Role of organic waste and biogas in the transition to low carbon economy in New Zealand

Without significant cost or effort, the upgrading of municipal and waste water treatment facilities and the co-treatment of trade waste to produce biogas can contribute an additional 3.0 PJ of energy and reduce greenhouse gas emissions of 515 kt CO_2-e pa by 2050. If national zero organic waste to landfill policies are enacted and agriculture is required to treat farm wastes to avoid runoff of nutrients into waterways then significantly more greenhouse gas emission reductions can be achieved. Complete diversion of domestic, commercial and industrial food waste from landfill to newly build anaerobic digestion facilities has a potential to reduce greenhouse gas emissions by further 789 kt CO_2-e pa by 2050, or 1,296 kt CO_2-e if domestic green waste is included

Anaerobic digestion has the potential to eliminate **1,811 kt CO_2-e pa by 2050**. This all can be achieved using **well-established technology** and **existing waste materials** with many other associated **environmental and socio-economic benefits**. Biogas can be used to generate electricity, produce heat, used as a vehicle fuel, and be a feedstock for manufacture of bio-based materials, further offsetting greenhouse gas emissions by substituting carbon-intensive resources.[1][2] This is 4.6PJ pa of energy.

1. Extracting value from waste instead of landfilling is a no brainer

All communities produce large amounts of organic waste which is treated as a problem and not an opportunity. Most is landfilled or treated in waste water treatment facilities and is a cost borne by those communities.

A paradigm shift in thinking about waste treatment can extract value and make a low-cost contribution to reducing greenhouse gas emissions.

By communities following the waste hierarchy of minimise, recycle, and reuse as priorities then treating the residual organic waste by composting or the production of energy - the result will be zero organic waste to landfill.

Rethinking how we treat waste has to be based on three principles;

[1] Acknowledgement to Calibre Consulting and BPO Systems for preparation of this Information Sheet.

[2] This Information Sheet is an update and expansion of Information Sheet 31 first published in June 2016.

- A national policy of zero organic waste to landfill by 2040.
- Minimise, recycle and reuse as much as economically possible.
- Aim to extract maximum value from waste by processing residual waste into compost, fertiliser and energy.

2. Green House Gas reduction and Biogas

Decaying organic matter produces methane and other gases which are referred to as biogas. Biogas can be used to produce heat or electricity, or can be cleaned to be biomethane which is a valuable transport fuel.

The NZ Greenhouse Gas (GHG) inventory accounts the global warming potential (GWP) of one tonne of methane as 25 times that of 1 tonne of fossil CO2. Methane is produced from organic matter placed in landfills, waste water treatment facilities, and decaying agricultural and food processing organic residues. Removal of methane emissions is therefore a key greenhouse gas mitigation opportunity.

Emissions from the waste sector contribute 3838.2 kt CO2-e or 4.9 % of NZ's total greenhouse gas emissions. The majority of waste methane emissions are from solid waste disposal (90%) followed by wastewater (10%). The waste sector produces mainly methane emissions (96.5%)3. This is made up of all emissions from solid waste and 67% of emissions from waste water treatment.

Table 1: Greenhouse gas emissions from waste*

Source	2016 emissions[4] (kt CO_2-e pa)	%
Solid waste disposal	3439	89.6
Biological treatment	0	0
Incineration	2.4	0.1
Wastewater	396.8	10.3
TOTAL	3838.2	

* This does not include farm waste emissions.

There are[5] 15 waste processing facilities collecting methane and using it as fuel to generate electricity:

- 11 landfill facilities with 29.4 MW electricity generation capacity. The facilities produce electricity only. Heat is discharged to atmosphere.
- 4 waste water treatment facilities with approximately 11.3MW electricity generation capacity. These are all cogeneration facilities with heat and electricity all consumed on-site for the processing of sewage.

The biogas from liquid and solid waste can be used to generate electricity, produce heat, used as a vehicle fuel and a feedstock for manufacture of bio-based materials. In 2017 biogas contributed a total of 3.66PJ of

[3] Source *New Zealand's Greenhouse Gas inventory 1990-2016*, Ministry for the Environment

[4] Net emissions after methane recovery. In 2016 1228.22 kt CO_2-e methane was recovered.

[5] As at 31 March 2018. Source *New Zealand's Greenhouse Gas inventory 1990-2015*, Ministry for the Environment, and *Biogas Production Potential from Municipal Wastewater Treatment Facilities*, Calibre Consulting, 2018.

energy[6] to the New Zealand economy made up of 2.45PJ electricity, 0.88 PJ cogeneration and 0.33PJ direct use.

Organic municipal waste can be processed by combustion with other solid biomass[7] to reduce methane emissions, but this option is not included within this Information Sheet.

Solid waste

In 2016 there were 45 managed landfill sites (39 Municipal) and 426 consented[8]. 24 landfill sites had operational methane recovery systems (18 operating and 6 closed sites). These 24 sites accounted for about 90% of waste disposed to municipal landfills. The remaining 25 smaller sites have no methane recovery system. Methane recovery efficiencies vary from 25 % to 90 %. On average 68% of methane produced is recovered at sites where gas is collected and averaged over all landfill sites 40% of produced landfill gas methane is collected. Most municipal landfills accept locally produced industrial solid and liquid waste as well as municipal waste. In 2016 2.71PJ of biogas was produced from landfill

All currently operational municipal landfill sites in New Zealand are managed sites. Most municipal landfills are mandatory participants in the NZ ETS with obligations to report and surrender emission units for their methane emissions. There are 34 managed landfill sites in total in the NZ ETS.

Table 2: Estimated composition of waste to municipal landfills in 2016

Food	Garden	paper	Wood	Textile	Nappies	Inert
17%	8%	11%	12%	6%	3%	44%

Wastewater

There are 367 waste water treatment facilities including 317 municipal facilities. 72% of wastewater treatment facilities are domestic, the other 28% are industrial. 66% by volume of all wastewater is treated at 11 large plant. Most WWTP treat domestic wastewater but on average 7% of wastewater treated is trade waste. The meat and pulp and paper industries comprise the two main sources of industrial wastewater in New Zealand. Most industrial wastewater treatment is aerobic.

In 2016 waste water treatment and discharge contributed 396.8kt CO2-e of emissions from the waste sector (10.3%).

In 2015, the total New Zealand population connected to wastewater treatment plants was estimated to be 3.7 million[3]. Domestic and commercial wastewater contributed the majority of emissions from 317 municipal wastewater treatment facilities and approx. There are 50 government or privately-owned treatment plants. Although most of the

[6] 2017 data from Energy in NZ, MBIE https://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/publications/energy-in-new-zealand

[7] Internationally waste-to-energy often refers only to the combustion of organic waste to produce energy, and anaerobic digestion is referred to separately under that term. In the context of the New Zealand waste market the term waste-to-energy is often used to refer to both combustion and anaerobic digestion technologies because anaerobic digestion is more common.

[8] *Low emissions economy*, New Zealand productivity Commission, 2018.

wastewater treatment processes are aerobic there are a significant number that use partially anaerobic processes such as oxidation ponds.

Small communities and individual rural dwellings are served mainly by simple septic tanks.

10 municipal treatment plants accept large amounts of industrial wastewater.

15 domestic wastewater treatment facilities remove methane via flaring or for energy production resulting in zero methane emissions from those sites.

Industrial wastewater contributed in 2013 196.1kt CO_2-e (43.5%) emissions from wastewater facilities. The major source of industrial wastewater emissions comes from the meat processing, and pulp and paper industries, and dairy processing. Most industrial waste water treatment is aerobic and most methane from anaerobic treatment is flared. However, there are a number of anaerobic ponds that do not have methane collection, particularly in the meat industry.

8 industrial waste water treatment facilities remove methane by flaring or for energy production resulting in zero methane emissions from those sites.

There is no methane recovery from the meat processing, wine, and pulp and paper sources. Since 2012 the wool processing industry has used aerobic treatment of wastewater, which is considered to produce no methane emissions.

The dairy industry predominantly uses aerobic treatment or land disposal. There is only one dairy processor (Fonterra Tirau) using anaerobic treatment and the methane is used directly as a heating fuel. Consequently, there are no methane emissions considered from the dairy processing sector.

An estimated 5% of manure from dairy cows is stored in anaerobic lagoons[9].

There are 5 agricultural facilities processing liquid waste through anaerobic digestion plant where methane is collected and used directly as energy:

- 2 piggeries
- 3 dairy farms

Outlook

Tools to collect the methane and process it so as to avoid GHG emissions and thus avoid the need to surrender emission units are proven and already available in NZ but are presently under-utilised. These processes produce and capture biogas which can then be used to generate electricity; be a source of heat; or used as a replacement fuel in vehicle engines. Once used (burnt), the biogas converts back to carbon dioxide which is GHG neutral as it is from atmospheric carbon dioxide that had been recently converted to organic matter and is just being re-released. It does not come from long ago sequestered fossil fuels (Oil and Coal) which add more fossilised carbon dioxide to the present total atmospheric GHG inventory. Many of the potential applications offer an attractive rate of return for facility operators when the released energy is used to reduce on-site operating costs.

---

[9] Ledgard and Brier 2004

3. Drivers

3.1 Traditional Economic Drivers for Anaerobic Digestion

The use of biogas production technologies to remove methane emissions can have a wide range of drivers, but it is often not until the full lifecycle costs and benefits are considered that the collective benefits from the opportunities become economic. Energy is only one of the benefits and not always the primary driver. Many of these benefits are public goods and not able to be captured by the facility owner/investor. These drivers can include:

- Reduction of GHG (methane) emissions that would otherwise escape from waste treated or disposed of by other means (from landfill in particular). This affects NZ's ETS position.
- Reduction of the ultimate waste disposal volume and organic load when finally disposed of back into the environment.
- Eliminating or minimising the amount of waste disposed on landfills extends the disposal facility life and complies with the Waste Minimisation Act.
- Production of energy-rich biogas, which can be used for heat, electrical energy, cooling, or as a replacement transport fuel.
- In comparison to its aerobic counterpart, anaerobic wastewater treatment requires considerably lower energy input and most of the energy is retained in the produced biogas.
- Anaerobic wastewater treatment processes generate substantially lower amount of waste sludge, since about 95% of the organic matter consumed is converted into biogas and only 5% is spent on production of new biomass (the same ratio is 50% : 50% for aerobic processes). This offers large operating cost savings for treatment of high-strength organic wastes. Digestate which is a good, stable fertiliser substitute. The use of digestate closes the nutrient loop cycle by returning nutrients back into the environment and reduces the use of carbon-intensive mineral fertilisers.
- Production of pathogen free high grade fertiliser.
- Generation of electricity for on-site use avoiding retail price electricity.
- With biogas storage the generation of high value quick start or peaking electricity.
- Reduction of the odours associated with disposal facilities, which reduces the social unacceptability of disposal facilities.
- Reduction of vermin at disposal facilities (rats, mice, birds, hedgehogs).
- Reduction of disposal facility land instability post facility closure.
- Deals with organic wastes accountability with a quick treatment (typically 21 days) as opposed to 20 years or so in landfill disposal facility (long term methane leakage) with consequently much harder accounting for GHG emissions.
- Provides employment opportunities.
- Can provide CO_2 enrichment for horticulture hothouse crops.

As shown in Figure 1 on a per capita basis New Zealand is already comparable to many other countries in processing municipal, and industrial solid and liquid waste to energy using anaerobic processes. However, New Zealand has the potential to do even better and by diverting waste from landfill to treatment in anaerobic facilities could cost-effectively more than quadruple the total amount of methane currently collected and processed into energy using proven technologies.

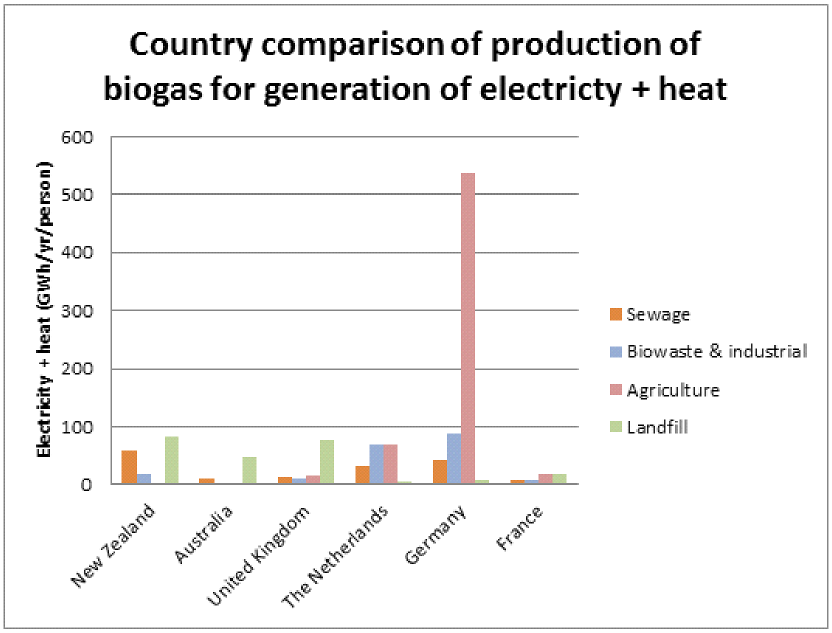

Figure 1: International per capita comparison of biogas production from waste for generation of electricity and heat (GWh/yr/person) Source; IEA Biogas country reports 2016

3.2 New Drivers for trade waste co-digestion

The high rate co-digestion process development in New Zealand[5] for industrial trade waste at the municipal wastewater treatment plant in Palmerston North has started a new chapter of anaerobic digestion for municipal and industrial waste – sludge digester capacity upgrades using existing municipal treatment plants as platform for industrial waste treatment services. The underlying commercial model is to invest in digester process efficiency upgrades of existing digester plants at a fraction of the cost for new digester plant, to intensify the gas production efficiency and capacity of existing municipal biosolids digesters 2-3 fold with the upgrades and use the freed-up treatment capacity to offer a new range of treatment services (waste co-digestion) for local industries.

Going forward, the level of benefits of co-digestion of selected organic trade and industrial waste at municipal WWTP can vary significantly on a case by case basis according to the existing equipment and how it is operated.

The benefit values taken from some recent case studies below show orders of magnitude of possible benefits[10]:

[10] *Improved trade waste co-digestion*. Thiele, Burt and Monaghan. Water e-journal (1) No3 2016,

1. Reduced amounts of municipal sludge solids due to improved digestion to biogas (20-60 % cost reduction, case by case)
2. Further reduced dewatered sludge cake amounts going to disposal due to improved dewatering after digestion.
3. On site electricity generation to offset electricity purchase for WWTP operation with a potential to achieve100 % electrical self-sufficiency.
4. Additional electricity generation for peak electricity export to grid with as much as tripled gas output from efficient waste co-digestion.
5. Option to attract new businesses that use biogas as industrial heat source via local biogas networks.
6. Additional revenue from peak electricity sales to grid, sales of genset generation capacity ("ripple control, frequency control") and gate fees for processed industrial trade waste. Gate fees typically exceed electricity generation related revenue.
7. Additional revenue for council from diversion of selected food waste from landfill disposal, reducing landfill gas emissions with a support for local businesses by avoiding landfill tipping fees for food waste.
8. Production of organic fertiliser from the food waste/industrial waste train for re-sale/re-use into landscaping, horticulture, agricultural businesses.
9. Reduced odour in the digested biosolids.
10. Improved digestate stabilisation grade, reduced vector attraction and thus improved quality for potential beneficial re-use.

Because of the inefficiencies of landfill to process organic material into useable methane it is ideal to have zero organic waste disposed to landfill.

The new services include total treatment for a wide range of selected liquid and solid trade waste materials (grease trap waste, institutional and commercial food residuals, industrial wastewater sludge). Treatment services will be paid for by a gate fee (paid by the waste generator) and increase thereby also the biogas and electricity production potential of the existing digester. The gas production increases up to 3-4 fold when concentrating on well digestible materials with high biogas yields. An attractive possibility exists to operate two parallel anaerobic digestion trains on the WWTP with the benefit to produce trade waste derived (i.e. not human waste based) digestate from one which can be readily usable as beneficial fertiliser.

3.3 New drivers for food waste digestions

Diversion of waste from landfill treatment

With waste representing about 5% of New Zealand's greenhouse gas (GHG) emissions and 90% of the methane (CH_4) coming from organic solid waste disposed to landfill[11], the diversion of organic waste from landfill should be a priority in all communities. Some regional and territorial councils are adopting such a goal by enacting "Zero organic waste to landfill" policies.

Methane emissions occur as organic waste decomposes. As nearly 40% of total waste to municipal landfills is organic, solid waste emissions reductions rely on reducing organic waste volumes to landfill in the first place, and better methane management once organic waste reaches landfill.

[11] New Zealand Productivity Commission, *Low-emissions economy*, August 2018

Better methane management does not require the development of new technology. While technological improvements can make mitigation more efficient, emissions can be effectively avoided by existing technologies, such as landfill gas recovery or anaerobic digestion systems.

Recovery of biogas from landfill is important for existing landfills already holding waste but the priority should be to avoid new organic waste being disposed to landfill. Landfill gas collection should be considered as a last step as conversion of organic waste in a landfill is a very inefficient means of treating waste and recovering energy. Waste treatment to produce energy should be undertaken in a purpose designed facility.

Improved waste management according to the waste hierarchy

Improved collection of waste with increased focus of business and communities on separation at source has proven to increase the level of recycling and reuse of organic waste which would otherwise have gone to landfill. The residual waste after separation for recycling and reuse is however able to be either treated by anaerobic digestion (for the wet portion of the waste); made into compost; or used as a fuel for the production of heat from combustion of the dry material.

The waste hierarchy concept as shown in Figure 2 is starting to drive waste policy in many communities. Businesses, in particular, are finding that beneficial use of production residues can improve business sustainability.

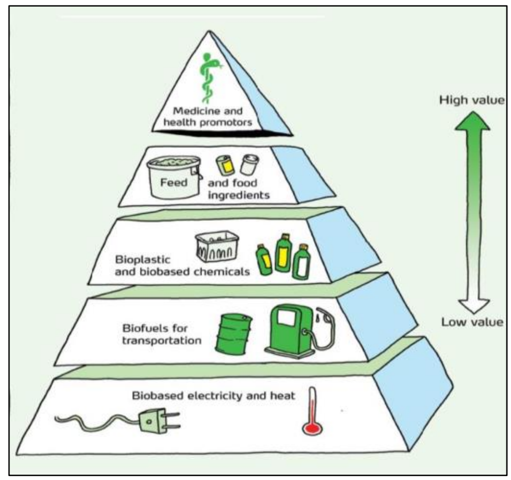

Figure 2: Waste hierarchy

Achieving sustainable business practices

Businesses incorporating circular economy principles acknowledge that disposal is a measure of last resort on the waste hierarchy. Where waste is inevitable, a circular economy encourages better waste use, such as via the waste to energy concept.

The New Zealand industrial sector is identifying that many of their food processing residues can be used to provide an additional revenue stream or at least reduce energy and waste disposal costs[12].

Rather than landfilling or otherwise disposing of waste, it is possible to reconsider waste as a source material. The waste-to-energy concept can be applied by transforming organic waste via anaerobic digestion into a renewable energy source - biogas. The biogas can be cleaned up to be biomethane which has a number of commercial uses, the simplest being use as a vehicle fuel.

4. GHG reduction opportunities

Methane is the major constituent of biogas (between 40 and 70%, the balance is Carbon dioxide and other minor constituents). Biogas is the natural result of organic material decaying in the absence of oxygen (anaerobically) and occurs anywhere organic material is left to rot, particularly in landfills. Landfills provide a large, generally biologically uncontrolled place for the dumped organic material to decay. Piles of organic matter, left untreated will naturally produce methane-containing biogas.

[12] New Zealand Productivity Commission, Low-emissions economy, August 2018

If organic waste from municipal, agricultural and industrial sources is not processed appropriately the methane (CH_4) produced is 25 time more potent greenhouse gas than carbon dioxide (CO_2).

Investment in appropriate disposal facilities or waste management/ treatment plant can eliminate the methane discharged into the atmosphere by converting it into CO_2 in an electricity generator, boiler or flare. This CO_2, being of biomass origin, is accounted for as GHG neutral[13], resulting in an almost complete elimination of GHG emissions from that source. The captured biogas, however, is valuable for the generation of electricity, heat and use as an engine fuel substitute. When some types of waste is treated in an anaerobic digester to produce biogas, the digestion residue (digestate) is a valuable fertilizer[14].

Detailed analysis of the opportunities undertaken for the Bioenergy Association is set out in reports by BPO[15] and Calibre Consulting[16]

4.1 Sources of GHG emission

In order to identify the opportunities for reduction of GHG emissions from waste the sources of GHG emission need to be separately considered as each waste stream requires a different approach.

Municipal waste water treatment

The operation of wastewater treatment plants results in direct GHG emissions from the biological processes such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), as well as indirect emissions resulting from energy consumption. There are three possible ways to reduce these emissions:

- minimisation through the change of operational conditions,
- treatment and use of the gaseous streams, and
- prevention by applying new configurations and processes to remove both organic matter and pollutants.

Solid waste treatment

Food wastage arises at all stages of the food supply chains for a variety of reasons that are very much dependent on the local production, processing, distribution and consumption stages. Much waste food can be reused, with the residual being either composted, put in a landfill or treated by anaerobic digestion processing.

GHG emissions from landfills significantly depend on the waste streams, landfill gas management practices and climate.

[13] https://www.usewoodfuel.org.nz/documents/admin/WBA18-Bioenergy-is-carbon-neutral.pdf

[14] https://www.bioenergy.org.nz/resource/biosolids-guidelines-report-2003

[15] BPO, *Assessment of Potential for Energy Generation from Expanding Industrial Wastewater Treatment Facilities*, March 2018, https://www.bioenergy.org.nz/documents/resource/Reports/Industrial-Waste-Treatment_rev1.pdf

[16] Calibre Consulting, *Biogas Production Potential from Municipal Wastewater Treatment Facilities*, April 2018. https://www.bioenergy.org.nz/documents/memberresource/Biogas-production-potential-from-municipal-WWT-facilities-Final-Report-Proj11.pdf

Landfill gas used to produce electricity or heat is considered to be carbon neutral even though the production of the energy will also produce CO_2.

Industrial and agricultural waste treatment

Some high-strength industrial liquid waste can be treated as a trade waste in a municipal WWTP. Currently, most industrial waste treated at municipal WWTPs is diluted by mixing with sewage and treated using energy-intensive technologies. Separate collection of organic waste streams enables a more economic treatment by diverting these energy-rich waste streams directly to the municipal anaerobic digesters.

Alternatively, dedicated anaerobic digesters can be built at industrial sites, which reduces the waste's transport cost and provides readily available energy source for direct on-site use.

During food production there is often significant amount of organic waste which can include dairy and piggery effluent, crop residues e.g. corn stover, and horticultural plant waste such as windfall apples, non-saleable fruit and vegetable. Some food production residues can be reused as animal feed while significant quantities are composted. The non-usable portion can be effectively treated by anaerobic digestion processing.

An advantage of using anaerobic digestion equipment is that it can be built any size and to the scale appropriate to the manufacturing process. It is modular so additional digesters can be added if production increases. There is little risk of oversizing as if the initial feedstock quantities diminish supplementary feedstock can be sourced from nearby farms.

4.2 GHG reduction avenues

There are no technology barriers for greater uptake of the use of biogas technologies to reduce methane emissions from waste. The main socio-economic barriers appear to be:

- the lack of 'desire to make it happen';
- the concern that economy of scale drivers for waste-to-energy/anaerobic digestion facilities will reduce incentives for waste minimisation or recycling;
- and the relative cost benefits of other use opportunities e.g. composting of municipal waste and distribution of untreated dairy effluent onto pasture as fertiliser.

In many situations, despite the attractive financial returns (3-4 year payback periods have been obtained on some recent application), the lack of desire to make projects happen are because of a lack of access to capital finance.

The focus for the reduction in methane discharge to atmosphere and thus GHG emission reduction is on maximising the value available from our organic wastes through use of anaerobic digestion technologies. Internationally it can be shown that well developed waste-to-energy facilities are likely to increase recycling and other uses of waste because it provides a cash flow from the energy and fertiliser products to subsidise the recycling activities.

The priority areas for reduction of methane emissions from waste are:

1. Communities to establish policies of **zero organic waste to landfill** by a specified date eg 2040.
2. Communities to monitor where waste is going and have programmes to **assist waste being avoided**, **recycled or used** and not placed in landfill.
3. Food processors and municipal waste water treatment plant operators, who produce organic waste and could economically convert this into biogas for energy, to be **assisted to evaluate the opportunities** from using waste to reduce on-site energy costs and maximise revenue from sale of biogas and fertiliser.
4. Ensure all significant landfill operations **collect and use the landfill gas** naturally produced (biogas) and / or **maximise the value of the biogas** they already collect.
5. Assist biogas producers to maximise its value by **improving the understanding of the biogas potential** for heat, electricity or transport and **provide guidance and demonstration on best practice** for each type of use.
6. **Assist agricultural businesses** that produce large volumes of organic waste (e.g. manure) to process this into biogas for **on-site energy use** before **recycling waste nutrients** back to the land.

An allowance has been made for the diversion of organic waste from landfills to digesters which will result in a reduction in the energy output from the landfill. The waste converted to methane at municipal or industrial WWTP has been taken from the landfill so any changes in landfill emissions are accounted for in the WWTP balance.

The focus of national and regional waste policies for the next decade should be on the first five priority areas because the opportunities in these sectors are significantly larger and have stronger drivers than may occur in agriculture. However, if agriculture is included within the NZ ETS, then bioenergy tools such as the reduction of methane from farm wastes can be an offset to animal generated methane emissions.

GHG emission reduction in agriculture has also not been evaluated in this analysis because of the large uncertainty over what could be achieved. The agricultural emission reduction is additional to the data shown below.

4.3 Scenarios

Three scenarios (Business as usual, Encouraged Growth and Accelerated Growth) were used to assess the robustness of the opportunities to reduce methane emissions from organic waste. Additional scenario was evaluated that assumes that disposal of organic waste to landfill is strictly enforced and food waste is directed to new treatment facilities. The scenarios for growth in the production and utilisation of biogas are:

- Business As Usual (BAU)
- Scenario 1: Encouraged transition
- Scenario 2: Accelerated transformation
- Scenario 3: Zero Organic Waste to landfill

Business As Usual (BAU)

This scenario assumes that municipal wastewater treatment owners make no particular efforts to maximise the biogas production in their facilities. Existing plants with digesters (15) will adjust their digester capacity to population growth. Population growth was assumed to be in line with Stats NZ projections (2016 – 2068). The BAU scenario further assumes that landfill owners are enticed to gradually improve the average landfill gas capture efficiency from 60 % (today) to 69 % (2050). Carbon price and electricity price are assumed to remain low and thus not an incentive for change.

Changes to industrial wastewater treatment is limited to only what is required to maintain resource consents.

In the BAU scenario it is assumed that there is minimal processing of agricultural or food production residues.

Total industrial and municipal biogas production by 2050 is assumed to be 0.50 PJ pa. which is an increase of 0.2 PJ above 2017 levels

The biogas from landfill is assumed to remain constant at 2016 levels to 2050 at 2.71 PJ with increases from some landfills being offset by natural decreases in biogas production at other landfills.

The 2050 nett GHG emission from industrial and municipal WWTP is practically 390 kt CO_2-e pa ("Zero carbon increase goal for councils"). Which is an increase of 40 k t CO2-e pa above 2017 levels.

Conditions:

- Based on existing policies and market conditions. No policy changes.
- Uses existing technologies and an extension of current trends.
- No 'maybes'. Only realistic activities based on existing sector participant's activities.
- Assumes current ETS 2 for 1 policy is deleted and the ETS administration is improved, with no other significant changes.

Scenario 1: Encouraged transition

In this scenario significantly more biogas is produced than in BAU via industrial and food waste digestion. All gas is assumed to be used for industrial heat in co-located commercial and industrial businesses and local biomethane (or biogas) based heating fuel networks. Electricity price is assumed to remain low and thus not an incentive for electricity generation from the biogas for onsite use or for export off-site. Scale of electricity generation is limited to what can be used on-site.

The industrial sector is assumed to makes low cost improvements to existing treatment facilities and there is an increased use of biogas as a fuel substitute.

Minimal treatment of agricultural waste is assumed as little incentives to change is provided for current least cost waste disposal solutions.

Total biogas production capacity from municipal and industrial operations in 2050 is assumed to be 2.3 PJ pa an increase of 1.8 PJ pa above 2017 levels.

Energy production from landfill biogas decreases to 2.61 PJ pa as a result of diversion of organic waste from landfill to digester plants with higher methane recovery efficiency.

The 2050 nett GHG emission from municipal WWTP and industrial anaerobic digestion plant is practically 100 kt CO_2-e pa which is a reduction of 220 kt CO_2-e pa

The nett GHG emission from the Scenario 1 is practically close to Zero for municipal wastewater treatment, while some emissions will still be emitted from treatment of industrial wastewater (Zero carbon emission goal for councils).

Conditions:

- Government signals that it wants to encourage domestic mitigation and avoid the need for the purchase of international units but provides minimal programmes to assist.
- Based on BAU conditions plus:
  - Limited number of complementary measures pursued and implemented.
  - Central Government introduces policies that change Government procurement procedures so that renewable energy, energy efficient and all additional benefits are included in a full life cycle cost analysis of options.
  - Local councils introduce policies for local government procurement, similar to central Government procurement policies. Enforcement that these must be considered when making investment decisions.
  - Government adopts a collaborative growth strategy with each renewable energy sector

Scenario 2: Accelerated transformation

This scenario assumes promulgation by Government and assistance to local authorities to minimise the organic waste disposal to landfill. In addition to that, significant increases in carbon price, industrial heat prices (natural gas), landfill costs for trade waste disposal and public pressure incentivise councils and water corporations (spread over 30 years) to upgrade large existing WWTP.

The 14 WWTP currently w/o anaerobic digesters will be upgraded to receive local trade waste, industrial and Industrial, Commercial and Institutional (ICI) food waste for co-digestion. The existing 15 municipal digesters will upgrade the digester capacities to also accept locally produced commercial trade waste/ICI food waste, suitable industrial waste and grease trap waste. Consequently, a total of 29 municipal WWTP would employ extended co-digestion operations. The nett effect of these changes is that the percentage of NZ population serviced with WWTP with anaerobic digestion will increase from 53 % (today) to 68 % (2050). This is a conservative assumption and the analysis of the NZ WWTP inventory shows that there is a potential for additional 14 large wastewater treatment plants that don't have anaerobic digestion to adopt such technology by 2050.

All trade waste BOD and a high proportion of locally produced grease trap waste (68 %) and other industrial waste (dairy, meat processing, 70 %) are converted to biogas at the municipal co-digestion plants following significant digester efficiency upgrades. Suitable trade waste nutrients (N, P, S) are converted to digestate fertiliser.

Overall population growth is assumed to be in line with Stats NZ projections.

Landfill owners are assumed to be enticed to gradually improve the average landfill gas capture efficiency from 60% (today) to 69% (2050).

Government supports R&D programme to achieve the goal of 100% high value use of outputs from anaerobic digestion of waste. Increased use of biogas occurs by use as a vehicle fuel, generation of electricity at peak electricity demand times, and by clustered use by co-located industry with electricity and heat requirements. Use of digestate as a high-grade fertiliser and combustion of biosolids with other biomass as a fuel for process heat expands.

Agriculture is included in the NZ ETS and farmers adopt bioenergy solutions which will provide offsets to the biological emissions. Farms adopt circular economy principles. Farms become producers of food plus fuel instead of just food. On-farm energy costs are reduced by use of farm waste to produce heat, electricity and vehicle fuel for on-farm use. The methane emissions reduction opportunities from the agriculture sector have not been evaluated as there is a lack of data and investigations are required.

Total biogas production capacity from municipal and industrial facilities in 2050 is 3.3 PJ pa which is an increase of 3.3 PJ pa.

The biogas from landfill decreases to 2.41 PJ by 2050as a result of diversion of organic waste from landfills to digester facilities with a higher methane recovery potential.

The GHG offset from farm operations due to farming coming into the ETS has not been calculated and will be additional to the emissions reductions identified in this report.

The nett GHG emission from this operation is practically ZERO in 2030 and negative in 2050 by about 515 kt CO_2-e pa which helps to offset GHG emissions from other sectors (Zero carbon emission goal for councils).

Conditions:

- Government encourages elimination of organic waste disposal to landfill
- Government seriously considers and adopts some complementary measures to the ETS
- As for Scenario 1 above, plus:
  - Government provides assistance to local government to investigate feasibility of modifying WWTP to maximise the treatment of trade waste diverted from landfills.
  - Low cost policies are introduced to address specific barriers across renewable energy sectors and within each sector.
    - Allows accelerated depreciation on capital expenditure
  - Government provides assistance to local government to modify WWTP by:
    - Reviewing the criteria for Crown Loans to move to being value based
  - Government carries out an annual cost-benefit analysis of forward offshore ETS purchase obligations vs acquiring domestic mitigation through a capital fund.
  - Successful R&D programme to investigate and provide guidance maximising value of outputs from anaerobic digestion;
    - Use of biogas as a vehicle fuel
    - Generation of electricity during electricity peak demand periods
    - Regulations for beneficial use of digestate as a fertiliser to land
    - Combustion of biosolids as a fuel for process heat
  - NZ primary processing industry buys into the co-digestion option due to convincing cost advantages.

Note:
The opportunities for emissions reduction from the agriculture sector (excluding biological emissions) will be very significant but analysis of this sector has not been done. This is a major gap as Table 3 shows that agriculture produces 15.4% of the potential emissions. It is the second biggest category.

Figure 2 gives the expected additional GHG emission reduction for the three scenarios based on the methane capture scenarios shown in Figure 3.

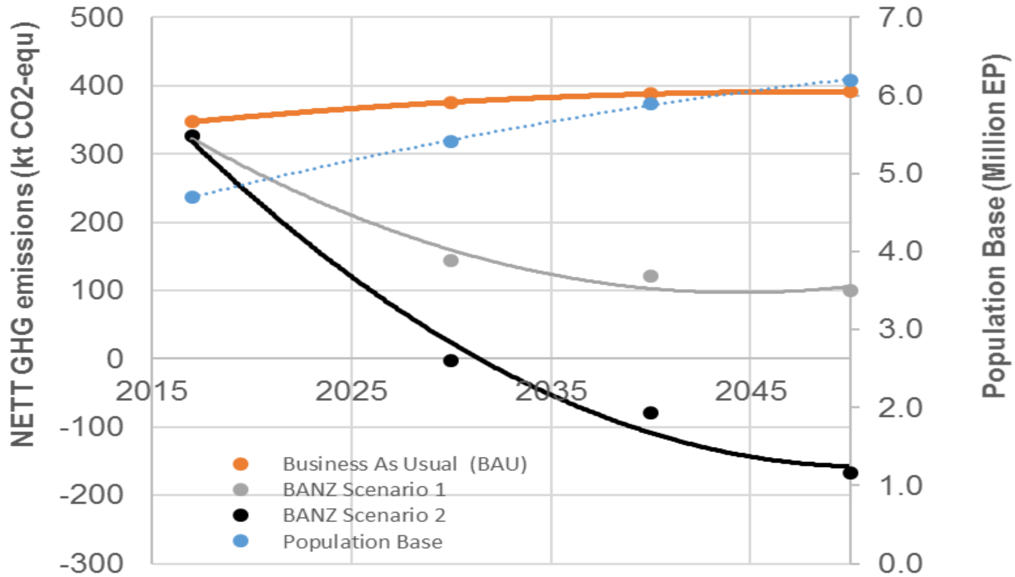

Figure 3: GHG abatement from municipal and industrial waste treatment facilities (from liquid waste treatment only) in the 3 scenarios

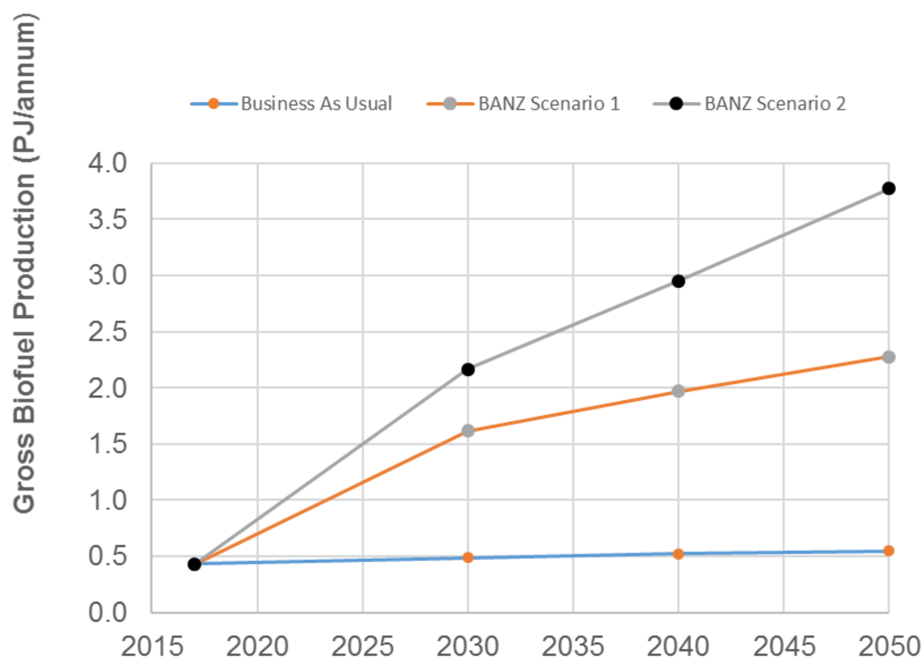

Figure 4: Scenarios for annual biogas capture from municipal and industrial liquid waste treatment

Analysis of the opportunities in the liquid and solid trade and industrial waste sectors shows that collectively, by 2050, with effective biogas plant construction encouragement policies, there could be:

Scenario 1: Encouraged transition

- A 3.2 and 4.6-fold increase in the annual production of biogas from liquid waste treatment by 2030 and 2050, respectively.

- The GHG emissions from waste will be reduced by 210 kt CO_2-e per year and 220 kt CO_2-e per year in 2030 and 2050, respectively in comparison to 2017.

Scenario 2: Accelerated transformation

- A 4.4 and 7.2-fold increase in the annual production of biogas from liquid waste, trade waste and ICI food waste treatment by 2030 and 2050, respectively.
- The GHG emissions from waste will be reduced by 410 kt CO_2-e per year and 515 kt CO_2-e per year in 2030 and 2050, respectively in comparison to 2017.
- A breakdown of the different waste classes (biosolids, grease trap waste, ICI food waste, industrial waste) utilised at municipal plants is shown in Figure 4 below

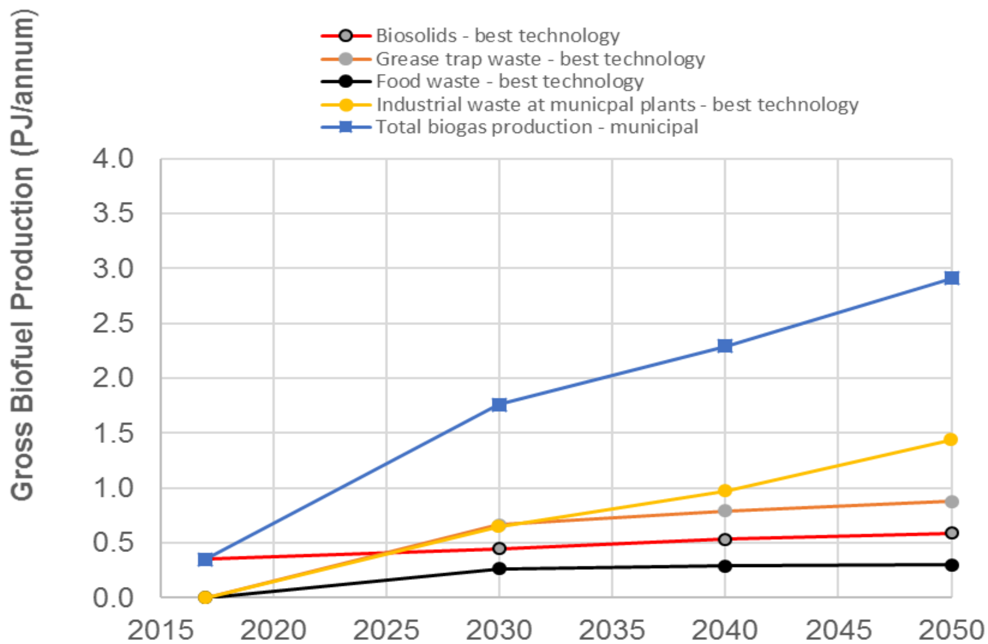

Figure 5: Waste feedstock breakdown for the expected annual biogas capture from liquid waste treatment

Scenario 3: Zero organic waste to landfill

The above described three scenarios are based on the maximum utilisation of existing capacities within the wastewater treatment plants and conservative growth of anaerobic digestion technology in New Zealand primarily resulting in construction of anaerobic digesters at large municipal wastewater treatment plants. These scenarios do not reflect the potential from diverting all residential, industrial and retail food waste from landfills, which will require a more aggressive approach from the central and local government. This would comprise **total ban on disposal of organic materials to landfill by 2030** and construction of a larger number of regional or local anaerobic digesters.

Based on the information reported in recent studies[17], the amount of food waste (residential, industrial and retail) currently disposed on landfill is equivalent to approximately 67 kg/person/year. Additional 43

[17] Goodman-Smith, F. (2018) - A quantitative and qualitative study of retail food waste in New Zealand, MSc Thesis at University of Otago, Dunedin, New Zealand.

kg/person/year of green waste is currently disposed on landfill. Using the predicted population growth, the food waste will amount to 415,300 tonnes of food waste in 2050 and 789 kt CO2-e pa of greenhouse gas emissions. Residential green waste will in 2050 be responsible for further 507 kt CO2-e pa. Adding this to the reduction potential determined for the Accelerated transformation Scenario (Scenario 2), a more aggressive enforcement of the "Zero organic waste to landfill" directive has therefore the potential, through anaerobic digestion, to reduce the greenhouse gas emissions by **1,811 kt CO2-e pa in 2050**.

Table 3 shows a summary of all the areas where methane produced by GHG emission reduction projects can come from by 2050 (accelerated transformation scenario).

Table 3: Sources of methane generation and the corresponding energy potential (2050 Accelerated transformation Scenario)

Methane generation sources	PJ/annum	%
Electricity, direct use of biomethane gas from landfill gas (biogas)	1	12%
Electricity, direct use of biomethane gas from industrial waste at industrial sites (biogas)	0.9	11%
Electricity, direct use of biomethane gas from co-digestion of industrial waste and grease trap waste in municipal WWTP	2.32	29%
Electricity, direct use of biomethane gas from co-digestion of WWTP biosolids in municipal WWTP	0.59	7%
Electricity, direct use of biomethane gas from co-digestion of ICI food waste in municipal WWTP	0.3	4%
Electricity, direct use of biomethane gas from direct digestion of residential food waste in dedicated new digester facilities	1.3	16%
New dairy farm uses (estimate)	1.61	20%
Total maximum biomethane energy potential in 2050	**10.5**	**100 %**

On a lifecycle costs and benefits basis, recovery of the WWTP capacity upgrade investment cost to facility owners is expected to occur within 3-6 years (under current conditions). Recovery of WWTP construction costs for new industrial digestion facilities is typically within 6-8 years (under current conditions) but can be faster in certain circumstances. Recovery of investment costs for new "greenfield" municipal digester plants designed for co-digestion of biosolids, selected trade waste and industrial waste is typical within 5-10 years (depending on size and local conditions; under current market conditions). Central and local government costs used to encourage methane emission reduction by stimulating municipal organic waste co-digestion schemes are estimated at around $500,000 p.a. for 5 years, and for the accelerated methane reduction scenario with co-digestion of industrial waste are estimated to be less than $800,000 p.a. for 5 years, excluding any investment in suspensory loans and the fiscal cost of deferred depreciation.

The total level of reduction in greenhouse gas emissions from bioenergy and biofuels below 2017 levels and the amount of energy produced from the use of biogas are set out in Tables 4 and 5.

Jones, E. (2018) - An investigation into food waste produced in New Zealand restaurants and cafes, MSc Thesis at University of Otago, Dunedin, New Zealand.

Reynolds, C. J., Mirosa, M., Clothier, B. (2016). New Zealand's Food Waste: Estimating the Tonnes, Value, Calories and Resources Wasted. Agriculture 2016, 6, 9; doi:10.3390/agriculture6010009w

Table 4: Greenhouse gas emission reduction below 2017 levels (kt CO_2-e pa)

	Methane reduction from waste to energy[1] (kt CO_2-e pa)			
Year	BAU	Encouraged transition[2]	Accelerated transformation[3]	Zero organics to landfill
2030	0	180	320	1,450
2040	+20	210	410	1,640
2050	+40	220	515	1,815

Table 5: Energy increase above 2017 levels[6] (PJ pa)

	Methane reduction from waste to energy[1] (PJ pa)			
Year	BAU	Encouraged transition[2]	Accelerated transformation[3]	Zero organics to landfill
2030	0	1.1	1.8	3.2
2040	0.05	1.4	2.4	3.9
2050	0.1	1.6	3.0	4.6

Notes

1. Bioenergy Association Information Sheet 31 – Greenhouse gas reduction using biogas technologies, September 2018
2. Based on implementation of NZEECS
3. Requires greater incentives than set out in NZEECS
4. Assumes that a significant volume of low temperature process heat currently produced from coal or gas can be substituted by heating from electricity by use of heat pumps.
5. To achieve the encouraged scenario quantity of coal fired process heat substitution requires around 74,000kt/year of wood fuel which is within the wood fuel suppliers capability to supply. To achieve the accelerated scenario quantities of substitution will require development of additional sources of biomass.
6. In 2016 2.7PJ of energy was produced from biogas. It is assumed that the biogas from landfill will decrease as a result of diversion of organic waste from landfill to anaerobic digestion facilities with higher methane recovery potential by 0.2PJ and 0.4PJ by 2050 in scenarios 1 and 2.
7. The GHG offset from farm operations due to farming coming into the ETS has not been calculated and will be additional to the emissions reductions identified in Figure 4.

3.5 Assumptions

The assumptions for the methane GHG reduction scenarios are that:

- Economies of scale and steady biogas plant operation are achieved in scenarios 1 and 2 by the sourcing of suitable selected trade wastes, and supplementary industrial waste feedstocks and in parallel, by gradually increasing the use of municipal WWTP digester from 53 % of the population (2017) to 68 % of the population (2050)
- Gate fees charged for accepting trade waste at a waste treatment plant reflect only 50 % of the cost of otherwise disposing/processing of such waste. (e.g. by landfill). This is intended to provide a waste management cost incentive for waste generators (trade waste, industrial waste) encouraging the efficient segregation of digestible waste reducing the processing cost for digestible waste. Councils and waste generators benefit from the resulting cost savings when diverting suitable trade waste from landfill to municipal WWTP.
- Local government encourages separation of non-edible food waste organic matter from municipal solid waste in Scenario 1 and mandates it in scenario 2.
- There is no new technology and no new anaerobic digestion research needed.

- Existing waste treatment facilities in BAU scenario continue to be utilised as today and will be gradually upgraded with co-digestion technology in scenarios 1 and 2.

- A very high proportion of the current municipal organic waste which ends up in a landfill, will then be disposed of in an anaerobic digester – either at municipal WWTPs of dedicated food waste digestion facilities capturing and utilising the biogas as natural gas substitute in the industrial heat market.
- Because discharge of 1t of methane to atmosphere has a 25 times greater global warming potential than 1t of fossil CO2, methane capture and use should and will be a logical priority for municipal waste management policies.
- In scenario 1, a target is set for the production, capture and use of methane at waste water treatment plants which provides an incentive to collect and use the biogas for on-site electricity generation, on-site heat utilisation and / or use as an industrial heat fuel replacement. In scenario 2 additional volumes of biogas are produced and electricity is generated for export from the site during peak electricity demand times.
- In scenarios 1 and 2, landfill operators use a greater portion of the biogas collected for replacement of fossil vehicle fuel but this further reduction of GHG emissions is not addressed in this analysis.
- GHG emission reductions (CO_2–e) calculations are based on:
    - Comparison to the 2015 discharge of methane, CO_2 and nitrous oxides from municipal, industrial and agricultural waste to atmosphere. Comparison to the 1990 emissions can then be easily established with existing GHG inventories (Ministry for the Environment).
    - Heat: combustion of biogas in a boiler compared to the use of natural gas as an industrial boiler fuel. The emission factor used was 53.3 kg CO_2-equ avoided / GJ of avoided natural gas use.
    - Pro rata avoided methane emissions caused by landfilled grease trap waste and landfilled WWTP biosolids when diverted from current and future landfill operations in New Zealand (land fill gas capture efficiency gradually increasing from 60 % to 69 % between 2017 and 2050)
- Where appropriate in scenario 2, urban bus transport utilises available biogas from waste water treatment plants as a fuel (biogas then becomes CNG). (e.g., as already used by “Go Bus” in Hamilton)
- There are presently only weak GHG drivers for the capture of dairy farm effluent biogas in scenario 1 and scenario 2. Emissions from farm operations (beef, dairy, other livestock) has thus not been included in the scenario calculations. But increasing demands for better farm effluent management for the protection of waterways or odour emissions can result in a moderate increase in the production of biogas for on-farm electricity, heat and replacement of vehicle fuel.