IEA Bioenergy
Technology Collaboration Programme

Task 37
Energy from Biogas

Final Task Report
Triennium 2019-2021

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Website:
http://task37.ieabioenergy.com/about-task-37.html

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INTRODUCTION

The specific objectives of the new Task as set out in the Triennium Proposal of September 2018 are:

- To provide expert advice on the optimal role of biogas in future energy systems

    - *Biomethane as a transport fuel:* Transport is the least decarbonised energy vector. Advanced biofuels are targeted at levels of 3.6% by energy content by 2030 in the recast Renewable Energy Directive (RED) indicating the immaturity of the market. Biomethane has a significant potential to provide sustainable gaseous transport fuel for buses and heavy commercial vehicles.

    - *Integration of biogas into the energy system:* Biogas facilities are dispatchable and can be operated in flexible mode. Such demand driven biogas facilities can operate intermittently to match periods of low electricity supply from intermittent renewable energy. Biogas can also provide a storage mechanism for renewable electricity in periods of high supply through use of power to gas upgrading ($4H_2 + CO_2 = CH_4 + 2H_2O$).

- To inform policy makes and developers of sustainability of biogas systems and methods to ensure good practice:

    - *Green gas certification & sustainability criteria:* Sustainability criteria are becoming more stringent and demanding higher levels of decarbonised renewable energy. Renewable energy systems need to be assessed for sustainability. This aligns with requirements in the recast RED such as for example renewable heat must satisfy 75% greenhouse gas savings by 2026. To prove such criteria and to minimize effort for the plant operators a standardized certification system is required. In the best case such a system may also be the basis for cross border trade of bioenergy products, in particular biomethane. Certification ensures that when green gas is purchased from the gas grid the purchaser is purchasing gas that is sustainable.

    - An objective is to ascertain how a scheme can move from the drawing board to implementation.
      Questions which need to be answered include: What are the practical requirements and the level of effort required to produce the data for the certificate? Who would run the scheme and what would be the cost of certification in terms of c/kWh or €/tCO_2 avoided? What is the potential for biogas plant operators to optimize the sustainability of the plant need?

    - *Good Management Practice of the anaerobic digestion facility:* It is crucial in a future energy system that optimal processes are in place to ensure sustainability, decarbonisation and optimal benefit to and minimal impact on the environment.

- To provide expert advice on the integration of anaerobic digestion into processes:

    - *Integration of anaerobic digestion into agricultural sector:* Biogas systems when employed in agriculture should be optimised and integrated using circular economy processes. All outputs including biogas and biofertiliser should maximise their potential to decarbonise the farm and minimise environmental impact on the environment.

    - *Increasing the range of feedstocks for anaerobic digestion:* Assess the potential for expansion of the anaerobic digestion industry through expansion of the array of feedstocks that can be employed to make biogas. This includes for pre-treatment of previously considered recalcitrant and ligno- cellulosic biomass.

  - *Integration of anaerobic digestion into biorefineries:* Asses the role of AD in the larger biorefinery concept.

- To provide technical support to policy makers and to the public through:

  - Providing a verified source of information on biogas production and utilisation to decision makers from both industry and governments.
  - Assisting both member and non-member countries in adopting appropriate energy crop, agricultural residue and waste management practices to improve environmental performance, reduce emissions, provide an additional source of renewable energy, improve the rural economy whilst producing an energy vector at an optimised price.
  - Providing verified data for determining greenhouse gas emissions used in sustainability assessment schemes.
  - Providing guidance to standards organisations in the development of appropriate standards supporting commercial exploitation of biogas/biomethane in the energy and fuels markets.
  - Stimulating interaction between RD&D programmes, industry and decision makers.
  - Informing the general public via the Task website.
  - Informing the general public through webinars and evidence of exemplar technologies in case stories.

BACKGROUND

The main objective of the Task 37 work programme is to address the challenges related to the economic and environmental sustainability of biogas production and utilisation. While there are many biogas plants in OECD countries, operation in the vast majority of cases can only be sustained with the help of subsidies to be able to compete with the fossil energy industrial sector. There is a clear need to enhance many of the process steps in the biogas production chain in order to reduce both investment and operating costs. This enhancement is now also required to effect significant decarbonisation and meet stringent sustainability criteria.
In 2013 – 2015 Task 37 produced reports on: substrates (sewage sludge, algae); pre-treatments including source separation of MSW; process optimisation (role of biogas in smart energy grids, process monitoring and nutrient recovery); and market development and trade of biomethane.In 2016-2018 Task 37 reported on: substrates (food waste); optimisation of the sustainability of the produced biogas through measurement and minimisation of methane slippage at biogas facilities; system optimisation (greening of the gas grid; the role of biogas in circular economies; integrated sustainable solutions). Best practice in the lab was assessed through interrogation of the biomethane potential assay. In 2019 – 2021 Task 37 reported on three broad themes: the role of biogas in energy systems; sustainability of biogas systems and methods to ensure good practice; and integration of biogas into processes.

To mitigate climate change, it is essential to develop integrated and sustainable decarbonised renewable energy systems. Heat and transport together, account for about 80% of final energy consumption. Significant progress has been made in renewable electricity but decarbonisation of transport fuel is problematic. Gaseous renewable energy carriers, such as renewable ‘green gas’ can have a considerable impact in future energy systems and play a key role in decarbonising heat and transport. Green gas at present is dominated by biomethane, which can be generated from the anaerobic digestion of organic biomass and residues produced in agriculture, food production and waste processing. Future interests include for renewable hydrogen, and the integration with existing natural gas infrastructure. Management of this process will require a green gas certificate scheme to ensure sustainability and to allow trade.

Recent EU policy measures facilitate the development of such pathways with progressively increasing obligations on decarbonisation. The share in renewable and low-carbon transport fuels (excluding first generation biofuels and including for electrification) is required to increase from 1.5% in 2021 to 6.8% in 2030, with advanced biofuels to make up at least 3.6% by that time. Biomethane can provide this advanced biofuel for intercity buses and heavy commercial vehicles.

The on-going requirement to decarbonise will lead to integration of anaerobic digestion systems in other processes, be they agricultural, agri-food, waste management and or beverage industry. Anaerobic digestion would also be seen as an integrated element in the biorefineries of the future.

REPORT ON THE TASK'S OBJECTIVES

The task had three objectives for the triennium as outlined below:

1. TO PROVIDE EXPERT ADVICE ON THE OPTIMAL ROLE OF BIOGAS IN FUTURE ENERGY SYSTEMS

The questions posed in this objective is what feedstocks can be used to make sustainable biogas, why are these feedstocks digested and how should the system be optimised. In this objective we included for three technical reports:

D7. Biomethane as a transport fuel

Target audience: Policy makers, Municipalities or Regional Authorities, Haulage Fleet, Bus services, Distribution services (Light Good Vehicle fleet), Biogas producers/developers, Gas Grid operator, Filling Stations

Champions: Sweden,Ireland, Norway, UK

A significant report of enhanced scale over that proposed (attracting a large budget) was published in December 2021 as below:

Ammenberg J., Gustafsson, M., O'Shea, R., Gray, N., Lyng, K-A., Eklund, M. and Murphy, J.D. (2021). Perspectives on biomethane as a transport fuel within a circular economy, energy, and environmental system. Ammenberg, J; Murphy, J.D. (Ed.) IEA Bioenergy Task 37, 2021:12.

Both the report and the two page summary are available for free to download at: http://task37.ieabioenergy.com/technical-brochures.html

Learning outcomes: *Natural gas systems should be a facilitator of the introduction of biomethane for transport, but the sustainability problems associated with natural gas negatively impact the view of biomethane. This is where arguments amongst the renewable sector actors can hinder progress.*
Biomethane and (power to methane) can utilize the existing gas grid and accelerate progress to decarbonization of the overall energy sector beyond just electricity and also to decarbonize chemical (such as ammonia and methanol) and steel production. This should be advantageous especially when realizing that more energy is procured from the natural gas grid than the electricity grid in the EU and the US; however, suggestions that biomethane is only greenwashing the natural gas industry, and in doing so extending the lifetime of natural gas, greatly impedes this progress. This report provides exemplars of very good biomethane based transport solutions, with a high technological readiness level for all elements of the chain from production to vehicles. Transport biomethane sits well in the broad circular economy, energy, and environmental system providing services across a range of sectors including reduction in fugitive methane emissions from slurries, treatment of residues, environmental protection, provision of biofertiliser, provision of food grade CO2 and a fuel readily available for long distance heavy haulage.

D8. Technical aspects of integration of biogas systems into the energy system:

Target audience: Biogas producers/developers, Grid operators, Energy customers, Municipalities, Policy makers.

Champions: Germany, Switzerland, Ireland

Collaboration: with Task 44 (Flexible bioenergy and system integration)

Report published in August 2020 as below:

Liebetrau, J., Kornatz, P., Baier, U., Wall, D., Murphy, J.D. (2020). Integration of Biogas Systems into the Energy System: Technical aspects of flexible plant operation, Murphy, J.D (Ed.) IEA Bioenergy Task 37, 2020:8

Both the report and the two page summary are available for free to download at: http://task37.ieabioenergy.com/technical-brochures.html

Learning outcomes: *Biogas is a versatile energy carrier which can be used to produce electricity, heat and after upgrading serve all functions of natural gas, including transport. Biogas systems are highly scalable in their energy output according to the demand from the particular energy sector. The flexibility of biogas systems can facilitate electricity production at a dynamic schedule to match an electricity demand profile, while facilitating voltage and grid stability. As a decentralised component of the overall energy system biogas systems can function as an infrastructure hub for local energy consumers in rural areas. Biogas can play an essential role (together with PV and wind) as part of a virtual power plant in local distribution energy grids. Biogas systems can operate as a biological battery in coupling the electricity and gas grids using surplus electricity to produce hydrogen to react with biogenic CO2 in biogas producing biomethane and increasing the output of biomethane (typically by 70 %). Innovation and ingenuity will be required of biogas operators in future energy systems.*

2. TO INFORM POLICY MAKES AND DEVELOPERS OF SUSTAINABILITY OF BIOGAS SYSTEMS AND METHODS TO ENSURE GOOD PRACTICE:

D9. Green gas certification & sustainability criteria:

Target audience: Policy makers, Biogas producers/developers, Gas Industry (Gas Grid Operators, Gas Traders), Gas customers

Champions: Germany, Ireland

Collaboration: Inter-Task project including for European Commission DG Energy, IEA Bioenergy Germany, IEA Bioenergy Sweden, IEA Hydrogen and IEA Bioenergy Tasks 37/40 & 45.

The work includes for collaboration on Renewable Gas and a second broader collaboration "Renewable Gas – Hydrogen in the grid" led by Uwe Fritsche.

Both the Task 37 report and the two page summary are available for free to download at: http://task37.ieabioenergy.com/technical-brochures.html

Report published in November 2021 as below:

Liebetrau, J., Rensberg, N., Maguire, D., Archer, D., Wall, D., Murphy, J.D. (2021) Renewable Gas – discussion on the state of the industry and its future in a decarbonised world, Murphy, J.D. (Ed.)

IEA Bioenergy Task 37, 2021:11.

Learning outcomes: *The existing natural gas infrastructure is very extensive in many industrialised countries and rather than being viewed as a future redundancy associated with a fossil fuel system, it could instead be seen as offering huge benefits for green renewable gas as a future decarbonised energy carrier. The whole natural gas infrastructure system was put in place at huge cost and includes for an extensive transport system of transmission and distribution pipes and connections to industries and homes. Within specific industries, gas boilers, CHP units and associated systems are in place to provide the necessary ingredients and energy provision for end products that range from ammonia to* *whiskey. Traditional renewable gas technologies (such as biogas and biomethane) can be considered mature. For example Denmark has at times substituted natural gas in the grid with over 25% biomethane. In terms of policy we have devised and put in place trading mechanisms for trade between producer and user of renewable gas, sometimes in different countries. The economic feasibility is questioned, however this is a green fuel which is being compared to a fossil fuel where the present cost of carbon in no way takes account of the climate emergency. As such, it is preferable to contrast the cost of renewable technologies with the cost of other renewable technologies which are viable in that sector; for example we should not compare the cost of abatement of mature technologies in readily decarbonised sectors (say PV arrays) with that of an advanced transport fuel that can power heavy transport but is at an early stage of development. We need to incentivize technologies at early market maturity and at low technology readiness levels (TRL) that are seen to have great potential for application as fuels of the future for hard to abate sectors such as hydrogen and associated electro-fuels.*

The above work provided content to a synthesis report:

Biomethane – factors for a successful sector development Synthesis Report of WP1 of the IEA Bioenergy Intertask project Renewable gas - deployment, markets and sustainable trade Authors: Jan Liebetrau, IEA Bioenergy Task 37 Uwe Fritsche, Hans Werner Gress, IEA Bioenergy Task 40

D10. Drivers for successful biogas schemes and their sustainability: International perspectives:
Target audience: municipality, academics, practitioners, farmers, agri-food, utlility gas grid operators, stakeholders, policy makers

Champions: Canada, Contributor: all.

The report is published and can be referenced as follows:

Wellisch, M., Green, J., McCabe, B., Rasi, S., Siemens, W., Ammenberg, J., Liebetrau, J., Bochmann, G., Murphy, J.D. (2020). Drivers for Successful and Sustainable Biogas Projects: International Perspectives – Report of a symposium held on March 26, 2020. Green, J., Wellisch, M., Szlachta, P., Murphy, J.D. (Ed.) IEA Bioenergy Task 37, 2020: 5

Learning outcomes: *The drivers for successful and sustainable anaerobic digestion projects are country and context specific. The challenge that such projects face - in all countries - is how to make anaerobic digestion projects financially viable. We know from countries that have biogas plants that supportive policies are required in a number of areas, including waste management, renewable energy and climate change mitigation. To make these projects work, financial assistance, such as capital grants and multi- year power purchase agreements with a significant premium, is needed to attract the necessary investment. In this symposium we heard from seven IEA Bioenergy Task 37 Member countries – Australia, Finland, The Netherlands, Sweden, Germany, Austria and Ireland. Collectively they painted a picture of how the right combination of feedstocks, technologies and policies are required for a successful and sustainable project. The solutions are not "one size" fits all, but country specific.*

The report is available for free to download at:
http://task37.ieabioenergy.com/technical-brochures.html

3. TO PROVIDE EXPERT ADVICE ON THE INTEGRATION OF ANAEROBIC DIGESTION INTO PROCESSES:

D11. Integration of anaerobic digestion into farming systems:

Target audience: farmers, agricultural stakeholders, policy makers

Champions: Australia, Canada, Italy, and the UK

The report is published and can be referenced as follows:

McCabe, B., Kroebel, R., Pezzaglia, M., Lukehurst, C., Lalonde, C., Wellisch, M., Murphy, J.D. (2020). Integration of Anaerobic Digestion into Farming Systems in Australia, Canada, Italy, and the UK. Lalonde, L., Wellisch, M., Murphy, J.D (Ed.) IEA Bioenergy Task 37, 2020: 8

Learning outcomes: *The four countries - Australia, Canada, Italy, and United Kingdom - differ with respect to their size, climate, and type of agricultural production. Canada and Australia have the largest landmass but vastly different climates. Anaerobic digestion and biogas production in the agriculture sector is highest in Italy, followed by the UK, Australia, and Canada. The adoption of anaerobic digestion (AD) has grown in all four of these countries over the last decades, albeit at different rates. In all cases, energy and climate change policies have been the dominant drivers that have enabled growth. The environmental sustainability of agriculture has many facets. In this section of the report, each country description provides a different lens on sustainability and the role of anaerobic digestion.*

The report is available for free to download at:
http://task37.ieabioenergy.com/technical-brochures.html

D12. Increasing the range of feedstocks for anaerobic digestion

Champions: Switzerland,

Contributors: Austria, Canada, China, Germany, Ireland

Audience: operators of biogas facilities, farmers and agricultural organizations, feedstock suppliers, policy makers and consultants

Expected completion date: unsure, maybe Q2, 2022

Scope:

- Describe substrate characteristics which define anaerobic degradability;
- Give examples and describe the characteristics, source and potential of recalcitrant feedstocks;
- Give an overview of possibilities and concepts for further treatment of digestate such as thermal conversion;
- Give an overview of technically available pre-treatment technologies for poorly degradable substrates and possibilities to implement them into the anaerobic digestion process;
- Present an overview of technically available concepts to enhance substrate digestibility through AD process alteration such as: multi-stage digestion; inline treatment (such as ultrasonic or maceration) or leaching processes followed by UASB.
- Detail decision making processes for assessing suitability of low-quality feedstocks.

- Provide examples of successful implementation of range expanding processes for substrate utilisation.

D14. Integration of anaerobic digestion into industrial bioprocessing:

Champions: Austria,

Contributors: Australia, Canada, China, Norway, Finland, Sweden

Audience: operators of biogas facilities, farmers and agricultural organizations, feedstock suppliers, policy makers and consultants

Expected completion date: unsure, maybe Q1, 2022

The report will focus on food and beverage and pulp and paper industries. A number of examples will be presented including for abattoirs, dairies, breweries, distilleries, olive mills, sugar factories, potato industry, wineries, juice factory. The analysis will include for feedstock, fermentation, process integration, gas utilisation and energy balances.

Extra Deliverable: Manure potential, economics, government investment, economics

Audience: operators of biogas facilities, farmers and agricultural organizations, feedstock suppliers, policy makers and consultants

Champions: Germany; Australia; Austria; Norway; Canada, Ireland and the UK

Both the report and the two page summary are available for free to download at: http://task37.ieabioenergy.com/technical-brochures.html

The report was published in June 2021 as follows:

Liebetrau, J., O'Shea, R., Wellisch, M., Lyng, K.A., Bochmann, G., McCabe, B.K., Harris,P.W., Lukehurst, C., Kornatz, P., Murphy, J.D. (2021) Potential and utilization of manure to generate biogas in seven countries, Murphy, J.D. (Ed.) IEA Bioenergy Task 37, 2021:6.

Learning outcomes: *Production of biogas from manure at a farm level is the very epitome of a sustainable bioenergy system. The system incorporates a circular economy decentralised production of organic biofertilizer and biogas for use in heat, power or transport fuel, whilst simultaneously reducing fugitive methane emissions from open slurry holding tanks, reducing smells and minimising pollution effects on rivers and wells. Why therefore is the practice of producing biogas from manure not more widespread? The characteristics of manure depend on farm animal source and the method of husbandry, which in turn leads to a wide range of levels of technically available manure resource and costs of biogas produced from manure. To exemplify this, IEA Bioenergy published this report which examines the potential of manure for utilization in biogas facilities across seven countries: Germany; Australia; Austria; Norway; Canada, Ireland and the UK. These countries have differing levels of biogas industry, very different farming practices and a range of climates. It is hoped that the country selection should allow the lessons learned from these seven countries to be applied to many countries across the planet.*

D4: Country Reports and Databases

See: http://task37.ieabioenergy.com/country-reports.html

IEA Bioenergy Task 37: A perspective on the state of the biogas industry from selected member countries
This publication contains a compilation of summaries of country reports from member countries of IEA Bioenergy Task 37 (Energy from Biogas). Each country report summary includes information on the number of biogas plants in operation, biogas production data, how the biogas is utilised, the number of biogas upgrading plants, the number of vehicles using biomethane as fuel, the number of biomethane filling stations, details of financial support schemes in each country and some information on national biogas projects and production facilities. The publication is a regular update and is valid for information collected in 2020-2021. Reference year for production and utilisation is 2020, unless stated otherwise.

IEA Bioenergy Task 37 – Country Reports Summaries 2019
This publication contains a compilation of summaries of country reports from members of IEA Bioenergy Task 37 (Energy from Biogas). Each country report summary includes information on the number of biogas plants in operation, biogas production data, how the biogas is utilised, the number of biogas upgrading plants, the number of vehicles using biomethane as fuel, the number of biomethane filling stations, details of financial support schemes in each country and some information on national biogas projects and production facilities. The publication is an annual update and is valid for information collected in 2019. Reference year for production and utilisation is as a rule 2018.

4. TO PROVIDE TECHNICAL SUPPORT TO POLICY MAKERS AND TO THE PUBLIC:

D.13. Case Stories

Fourteen case stories were published.
See: http://task37.ieabioenergy.com/case-stories.html:

Integration of anaerobic digestion into farming systems

- Corn straw biogas production in cold northern region of China, December 2021
- Minhe Chicken Manure Biogas Plant: Circular economy management of chicken manure, June 2021
- Deep bedding: a co-digestion substrate with significant potential Danish experience with handling and feeding deep bedding, November 2020
- Mono-digestion of chicken litter: Tully Biogas Plant, Ballymena, Northern Ireland, January 2019
- Compact and automated on-farm biogas production in South Western Ontario, Canada, April 2020 Case Story Canada

Integration of anaerobic digestion into energy systems

- Greening the gas grid in Denmark, February 2019
- Distributed generation using biogas in a microgrid in the Western Region of Parana, Brazil, February 2019

Integration of anaerobic digestion into food systems

- Production of food grade sustainable CO2 from a large biogas facility GO’CO2 at The Korskro Biogas Plant, Denmark, November 2020

- Biogas production from kitchen wastes in Jinhua, China, December 2021

Integration of anaerobic digestion into industrial processes

- Treatment of pigment wastewater and generation of natural gas standard biomethane in Hangzhou, China, December 2021

- Circular economy system integrating biogas into process to produce high quality products from recycled paper, July 2021

Integration of anaerobic digestion in organic farming

- Organic biogas improves nutrient supply, Kroghsminde Bioenergy I/S, Denmark February 2019

Integration of anaerobic digestion in electro-fuel production

- Green methanol from biogas in Denmark a versatile transport fuel, November 2020

Integration of anaerobic digestion in biorefineries

- BIOWERT GRASS BIOREFINERY, BIOBASED PLASTICS, GERMANY June 2019

SUCCESS STORY

Problem Statement: How do we integrate anaerobic digestion and biogas systems into processes to maximize overall decarbonization and environmental protection?

Synthesis of output: This triennium (2019 – 2021) concentrated on the integration of anaerobic digestion and biogas systems into processes with the overarching aim of reducing the carbon footprint of the processes and enhancing environmental protection. This may be exemplified in industrial applications in the treatment of pigment wastewater [1] and in processes producing products from recycled paper [2].

However biogas is typically perceived and assessed as an energy vector. In this regard we do not see biogas as an energy vector that can be readily compared with a wind turbine or a PV array; it is not a stand-alone system with one output. It fits into a system or process and ideally enhances that system through reduction of carbon footprint and improvement of the environment. When energy analysts assess the marginal abatement cost of renewable energy technologies, it is essential for anaerobic digestion systems that the boundary be expanded for all the products and services provided. For example a typical farm digester provides biogas as an energy source but can also provide biofertilizer for an organic farm [3] and food grade CO_2 [4].

In assessing biomethane as a transport fuel it is difficult to compare with electrification or hydrogen (from electrolysis of renewable electricity) as biomethane is only one output of the anaerobic digestion process [5]. Transport biomethane sits well in the broad circular economy, energy, and environmental system providing services across a range of sectors including reduction in fugitive methane emissions from slurries, treatment of residues, environmental protection, provision of biofertiliser, provision of food grade CO_2 and a fuel readily available for long distance heavy haulage [5].

The role of gas as an energy vector and as an ingredient in the production of essential chemicals is exemplified when we note that up to twice as much energy is taken from the gas grid as the electricity grid in the US and the EU [6]. The existing natural gas infrastructure was put in place at huge cost and includes for an extensive transport system of transmission and distribution pipes and connections to industries and homes. Within specific industries, gas boilers, CHP units and associated systems are in place to provide the necessary ingredients and energy provision for end products that range from ammonia to whiskey. Biomethane (and hydrogen) have a huge role to play in providing decarbonised hydrogen molecules for ammonia (NH_3) and methanol (CH_3OH) [6]. Denmark has managed at times to provide 25% of their gas demand from biomethane [7] whilst some of these plants have simultaneously satisfied the 65,000 t/a CO_2 market [4].

Renewable gases (biomethane and hydrogen) are essential tools for decarbonisation especially of the hard to abate sectors of heavy transport, industry, production of chemicals and steel, and of course agriculture.

Relevant publications, technical reports, case stories and databases:

1. Treatment of pigment wastewater and generation of natural gas standard biomethane in Hangzhou, China, December 2021

2. Circular economy system integrating biogas into process to produce high quality products from recycled paper, July 2021

3. Organic biogas improves nutrient supply, Kroghsminde Bioenergy I/S, Denmark February 2019

4. Production of food grade sustainable CO2 from a large biogas facility GO'CO2 at The Korskro Biogas Plant, Denmark, November 2020

5. Ammenberg J., Gustafsson, M., O'Shea, R., Gray, N., Lyng, K-A., Eklund, M. and Murphy, J.D. (2021). Perspectives on biomethane as a transport fuel within a circular economy, energy, and environmental system. Ammenberg, J; Murphy, J.D. (Ed.) IEA Bioenergy Task 37, 2021:12.

6. Liebetrau, J., Rensberg, N., Maguire, D., Archer, D., Wall, D., Murphy, J.D. (2021) Renewable Gas – discussion on the state of the industry and its future in a decarbonised world, Murphy, J.D. (Ed.) IEA Bioenergy Task 37, 2021:11.

7. Greening the gas grid in Denmark, February 2019

Benefits to Industry:

The triennium has produced 6 significant technical reports and 14 case stories that provide a narrative on integration of anaerobic digestion and biogas into systems which enhance decarbonisation and improve environment.

We presented a synthesis of these findings in Australia (Virtually) initially at a Bioenergy Australia event and shortly after at two sessions of the IEA ExCo Conference

Workshops

http://task37.ieabioenergy.com/workshops.html

- IEA Bioenergy ExCo Conference State of the art and innovation in Green Gas, Thursday 2 Dec 2021
  See: https://www.ieabioenergyconference2021.org/#agenda

- IEA Bioenergy ExCo Conference Green Gas Perspectives Thursday 2 Dec 2021
  See: https://www.ieabioenergyconference2021.org/#agenda

- Bioenergy Australia Webinar: IEA Bioenergy Task 37 - The role of renewable gas in decarbonization and current status of biomethane frameworks in IEA Bioenergy member countries.
  See: https://www.bioenergyaustralia.org.au/events/117500/

CONCLUSIONS AND RECOMMENDATIONS

Current state-of-the-art and future potential

The main objective of the Task 37 work programme is to address the challenges related to the economic and environmental sustainability of biogas production and utilisation. While there are many biogas plants in OECD countries, operation in the vast majority of cases can only be sustained with the help of subsidies to be able to compete with the fossil energy industrial sector. There is a clear need to enhance many of the process steps in the biogas production chain in order to reduce both investment and operating costs. This enhancement is now also required to effect significant decarbonisation and meet stringent sustainability criteria.

In 2013 – 2015 Task 37 produced reports on: substrates (sewage sludge, algae); pre-treatments including source separation of MSW; process optimisation (role of biogas in smart energy grids, process monitoring and nutrient recovery); and market development and trade of biomethane.

In 2016-2018 Task 37 reported on: substrates (food waste); optimisation of the sustainability of the produced biogas through measurement and minimisation of methane slippage at biogas facilities; system optimisation (greening of the gas grid; the role of biogas in circular economies; integrated sustainable solutions). Best practice in the lab was assessed through interrogation of the biomethane potential assay. In 2019 – 2021 Task 37 reported on three broad themes: the role of biogas in energy systems; sustainability of biogas systems and methods to ensure good practice; and integration of biogas into processes.

To mitigate climate change, it is essential to develop integrated and sustainable decarbonised renewable energy systems. Heat and transport together, account for about 80% of final energy consumption.

Significant progress has been made in renewable electricity, but decarbonisation of transport fuel is not advanced. Gaseous renewable energy carriers, such as renewable 'green gas' can have a considerable impact in future energy systems and play a key role in decarbonising heat and transport. Green gas at present is dominated by biomethane, which can be generated from the anaerobic digestion of organic biomass and residues produced in agriculture, food production and waste processing. In the short term, the development of green gas projects, including the injection of biomethane to gas networks will be the primary focus of this developing industry.

Recent EU policy measures facilitate the development of such pathways with progressively increasing obligations on decarbonisation. The share in renewable and low-carbon transport fuels (excluding first generation biofuels and including for electrification) is required to increase from 1.5% in 2021 to 6.8% in 2030, with advanced biofuels to make up at least 3.6% by that time. Biomethane can provide this advanced biofuel for intercity buses and heavy commercial vehicles.

The on-going requirement to decarbonise will lead to integration of anaerobic digestion systems in other processes, be they agricultural, agri-food, waste management and or beverage industry. Anaerobic digestion would also be seen as an integrated element in the biorefineries of the future.

Challenges

Biogas technology can be seen as proven technology with thousands of applications and numerous system configurations to handle specific substrates and site conditions. There is still a vast potential of unused substrates which are available for sustainable energy provision, though these may be economically challenging. The differences in development of the industry worldwide are significant and these differences are mirrored in the state of the industry in the task member countries. At the extremes some countries are still struggling to set concise conditions for the start of sector development, while others (take the example of Germany) discuss what to do next with a sector with 10 000 plants in operation.

Costs, acceptance and sustainability are the major points in the ongoing debate about if and how to develop biogas applications.

The topics for the new triennium 2022-2024 confront these challenges and provide expert evidence in areas where biogas systems offer integrated and innovative solutions – which have benefits beyond pure energy provision. Renewable gas and in particular biomethane offer a carbon neutral energy carrier for sectors which cannot be substituted by electricity. It is obvious that biogas applications will not satisfy the energy demand of a whole nation. But we believe that the future energy system will be decentralised, diverse and will demand a high flexibility; biogas can play a significant role with these conditions.

Evidence and advice is needed to ensure best practice and compliance with stringent sustainability criteria, whilst ensuring minimum cost of energy. An overarching challenge is the communication of the evidence to highlight the benefits of the biogas industry.

Realising the IEA Bioenergy Strategic Plan

All deliverables play a role in realising the objectives of the IEA Bioenergy Strategic Plan 2015-2020.

Work programme

The work programme was compiled in discussion with the prospective Task participants and where possible, IEA Bioenergy members using:

- Information collated on the specific interests and on-going programmes in the IEA Bioenergy Member Countries through Task Members.
- Discussion and adoption of the Work Programme with the Task 37 members after their feedback from the national ExCo members.

<u>Future Potential and major Topics for the 2021-2023 Task period</u>

WP 1 Role of anaerobic digestion in agriculture

1.1. Assessment of co-benefits of biogas in a circular economy system

Co-benefits (or positive externalities) have been raised within the Task several times and was addressed in parts in existing reports. It is very often stated that biogas is much more than energy, but this demands a comprehensive presentation with qualitative or definitive quantitative evidence.

Therefore the overarching concept is to qualitatively and quantitatively describe relevant co-benefits or externalities (positive and negative) of the anaerobic digestion process and system if plausible to quantify the monetary benefits of these.

1.2. Detailed assessment of an optimised utilization of manure

A follow up topic from last triennium is the planned specific analysis of strategies to optimise manure utilization. Manure is a crucial substrate for AD applications for several reasons and the increase of its utilization should be enacted.

Since size of the biogas plants is crucial for costs and many farms do not have sufficient amounts of manure available, optimization will need some sort of concentration measures – either of manure or of fractions of it. Nutrient management will be part of the study; the resulting impact of measures on will assess saved fugitive methane. The transferability of results to a range of countries with different climatic and policy conditions will be addressed and resulting strategies for an efficient manure utilization will be evaluated.

WP 2 Role of biogas in decarbonisation of industry

2.1. Decarbonisation of food and beverage industry

This proposed task will examine routes to decarbonisation of large food and beverage industries such as distilleries, breweries, cheese and infant formula manufactures. These facilities tend to be large consumers of natural gas and large producers of wet organic by-products and/or wastes. They also want to brand themselves as sustainable. Anaerobic digestion with associated production of biogas is in theory an ideal means of replacing natural gas in existing boilers and reducing emissions. The use of biofertilizer would reduce emissions as well. The challenge is that biogas technology does not reduce the mas of residues and changes these residues to a digestate. In particular for large scale systems the addition of a wastewater treatment facility or involvement in non-core business such as nutrient management planning might discourage industry. The report has an ambition to tell the story of the benefits and barriers to decarbonise food and beverage industries using anaerobic digestion. Emphasis shall be on large scale solutions and the resulting consequences for plant design, infrastructure and best technology, with a specific view on digestate handling.

WP 3 Biogas in the energy system

3.1. Energy and transport fuels from renewable gases

Power to X or electrofuels are seen as a flexible future option for integration of the electricity grid and the gas grid. The first technology of the Power to X technologies is production of hydrogen using a range of different potential types and scales of electrolysers.

A potential next step of the Power to X technologies is the reaction of the produced hydrogen with (preferably biogenic) carbon dioxide to produce a synthetic methane. This has application options either via a catalytical process (known as a Sabatier Process) or a biological process (known as biomethanation). Logistics and configuration of such systems can vary greatly. Throughout the electro-fuel system there may be co-benefits: oxygen from the electrolyser may be valorised improving the economics; Power to X can facilitate intermittent renewable electricity and provide services to the electrical gird operator; other circular economy benefits such as acting as a means of upgrading biogas to biomethane can be valorised. These system enhancements can result in lower marginal abatement costs.

As follow up to the results from the project from last triennium this project looks in detail into technical aspects of support mechanisms for emerging biomethane grid injection. Many member countries signalled interest in a starter guide to develop biomethane markets, gas to grid systems and assess effective policy development. Drawing on other countries' experiences the process could determine what are effective mechanisms to support the sustainable development of renewable natural gas/green gas/power to gas/ grid injection facilities/gas standards to be met including the portion of hydrogen allowed in the gas grid. It could assess how policy would look like and how gas standards are created.

Task 37 sees here potential for collaborative activities with other tasks across IEA Bioenergy in particular with Task 44 on the intertask project related to electro-fuels.

WP 4 Emissions, process development and monitoring

4.1 Efficacy of continuous tests

This rather technical topic is the continuation of Task 37 publication "Value of Batch tests for Biogas" (2018). The batch test is a quick and crucial tool but provides somewhat limited information. Continuous tests demand much more effort and time, but deliver important answers to process dimensions and biochemical characteristics. However at present the simulation of the biogas process by means of continuous tests does not have an agreed international standard or guideline. Different lab procedures within task member countries will be discussed, the operation of the test, the evaluation of results and the conclusions to be drawn will be analysed and put in a context. The report is aims at an audience of laboratories (to give some information on practice in other countries) and of design engineers and farmers (to support the correct interpretation of data from experimental test). Last but not least it shall help to interpret data given from component provider e.g. for pre-treatment technologies or dimensions of biogas facilities.

4.2. How to treat and reduce the methane slip at biogas systems and landfill

This report will serve as a follow on to the 2017 methane emissions work but this work will concentrate on treatment of gases with low content of methane. Off gases with low methane content occur at several process steps at biogas and biomethane plants. Due to the high impact of methane on the overall GHG balance any reductions of even small amounts of methane can have a substantial effect on the GHG balance. Off gases containing methane occur at the CHP, at the process of biogas upgrading to biomethane, at specific digestion processes (such as garage style batch digesters), they might be emitted from external digestate storages or from air ventilation from manure storages. Available technologies have been developed for landfill applications, since reduced methane content in off gases is a standard issue in old landfills.

The report will give an overview on technical options, their advantages and limitations, options for combination with existing infrastructure and overall efficiency.

WP 5 Best Practice and knowledge sharing

5.1. Economics and GHG marginal abatement costs

Economics are difficult to deal with on an international level, since conditions vary greatly. However, the costs are a crucial factor for successful development and so the attempt is made to identify trends and in particular develop a roadmap for country level introduction of cost effective sustainable biogas and biomethane. Assuming a CO2 pricing in the future the costs per energy unit has to be complemented by the costs for abatement of CO2. This report relates to the report outlined in (1.1) since the formal assessment of co-benefits are part economics and part sustainability; costs are required for putting any co- benefit into a context. Cost analysis will be done on the basis of example cases of representative plants.

It is important to deal with costs in association with environmental sustainability, as they are interdependent variables and sometimes contradict each other.

WP 6 Strategic/Intertask projects:

Task 37 is open for collaborations with other tasks. Experience shows, that a close link to task internal projects is recommendable. In particular the renewable gas related topics are likely to connect with activities of other task. We are already in discussion with task 44 on electro-fuels.

ATTACHMENTS

- Task leadership and Operating Agent
- List of Participating Countries and National Team Leaders
- Task meetings and participation in major events
- Deliverables
- Co-ordination with other Tasks within IEA Bioenergy

TASK LEADERSHIP AND OPERATING AGENT

Operating Agent: Matthew Clancy, Sustainable Energy Authority of Ireland, Dublin, Ireland.

Task Leader: Prof Jerry D Murphy, MaREI Centre, Environmental Research Institute, University College Cork, Ireland.

LIST OF PARTICIPATING COUNTRIES AND NATIONAL TEAM LEADERS

The Task is organised with 'National Teams' in the participating countries. The contact person (National Team Leader) in each country and the alternate(s) are listed below:

Country	National Team Leader	Institution
Australia	Bernadette McCabe	University of Southern Queensland
Austria	Bernhard Drosg Gunther Bochmann	BOKU University, IFA-Tulln BOKU University, IFA-Tulln
Brazil	Rafael González Felipe Marques Renata Abreu	Centro Internacional de Energias Renováveis - Biogás, Foz do Iguaçu, Brazil
Canada	Maria Welsch	Agriculture and Agrifood Canada
China	Renjie Dong	State International Center for BioEnergy Science and Technology (BEST), Ministry of Science and Technology
Denmark	Teodorita Al Seadi Jakon Lorenzen	BIOSANTECH Dansk Fagcenter for Biogas-DFFB
Estonia	Timo Kikas	Estonia University of Life Sciences
Finland	Saija Rasi	Natural Resources Institute Finland (Luke)
France	Julien Thual	ADEME
Germany	Jan Liebetrau Peter Kornatz	Rytec, Germany DBFZ, Leipzig, Germany
India	Harshad Velankar	Hindustan Petroleum Green Research & Development Centre (HPGRDC), Bangalore, India
Ireland	Jerry D Murphy David Wall	MaREI centre, University College Cork MaREI centre, University College Cork
Italy	Marco Pezzahlia	Italian Biogas Consortium
Korea	Soon Chul Park	Korea Institute of Energy Research
Netherlands	Bert van Asselt	Netherlands Energy Agency
Norway	Kari-Anne Lyng	Norweigan Institute for Sustainable Research
Sweden	Jonas Ammenberg Mats Eklund	Linkoping University Linkoping University
Switzerland	Urs Baier Hajo Nagele	ZHAW Zürcher Hochschule für Angewandte Wissenschaften
United Kingdom	Clare Lukehurst Oliver Harwood	Probiogas UK

TASK MEETINGS AND PARTICIPATION IN MAJOR EVENTS

TASK MEETINGS

Minutes meeting IEA Task 37 1st Meeting, May 2019 Tartu

Minutes meeting IEA Task 37 2nd Meeting, October 2019 Seoul

Minutes meeting IEA Task 37 3rd Meeting, March 2020 Toronto (Virtual)

Minutes meeting IEA Task 37 4th Meeting, September 2020 Switzerland (Virtual)

Minutes meeting IEA Task 37 5th Meeting, January 2021 (Virtual)

Minutes meeting IEA Task 37 6th Meeting, April 2021 Austria (Virtual)

Minutes meeting IEA Task 37 7th Meeting, July 2021(Virtual)

Minutes meeting IEA Task 37 8th Meeting, November 2021 Australia (Virtual)

WORKSHOPS

http://task37.ieabioenergy.com/workshops.html.

- IEA Bioenergy ExCo Conference State of the art and innovation in Green Gas, Thursday 2 Dec 2021.
  See: https://www.ieabioenergyconference2021.org/#agenda

- IEA Bioenergy ExCo Conference Green Gas Perspectives Thursday 2 Dec 2021.
  See: https://www.ieabioenergyconference2021.org/#agenda

- Bioenergy Australia Webinar: IEA Bioenergy Task 37 - The role of renewable gas in decarbonisation and current status of biomethane frameworks in IEA Bioenergy member countries.
  See: https://www.bioenergyaustralia.org.au/events/117500/

- “Workshop Biomethane: timely solutions for successful implementation and use.”
  Hosted by the University of Natural Resources and Life Sciences, April 5th, 2021.

- Biomass to energy in Switzerland: Achievements and Perspectives Centre General Guisan, Pully and Switzerland and on line, September 10th 2020.

- International Perspectives Symposium 2020: Drivers for Successful and Sustainable Biogas Projects Location: in association with Canadian Biogas Association held on line via GoToMeetings, March 26th 2020.

- 8th International Renewable Energy Conference 2019. Location: COEX, Seoul, Korea, October 10th 2019

- Biosystems Engineering 2019 Conference, Estonian University of Life Sciences, Tartu , Estonia, May 9th 2019

DELIVERABLES

IEA TASK 37 TECHNICAL REPORTS

http://task37.ieabioenergy.com/technical-brochures.html

1. **Perspectives on biomethane as a transport fuel within a circular economy, energy, and environmental system.**

   Ammenberg J., Gustafsson, M., O'Shea, R., Gray, N., Lyng, K-A., Eklund, M. and Murphy, J.D. (2021). Perspectives on biomethane as a transport fuel within a circular economy, energy, and environmental system. Ammenberg, J; Murphy, J.D. (Ed.) IEA Bioenergy Task 37, 2021:12.

2. **Integration of Biogas Systems into the Energy System: Technical aspects of flexible plant operation.**

   Liebetrau, J., Kornatz, P., Baier, U., Wall, D., Murphy, J.D. (2020). Integration of Biogas Systems into the Energy System: Technical aspects of flexible plant operation, Murphy, J.D (Ed.) IEA Bioenergy Task 37, 2020:8

3. **Renewable Gas – discussion on the state of the industry and its future in a decarbonised world**

   Liebetrau, J., Rensberg, N., Maguire, D., Archer, D., Wall, D., Murphy, J.D. (2021) Renewable Gas - discussion on the state of the industry and its future in a decarbonised world, Murphy, J.D. (Ed.)
   IEA Bioenergy Task 37, 2021:11.

4. **Drivers for Successful and Sustainable Biogas Projects: International Perspectives**

   Wellisch, M., Green, J., McCabe, B., Rasi, S., Siemens, W., Ammenberg, J., Liebetrau, J., Bochmann, G., Murphy, J.D. (2020). Drivers for Successful and Sustainable Biogas Projects: International Perspectives – Report of a symposium held on March 26, 2020. Green, J., Wellisch, M., Szlachta, P., Murphy, J.D. (Ed.) IEA Bioenergy Task 37, 2020: 5

5. **Integration of Anaerobic Digestion into Farming Systems in Australia, Canada, Italy, and the UK**

   McCabe, B., Kroebel, R., Pezzaglia, M., Lukehurst, C., Lalonde, C., Wellisch, M., Murphy, J.D. (2020). Integration of Anaerobic Digestion into Farming Systems in Australia, Canada, Italy, and the UK. Lalonde, L., Wellisch, M., Murphy, J.D (Ed.) IEA Bioenergy Task 37, 2020: 8

6. **Potential and utilization of manure to generate biogas in seven countries,**

   Liebetrau, J., O'Shea, R., Wellisch, M., Lyng, K.A., Bochmann, G., McCabe, B.K., Harris,P.W., Lukehurst, C., Kornatz, P., Murphy, J.D. (2021) Potential and utilization of manure to generate biogas in seven countries, Murphy, J.D. (Ed.) IEA Bioenergy Task 37, 2021:6.

CASE STORIES

http://task37.ieabioenergy.com/case-stories.html:

1. Treatment of pigment wastewater and generation of natural gas standard biomethane in Hangzhou, China, December 2021

2. Biogas production from kitchen wastes in Jinhua, China, December 2021

3. Corn straw biogas production in cold northern region of China, December 2021

4. Circular economy system integrating biogas into process to produce high quality products from recycled paper, July 2021

5. Minhe Chicken Manure Biogas Plant: Circular economy management of chicken manure, June 2021

6. Green methanol from biogas in Denmark a versatile transport fuel, November 2020

7. Deep bedding: a co-digestion substrate with significant potential Danish experience with handling and feeding deep bedding, November 2020

8. Production of food grade sustainable CO2 from a large biogas facility GO'CO2 at The Korskro Biogas Plant, Denmark, November 2020

9. COMPACT AND AUTOMATED ON-FARM BIOGAS PRODUCTION IN SOUTHWESTERN ONTARIO, CANADA, April 2020 Case Story Canada

10. BIOWERT GRASS BIOREFINERY, BIOBASED PLASTICS, GERMANY June 2019

11. GREENING THE GAS GRID IN DENMARK, February 2019

12. ORGANIC BIOGAS IMPROVES NUTRIENT SUPPLY, Kroghsminde Bioenergy I/S, Denmark February 2019

13. DISTRIBUTED GENERATION USING BIOGAS IN A MICROGRID: in the Western Region of Parana, Brazil, February 2019

14. MONO-DIGESTION OF CHICKEN LITTER: Tully Biogas Plant, Ballymena, Northern Ireland, January 2019

COUNTRY REPORTS

http://task37.ieabioenergy.com/country-reports.html

- IEA Bioenergy Task 37: A perspective on the state of the biogas industry from selected member countries

- IEA Bioenergy Task 37 – Country Reports Summaries 2019

DATABASES

http://task37.ieabioenergy.com/plant-list.html
Upgrading plant lists 2019.

NEWSLETTERS

Typically, 12 per year

CO-ORDINATION WITH OTHER TASKS WITHIN IEA BIOENERGY

Biomethane – factors for a successful sector development Synthesis Report of WP1 of the IEA Bioenergy Intertask project Renewable gas - deployment, markets and sustainable trade Authors: Jan Liebetrau, IEA Bioenergy Task 37 Uwe Fritsche, Hans Werner Gress, IEA Bioenergy Task 40

IEA Bioenergy

Technology Collaboration Programme

Further Information

IEA Bioenergy Website
www.ieabioenergy.com

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www.ieabioenergy.com/contact-us/