Summary Series

IEA Bioenergy: Task 37: 03 2025

Executive Summary - Potential for Manure-based Anaerobic Digestion - Motivations, Barriers and Approaches in Six Countries

Authors: Angela Bywater, Kari-Anne Lyng, Lina Plataniti, Maria Wellisch, Mingyang Liu, Renjie Dong, Saija Rasi, Sari Luostarinen

Edited by: Renjie Dong, Maria Wellisch

From a feedstock supply perspective, there is great potential to convert more manure to renewable energy via anaerobic digestion (AD) technology platforms. Abundant in all parts of the world, manure is easily converted into biogas, stable organic matter and nutrients via AD while delivering, in addition to a renewable energy carrier, important services such as the reduction of greenhouse gases, protection of air and water quality, creation of jobs and more efficient use of natural resources. However, currently only a small percentage of manure is converted into biogas. This report builds on the IEA Bioenergy Task 37 report “Potential and utilization of manure to generate biogas in seven countries” (Liebetrau et al., 2021), and reviews the motivations for the adoption of manure-based AD, the policy contexts, the main barriers and the approaches taken in six Task 37 Member countries: Canada, China, Finland, France, Norway and the United Kingdom.

In spite of being located on three different continents and ranging significantly in size, these six countries share many of the same motivations for the utilization of manure for energy and nutrient recovery. Renewable energy production to replace fossil fuels, direct and indirect greenhouse gas reduction, sustainable animal production, prevention of water and air pollution, soil carbon and nutrient management, circularity and less dependence on synthetic fertilizers, farm income diversification and energy self-sufficiency rate as the principal reasons, although the order of priority varies between countries. In Finland, for example, the production of biomethane for use in heavy transport is a key driver for centralized manure-based AD as it helps the country to meet its goal of carbon neutrality by 2035. Differently in China, here manure-based AD provides important environmental solutions for the expansion of animal production in certain regions. The contribution that the AD technology platform can make towards the delivery of these valuable services and sustainable development goals depends on the degree of uptake in the country.

UTILIZATION OF LIVESTOCK AND POULTRY MANURE FOR ENERGY PRODUCTION

To develop manure-based AD, manure must be easy to collect to amass significant concentrations in a given area, and this typically occurs on dairy, swine, poultry, sheep and horse farms, and in beef feedlots. Today, most manure is stored and directly applied to agricultural land at appropriate times of the year to support crop production, and reduce synthetic fertilizer use. Composting, drying and solid-liquid separation of manure are practiced to a small extent, with China reporting the highest composting rates. Large livestock farms housing grower hogs, dairy cattle and finishing beef compost approximately 20% of the manure, while large poultry farms compost between 60 and 70%.

Of the six countries, France has the highest adoption of AD, digesting 19% of available manure or 25 million tons annually with an estimated calorific value of 22 TWh. Scenario projections for 2050 expect that energy from manure could level out at 24.5 TWh, hinting that France may be reaching its maximum realizable potential for manure digestion.

As presented in Table 1, the countries differ in terms of total manure production, the number of manure-based AD plants, and the end-uses of biogas. Today, most existing plants produce electricity and heat from biogas. Many new AD plants are larger and upgrade the biogas to biomethane, thereby benefiting from economies of scale and contributing greater GHG reductions by displacing natural gas or diesel fuel.

POLICIES, REGULATION AND FINANCIAL INCENTIVES AS KEY ENABLERS

In all six countries, policy, regulatory and financial instruments have been used to build and operate manure-based AD. Unlike the municipal waste and wastewater sector where AD systems are considered to be public infrastructure, in the agriculture sector it is the agricultural producer who typically raises the capital and owns and operates the AD system as an activity outside of his/her core business and core competences. As such there needs to be a business case with stable revenue streams and a reasonable payback period to justify an investment decision. Two other important considerations for manure-based AD are the low methane potential of manure, compared with e.g. food waste; and the need for a long-term energy purchaser as the biogas produced far exceeds the farm's energy demand.

All six countries have policies in place that encourage the adoption of manure-based AD, either directly by recommending manure treatment, such as in China, or by providing grants and operating incentives for manure-based projects, as in China, Finland, France and Norway; or indirectly by providing premiums for renewable energy such as in Canada and the UK. Finland, France and Norway have also set country specific targets for energy from manure. With respect to the digestate co-product, most countries have regulations and guidelines in place to ensure its beneficial use on agricultural land. Finland also provides investment support for recycled fertilizer products, in the form of grants for phosphorus recovery.

With the expanded availability of renewable electricity and focus on climate change action, today's policies and incentives promote biomethane production, i.e. biogas upgrading over CHP. This presents a challenge to manure-based AD, particularly for smaller farm installations that are not located near natural gas pipelines. China, Finland, France and Norway continue to support CHP projects, while Canada only has incentives for biomethane production and UK programs favour higher energy feedstocks over manure.

However, it was noted that countries do face push back on providing public support for renewable energy projects – in terms of both the type and size of the support, and its duration. That is, policymakers would like to see a decline in the cost of biomethane so governments can reduce their public support. In the UK, budgetary control on spending continuously reduces the tariff rate, making many AD projects financially unviable. Consequently, manure-based AD needs to be well justified to public and private sector investors, and all of its contributions to society need to be brought to the forefront.

BARRIERS AND APPROACHES TO GREATER ADOPTION OF MANURE-BASED AD

High capital and operating costs for both AD systems and supporting infrastructure, few revenue streams and low energy prices are the main financial barriers to the adoption of AD as they hinder the profitability of these systems.

Table 1: Overview of Manure Production, AD Plants and Biogas Use

Country	Animal Manure Production	% Manure Treated via AD	Number of AD Plants*	Biogas Use & Trends
Canada	21 million dry tons; 6.8 million dry tons available for AD	< 1% of total manure (mostly dairy)	43	Mostly dairy cattle co-digestion with food waste; 500 kW plants producing electricity and heat; New plants are larger, centralized and upgrade biogas to biomethane for injection into grid
China	3.05 billion tons; mainly swine, dairy and beef followed by poultry	< 1% of total production in 2015	102,637	61,054 large scale plants (> 60%); Biogas use has shifted from domestic gas supply to CHP to biogas upgrading to biomethane (today)
Finland	13 million tons; mainly cattle (3.6 TWh energy potential); 73 ktons N; 15 ktons P	2.6% of total manure	32	Mostly small plants digesting cattle manure; Biogas use from small plants: CHP; from cooperative plants: either CHP or biomethane; one large plant upgrades biogas to biomethane that is compressed for transport fuel or industrial use
France	120 million tons total	19% of available manure; 25.3 million tons	1,271	1,020 on-farm plants: 1,136 GWh electricity and 4,916 GWh biomethane; 179 centralized plants: 480 GWh electricity and 2,235 GWh biomethane; Most biomethane is injected into the grid
Norway	8.2 million tons; mainly cattle and sheep	1.3% of total manure; 107,000 tons	12	Small scale plants: biogas to electricity and heat; large scale plants: biogas upgraded to biomethane (compressed or liquefied) and transported to biomethane filling stations
United Kingdom	80-100 million tons; mainly beef and dairy (gross energy potential 22.5 TWh); 430 ktons N; 231 ktons P; 534 ktons K	3% of total manure	370	Most existing plants convert biogas to CHP with increasing trend of biomethane for grid injection (B2G); Biogas use at new plants will be B2G, plus a small number of farm or 'passive AD' (gas capture from slurry storage) being built.

*Values reported in 2024 country report (Gustafsson, M. et al., 2024).

While some manure-based facilities generate revenue from co-digesting food waste or biowaste, it is rare for facilities to receive income from digestate or biogenic CO_2. Financial viability is even more challenging for smaller farm AD systems that cannot take advantage of economies of scale. For these reasons, supportive policies and financial assistance for energy production and nutrient recovery from manure are critical for the adoption of manure-based AD projects at different, but especially at small scales.

Situations also exist where manure-based AD is not profitable based solely on energy sales but it is justified for other reasons, such as the protection of air, water and/or soil resources. For example, the publicly owned Terragr'Eau AD plant in Vinzier, France collects and treats manure from 41 farms to protect the water quality of the impluvium. In some countries, such as the UK and Finland, manure-based AD and digestate processing help to prevent nitrogen and phosphorus overloading in agricultural soils. These examples point to the additional services, beyond renewable energy production and GHG reduction, that can be provided by AD systems but are not always explicitly recognized nor compensated for.

The trend to build larger manure-based AD projects for biomethane production has significantly increased the capital cost investment over the last few years, notwithstanding the impact of inflation. Consequently, such projects are becoming less attractive investments for single farm operations, and countries such as Canada, Finland and Norway are seeing a shift to ownership by agricultural collectives or other third-parties who both own and operate these larger AD facilities.

Other barriers to the adoption of AD include feedstock quality and consistent supply; complexity of the approval processes including community resistance; limited infrastructure and logistical challenges; inappropriate field application of digestates; technology challenges and lack of expertise for design and operation; lack of or inappropriate standards and guidelines; and lack of common methodologies for GHG emissions accounting and emissions reduction. While the six countries have found ways to address most of these hurdles, certain conditions such as long periods of cold climate, the structure and spatial distribution of the livestock industry, and the existing natural gas network in rural areas are more difficult to change.

Feedstocks: While manure is abundant, it can be dispersed over very large areas and both feedstock quality and quantity issues present as challenges. As a result, most countries have adopted co-digestion with manure to both address the inherent low methane potential of manure and to achieve sufficient feedstock volumes and biogas production to take advantage of economies of scale. Countries such as Canada and Norway co-digest with food waste, while Finnish plants typically co-digest with grasses and potato processing waste, and France supports the use of intermediate crops, referred to as CIVE, to supplement manure. China often supplements manure with straw and other locally available crop residues. Recently, Norway has started using fish silage and fish sludge as co-substrates with high methane potential values.

Project Approval: In some countries, there are challenges with current biogas project approval processes because of environmental and safety concerns, as well as low community awareness and resistance to large biogas projects. It was noted that there can be scepticism within some agricultural communities as not all producers are able to see how they will benefit in a large project with many actors from sectors they haven't worked with before. In France, many communities will accept smaller manure-based projects but not want to support large AD plants. Solutions to improving biogas project approval include good design and operation of existing facilities to achieve predicted biogas yields and minimum fugitive emissions; knowledge transfer and education of policymakers, investors, agriculture producers and all of the actors in the value chain; and effective communication and relationship building with the surrounding community. China and UK expressed hope that more standardized and modular AD systems could potentially receive approval more easily.

Infrastructure and Logistics: Livestock farms are almost always located outside of urban areas and not necessarily close to a natural gas network. The manure-based AD facility must have a minimum size for biogas upgrading. For these reasons, most countries are developing larger, centralized AD systems sited close to an accessible natural gas network. Another solution adopted in Finland and Norway is to compress or liquefy the biomethane that is subsequently trucked to users and fuelling stations. The capacity limitation of a local gas distribution network can present another barrier to biomethane use. To address this, France has already added 20 reverse flow/recompression stations to compress the excess gas in local distribution lines and redirect it to the transmission network.

Equipment and Technology: Most AD facilities are custom designed to accommodate specific circumstances such as the feedstock mixture and concentration, climate, proximity to the natural gas network, nutrient profile of the agricultural area, etc. Canada imports a great deal of AD equipment and know-how from Germany and Denmark, while the other five countries have domestic or regional equipment manufacturing and significant design expertise. Also, China would like to see greater AD equipment standardization, modularization and automation. Efficient operation of AD facilities to minimize downtime, maximize biogas yield and produce good fertilizer products is key. Knowledge sharing, operator training and continuing education are necessary, and are carried out by equipment suppliers, biogas industry associations and academic institutions. Norway has a number of educational farm-based AD at special upper secondary schools, where students are trained in locally manure AD processing, producing biogas and the other beneficial co-products. China has developed numerous biogas projects to demonstrate closer integration of animal and crop production using AD platforms, which serve as successful models for regional promotion of sustainable agriculture.

MORE OPPORTUNITIES EXIST TO EXPAND MANURE-BASED AD

With increased urgency for GHG emission reduction, in particular methane reduction, and greater interest in circular economy strategies, recent years have witnessed efforts to expand the capacities of existing manure-based AD facilities and to invest in new AD projects. From the feedstock perspective, all six countries have opportunities to grow manure-based AD. Greater adoption translates into more impact in terms of renewable energy production, GHG reduction, nutrient recycling from food waste and fish processing, protection of water resources, and numerous other regional benefits. There is a lot of manure available in smaller concentrations, and here AD can provide important environmental and social benefits but this requires dedicated policy support. Given that these value chains involve many different activities from various sectors of the economy, knowledge sharing on the needs, barriers and exciting new developments is vital. Learning from other countries' experiences is one of the objectives of IEA Bioenergy Task 37 to encourage more widespread adoption of this versatile technology platform.

REFERENCES

Gustafsson, M., Meneghetti, R., Souza Marques, F., Trim, H., Dong, R., Al Saedi, T., Rasi, S., Thual, J., Kornatz, P., Wall, D., Berntsen, C., Saxegaard, S., Lyng, K.A., Nägele, H.J., Heaven, S., Bywater, A. (2024). A perspective on the state of the biogas industry from selected member countries. Gustafsson, M., Liebetrau, J. (Ed.) IEA Bioenergy Task 37, 2024:2M. et al. (2024). A perspective on the state of the biogas industry from selected member countries. Gustafsson, M., Wellisch, M., Liebetrau, J. (ed.) IEA Bioenergy Task 37, 2024:2.

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.