

# Final report

## 1. Project details

<b>Project title</b>	Energi- og omkostningsoptimering af bionaturgasproduktion / Energy and cost optimization of biomethane production
<b>File no.</b>	64018-0512
<b>Name of the funding scheme</b>	EUDP
<b>Project managing company / institution</b>	Dansk Gasteknisk Center a/s / Danish Gas Technology Centre
<b>CVR number</b> (central business register)	12105045
<b>Project partners</b>	PlanEnergi, Aarhus Universitetet, Biogas Danmark, Dansk Fagcenter for Biogas, Evida Nord A/S & Evida Syd A/S.
<b>Submission date</b>	20 October 2021

In this report the terms describe:

**Biogas:** Gas consisting of methane (approx. 60%) and carbon dioxide / CO<sub>2</sub> (approx. 40%), which is formed when organic material decomposes under oxygen-free / anaerobic conditions. Organic material is livestock manure and organic residues from agriculture, industry and households, and possibly a small amount of energy crops.

**Upgraded biogas:** Gas produced from biogas. Can technically and safely can be injected into the Danish gas system (the gas quality meets the requirements of Executive Order no. 230 of 21/03/2018 on gas quality). Also called biomethane.

## 2. Summary

### Danish summary

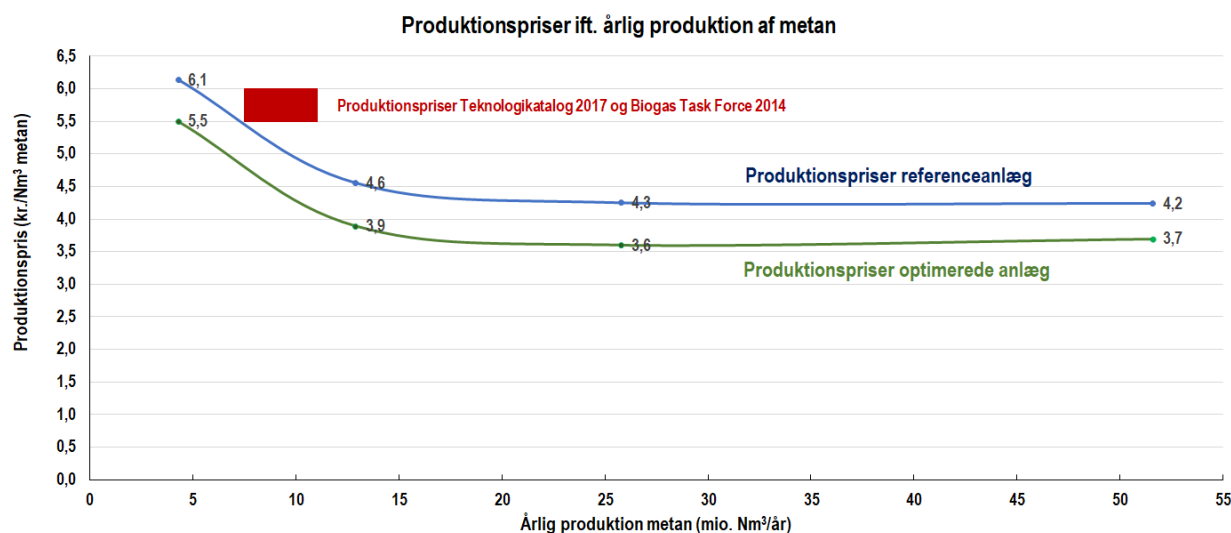
Projektets resultater viser, at opgraderet biogas kan produceres markant billigere end tidligere vurderet, og at der er potentiale for at sænke produktionsprisen yderligere. Der er identificeret optimeringspotentialer mellem 10 % og 16 %, afhængig af anlægsstørrelse og -konfiguration, inden for områderne:

- Gyllehåndtering og forbehandling
- Biomasseforbehandling
- Biogasproduktion
- Biogasopgradering
- Energiintegration af biogasproduktion og biogasopgradering.

Optimeringstiltagene kan gennemføres med dagens viden, kendt teknologi og udstyr, der er tilgængeligt på markedet i dag. Der er en række andre effekter, der også kan sænke produktionsprisen for opgraderet biogas. Disse effekter er ikke kvantificerede i dette projekt, men kvalitativt beskrevet. Effekterne kan være:

- Drift af flere anlæg i samme organisation
- Udvidelse af markeder ved etablering af mange nye biogasanlæg
- Generel læring og udvikling i biogasbranchen
- Metantabsmåleprogrammer.

Figuren nedenfor viser produktionspriser for forskellige anlægsstørrelser ift. årlig metanproduktion. Figuren viser, at produktionsprisen kan komme under 4 kr./Nm<sup>3</sup> metan. Energistyrelsens og Energinets teknologikatalog angiver en samfundsøkonomisk pris på 5,5 kr./Nm<sup>3</sup> metan. Der er kun angivet priser for en "typisk" biogasanlægsstørrelse på 7,5 mio. Nm<sup>3</sup> metan/år. Ea Energianalyse angiver i en rapport udarbejdet for Energistyrelsens Biogas Taskforce en samfundsøkonomisk produktionspris på 5,5-6,0 kr./Nm<sup>3</sup> metan, afhængig af biomassesammensætning, for en biogasanlægsstørrelse på 11,2 mio. Nm<sup>3</sup> metan/år.



## English summary

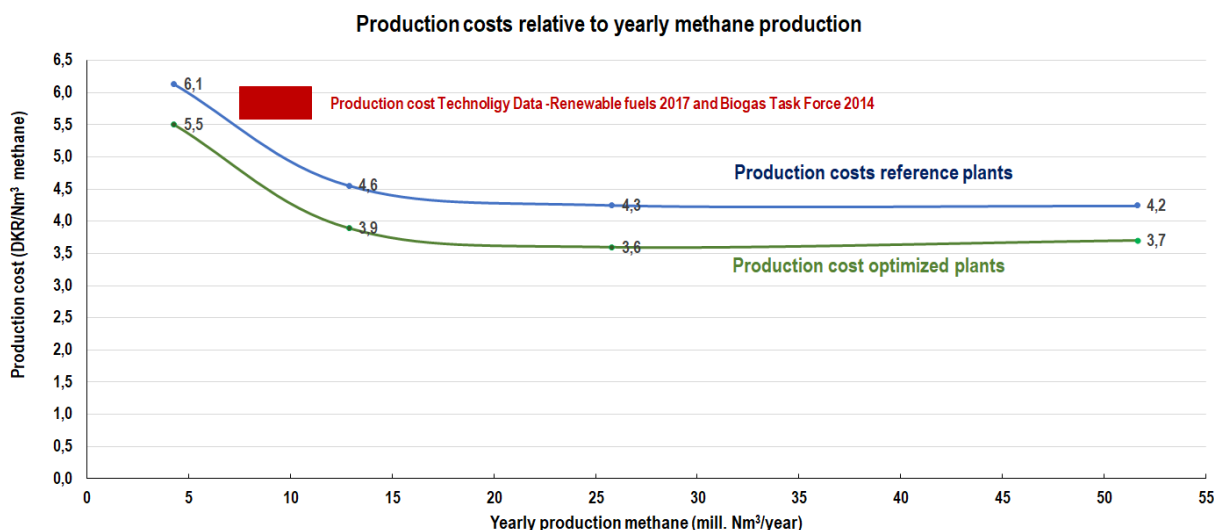
The results of the project show that upgraded biogas can be produced significantly cheaper than previously assessed, and that there is potential to reduce the production price further. Optimization potentials have been identified between 10% and 16%, depending on plant size and configuration, within the areas:

- Manure handling and pre-treatment
- Biomass pre-treatment
- Biogas production
- Biogas upgrading
- Energy integration of biogas production and biogas upgrading.

The optimization measures can be implemented with today's knowledge, known technology and equipment available on the market today. There are several other effects that can also reduce the production price of upgraded biogas. These effects are not quantified, but qualitatively described. The effects can be:

- Operation of several plants in the same organization
- Expansion of markets through the establishment of many new biogas plants
- General learning and development in the biogas industry
- Methane loss measurement programs.

The figure below shows production prices for different plant sizes in relation to annual methane production. The figure shows that the production price can fall below 4 DKK/Nm<sup>3</sup> methane. The Danish Energy Agency's and Energinet's Technology Data state a socio-economic price of 5.5 DKK/Nm<sup>3</sup> methane. Prices are only stated for a "typical" biogas plant size of 7.5 million Nm<sup>3</sup> methane/year. In a report prepared for the Danish Energy Agency's Biogas Taskforce, Ea Energianalyse states a socio-economic production price of 5.5-6.0 DKK/Nm<sup>3</sup> methane, depending on the biomass composition, for a biogas plant size of 11.2 million Nm<sup>3</sup> methane/year.

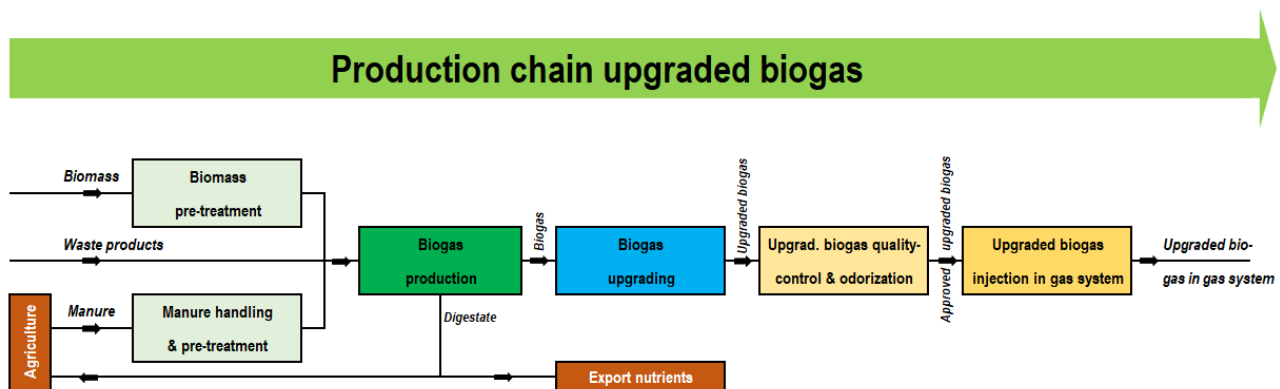


### 3. Project objectives

The main objectives of the project are to increase income, reduce cost, and reduce methane losses from production of upgraded biogas. The project addresses:

- Reduction of the energy consumption for biogas production and biogas.
- Increased use of recovered heat from the upgrading process and reduction of costs by integration of biogas upgrading and biogas production.
- Increased biogas yield by pre-treatment of biomasses.
- Reduction of methane losses in manure handling, biomass pre-treatment, in the biogas production and in the biogas upgrading.
- Reduced cost of quality control of upgraded biogas, injection into the gas system, and possibly compression.

The project addresses all steps in the production chain:



The project will result in suggested measures for:

- Methane loss reductions in stable systems, and the other steps of the upgraded biogas production.
- Increased biogas yield by pre-treatment of biomasses.
- Reduction of costs for pre-treatment of biomasses.
- Reduction of costs for transport of manure from supplier to biogas plant.
- Reduction of costs for process electricity and heat in the biogas plant and biogas upgrading plant.
- Reduction of costs for quality control and injection of upgraded biogas into the gas system.

The results of the project will be evaluated in an RDD (Research, Development and Demonstration) catalogue, so all stakeholders in the biogas business (consultants, suppliers, biogas plant owners and investors) will have an easily accessible tool to assist the decision on which measures are relevant for further evaluation in their specific plant.

The measures will be evaluated by weighing a decreased OPEX against any necessary increases in CAPEX, as well as by the climate improvement/reduction of methane losses.

As the identified and evaluated optimization measures can be implemented with today's knowledge, known technology and equipment available on the market today, no specific energy technology has been developed in the project.

## 4. Project implementation

The project evolved almost as initially planned, but with a delay of 5 months. The delay was caused mainly by COVID-19 lockdown in the spring 2020. During the lockdown, biomass pre-treatment tests were paused. The overall budget was not changed during the project, but reallocations between the project partners were made to tune the focusses in the project.

The project partners' organisations, and the assigned staff, remained unchanged during the implementation period.

During the implementation period (1¾ year/21 months) the biogas sector developed rapidly. The size of newly built biogas plants doubled in capacity, and more biogas plants increased the retention time in the biogas digester to accommodate slowly degradable biomasses.

Adjustment had to be made to the modelling of reference plants to include a very large biogas plant with short and long retention time. The number of calculations of the effect of optimization measures increased because of this.

During the implementation period, the three gas distribution companies merged into one, Evida. Before the merger each of them had different approaches to implementation of gas system injection facilities. During the merger, Evida, developed a uniform and optimized approach to the gas system injection facilities. This limited the possibilities to identify further optimization measures within this project.

## 5. Project results

### Objectives fulfilment

The original objectives of the projects were fulfilled with a few minor exceptions, e.g. suggested optimization measures for gas system injection facilities are limited due the merger of gas distribution companies in Denmark. During the merger, the gas system injection facilities were uniformed and optimized, thus limiting the potential for optimization withing this project

The project has addressed the EUPD targets:

Less dependency on fossil fuels: Production of upgraded biogas replaces fossil gas in the gas system.

Climate and environment: An efficient use of the process energy reduces the need for fuels, and reduced loss of methane reduces the climate impact.

Cost efficiency: Increased biogas yield increases the income as more biogas is produced from a given amount of biomass. A more efficient use of energy reduces the need for fuels, thus reducing operating costs. Reducing methane loss increases the income, as a larger share of the biogas is used for production of bio-methane. Reduction of the cost of the gas system connection reduces the connection fee and the operating costs.

Growth and jobs: Production of upgraded biogas provides jobs, both when biogas plants are being built, and later for the operation. The jobs are mainly in rural areas.

### Technological and commercial results

The results of the project show that upgraded biogas can be produced significantly cheaper than previously assessed, and that there is potential to lower the production price further. Optimization potentials have been identified between 10% and 16%, depending on plant size and configuration, within the areas:

- Manure handling and pre-treatment
- Biomass pre-treatment

- Biogas production
- Biogas upgrading
- Energy integration of biogas production and biogas upgrading.

In the project, a large number of optimization measures have been identified and analysed. The optimization measures can be implemented with today's knowledge, known technology and equipment available on the market today. Please refer to the public reports for details. A list of published reports is provided later in this section.

### Target group and added value for users

The target groups for the project's results are:

- Biogas plant operators and owners
- Consultants in the biogas sector
- Biogas and gas industry associations
- Public renewable energy administration.

The added values are:

- A comprehensive value chain analysis for production of upgraded biogas, which has been widely discussed with stakeholders in the biogas industry
- A large number of identified and analysed optimization measures
- Recommendations for implementation and further development projects.

### Dissemination

The project's results will be disseminated in:

- Public reports
- Articles in technical journals
- Presentations in conferences and seminars.

#### Public reports

The project's results are disseminated in public reports (in Danish). All reports can be downloaded from the Danish Gas Technology Centre's website:

<https://www.dgc.dk/produktion-af-opgraderet-biogas-optimering-af-omkostninger-og-klimaeffekt>

Main report with conclusions, recommendations and summaries and reports covering specific subjects:

- *Report title: Produktion af opgraderet biogas - optimering af omkostninger og klimaeffekt*  
ISBN no: 978-87-7795-428-3. Published: 25<sup>th</sup> November 2020  
Author: Dansk Gasteknisk Center a/s. Contact person: Thomas Hernø (email: [the@dgc.dk](mailto:the@dgc.dk))

Reports covering specific subjects:

- *Report title: Gyllehåndtering og forbehandling, optimering* (project work package 3)  
Published: 25<sup>th</sup> November 2020  
Author: PlanEnergi. Contact person: Karl Jørgen Nielsen (email: [kjn@planenergi.dk](mailto:kjn@planenergi.dk))
- *Report title: Biomasse forbehandling og optimering* (project work package 4)  
Published: 25<sup>th</sup> November 2020  
Author: Århus Universitetet.  
Contact person: Henrik B. Møller (email: [henrikb.moller@eng.au.dk](mailto:henrikb.moller@eng.au.dk))
- *Report title: Biogasproduktion, optimering* (project work package 5)

Published: 25<sup>th</sup> November 2020

Author: PlanEnergi. Contact person: Karl Jørgen Nielsen (email: [kjn@planenergi.dk](mailto:kjn@planenergi.dk))

- *Report title: Potentiale for optimering af biogasopgradering* (project work package 6)  
ISBN no: 978-87-7795-430-6. Published: 25<sup>th</sup> November 2020  
Author: Dansk Gasteknisk Center a/s. Contact person: Anette Hansen (email: [amh@dgc.dk](mailto:amh@dgc.dk))
- *Report title: Svovlrensning – metoder og anbefalinger* (project work package 6)  
ISBN no: 978-87-7795-431-3. Published: 25<sup>th</sup> November 2020  
Author: Dansk Gasteknisk Center a/s. Contact person: Anette Hansen (email: [amh@dgc.dk](mailto:amh@dgc.dk))
- *Report title: Energiintegration af biogasproduktion og opgradering* (project work package 7)  
Published: 25<sup>th</sup> November 2020  
Author: PlanEnergi. Contact person: Karl Jørgen Nielsen (email: [kjn@planenergi.dk](mailto:kjn@planenergi.dk))
- *Report title: Tilslutning til gassystemet* (project work package 8)  
ISBN no: 978-87-7795-432-0. Published: 25<sup>th</sup> November 2020  
Author: Dansk Gasteknisk Center a/s. Contact person: Thomas Hernø (email: [the@dgc.dk](mailto:the@dgc.dk))

#### Articles in technical journals

Articles about the project results will be published in:

- Bioenergimagasinet
- GASenergi
- Evida's quarterly report.

The articles have been agreed with the publishers and are currently being drafted.

#### Presentations in conferences and seminars

The project's approach and results have been presented in the following seminars and meetings and conferences:

- 6<sup>th</sup> March 2019 - Driftsledermøde (for operators of co-operative biogas plants).  
PlanEnergi. Subject: Project introduction.
- 13<sup>th</sup> May 2019 - Gastekniske Dage (Danish Gas Association conference)  
PlanEnergi. Subject: Manure handling.
- 9<sup>th</sup> October 2019 - Driftsledermøde (for operators of co-operative biogas plants).  
Danish Gas Technology Centre and PlanEnergi. Subject: Input for reference plant modelling.
- 3<sup>rd</sup> December 2019 - Økonomiseminar (Biogas Danmark conference).  
Aarhus Universitet. Subject: Biomass pre-treatment.
- 22<sup>nd</sup> October 2020 - Grøn Gas forum (Energinet seminar)  
Biogas Danmark. Subject: Optimeringspotentialer.

Planned presentations:

- 9<sup>rd</sup> December 2020 - Økonomiseminar (Biogas Danmark conference).  
Danish Gas Technology Centre: Subject: Project results  
Aarhus Universitet. Subject: Biomass pre-treatment  
PlanEnergi. Manure handling.

## 6. Utilisation of project results

### Utilisation of technological and commercial results

The project's results will be utilised by:

- Biogas plant operators and owners
- Consultants in the biogas sector
- Biogas and gas industry associations
- Public renewable energy administration.

The identified and analysed optimization measures give a broad overview of possibilities for reducing the cost for upgraded biogas. The measures can immediately be implemented in new and existing biogas plants.

The methodology and the prerequisites used for analysis of each optimization measure in the project can be used as template for customized evaluation of the feasibility of implementing the measure in a specific biogas plant.

The comprehensive value chain analysis for production of upgraded biogas, developed in this project, can be used for a homogenous cost evaluation for each step of the production process, e.g. when making feasibility studies for new biogas production and upgrading plant.

The value chain analysis can also provide input for a highly needed update of the "Technology Data – Renewable fuels" publication (Danish Energy Agency and Energinet 2017)

As shown, the production cost of upgraded biogas can be reduced significantly compared to what has been previously assessed. Potentially this allows biogas playing a more predominant role in the on-going green transition of the gas system if the appropriate incentives that are taking the findings into account are implemented.

## 7. Project conclusion and perspective

Biogas upgrading, with the close link between agriculture and large-scale energy production, is a relatively young sector. Biogas production has taken place in decades, where the biogas has been used for heat production in boilers, or production of electricity and heat in engines.

The first Danish biogas upgrading plant was established in 2011 at a wastewater treatment plant. Upgrading of agricultural-based biogas started in a large scale in 2015, when the current subsidy scheme came into force. It is expected that by the end of 2020, there will be 50 biogas plants with upgrading of biogas connected to the gas system. In the recent years, the trend has been towards very large biogas plants to reduce production costs.

The rapid development of the sector and expected future requirements for reducing the carbon footprint of green energy production, will require further development to mature the technology of biogas production and upgrading, as well as operational capabilities.

Biogas production and upgrading to the gas system have benefits for agricultural recycling of nutrients and greenhouse gas emissions, and for the energy system due to substitution of fossil gas. Energy from upgraded biogas is significantly more expensive than energy from wind and solar but has advantages in that gas can be stored cheaply, both in the short and long term, in contrast to the fluctuating production from wind and solar. Both producers and the state have a strong interest in reducing production costs for upgraded biogas.



The project has identified and analysed several optimization measures, that can increase revenues or reduce the costs and climate impact of the production of upgraded biogas. The optimization measures can be implemented with today's knowledge, known technology and equipment available on the market today, so the measures can be implemented immediately.

At the beginning of 2019, the entry of new grant recipients was closed under the current grant scheme, however, with exemption options for facilities that were under establishment. The reason was that the government's expenditure was too high and that the Ministry of Finance did not have the opportunity to make budgets, as before the intervention there was no ceiling on the number of facilities and the extent to which they could obtain support.

A new grant scheme is being established with a tender model as a basis for awarding grants. The new subsidy scheme will probably start in 2022. The tender model will give a strong focus on production prices of upgraded biogas.

Today there are no limits for methane loss from production of upgraded biogas (or biogas for other purposes) in e.g. legislation, methane loss is not linked to the size of the upgrade grant, and participation in methane loss measurement programs is voluntary. There is a general focus on reducing the carbon footprint from production of upgraded biogas, and the Minister of Climate, Energy and Supply already has legal authority to regulate the area. However, measurement of methane losses is difficult to do with sufficient accuracy, so the measurement results can e.g. be used for incentive or penalty in a grant scheme. Further development for reducing methane losses is needed, as well as development of mechanisms to initiate the sector to reduce losses.

## 8. Appendices

All public project reports can be downloaded from the Danish Gas Technology Centre's website:

<https://www.dgc.dk/produktion-af-opgraderet-biogas-optimering-af-omkostninger-og-klimaeffekt>