project Complexity
4) Risk Management

# Polling Question 1: Project Challenges

Select the most significant challenge to getting RNG projects completed based on your own experience:

- Project planning & management resources
- Equipment and technology
- Adequate and timely financing
- Offtake agreements
- Feedstock & supply

## Michael Støckler

### Food & Biogas Cluster, Denmark

# Biogas Webinar
# Historic biogas development and market drivers of Denmark

**04 August 2022**

**Online**

Food & Bio Cluster
Denmark

**Denmark's national cluster for food and bio-ressources**

# Meet the FBCD Biogas Team…

Thorkild Frandsen

Claus Mortensen

Knud Tybirk

Michael Støckler

Louise Johnson

Gunnar Mikkelsen

# Our biogas focus – environmental advances

Energy production
- Optimize utilization (upgrading – methanization)

Providing resources for the biogas plants
- Straw in biogas plants
- Residues from food production

Recirculation of nutrients
- Regional distribution of nutrients
- Optimizing biofertilizer products

Reducing emissions
- $NH_4$, $CH_4$ and $N_2O$ evaporation from slurry tanks and field application
- $NO_3$ leaching
- $CH_4$ leakages from biogas plants

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# Incentives for biogas production

The current development in the Danish biogas production has been achieved through a set of incentives in the environmental-, agricultural- and energy regulation, including

- Dedicated governmental support schemes
- Taxes on consumption of fossil fuels
- Restricted use of fertilizer/manure on fields
- Ban on organic waste on land fill since 1998
- Fees for waste treatment
- Dialogue and joint efforts with key stakeholders through follow-up programs and a Biogas Taskforce
- Support for research, development and demonstration of new technologies
- Limit on the use of energy crops in biogas production

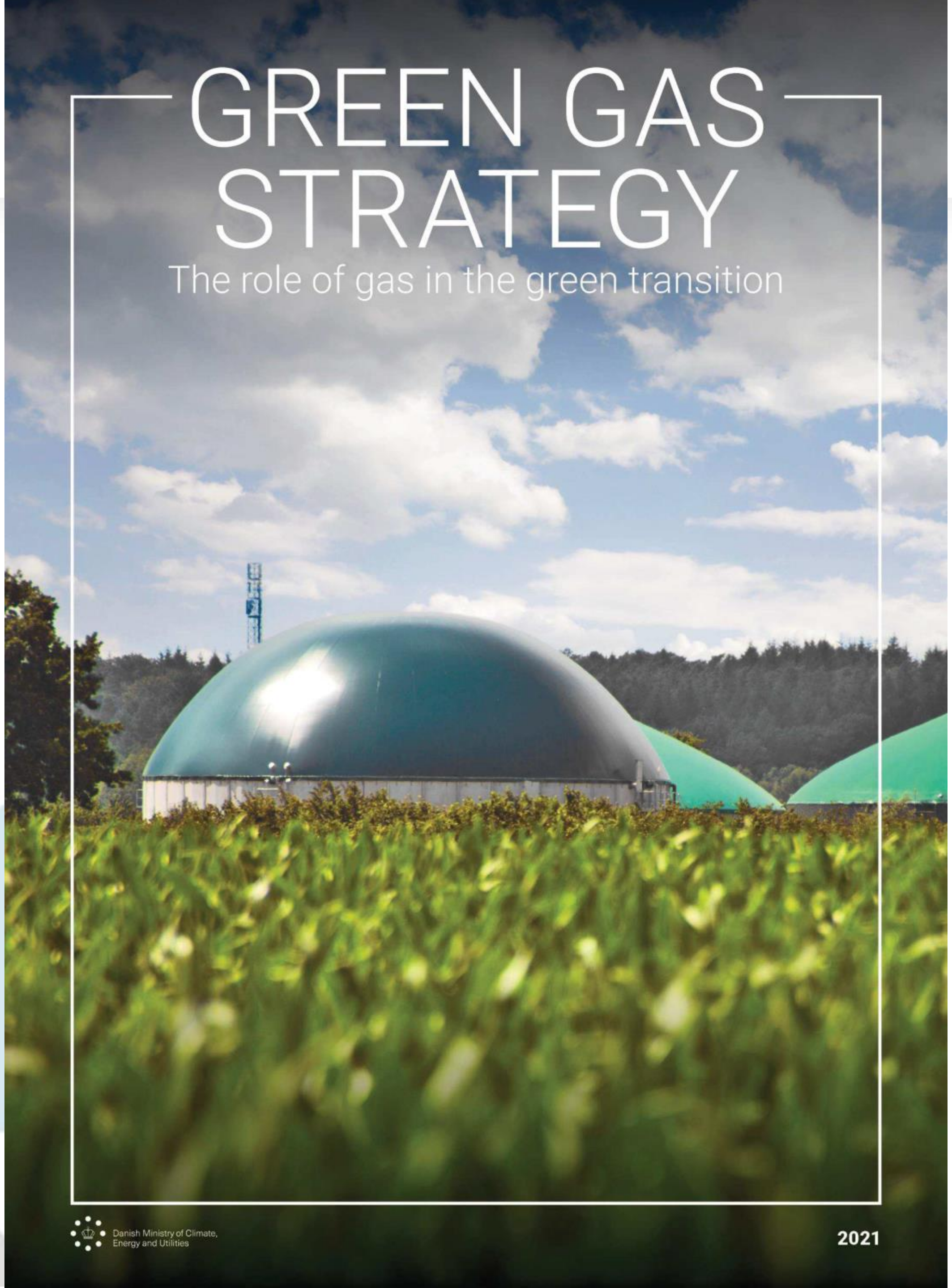
# Governmental support schemes

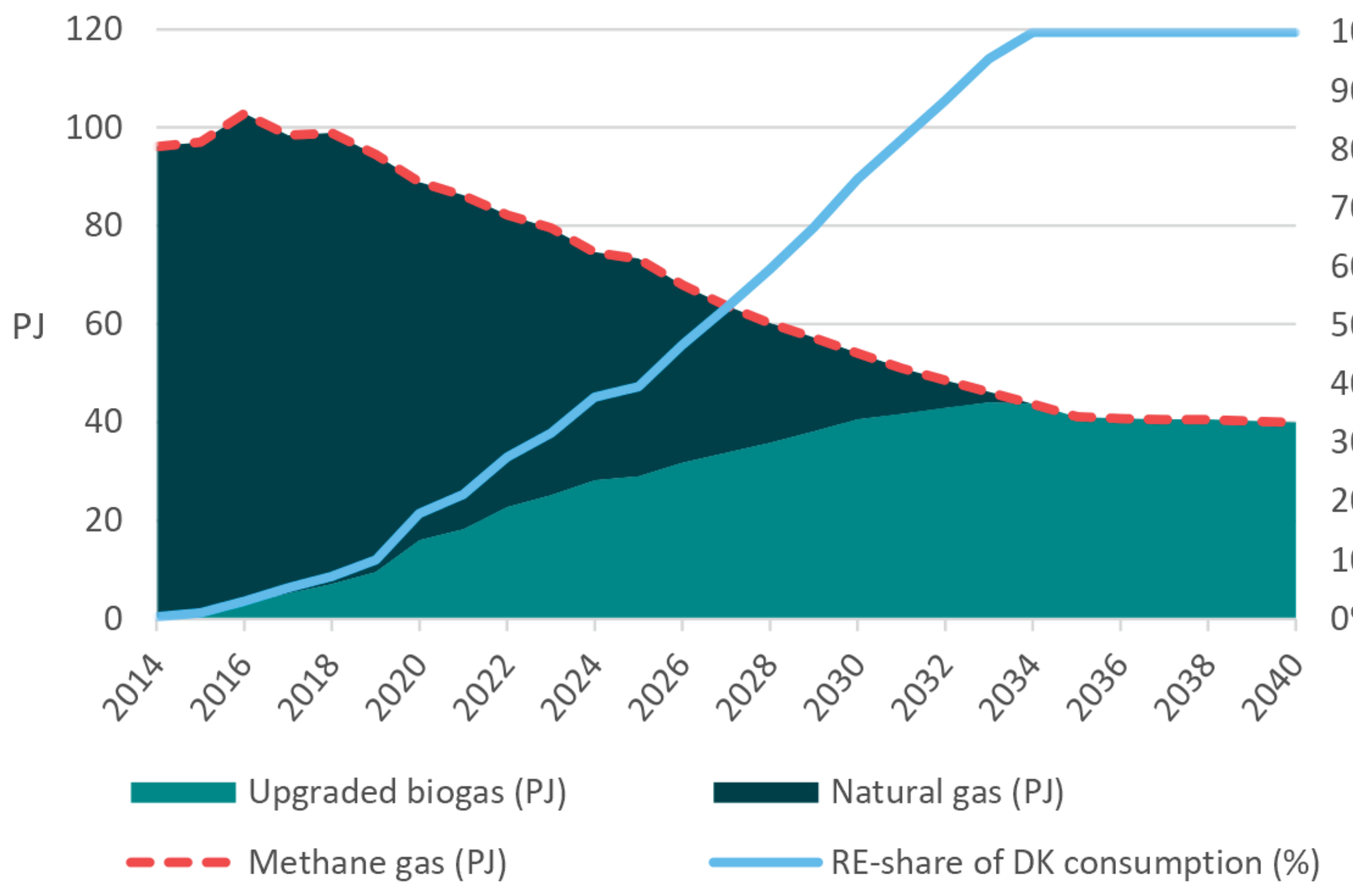
The following uses of biogas receive support as stated in the table below:

- Production of electricity
- Upgraded biogas delivered to the natural gas grid or cleaned biogas delivered to a town gas grid
- Use of biogas for process purposes in the industry
- Use of biogas as a transport fuel
- Use of biogas for heating purposes

| Price surcharge total | | $ | | | |
|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2022 |
| Electricity production fixed settlement | cents/kwh | 14,1 | 17,0 | 18,4 | 11,5 |
| Electricity production supplement | cents/kwh | 10,1 | 12,9 | 14,3 | 6,3 |
| Upgrading | dollars/GJ | 14,5 | 17,4 | 18,8 | 11,5 |
| Process | dollars/GJ | 9,3 | 12,1 | 13,4 | 5,4 |
| Heat | dollars/GJ | 3,9 | 6,7 | 8,1 | 0,0 |

| Price surcharge total | | $ | | | |
|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2022 |
| Electricity production fixed settlement | dollars/M3 CH4 | 1,41 | 1,70 | 1,84 | 1,15 |
| Electricity production supplement | dollars/M3 CH4 | 1,01 | 1,29 | 1,43 | 0,63 |
| Upgrading | dollars/M3 CH4 | 0,58 | 0,69 | 0,75 | 0,46 |
| Process | dollars/M3 CH4 | 0,37 | 0,48 | 0,54 | 0,21 |
| Heat | dollars/M3 CH4 | 0,16 | 0,27 | 0,32 | 0,00 |


GREEN GAS STRATEGY
The role of gas in the green transition
Danish Ministry of Climate, Energy and Utilities
2021

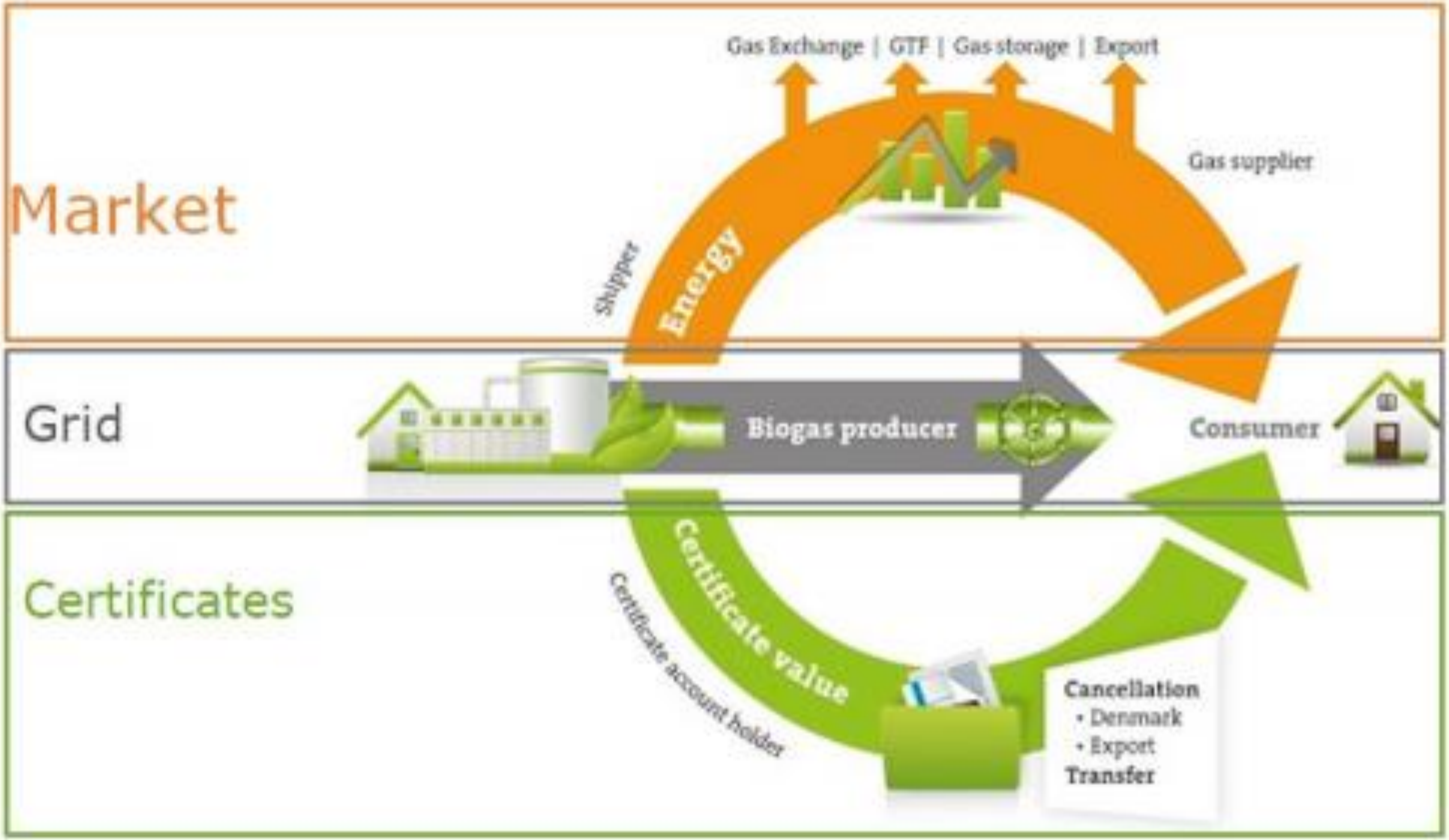



*Consumption of methane gas by energy type and share of renewable energy in gas consumption.*
*Source: The Danish Energy Agency's 2021 Analysis Assumptions for Energinet (AF21).*

Traditional gas market model

Grid connection

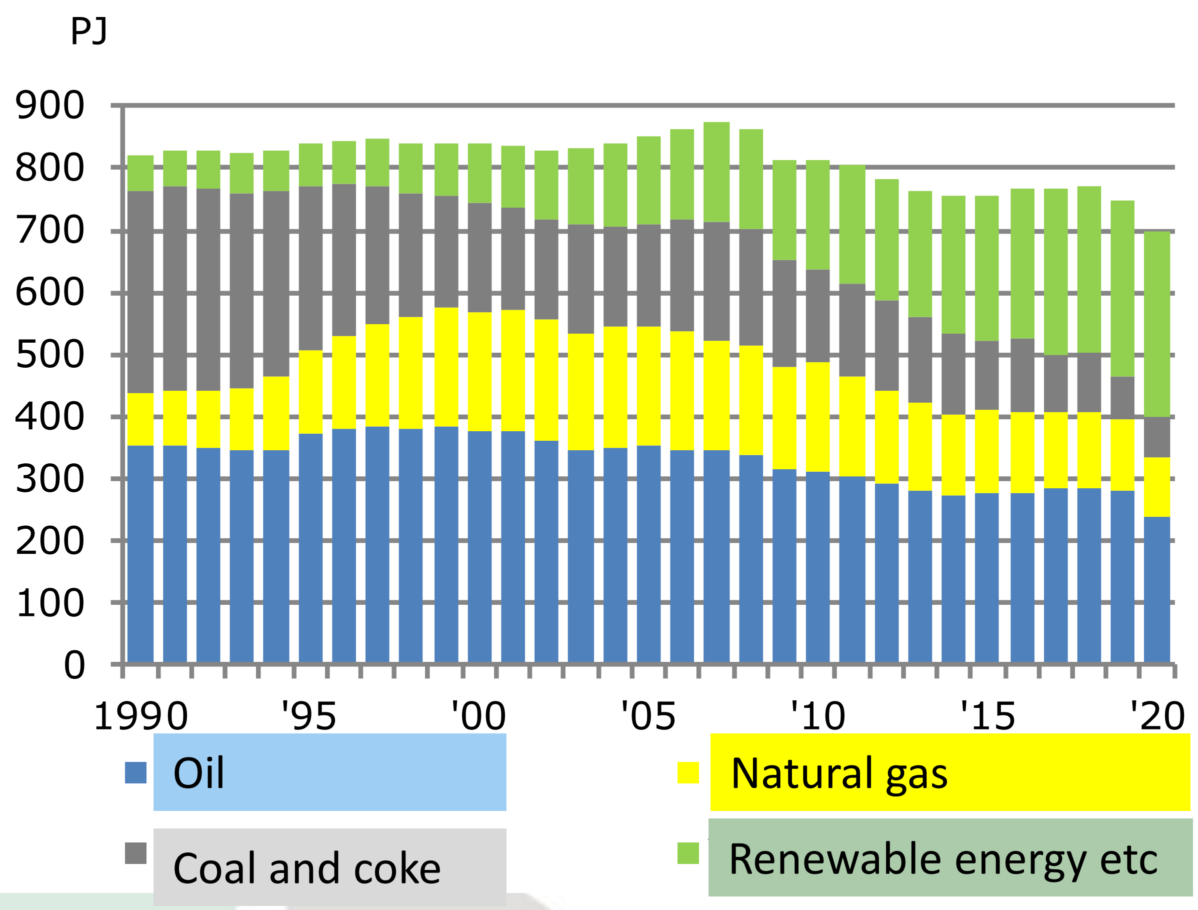
Trade of the green value



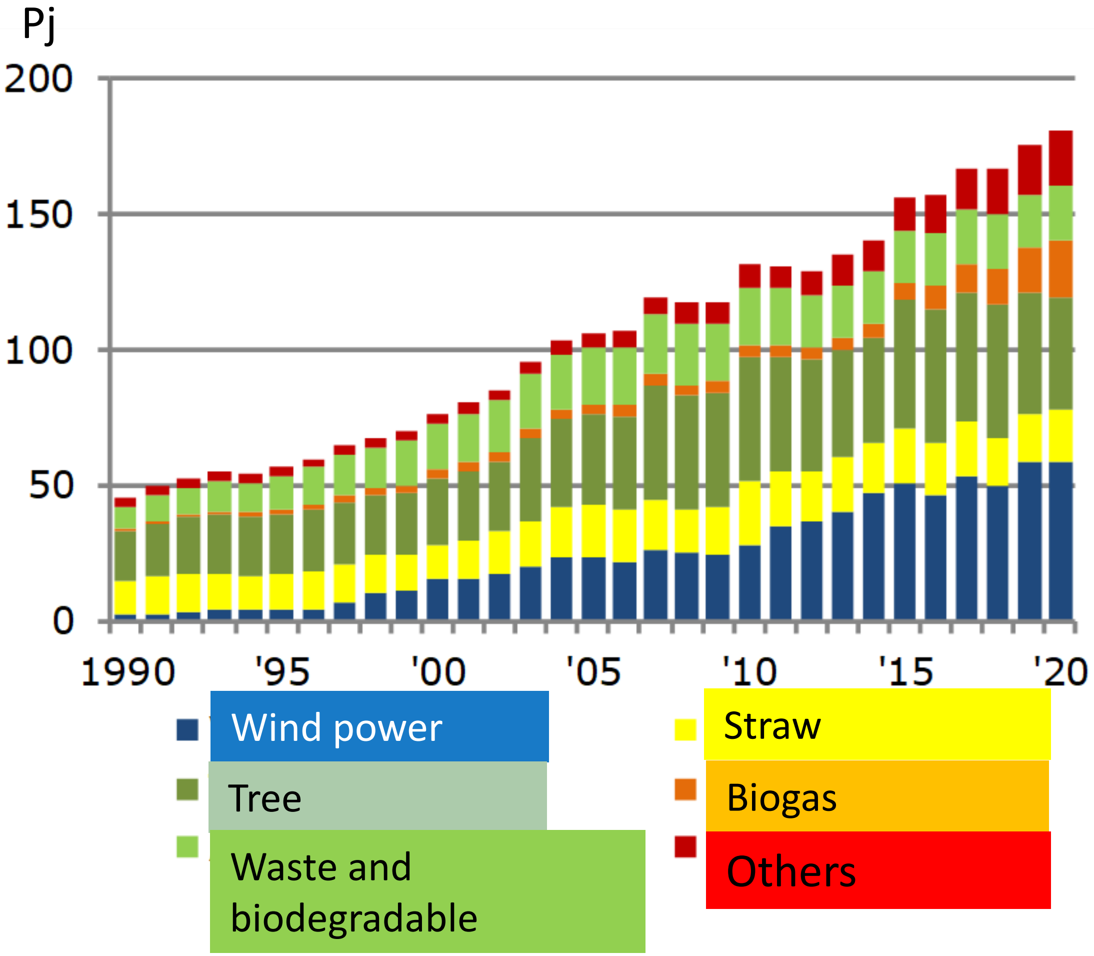
Food & Bio Cluster
Denmark

# Denmark

## Gross energy consumption divided by fuels

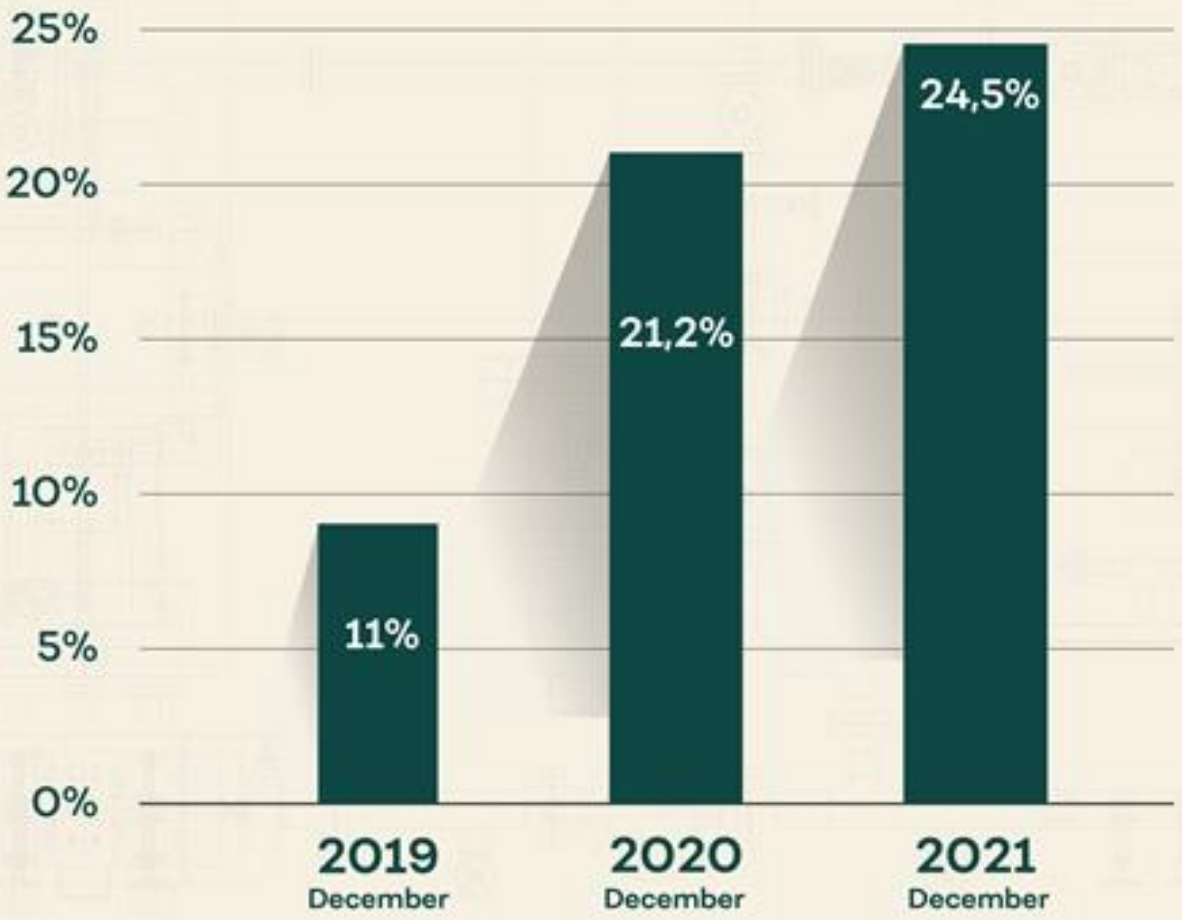



## The production of renewable energy divided by energy products

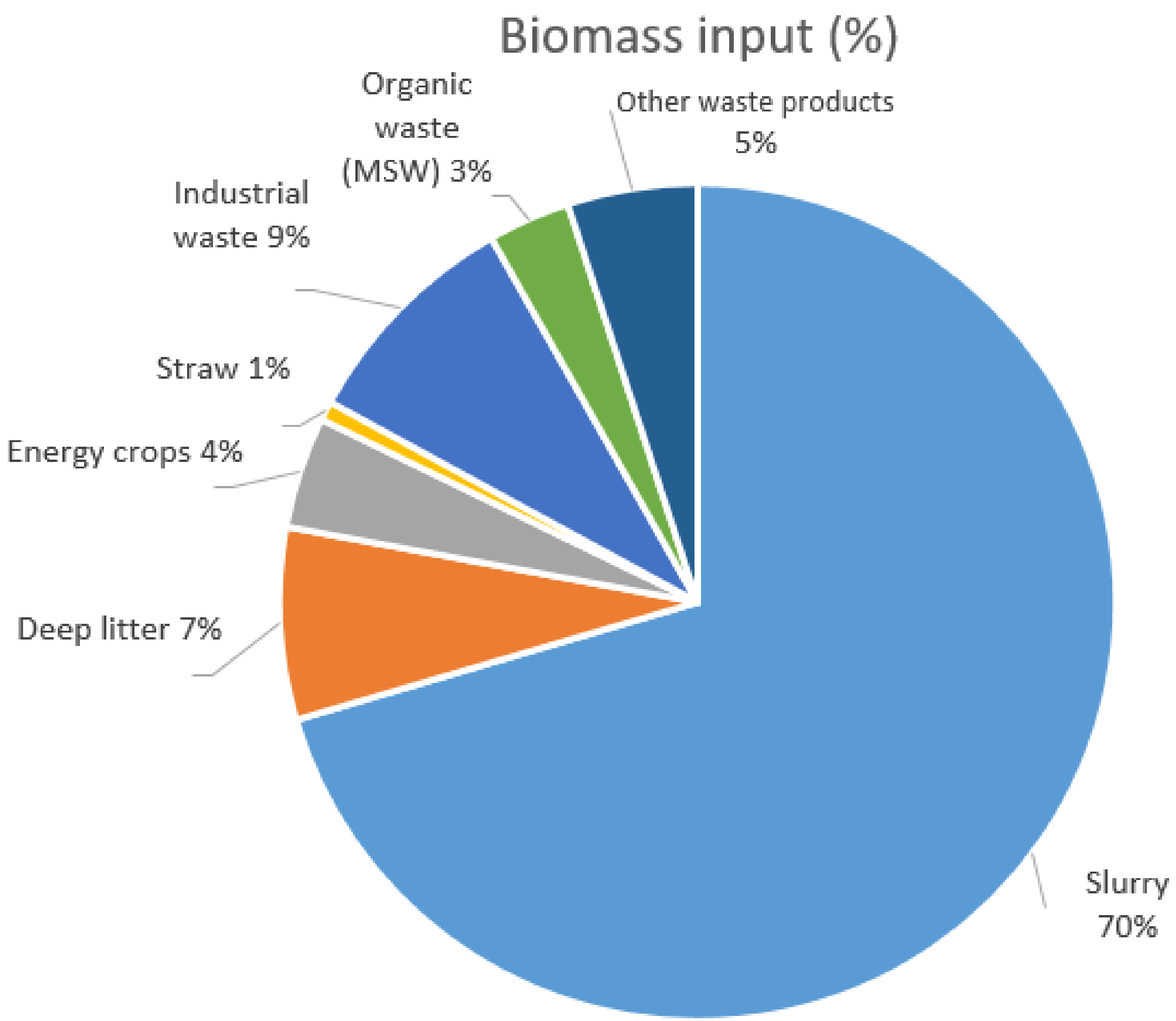


# Biogas sets a new record

The share of biogas in the gas network

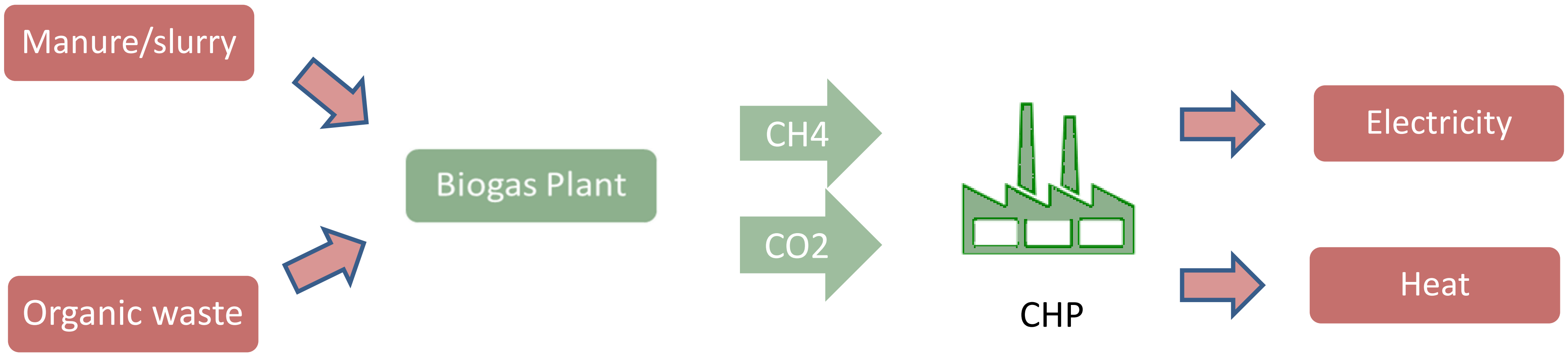



Evida

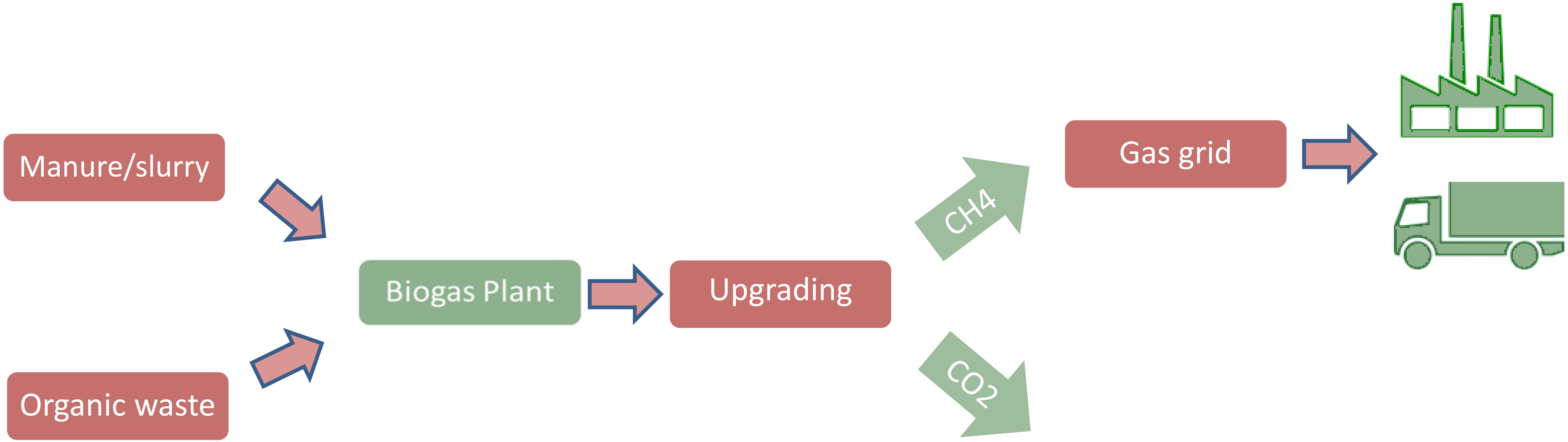


Biomass input (%)
Organic waste (MSW) 3%
Other waste products 5%
Industrial waste 9%
Straw 1%
Energy crops 4%
Deep litter 7%
Slurry 70%

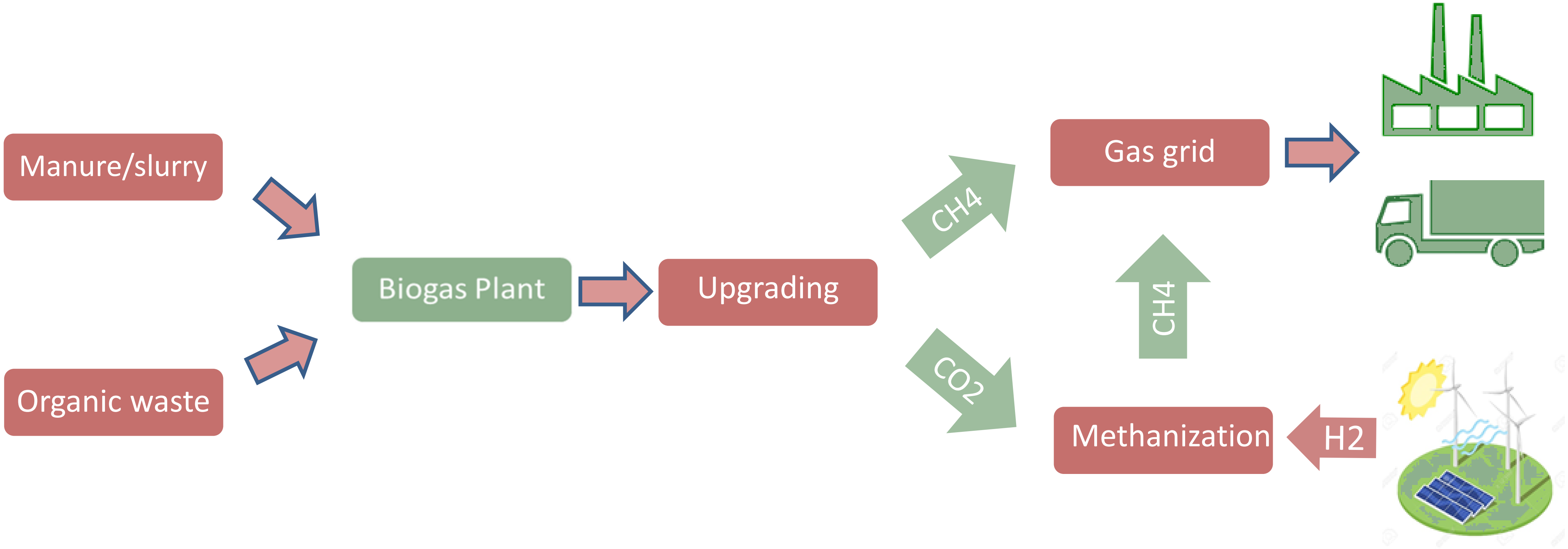
# Optimizing energy production



# Optimizing energy production - upgrading



# Optimizing energy production - methanization

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# Optimizing input - straw

Straw is an abundant and reliable resource for biogas production

Deep litter and "poor quality straw" is especially interesting, as alter ice is low)

Plant design must be adapted to receive and process large amounts of straw:

- Longer retention time
- Pretreatment/mixing/feed-in equipment
- Stirring in digester must be looked after

Field application of digestate must take into account the high DM content in order to optimize nutrient utilization

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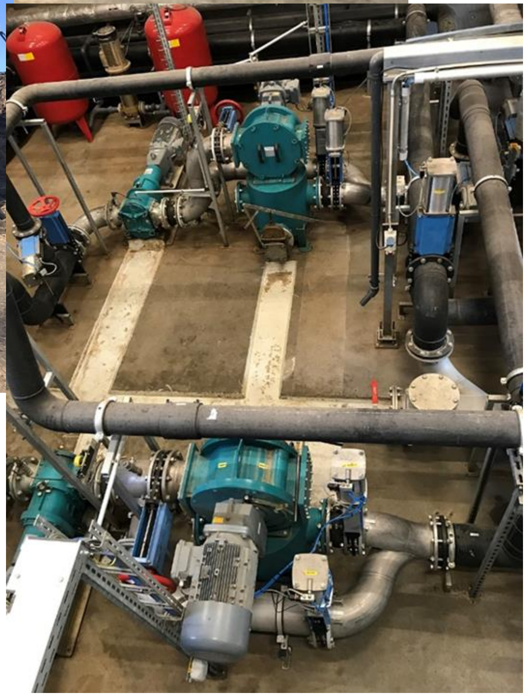
# Optimizing input

Pretreatment of biomass

(Co-)ensiling straw, e.g. with grass/turnip (-top)

Feed-in systems



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# Optimized application

Separation after digestion

”Designer” fertilizer products

F.x. Start-fertilizer for maize

…the better the utilization, the lesser the environmental impact!!!

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# Biogas Go Global

Biogas Go Global provides a **commercial, R&D and policy knowledge sharing platform** for the accelerated growth of the biogas industry in the United States, Denmark and other partner countries by establishing collaboration between industry, academia and the private sector.

The goal of Biogas Go Global is to **grow the global biogas sector** through partnerships between Danish and partner country stakeholders.

**www.biogasgoglobal.com**

WASTE, RECYCLING AND BIOGAS ADVISORY

Food & Bio Cluster Denmark

Danish Energy Agency


INDUSTRIENS FOND FREMMER DANSK KONKURRENCEEVNE

The Danish Industry Foundation

# Find more information…

www.foodbiocluster.dk

www.valuewaste.eu

www.biogasgoglobal.com

Contact:
Michael Støckler, mcs@foodbiocluster.dk
Claus Mortensen, cm@foodbiocluster.dk


- Less smell and leaching
- Less methane and laughing gas slip
- Jobs through local value chains
- Higher availibility of nutrients
- Increased recycling of nutrients
- Renewable and storable gas

# Polling Question 2: Equipment Challenges

For equipment & technology selection, which factor was the most important to your project success?

- Cost of ownership: capital & operating
- Methane slippage
- Uptime & dependability
- Lead-time to fabricate & install
- Complexity to operat

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# Kristian Laursen

## Ammongas A/S


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# History of Ammongas A/S

Now

2022 – Ammongas is acquired by European Energy A/S

2021 – Ammongas wins National District heating Award due to CCUS-project

2020 – Ammongas initiates CCUS-project with Technical University of Denmark and Thisted Municipality

2019 – Ammongas acquires Pro-unit Frames

2013 – First commercial biogas upgrading plant is built

2011 – First pilot biogas upgrading plant is built

2002 - Ammongas A/S is founded by Current CEO Anker Jacobsen.

2001 – Coolsorption is acquired by Aker Group and Current CEO Anker Jacobsen resigns as CEO of Coolsorption

1982 - Current CEO Anker Jacobsen registers "stripper-absorber concept for recovery of petrol Vapour"

1980 - Current CEO Anker Jacobsen founds the company Coolsorption

Then

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# AMMONGAS – ENGINEERING & CONSTRUCTION

**Office Location**
Copenhagen, Denmark

**Track record**
40+ plants around the world.
Russia, Brazil, Scandinavia

**Biogas upgrading**
Key-product. Earliest reference in 2011.
Total of 27 upgrading plants ranging from 88-5585 cfm

**Pro-Unit Frames**
In **2019**, Ammongas acquired Pro-Unit Frames, who helps construct the Ammongas plants.


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Biogas upgrading

$CO_2$-Polishing

Carbon-Capturing & Liquefaction

# Our role in Danish Biogas History

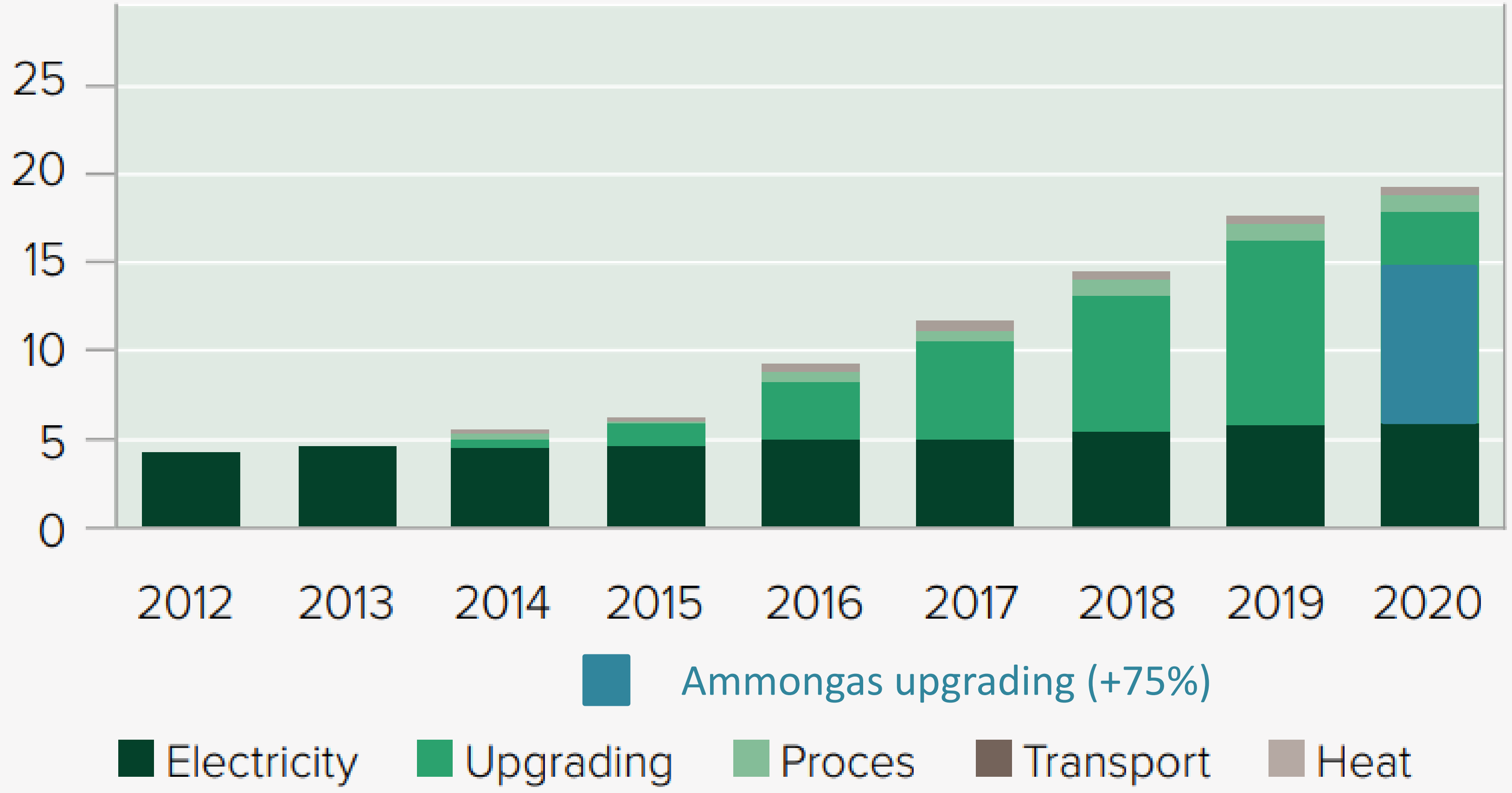
Heat & Electricity was initially the primary product of biogas

However utilizing biogas can only be done locally and can´t be transported easily

The Danish government initiated a subsidy program encouraging the development of biogas to biomethane economy

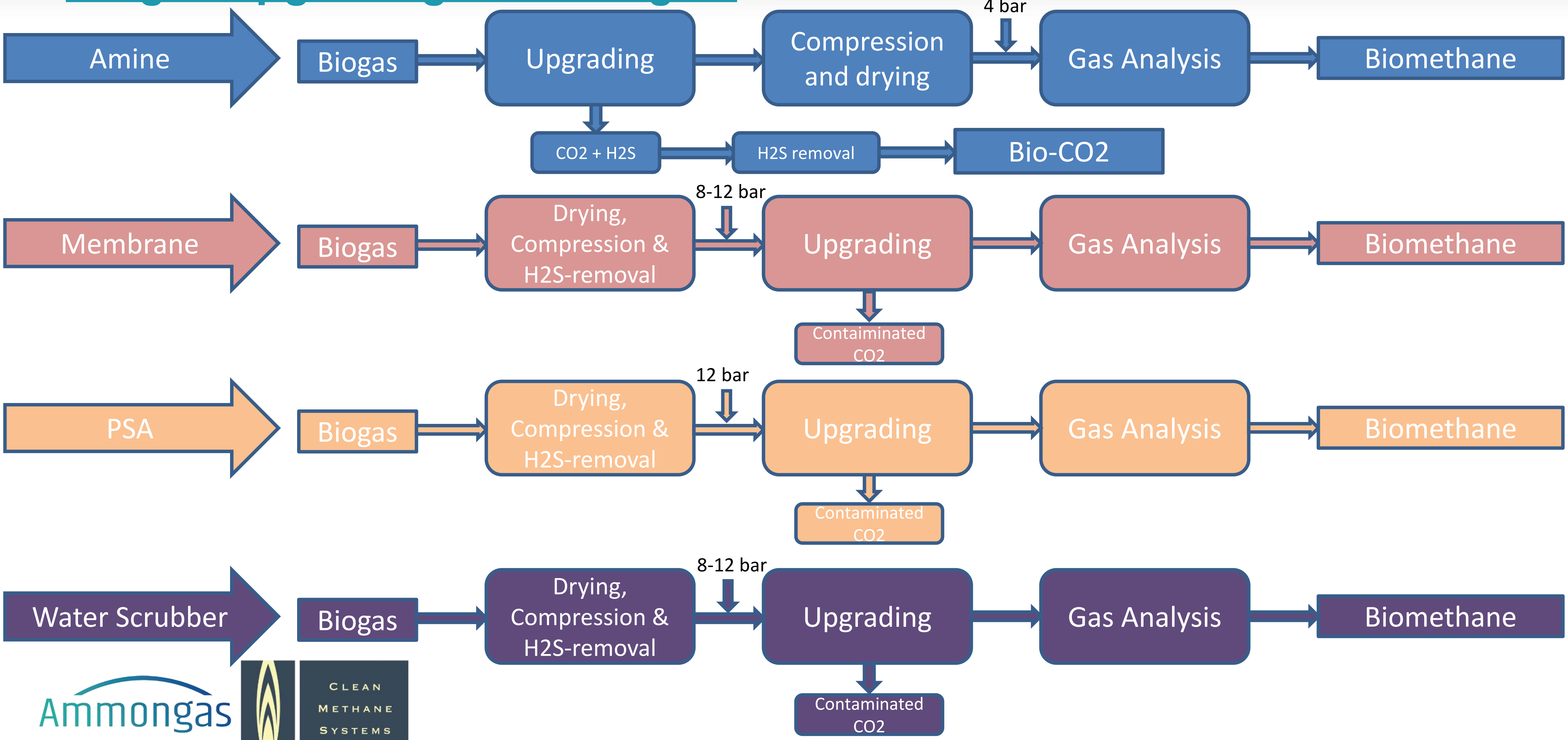
This supports circular economy not only locally, but is able to provide gas even to rural areas

Recent and expected biogas production and use in Denmark 2012-2020 (PJ).




Reference: “Biogas Production” by Michael Støckler

# Biogas upgrading technologies

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# THE BASIC FACTS


- Non pressurized system
- Low electrical consumption
- High CO2 and CH4 separation (>99.9 % CH4 possible)
- Methane loss guarantee less than 0.09%
- Pre-treatment of the biogas not required (H2S, VOC)
- 99% of the H2S is removed from the CO2
- CO2 can be used for other applications

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# PHASE 1: UPGRADING BIOGAS TO BIO METHANE

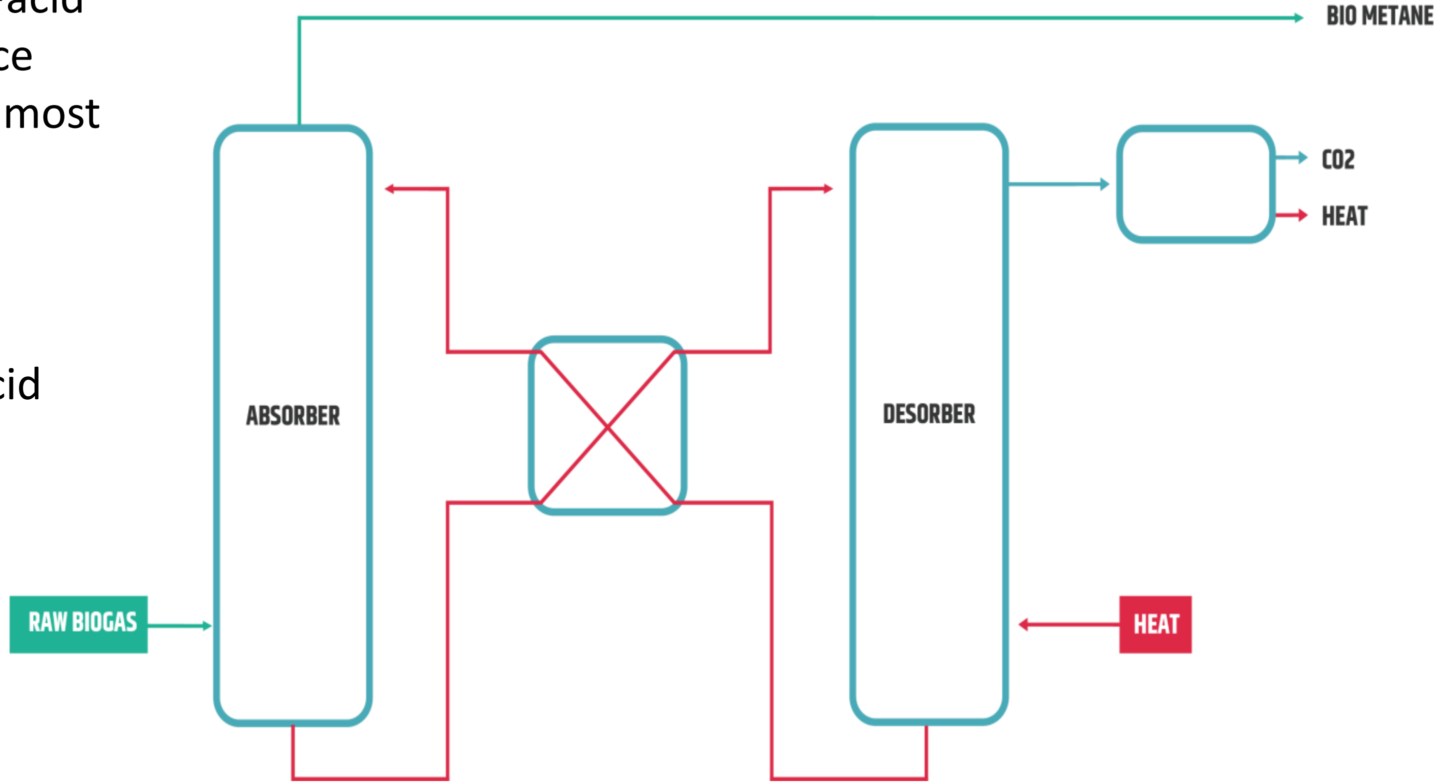
The amine-based chemical absorption process has been used for CO2 and H2S removal—acid gas removal—from gas-treating plants since 1950s and are considered to be by far the most developed CO2 capture process.

- Absorption/Desorption of $CO_2$ using amines
- CO2 reaction with water → carbonic acid

$$CO_2 + H_2O \Leftrightarrow H_2CO_3$$

- Carbonic acid reacts with amine.

$$RNH_2 + H_2CO_3 \Leftrightarrow RNH_3^+ + HCO_3^-$$

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# PHASE 1: UPGRADING BIOGAS TO BIO METHANE

## Absorption of $CO_2$

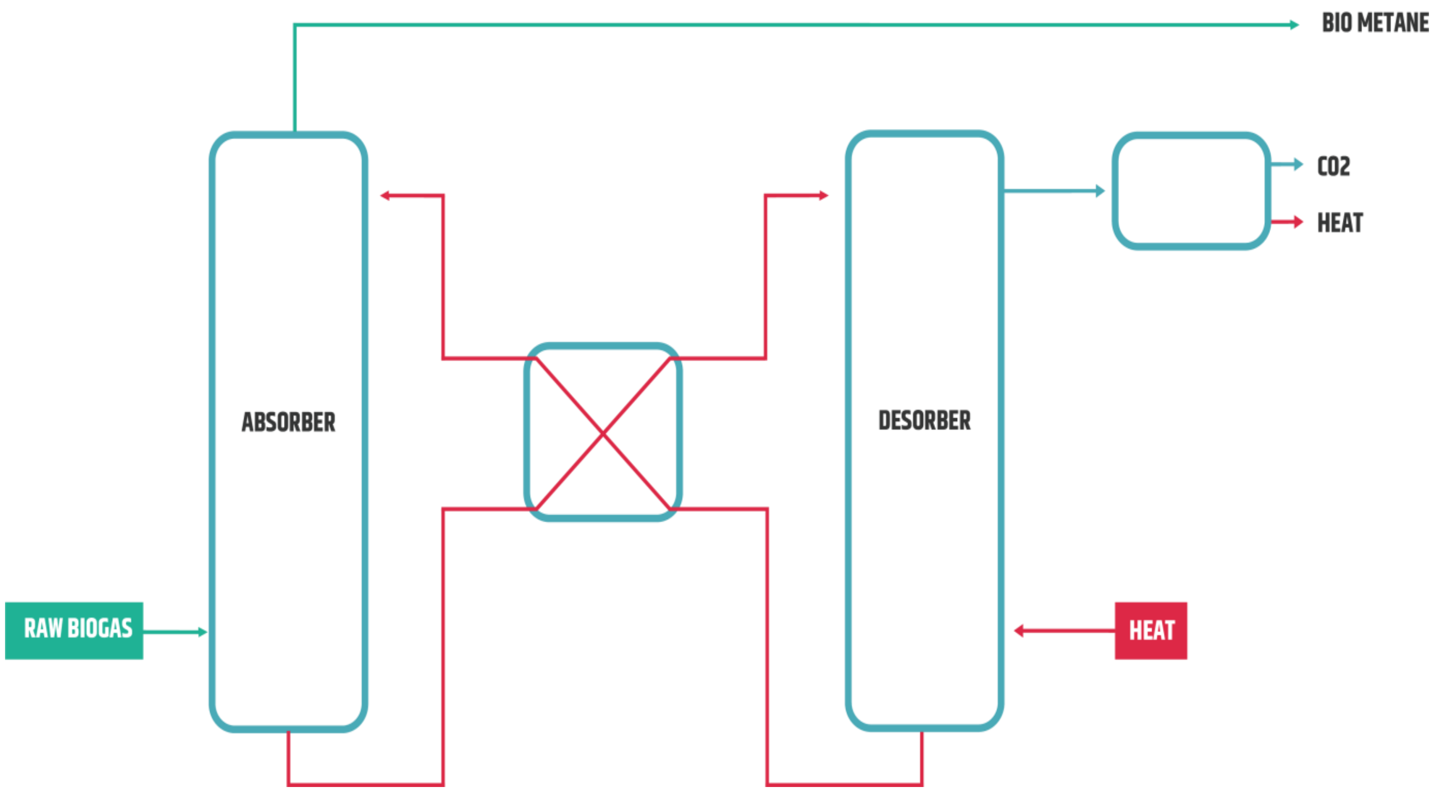
- $CO_2$ absorber (K1)
- Amine solution (alkaline liquid)

## Desorption of $CO_2$

- $CO_2$ desorber (K2)
- $CO_2$ saturated amine is regenerated

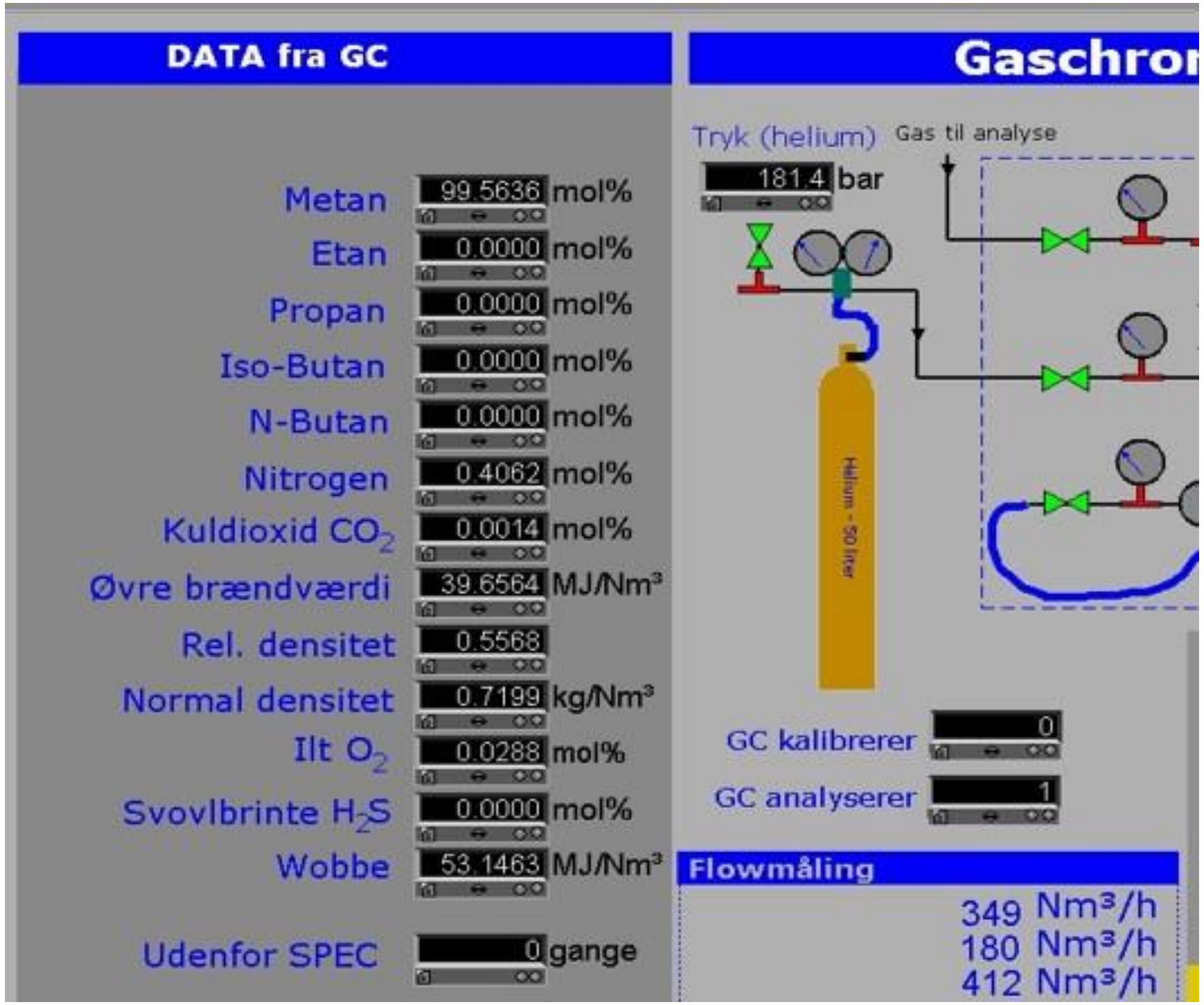
## Liquid handling

- Circulation between columns
- Cooling of $CO_2$
- Heating of amine



# BIOMETHANE PURITY

- CH4: 99.56 mol %
- CO2: 0.0014 mol %
- H2S: 0.000 mol %
- Methane slip: 0.09 %

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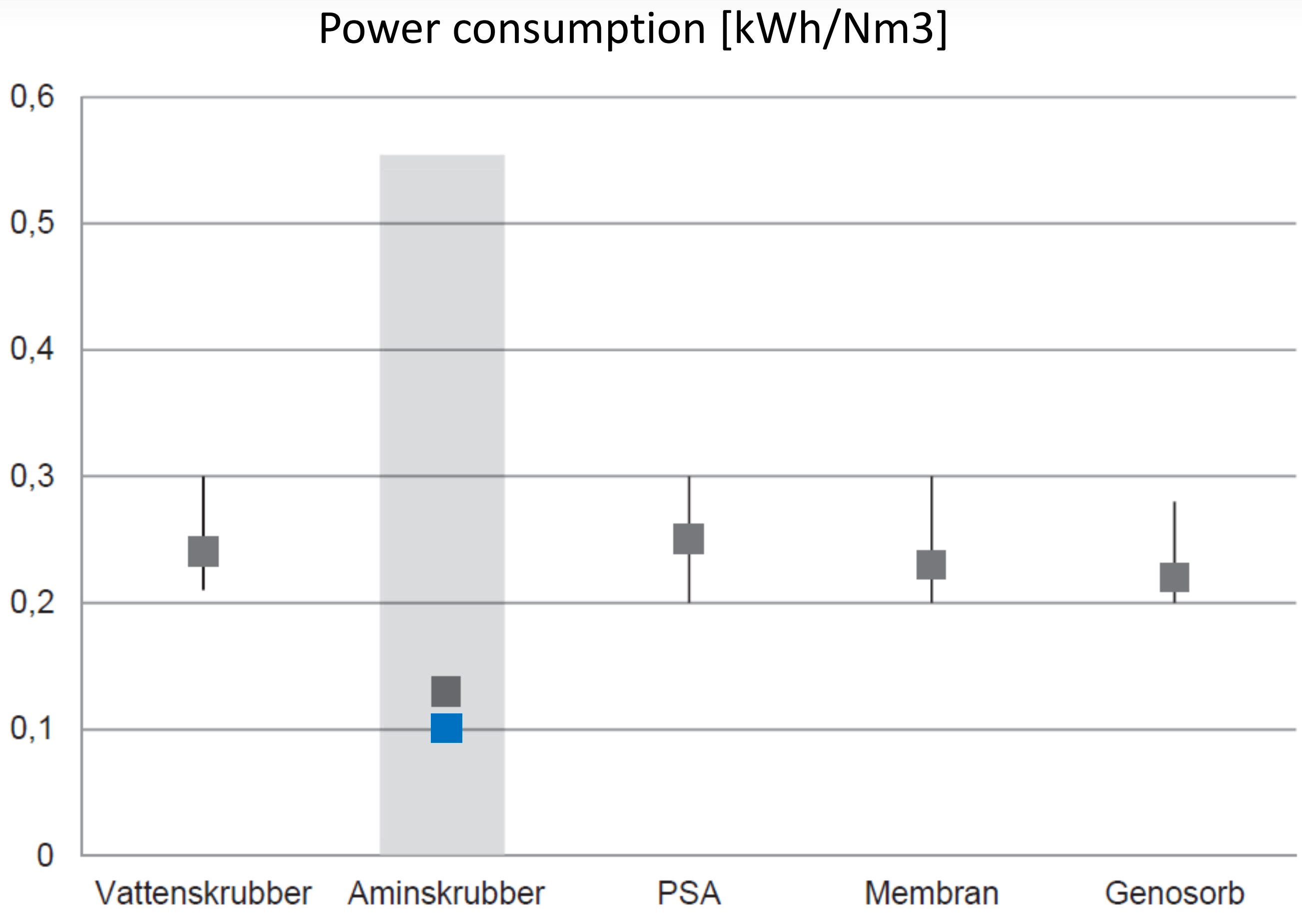
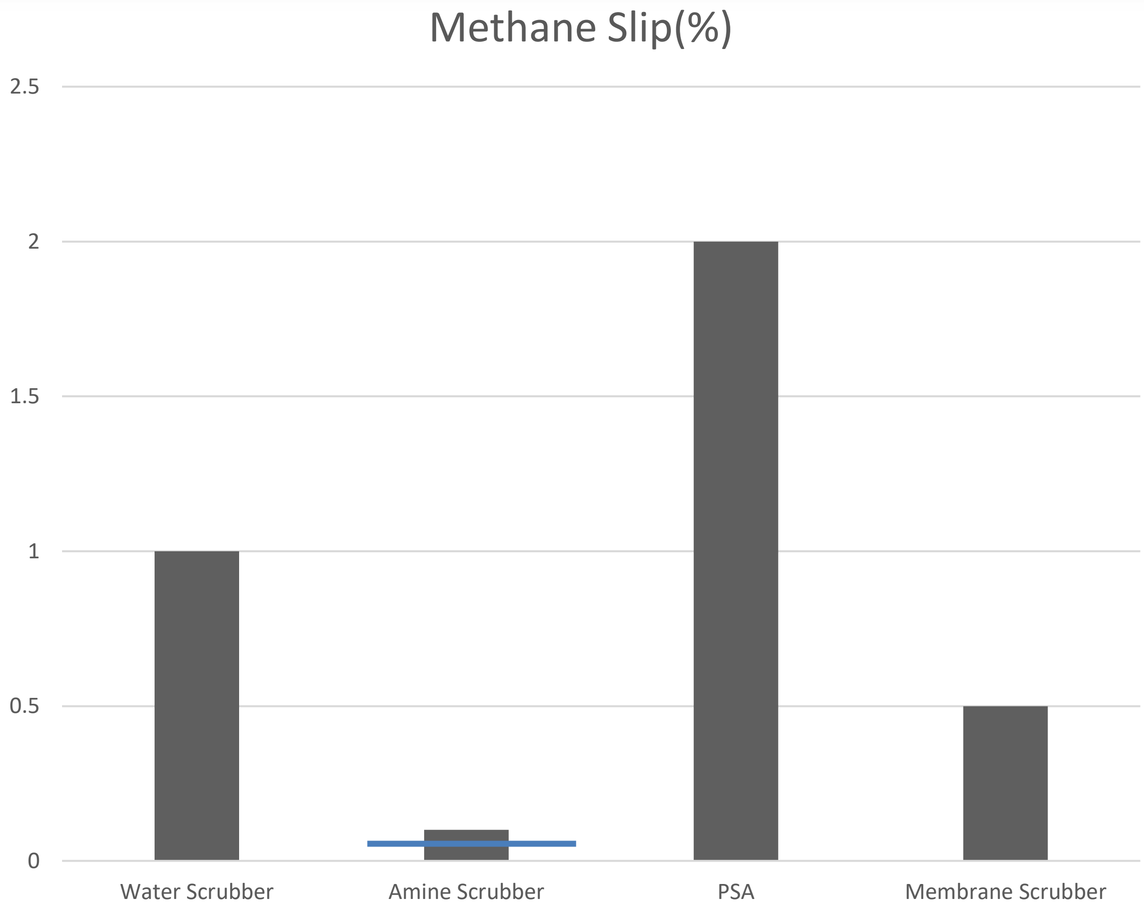
# ENERGY CONSUMPTION & LOSS OF INCOME

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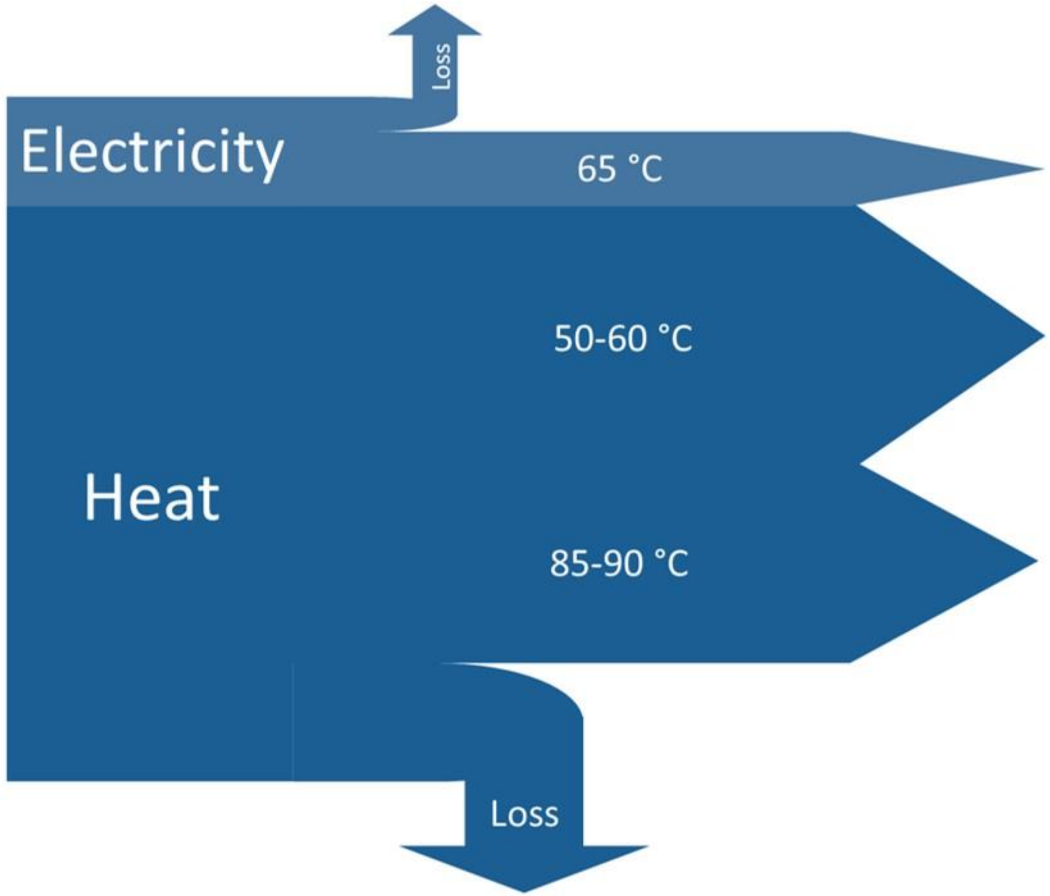
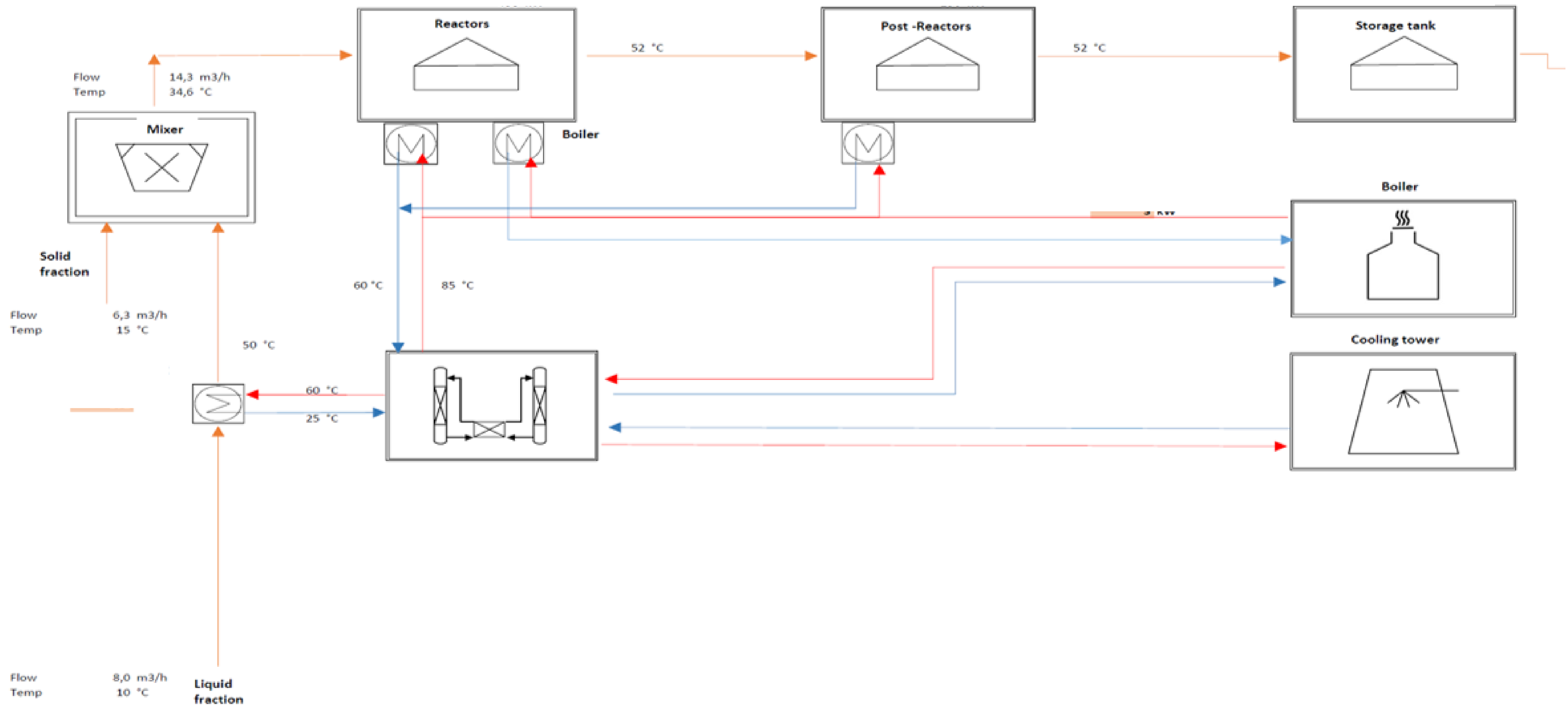
# HEAT INTEGRATION




- Amine uses heat to strip out CO2
- Heat can be recovered
  - 80 – 90 %
  - 35 – 40 % High Temperature
  - 45 – 50 % Medium Temperature

# HEAT BALANCE EXAMPLE



# MADSEN BIOENERGI, SKIVE DK

High temperature heat

Biomass heat exchanger

90 % Heat Recovery

Picture by Lundsby Biogas

# PRODUCTION

- AMMONGAS production site in Denmark
- High quality stainless steel
- Renowned sub-suppliers
- Built for easy maintenance and access

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# PRODUCT

- Skid mounted solutions “standard”
- Build in existing building
- Build in technical house
- Frames can be customized

- Container based solution
- One frame
- Smaller plants


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# HASHOJ, DK

- Pilot plant
- Capacity of 150 cfm (250 m3/h)
- Commissioned in 2011
- Currently used to test new solvents and working conditions
- We have a close cooperation with costumers and suppliers to continuously improve our systems

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# SAMPLE CONTAINERIZED UNIT < 200 scfm


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# UPGRADING PLANTS

**Hamar, Norway – 180 cfm (300 m$^3$/h)**

**Stormossen, Finland – 180 cfm (300 m$^3$/h)**

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# UPGRADING PLANTS

**Skive, Denmark – 700 cfm (1200 $m^3/h$)**

**Ivar, Norway – 765 cfm (1300 $m^3/h$)**

# UPGRADING PLANTS

## Iglsø, Denmark (1000 ppm H2S)

### Activated Carbon Filter

| Activated Carbon filter | Annual consumption |
|---|---|
| Activated Carbon | 201,060 lbs |
| Cost per lbs | 1.50 USD |
| Total annual expenses | 301,590.00 USD |

### Biological Desulphurization

| Biological Scrubber | Annual consumption |
|---|---|
| NPK | 1220 lbs |
| Cost per lbs | 1.20 USD |
| Total annual expenses | 1460.00 USD |

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# UPGRADING PLANTS

**Horsens, Denmark – 1770 cfm (3000 $m^3$/h)**

# Vinkel Bioenergi 4400 cfm (7500 m$^3$/h)

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# Vinkel Bioenergi 5400 cfm (9200 m³/h)

- From 7500 → 9200 through change of components
- Uses biological desulphurization instead of activated carbon filter

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# Vinkel Bioenergi 5400 cfm (9200 $m^3/h$)

Ammongas A/S upgrading plant at Vinkel produces CO2 as a by-product

Can be used in:

- Green houses
- Industries
- Green hydrocarbons
- Soft drinks
- Etc.

Biogas production becomes carbon negative


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## Timothy Robinson

## Clean Methane Systems

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# Addressing Market Access

**Market Access:** Logistics for producers to get biogas from the digester to a market for sale can be intimidating and expensive. Most significant are supply and feedstock agreements, logistics and gaining the cooperation of local gas distribution companies for grid injection.

**How has Denmark handled these challenges?**

# Project Suitability

**What makes a good project:** The vast majority of biogas projects are small and medium sized.  What are the metrics that make a good project and are there contracting, program and technology solutions to help?

**How has Denmark handled these challenges?**

# Complexity as a market obstacle

**Complexity:** Gas projects by nature have a lot of interested parties (gas producers, utilities, regulators, offtakers and consumers). As such the sheer complexity can by a barrier to entry. The producer and the utility often have difficulty interfacing over gas specs and testing requirements for example. Feedstock partners may not understand the contracting needs of the producer.

**How has Denmark handled these challenges?**

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# Managing the Risk

**Key Risks:** The RNG market is underdeveloped in part because of investor concerns over asset management strategies and one-off technology solutions. Such concerns mean that layers of “de-risking” costs are built into a point where only a few large and high-return projects are funded.

**How has Denmark handled these challenges?**

# Questions and Answers

**Tim Robinson**
**Clean Methane Systems (Moderator)**

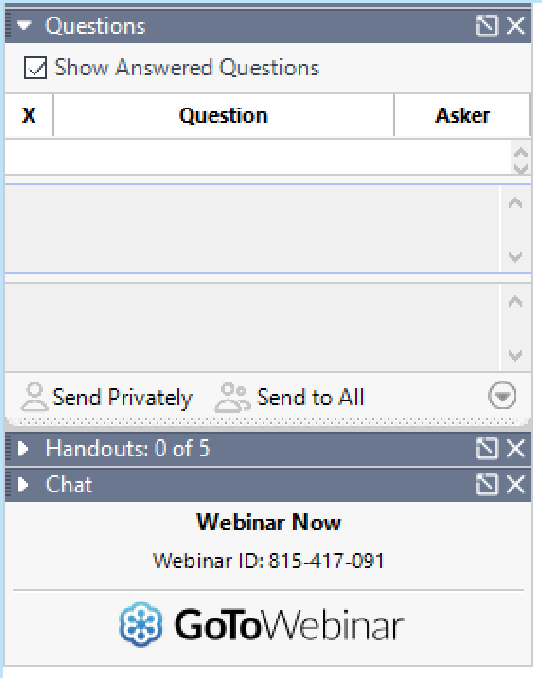
**Kristian Laursen**
**Ammongas**

**Michael Stockler**
**Food & Bio Cluster**

**Ask Questions using the Questions Panel on the right side of your screen.**

All questions and comments will be recorded.

A recording of the webinar and slides will be available by 1/23 to all ABC Members and all attendees of the webinar



# Upcoming Webinar:

## Biogas Desulfurization Experiences with THIPAQ Scrubbers

Wednesday, August 24, 2022 | 1:00 – 2:30 PM ET

All biogas and landfill gases contain hydrogen sulfide which needs to be significantly reduced in order to allow for beneficial use of the gas. A variety of technologies are available to remove hydrogen sulfide from gases. In this webinar, the THIOPAQ® hydrogen sulfide removal process will be explained and case studies from Paques' 27 year history implementing these systems will be presented.

**Speakers**:
Andrew Delgado, Total Process Systems
Martin Tielbaard, Paques Environmental Technologies

Register at americanbiogascouncil.org/webinars

# Thank you!

Don't forget to fill out the survey after the webinar

Become a member!

-Receive regulatory and policy intelligence

-Connect with other biogas and anaerobic digestion leaders

-Support the industry's growth and outreach

Thanks for attending!