XD Consulting
Sustainable Energy Engineers

Feasibility Study on Anaerobic Digestion in Duhallow

Final Report

Client: IRD Duhallow

Consultancy Team: Xavier Dubuisson, Tim Clarke, Siddarth Joshi, Trevor Sweetnam

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XD Sustainable Energy Consulting Ltd

+353 (0)86 0476124
xavier@xdconsulting.eu
www.xdconsulting.eu

Directors
Xavier Dubuisson
Susan O'Flaherty

Registered address
Rocksavage, Clonakilty,
Co. Cork, P85 AP20, Ireland

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List of Acronyms

AD: Anaerobic Digestion
CBM: compressed biomethane
CH_4: methane (Biomethane)
CNG: compressed natural gas
DM: dry matter
ED: electoral district
EMP: Energy Master Plan
GWh: gigawatt-hour or a million kWh
GW: gigawatt capacity
kWh: kilowatt-hour or a thousand Wh of energy
kW: kilowatt capacity
kWe: kilowatt electrical capacity
IRR: Internal Rate of Return
LCOE: Levelised Cost of Energy
MWh: megawatt-hour or a thousand kWh
MWe: megawatt electrical capacity (1,000 kWe)
Nm^3: normalised cubic meter
NPV: Net Present Value
RE: Renewable energy
RES-e: electricity produced from renewable energy sources
RES-heat: Heat produced from renewable energy sources
tCO_2: tonne of CO_2
tDM: tonne of dry matter
tVS: tonne of volatile solid
tFM: tonne of wet matter
TWh: Terawatt-hour, or a billion kWh

Summary of the Feasibility Study on Anaerobic Digestion in Duhallow

Climate change, with increased risks of flooding, droughts and storms, is a critical threat to the IRD Duhallow region's ecosystem and by extension its agriculture. Conversely, climate action represents real opportunities for the region, including:

- Leveraging land as its primary asset to produce renewable energy.
- Adopting circular economy practices, using organic wastes as a valuable resource which can generate a high-quality fuel.
- Pioneering innovative, sustainable solutions to meet our national and global commitments to decarbonisation.

IRD Duhallow aims to be at the forefront of this transformation together with key stakeholders in the region, including the agricultural and food processing sector, and has commissioned XD Sustainable Energy Consulting Ltd. to undertake a feasibility study on anaerobic digestion[1] in the region. The overall objective of the study is to investigate the potential for biogas production to contribute to the region's energy needs in an affordable, secure and sustainable manner.

The first step of the study was to assess the potential feedstocks available in the study area for AD, including agricultural sources (grass silage, slurry and manures) and municipal/industrial sources of organic waste (e.g. food waste, municipal sewage sludge, industrial sewage sludge, food processing waste, etc.). The assessment, including field surveys and desktop research, concludes that the practical potential of AD feedstocks is equivalent to 337 GWh/year in energy content, enough to meet the heating requirement of close to 5,000 homes or a third of the region's estimated total energy demand.

Summary of biogas feedstock analysis.

Feedstock	Feedstock potential (tDM/year)	Biomethane potential (,000 Nm3/year)	Energy Potential (GWh/yr)	Equiv. Home Heating Energy (# homes)
Grass Silage	60,400	21,986	220	3,100
Cattle Slurry	84,474	8,154	81.5	1151
Domestic Food Waste	378	91	0.9	13
Commercial Food Waste	134	32	0.3	5
Milk Processing By-Product	16,700	2,422	24.2	342
Municipal WWTP Sludge	351	35	0.4	5
Totals	**162,436**	**33,689**	**337**	**4,754**

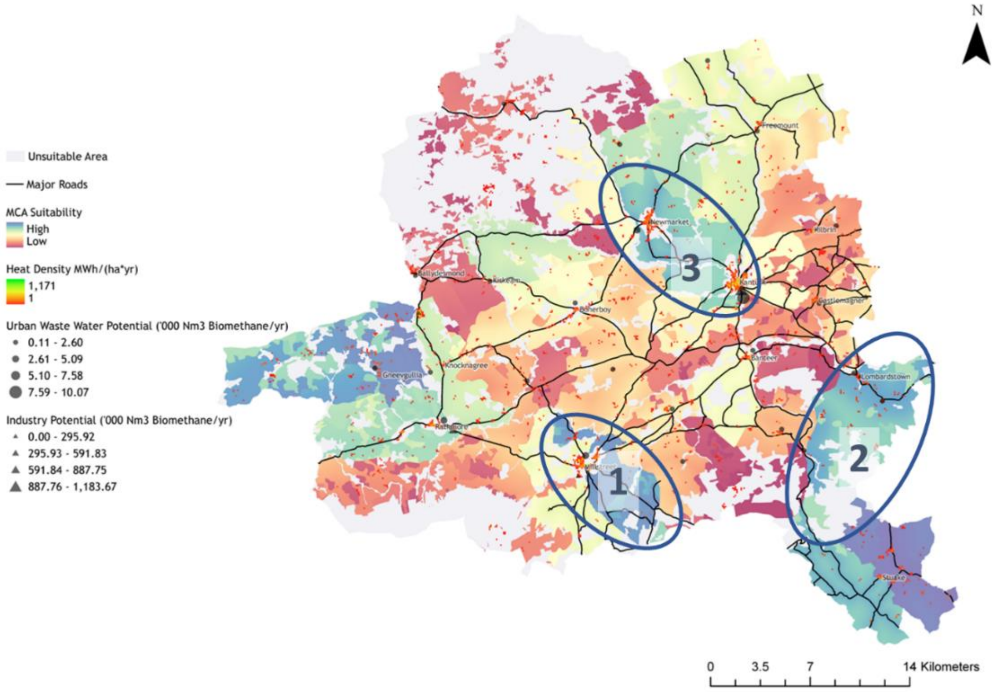
Grass silage is an important resource for AD development in the region (65% of the potential), however its availability will be strongly conditioned by its existing demand as a cattle feed in the winter, future changes in local agricultural systems and/or improved grass land management, and very importantly the price paid to farmers for it. Cattle slurry represents another 27% of the potential resource identified, is a low-cost feedstock and its treatment in an AD plant contributes to a better nutrient management on the farms where the resulting digestate is spread, reducing the need for artificial fertilisers. This also lowers the environmental impact of slurry spreading in terms of odour, and pollution of water bodies due to run-offs to rivers and leaching into groundwater.

Industrial and municipal organic waste represent less than 8% of the total feedstock potential, but they can play an important role in AD development because they typically attract gate fees and contribute to local, circular waste management in the study area. The feedstocks available in IRD Duhallow region have a biogas potential sufficient to

[1] Anaerobic Digestion (AD) is the process of breaking down organic materials to produce biogas (methane (CH_4) + carbon dioxide (CO_2)).

meet the needs of close to 17 medium-sized AD plants (20 GWh/yr biogas production) installed in a farm setting, or up to 9 larger (40 GWh/yr), centralised plant more likely to be in an industrial setting.

A detailed spatial analysis of the region was undertaken to identify most suitable locations for AD development using a geographical information system and considering a range of criteria including feedstocks availability, energy demand, environmental protection, land cover, road infrastructure, special amenity areas, etc. While there are significant areas that are unsuitable or have a low suitability in the study area, the spatial analysis highlighted three areas with a strong potential for developing AD projects: 1) the area around Drishane ED due to the concentration of agricultural feedstocks available plus the proximity to significant energy users in Millstreet and Rathmore, 2) the area around Kilshannig ED again with a strong concentration of agricultural feedstocks and good road access to the gas grid connection planned for Mitchelstown, 3) area in and around the Newmarket and Kanturk EDs also score high in the MCA, due to the availability of agricultural feedstocks but also organic waste from local agri-food processors and food waste in the local towns.

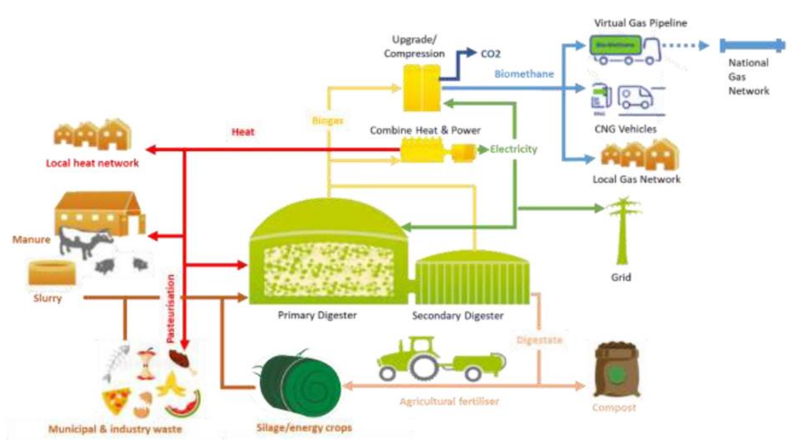


Map showing the results of the spatial multicriteria analysis & areas deemed most suitable for AD development.

The study also includes a detailed review of key sustainability considerations for the development of AD in the study area, and the associated regulatory and compliance framework. In line with the proposed model for AD development at national level, it is intended that grass silage will be sourced primarily from beef farmers who will increase their yields by boosting their grassland fertility (initially with artificial fertilisers and lime, and then maintaining it with the application of AD digestate). The advantages of switching to Multi-Species Swards from ryegrass monocrops have also been discussed.

The environmental benefits of treating slurry with AD against spreading raw slurry have also been reviewed, including reducing odours, the pathogen load to the environment, and increasing the availability of nitrogen to plants. Capturing methane from slurry prevents it from being released to the atmosphere, thereby having the effect of being carbon negative and improving the overall GHG savings of the AD facility. Slurry therefore plays a key role in meeting the Revised Renewable Energy Directive's Sustainability Criteria (80% reduction in GHG emissions against fossil fuel comparators), and proposed AD project include 40% slurry in their feedstock mix. Since the slurry will have to be sourced from a number of farms in the study area, the Animal By-Products regulations will apply and require treatment with pasteurisation.

Applying the digestate as an organic fertiliser to the farmland producing the grass silage used for AD plant will help close the nutrient cycle in the project catchment area. It will also play an important role in improving the sustainability of the agricultural system underlying it. However, there are concerns relating to the potential increase in ammonia (NH3) and nitrogen oxide emissions (NO2), as well as the potential for excess phosphorus to leach into water bodies, when applying straight digestate compared to animal slurries. Managing the digestate is an important aspect of a sustainable AD project development and will require the application of appropriate application practices and a robust nutrient management plan in conjunction with the farmers involved in the project. There is also a business case of adding a nutrient recovery system to the proposed AD projects to improve the quality of the organic fertilisers derived from the digestate, with significant added value for the environment and the project stakeholders.



The next step was to analyse and compare a range of AD technological pathways that would be appropriate for the development of AD appropriate in Duhallow. These pathways combine different sources of feedstocks (agricultural only or with organic waste), different sizes of AD plant (20 GWh/yr and 40 GWh/yr of biogas output), different settings (farm-based or co-located with a food processor), the biogas conversion processes (upgrade to biomethane, use of a combined heat & power generation (CHP) to meet onsite energy requirements). They also consider different options of end-use & commercialisation of the biomethane (used on site, sold to local energy users, exported for injection into the natural grid), as well as the valorisation of by-products (CO2 liquification, separation of the solid fraction of digestate and production of compost). The graph below illustrates the different elements of the pathways assessed.

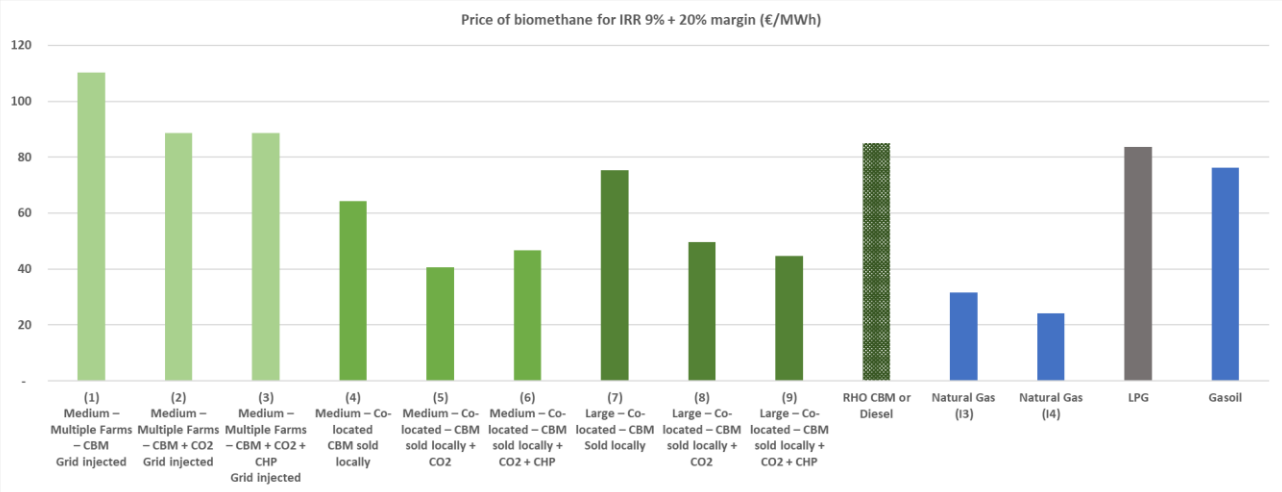
A detailed lifecycle analysis of the capital costs, operating costs and revenues of these AD pathways was undertaken. The table below summarises the results of the financial analysis of the 3 sets of pathways: a) for a 20 GWh/yr farm-based plant (1-3) exporting its CBM for injection in the gas grid; b) a 20 GWh/yr plant collocated with a food processing plant (4-6) and c) a 40 GWh/yr plant co-located with a food processing plant (7-9) where the CBM produced is used on site. By way of assessing the financial profitability and competitiveness of the pathways analysed against incumbent fossil fuels, the value of biomethane required to achieve an Internal Rate of Return (IRR) of 9% plus a 20% profit margin for the project was calculated.

Results of the Financial Analysis of Selected AD Pathways

Financial Assessment		(1) Medium – Multiple Farms – CBM Grid injected	(2) Medium – Multiple Farms – CBM + CO2 Grid	(3) Medium – Multiple Farms – CBM + CO2 + CHP Grid injected	(4) Medium – Co-located CBM sold locally	(5) Medium – Co-located – CBM sold locally + CO2	(6) Medium – Co-located – CBM sold locally + CO2 + CHP	(7) Large – Co-located – CBM Sold locally	(8) Large – Co-located – CBM sold locally + CO2	(9) Large – Co-located – CBM sold locally + CO2 + CHP
CAPEX	*Mio€*	5,039,543	5,560,000	5,850,695	4,839,177	5,360,000	7,200,695	8,885,759	9,260,000	9,868,888
Total Revenue	€/y	2,036,752	2,067,179	2,134,814	1,308,602	1,336,402	1,570,325	2,895,911	2,885,030	3,075,967
Total OPEX	"	1,567,381	1,547,535	1,588,070	855,240	835,459	897,745	2,065,985	2,019,800	2,153,682
Depreciation	"	228,803	263,500	282,880	218,778	253,500	345,880	428,217	453,167	493,759
Loan Interest	"	120,949	133,440	140,417	116,140	128,640	172,817	213,258	222,240	236,853
Price of biomethane for IRR 9% + 20% margin	***€/MWh***	**110**	**89**	**89**	**64**	**41**	**47**	**75**	**50**	**45**
Profit/Loss	***"***	**119,619**	**122,704**	**123,448**	**118,443**	**118,803**	**153,883**	**188,450**	**189,823**	**191,672**
Return on Capital	***%***	**4.9%**	**4.7%**	**4.6%**	**5.0%**	**4.7%**	**4.6%**	**4.6%**	**4.5%**	**4.4%**
NPV	***€/2021***	**366,575**	**423,723**	**445,140**	**380,445**	**408,386**	**544,411**	**671,303**	**703,331**	**751,317**

The graph below indicates that in collocated AD plants (pathways 4-9), biomethane is competitive with gasoil and LPG, the predominant heating fuels for commercial energy users in the study area. However, biomethane is significantly more expensive than natural gas for large users on the gas grid. These pathways would be able to profitably supply biomethane at the value anticipated by Gas Network Ireland to be achieved in the framework of the Renewable Heat Obligation scheme.

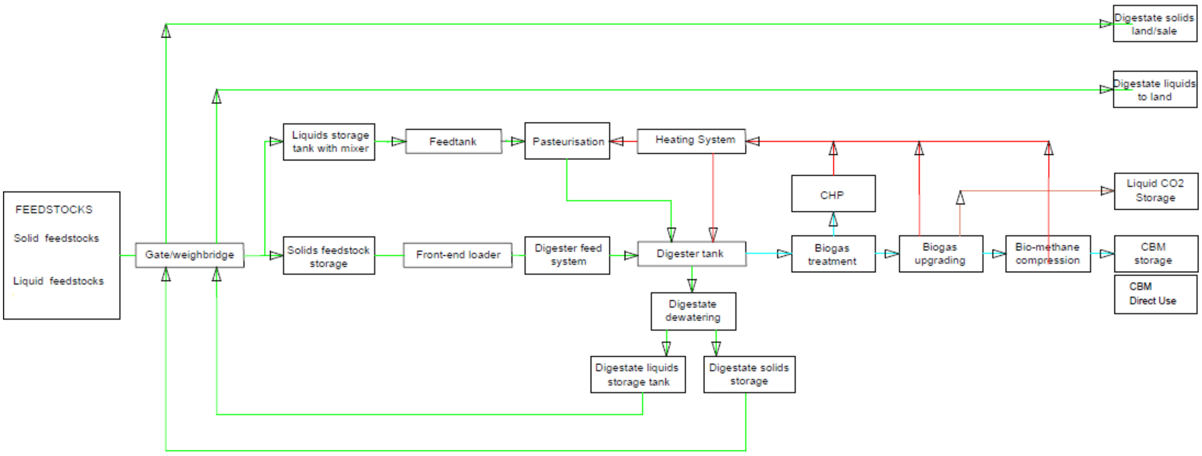
The most profitable pathways (4-9) involve the use of feedstocks available at no/low cost on site (milk processing waste is particularly relevant here) and/or feedstocks that attract a gate fee (e.g. food waste). The extraction and liquefaction of CO_2 for sale in the food industry increases significantly revenues and profitability. The sale of compost and to a smaller degree heat also make a useful contribution in that regard. The economies of scale anticipated in the large co-located plant (pathways 7-9) do not materialise in noticeable increases in return on investment, primarily because they rely on a high proportion of grass silage, an expensive feedstock. The impact of adding a CHP unit to reduce the cost of electricity supply to the plant is limited as it reduces the amount of biogas available to produce biomethane – the prime driver for revenue, unless the heat produced (together with the waste heat of the biogas upgrade and CO_2 liquification processes) is valorised e.g. in a co-located food processing plant. Pathways that valorise by-products such as CO_2, compost and excess heat, in addition to biomethane, also do significantly better.



Comparison of CBM value required to achieve 9% IRR with a 20% profit margin, against existing fuels.

Commercialising biomethane as an alternative, renewable transport fuel should also be considered carefully. It would be ideally suited as a substitute to diesel for captive fleets of heavy goods vehicles (a hard to decarbonise sector) in the study area, serviced by CBM refuelling stations adjacent to the AD plant or located at the client's site. With reduced excise duties and assuming a steep rise in carbon taxes, biomethane is a significantly cheaper alternative to diesel.

The next step was to study in further detail three AD 'use case' projects responding to the three areas highlighted by the spatial analysis for AD development and the results of the comparative analysis of pathways undertaken. These 'use case' projects are: 1) a farm-based AD plant of 20 GWh capacity in area in and around Drishane ED, producing biomethane supplied to large energy users (businesses, HGV fleet, etc.) in the area via a virtual pipeline (high pressure tanks on trailer), 2) a similar farm-based plant based in and around the Kilshannig ED, dedicated to exporting the biomethane via virtual pipeline for grid injection in Mitchelstown, 3) a larger (40 GWh/yr) AD plant co-located with a food-processing factory and using organic waste as well as agricultural feedstocks, where the biomethane is used to meet the processor's energy needs. The following diagrams illustrate the process flow of these Use Case projects. Generic plant layouts for the AD systems associated with these Use Cases are presented in Chapter 6.B.3.



Use Case Projects 1 and 2: Process flow diagram of farmed-based AD producing CBM and CO2 for export, with CHP.

A more detailed financial analysis of the proposed Use Case AD projects systems was conducted based on their preliminary design to ascertain the viability of these potential projects. This techno-economic analysis indicates that these projects could provide a robust return on investment. In this analysis, a biomethane value of c€ 8.5/kWh has been applied to Use Cases 1 and 2 (biomethane injected to the grid or used locally), and c€ 6/kWh for Use Case 3 for biomethane being competitive with LPG or gasoil at a food processing plant. The analysis shows that all three AD Use Cases envisaged could be profitable and generate a healthy return on investment with Internal Rate of Returns before tax of 14%, 11% and 18% respectively, and Net Present Values of €2.54 million, €1.3 million and €7.4 million respectively. These results indicate that Use Case 3 is the most profitable as the biomethane produced is used on site, which simplifies the infrastructure required and helps reduce operating costs. Use Case 2 is less profitable than Use Case 1 because of the increase operational costs of having to transport and inject biomethane into the natural gas grid at a considerable distance. These two Use Cases use agricultural feedstocks only, with grass silage representing a very significant operating cost, which reduces the level of return on investment compared to Use Case 3 benefitting from reduced feedstock costs. By-products from the CBM production (CO_2, compost and to a lesser extent heat) play a very important role in the viability of the projects, without these revenue streams they have a negative return on investment.

A co-operative society structure is recommended as the most appropriate business model for the development of AD in West Cork, promoting wide, democratic participation in ownership and control. It also more likely to engender local support and additional benefits for the community in terms of job creation, training and innovation, notably in terms of the green economy. Financing one or several AD projects will require combination of institutional financing instruments such as loans or debentures, as well as raising equity through community shares and subsidies. Partnership with a commercial developer is also an option in that it can bring valuable experience and financial capability, however this is likely to reduce potential dividends for the community.

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Chapter 1. Introducing the Feasibility Study

The study area, the IRD Duhallow region, is approximately 1,800 sq.km and has a population density of 16 per sq.km. It is a largely rural area and over 85% of the population live in the open countryside or in settlements of less than 200 people. It has four market towns: Kanturk (Pop 2263), Millstreet (Pop 1574), Newmarket (Pop 988), Rathmore (Pop 778) and 36 villages. There are 48 EDs considered part of the study area, as represented in

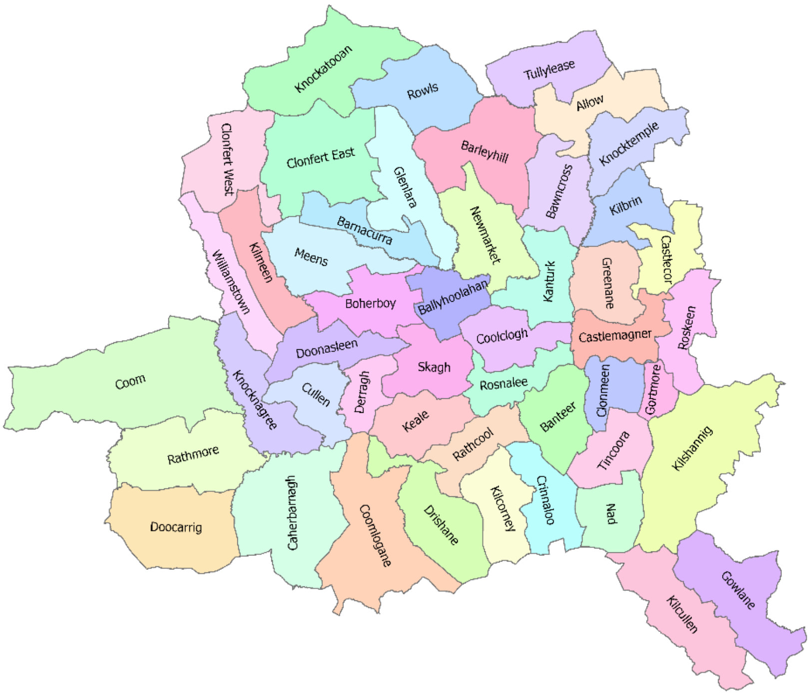


Figure 1 below.

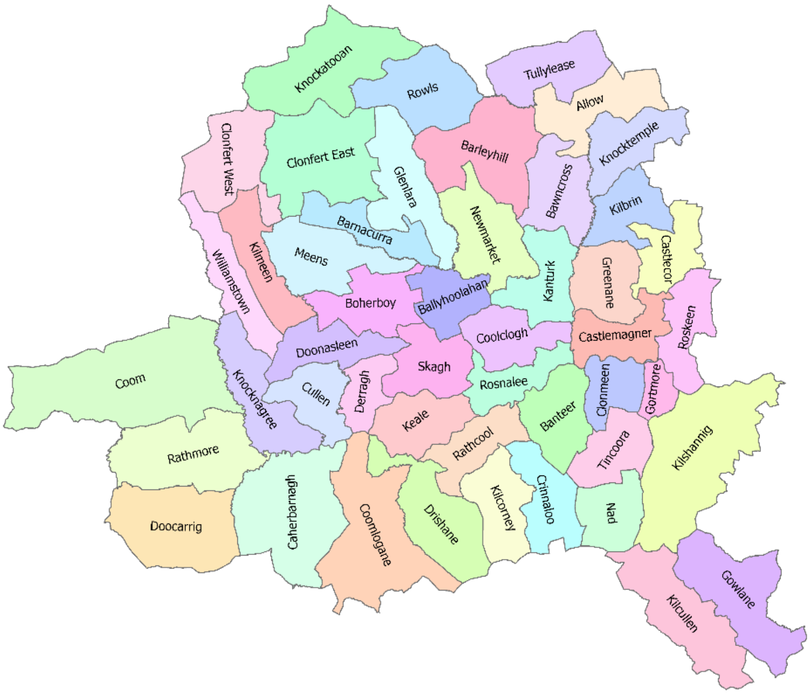


Figure 1: Map of the IRD Duhallow region and its Electoral Districts.

Climate change, with increased risks of flooding, droughts and storms, is a critical threat to the region's ecosystem and by extension its agriculture. Conversely, climate action represents real opportunities for the region, including:

- Leveraging land as its primary asset to produce renewable energy.

- Adopting circular economy practices, using organic wastes as a valuable resource which can generate a high-quality fuel.
- Pioneering innovative, sustainable solutions to meet our national and global commitments to decarbonisation.

IRD Duhallow aims to be at the forefront of this transformation together with key stakeholders in the region, including the agricultural and food processing sector, and has commissioned XD Sustainable Energy Consulting Ltd. to undertake a feasibility study on anaerobic digestion[2] in the region. The overall objective of the study is to investigate the potential for biogas production to contribute to the region's energy needs in an affordable, secure and sustainable manner.

The specific objectives of the feasibility study are:

- To conduct a comprehensive assessment of the biomass resource available in the study area to determine their practical potential for biogas, their spatial distribution and cost.
- To initiate engagement with key stakeholders with a view to define a shared vision for anaerobic digestion and identify the core principles which should govern its development.
- To undertake a multi-criteria spatial analysis aiming to identify areas suitable for the development of anaerobic digestion plants.
- To investigate and compare suitable technical biogas pathways, from feedstock to energy end-use, considering their environmental, social and economic impacts.
- To conduct a preliminary design and a lifecycle cost analysis of selected anaerobic digestion systems based on the pathways deemed as being most feasible.
- To review business and financing models appropriate for community participation and provide the community with a roadmap for the deployment of anaerobic digestion in the region and guide the next steps for project development.

The study, funded by Gas Networks Ireland, is undertaken by XD Sustainable Energy Consulting Ltd., with a team of experts in biogas system design and engineering, advanced renewable energy systems and spatial planning.

Chapter 2. Anaerobic Digestion Feedstocks Analysis

A. Introduction

The objective of the feedstock analysis is to understand the potential of biogas production in the study area, based on a detailed assessment of the organic materials available, in terms of suitability for anaerobic digestion, quantities that can be mobilised and cost. The analysis draws from the Central Statistical Office (CSO)'s Population Census (2016) and Agriculture Census (2010), EPA licensing data for industrial sites and waste management facilities, as well as other published sources of data and information.

The following feedstocks have been analysed:

- Agricultural feedstocks: grass silage and cattle slurry.
- Municipal and industrial feedstocks: sewage sludge, food waste, milk processing by-products.

B. Agricultural Feedstocks

The following agricultural feedstocks have been considered in terms of potential for biogas:

a) **Grass silage:** forage biomass harvested and ensiled for use as winter fodder for cattle and sheep. Although silage is primarily produced as a feed, it is also an excellent feedstock for anaerobic digestion. Grass silage has a number of advantages: grass is widely available in the area, grass silage has a high density and methane content, it can be transported over reasonable distances and can be stored seasonally. The disadvantages are that it is an expensive feedstock for AD, which is a key component of the existing agricultural system.

[2] Anaerobic Digestion (AD) is the process of breaking down organic materials to produce biogas (methane (CH_4) + carbon dioxide (CO_2)).

b) **Cattle slurry:** captured when the cattle are housed during the winter (typically 100 days) and generally stored under the cattle shed, or in adjacent above or below ground tanks in some cases. Cattle slurry is normally spread on land as an organic fertiliser. Its water content is high (above 90%).

Manure from sheep is not considered as practical feedstock for AD.

1. Grass Silage

The potential of grass silage as an AD feedstock was determined based on the CSO Agricultural Census 2010 data, which provides detailed figures for crops and livestock down to the electoral division (ED) level. A total of 89 thousand hectares were farmed in the study area, of which c.94% is grassland. Three classes of grassland are inventoried under the census: silage (28,000 ha), pasture (49,000 ha) and rough grazing (6,800 ha). The other factor affecting the potential of grass silage is grass yields. Dairy farms recording farm cover regularly on PastureBase Ireland have grown between 12-14 tonnes of dry matter per ha per year (t DM/ha/year) over the 2013-15 period, while drystock farms have grown between 10.5 – 12.3 t DM/ha/year for the same period (Micheál O'Leary, 2016). Records on PastureBase for 2015 indicate that the Duhallow area rates among the highest nationwide in terms of grass production, going up to 15.9 tDM/ha/year (see Figure 2), average yields across the study area are lower than the best practice yields used above.

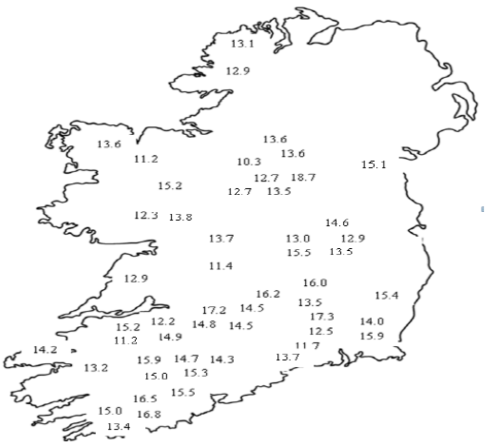


Figure 2: Grass dry matter production from PastureBase Ireland dairy farms across the country in 2015. Source: (Micheál O'Leary, 2016).

Recognising that grass yields will vary in the region to reflect local conditions (soil, drainage, etc.) and grass management practices, three levels of average grass yields were assumed based on the stocking rates (heads of cattle per ha of grassland) in each electoral district:

- 12 tDM/ha/year where stocking rates are above 2.5 heads of cattle/ha, typically in EDs where dairy farming is the prominent farming enterprise.
- 8 tDM/ha/year where stocking rates are between 1.7 and 2.5 heads of cattle/ha, typically in EDs where beef farming is prominent.
- 5 tDM/ha/year where stocking rates are below 1.7, typically in EDs with low intensity farming and significant areas of rough grazing.

The potential availability of grass silage was calculated by multiplying the total area of grassland classified as 'silage' and 'pasture' in each ED, by the relevant yield figure above according the ED's stocking density.

This results in a theoretical grass availability of 563 thousand tonnes DM (average yield of 7.4 tDM/ha/year). Grass silage can yield 400 Nm^3 CH_4/t_{VS} (tonne of volatile solid), at 91% VS per dry matter weight. This is equivalent to 364 Nm^3 CH_4/t_{DM}. The total theoretical biomethane potential in the study area was therefore estimated at 205 million Nm3 of biomethane. This amount of biomethane has an energy content of 20.5 GWh/year, equivalent to the fuel used for heating over 1600 homes.

In practice, all this grass is already accounted for feeding the cattle and sheep in the area, as fresh grass or silage. Following consultation with key stakeholders in the agricultural sector, it is assumed that most of the grass silage potentially available for anaerobic digestion would be derived from grassland where beef farming is prominent. The latest Farm Survey Results 2019 for the South-West region indicates that approximately 40% of dry cattle farms, 40% of sheep farms and 12% of dairy farms are vulnerable economically and could be incentivised to diversify towards the production of silage for biogas.

Considering our analysis of stocking rates within the study area above, we assume there are circa 1580 farms in the study area that are primarily specialised in beef production, farming a total of 15,100 ha for silage and 26,000 ha permanent pasture. If improved grassland management and increased fertility led to an increase in average silage yields from 8 tDM/ha/year to 12 tDM/ha/year, this could deliver an additional 60,400 tDM/year of silage technically available for AD. This represents a technical potential of 22 million Nm3 CH4/year with an energy content of 220 GWh/yr, equivalent to the heating fuel requirement of 3,100 homes.

2. Slurry and manure

a) Cattle slurry

The theoretical potential of cattle slurry for biogas was calculated based on the numbers of cattle per type taken from the census 2010 data. These data were adjusted to reflect growth in cattle numbers between 2010 and 2020, using national statistical data from the CSO on livestock numbers[3]. The results have been combined with indicators of slurry production (in tonnes of fresh weight) by cattle type taken from a study by Teagasc [13], see Table 1 below.

The DM content of slurry was taken to be 7% and its biomethane potential as 107 Nm^3 CH_4/t_{DM}. The practical biogas potential from slurry considers that slurry loses (10%) of gases during storage. The length of time of storage of waste in tanks negatively impacts gas yields, so cattle slurry's availability will vary seasonally.

Table 1: Slurry Production by cattle type.

Cattle Type	Slurry Production (tonnes/year/head)	Head of cattle acc. Ag Census 2010	Head of cattle (after adjusting for national trends)
Dairy Cows	5.84	44,000	64,100
Bulls	5.84	1,300	1,305
Other Cow	5.20	15,800	13,500
Other Cattle	4.10	88,000	95,800

Our modelling suggests there is close to 174,700 thousand head of cattle in the study area that produce 84,500 tonnes dry matter per year (tDM/year) of slurry when housed, including a small contribution from cow slurry collected at dairy parlours year-round. This slurry can be harvested for anaerobic digestion purposes and potentially produce 8,150 thousand Nm3 of biomethane per year, with 82 GWh/year in energy content, equivalent to the fuel use for heating of 1150 homes.

3. Results of a survey conducted with farmers in IRD Duhallow

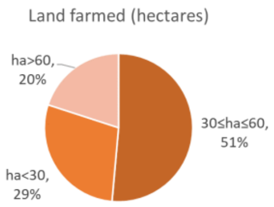
Since farmers will be key stakeholders in the development of AD in the region and for the supply of essential feedstocks such as grass silage and slurry, a survey was conducted with the support of Michael Morrisey at IRD Duhallow. A total of 35 responses were received, which provides a sample sufficiently large to get an insight into attitudes and trends in the farming population of the study area.

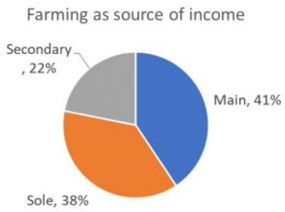
The key results are presented and commented herewith:

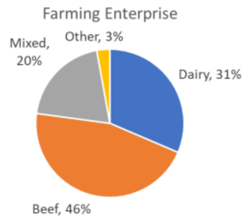
- 70% of farmers surveyed declared being members of a co-operative.
- The average land area farmed is 53 ha per farm, which is well above the average in the study area at 36 ha/farm, and about 20% of respondents farm above 60 ha.

[3] See CSO database here: https://data.cso.ie/table/AAA06

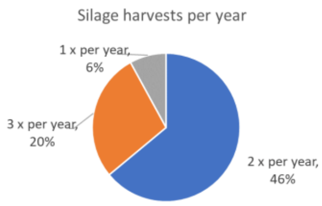
- Farming is the sole or main source of income for almost 80% of the respondents. Beef farming is the predominant enterprise (46%) with dairy farming coming second (31%), above mixed farming (20%).

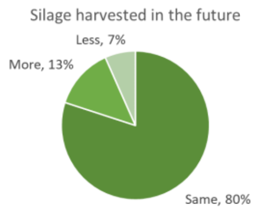




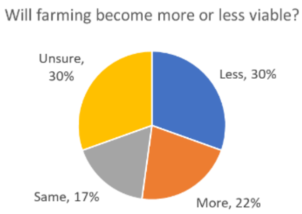


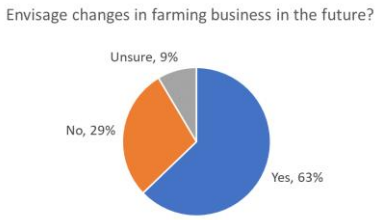
- In average, farmers house their cattle for 5 months per year. About 700 tFM/yr of slurry is collected in average when cattle are housed or from the dairy parlour, typically stored in slatted tanks. 30% of respondents declare having excess slurry.
- Silage harvested on 40% of farmed land (21 ha average) among respondents and 70% of them store silage in bales. 20% of farmers buy or sell silage, and the average price of the silage traded is €24 per bale or c.€31/tonne. 80% of respondents plan to harvest the same amount of silage in the future.





2/3rd of farmers have help on the farm, in average 25 hrs/week. When asked if farming in Duhallow is viable, 57% answered "Yes", and 26% answered "No" or "Just about". Generally, respondents with a cautious or negative outlook are beef farmers or are involved in mixed farming. A significant number of respondents are planning to diversify their farming enterprise (30%), 14% to retire and 11% to scale back.





C. Non-Agricultural Feedstocks

The collection and local treatment of municipal & industrial organic waste with anaerobic digestion has key benefits:

- It contributes to the circular management of organic waste, at a local level.
- It can generate revenue from the collection of gate fees for the waste management service.
- It reduces the amount of waste going to landfill and helps the region meets the legislative requirements in this regard.
- It avoids the environmental burden of traditional organic waste disposal approaches, in terms of GHG emissions, water and air emissions.

The following sections provide a preliminary inventory of municipal and industrial organic waste in the study area, based on published data.

1. Municipal Waste

a) Sewage Sludge

The practical potential for sewage has been calculated based on quantities of sewage sludge removed from wastewater treatment plants (WWTP) in the study area provided by the EPA. In total, treatment plants in the study area have the capacity to treat 16,020 population equivalent[4] (PE). Assuming these WWTPs operate at their nominal capacity year-round, it is estimate they would produce 1950 tonnes of sludge, with a dry matter content of 18%. Using a biomethane potential factor of 120 Nm^3CH4/t_{DM} for sewage sludge, the biomethane potential of the study area from this resource is estimated at35 thousand Nm^3CH4/year, with an energy content of 0.35 GWh/yr, enough to heat 5 homes.

Please note that the practical use of WWTP sludge is extremely limited due to environmental regulations and Bord Bia's guidelines regarding use of digestates containing this waste on food-producing land - even after pasteurisation. This restricts recycling of digestate containing sewage sludge to few outlets such as forestry and energy crops.

b) Food waste

The treatment of food waste in anaerobic digestion is an efficient way to recover energy and nutrients from this resource and reduce CO2 emissions associated with its decomposition. There are two main sources of food waste in the study area: a) from households, b) from commercial/public streams. The total household food waste resource available was estimated using a figure of 85 kg of fresh food waste/person/yr factor (Cre, 2010) and a collection rate of 50% average between rural and urban areas (Southern Waste Region, 2017). This gives a total potential resource of 1230 tonnes of household food waste per year (378 tDM/yr).

The average non-household source segregated organic waste collected in the South-West region during the 2011-2012 period was equivalent to 15 kg/inhabitant/yr, which gives a total potential in the study area of 440 tonnes of fresh organic waste per year (134 tDM/yr).

Overall, the residential and non-residential food waste available in the area was estimated at 512 tDM/yr, with a biomethane potential of 124 thousand Nm3 per year, with an energy content of 1.2 GWh/yr, enough to heat 18 homes.

2. Industrial waste

a) Milk processing waste

There are four milk processing plants for which Annual Environmental Reports to the EPA are available in the study area, in some cases complemented with data provided directly by the plants' operators. These reports indicate that there are approximately 19,600 tonnes of fresh organic waste (whey and WWTP sludge) with a biomethane potential estimated at 2,400 thousand Nm3/yr. The overall biomethane potential of these milk processing facilities has an energy content of 24.2 GWh/yr, enough to heat 342 homes.

D. Summary of AD feedstock analysis

Table 2 summarises the AD feedstock analysis in terms of quantities potentially available, the associated biomethane potential, energy content and equivalent home heating energy use.

[4] This is a measurement of total organic biodegradable load, including industrial, institutional, commercial and domestic organic load, on a wastewater treatment plant, converted to the equivalent number of population equivalents (PE). One person is considered to generate 60g of BOD per day (BOD is the 5-day biochemical oxygen demand); and 1 PE is defined as being equivalent to 60g of BOD per day.

Table 2: Summary of biogas feedstock analysis.

Feedstock	Feedstock potential (tDM/year)	Biomethane potential (,000 Nm3/year)	Energy Potential (GWh/yr)	Equiv. Home Heating Energy (# homes)
Grass Silage	60,400	21,986	220	3,100
Cattle Slurry	84,474	8,154	81.5	1151
Domestic Food Waste	378	91	0.9	13
Commercial Food Waste	134	32	0.3	5
Milk Processing By-Product	16,700	2,422	24.2	342
Municipal WWTP Sludge	351	35	0.4	5
Totals	**162,436**	**33,689**	**337**	**4,754**

Overall, the above analysis has identified a range of AD feedstocks for which the estimated quantity available is 162.4 thousand tonnes dry matter. The total biomethane potential associated with these feedstocks has been estimated at 33.7 million Nm3, with an energy content above 337 GWh per year. This would be sufficient to meet the needs of close to 17 medium-sized AD plants (20 GWh/yr biogas production) installed in a farm setting, or up to 9 larger (40 GWh/yr), centralised plant more likely to be in an industrial setting.

While silage is seen as a key for the deployment of AD in Ireland, it is costly as a feedstock. Its availability will be strongly conditioned by its existing demand as a cattle feed in the winter, future changes in local agricultural systems linked to diversification in farming enterprises and/or improved grass land management, and very importantly the price farmers would receive for its supply to an AD project.

Cattle slurry represents a substantial feedstock (approximately 27 % of the total estimated resource). On the one hand, slurry is a free or low-cost feedstock for AD and its treatment in an AD plant contributes to a better nutrient management on the farms where the resulting digestate is spread, reducing the need for artificial fertilisers. This also lowers the environmental impact of slurry spreading in terms of odour, and pollution of water bodies due to run-offs to rivers and leaching into groundwater.

While with a smaller potential (8% of total potential), municipal and industrial feedstocks in the region would also play a part, as they typically attract a gate fee of between €20 and €50 per wet tonne and contribute to transition to a circular waste management system. Further research into the potential of municipal and industrial waste from outside of the study area would be justified in terms of generating gate fee revenues for an AD plant based Duhallow, considering potential competition with other AD plants or existing treatment options for these wastes.

The seasonality of feedstocks must also be taken into consideration. The seasonality of slurry and silage harvesting, and storage will impact the potential material flows into AD plant(s) in the study area and this should be considered carefully in the planning of the feedstock supply logistics. Equally, milk processing sludges availability will vary with changes in milk production between summer and winter.

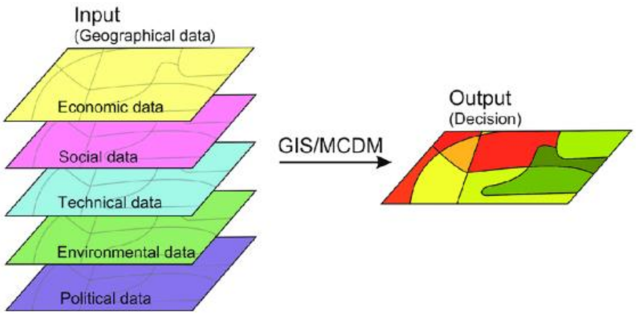
While there are no specific references on energy use in the study area, a simple calculation based on the national total energy use[5] per capita ratio of 35.3 Megawatt hour (MWh/yr) gives an estimated 1,017 GWh/yr energy use in the Duhallow region, across the whole economy (including for heat, electricity and transport). At a high level, this is promising in that the above analysis indicates that anaerobic digestion could potentially meet about a third of the region's energy requirements, using local feedstocks to contribute to the local economy in a sustainable, circular manner.

The next steps will include a spatial analysis of the region to identify most suitable locations for the development of AD projects (chapter 3) and then the technical and financial assessment of different technological pathways whereby biogas can be converted to useful energy for heat, electricity and transport (chapter 4).

[5] This is the 'primary energy use' and it includes the fuels used in the production of electricity.

Chapter 3. Spatial Multi-Criteria Analysis

A. Introduction



The overall objective of this section of the study was to identify areas with a high degree of suitability for the location of potential AD projects, using a spatial multi-criteria analysis approach (MCA).

The key steps for the spatial MCA included:

- Identify key criteria to be considered and acquisition of relevant GIS datasets.
- Define scoring matrix for individual criteria in terms of suitability for AD development.
- Apply an overall suitability scoring system for all the parcels of land in the study area, compiling the individual criteria scoring.
- Produce a map with the overall scoring results with visual aids to help identify areas that are most suitable areas for AD development.

The spatial MCA will then enable conduct more detailed investigations on potential locations that have been shortlisted, as a follow up to this feasibility study and in support of future planning application(s). The spatial MCA will also provide a basis to engage with the local community and key stakeholders at the early stages of potential project development.

B. Criteria Considered

In a spatial MCA, *criteria* are defined as the set of guidelines or requirements used as basis for a decision. There are two types of criteria: *factors* and *constraints*. A *factor* is a criterion that enhances or detracts from the suitability of a specific alternative for the activity under consideration. *Constraints* serve to limit the alternatives under considerations. These are areas that are categorically unsuitable for development, and therefore are eliminated from the analysis. Various geographic layers containing information about the spatial distribution of factors and constraints relevant to siting an AD development have been sourced and form the key inputs into the analysis. These are summarised as follows:

Table 3 Geographical layers included in the analysis.

Layer	Spatial Resolution	Source
Total Heat Density (2015)	100m x 100m	Hotmaps Project (2016)
Silage Potential	ED Level	Agriculture Survey 2010
Slurry & Manure Potential	ED Level	Agriculture Survey 2010
Municipal & Industrial Waste Potential	Point data	Environmental Protection Agency licensed sites (2020)
Land cover	100m x 100m	CORINE Land Cover 2018
Special areas of conservation (SACs) or special protected areas (SPAs)	Vector Data	National Park and Wildlife Services (2019)
Slope	90m x 90m	National Aeronautics & Space Administration (2012)

C. Factors

1. Heat Density

Heat density data was taken as a proxy to identify areas of high energy demand, where AD plants could contribute to the local energy supply. This is particularly relevant for district heating applications whereby the heat produced by an AD plant can be distributed to users in a concentrated area via a pipe network circulating hot water. An alternative would be to distribute the biomethane produced by an AD plant via an existing or newly installed gas distribution network.

Heat demand (or heat density) has been calculated for buildings in the EU28 + Switzerland, Norway and Iceland as part of the Hotmaps project[6] . The data were extracted and clipped to the bounds of the study area (Fig. 1). The total heat density ranges from 0 – 1350 MWh/(ha*year). As expected, areas of high heat demand are clustered around settlements. The heat density layer was normalised to range from 0-255 (0 = least suitable for AD development, 255 = most suitable for AD development). All mapped factors were normalised to this scale for the purpose of comparison.

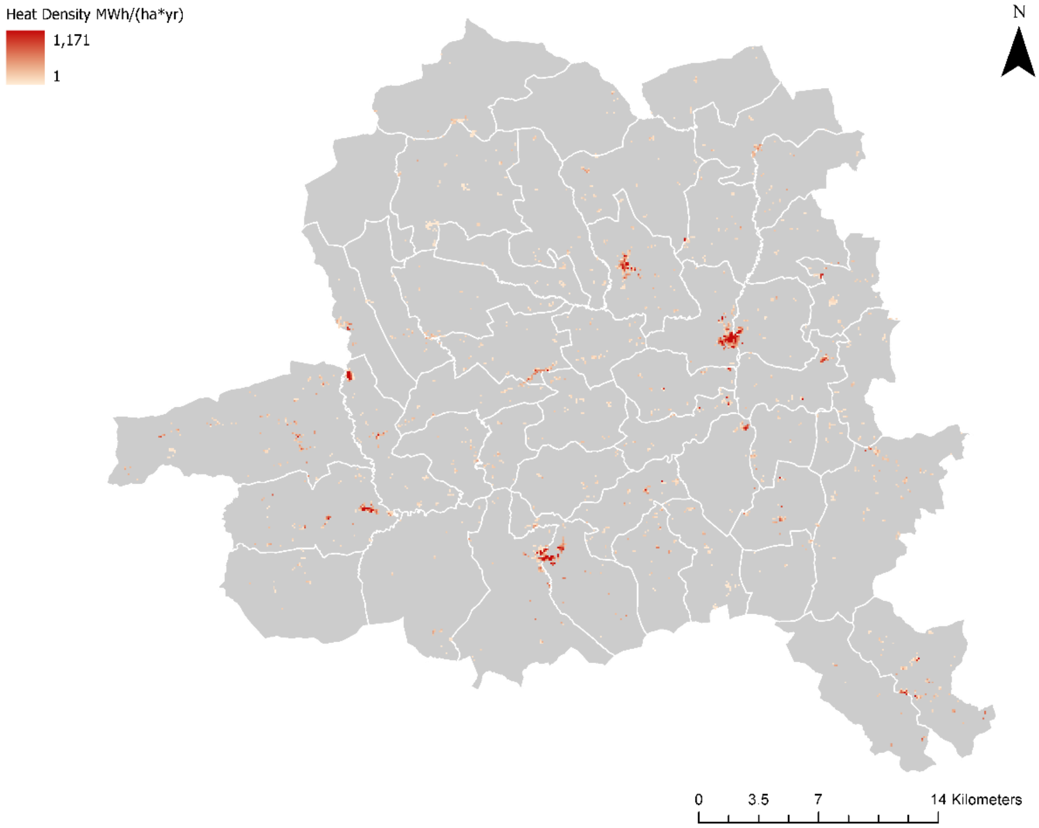


Figure 3: Heat demand in the study area. Source: Hotmaps.eu (2016)

2. Silage Potential

The practical silage potential has been mapped at the ED level as part of the feedstock analysis section of the report. This factor represents the availability of silage as a potential feedstock. The practical silage potential layer was normalised to a scale of 0-255 for the purposes of the MCA. The ED boundary vector polygons were then converted to a raster grid with a resolution of 10m x 10m for the MCA analysis. High silage potential is concentrated in the South-Eastern and North-Eastern sides of the study area. A sizable potential is also observed in the western and middle side of the study area.

[6] EU H2020 Project: Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables). WP1 Report. 2016.

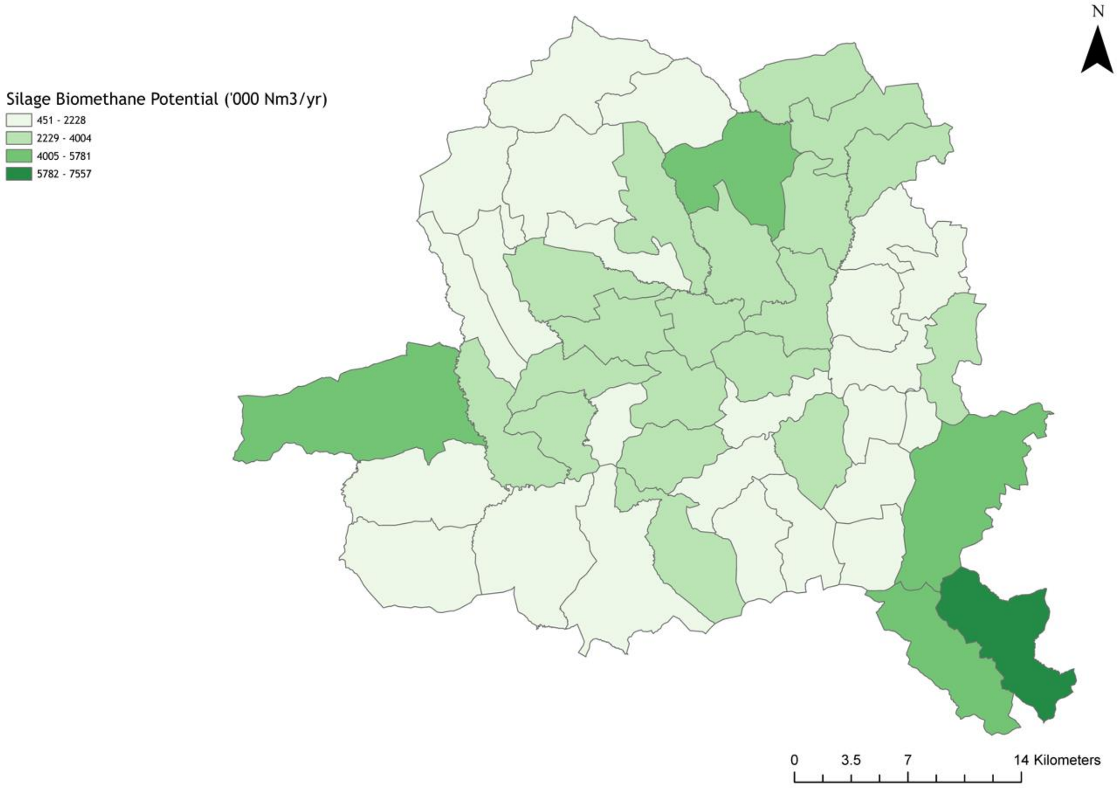


Figure 4 Practical silage potential per ED.

3. Cattle Slurry Potential

The practical slurry potential has been mapped at the ED level as part the feedstock analysis. This factor represents the availability of slurry as a potential feedstock. The practical slurry potential layer was normalised to a scale of 0-255 for the purposes of the MCA. The ED boundary vector polygons were then converted to a raster grid with a resolution of 10m x 10m for the MCA analysis. High slurry potential is concentrated in the South-Eastern and North-Eastern sides of the study area (cattle concentration naturally coincides with areas of high grass silage potential), with few EDs in Southern and Western areas of the study region also showing higher potentials for slurry. No intensive agriculture sites (poultry and pig farms) were considered as part of this spatial analysis.

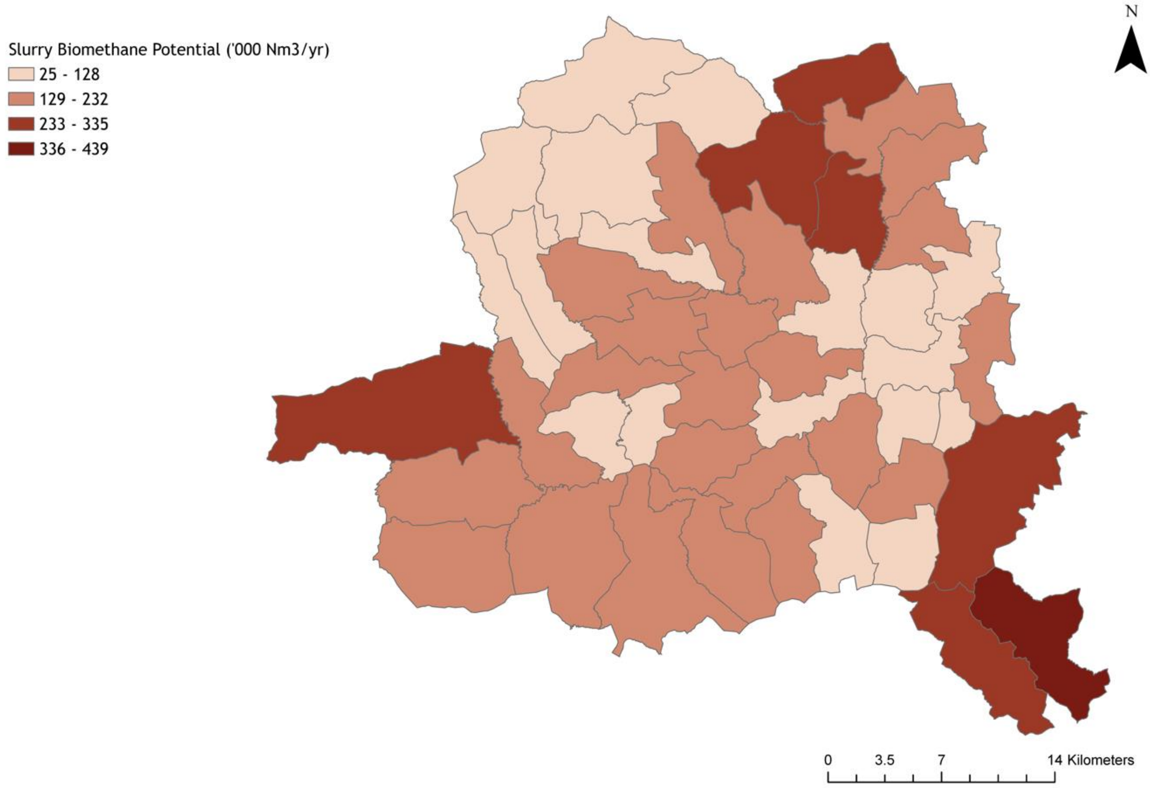


Figure 5 Practical slurry potential per ED.

4. Municipal and Industrial Organic Waste Potential

This factor represents the availability of organic waste suitable for AD arising from specific sites in two groups: municipal (wastewater treatment plants' sludge); industrial (slaughterhouses, milk and meat processing plants). The biomethane potential of these sites were assessed as part of the feedstock analysis in chapter 2 and are represented as points in the MCA. Household and commercial/municipal food waste was assessed in the feedstock analysis in chapter 2. Its availability at a given location depends on the logistics of municipal solid waste collection in the study area, but the potential is likely to be concentrated around urban centres which can be clearly identified from land cover and the heat density maps.

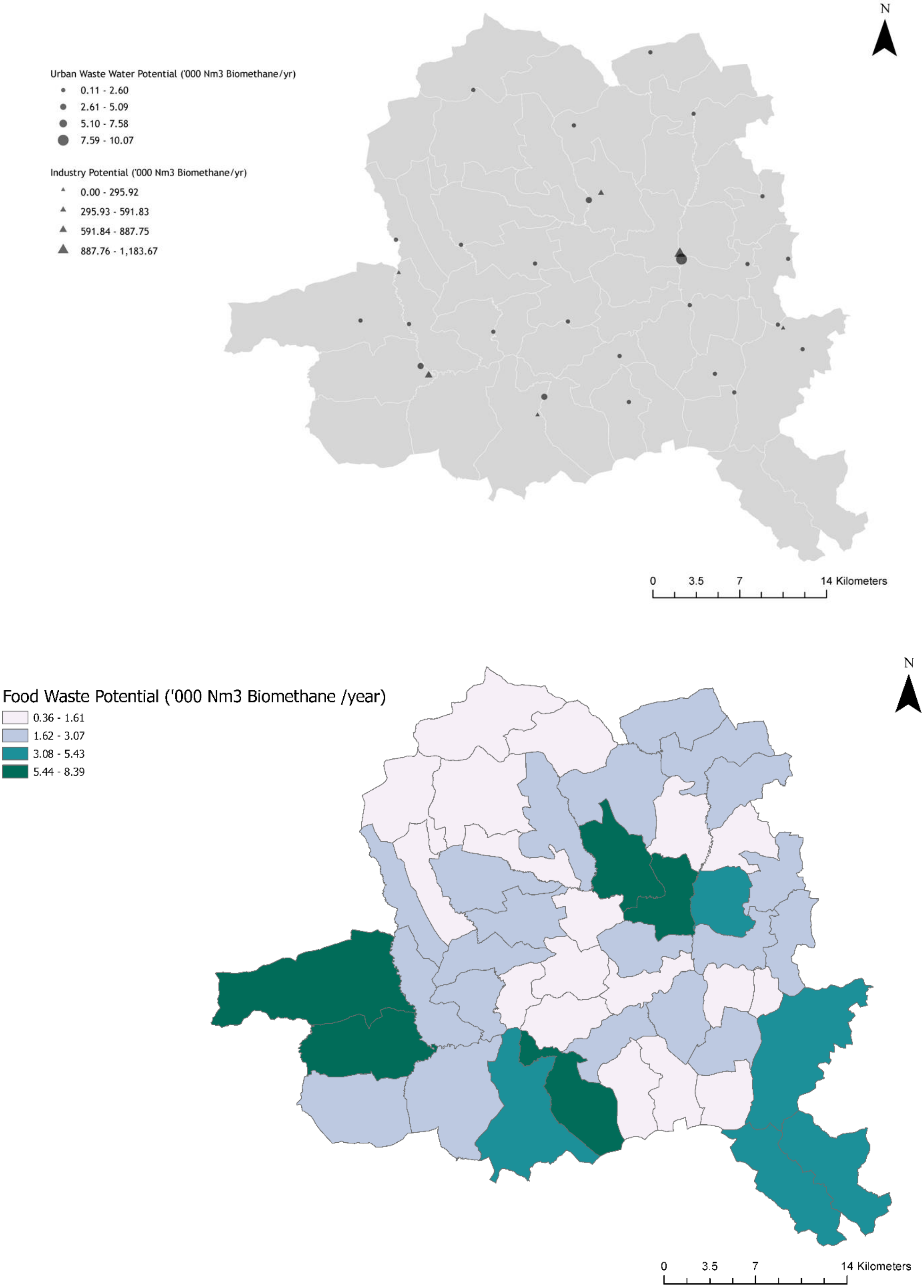


Figure 6: Municipal/Organic waste sites

5. Land cover

The land cover layer was sourced from the European CORINE Land Cover dataset for 2018. Sixteen land cover types were present within the study area. These were assigned scores (ranging from 0-255) based on their desirability as land cover types for AD development. Since these were categorical data, the scores assigned reflect the relative desirability of the different land cover types. The scores assigned to the land cover types were:

- Pastures = 255 (most desirable)
- Land principally occupied by agriculture with significant areas of natural vegetation, and natural grasslands = 255 – 25%(255) = 161
- All other land cover types = not scored (neither desirable nor undesirable)

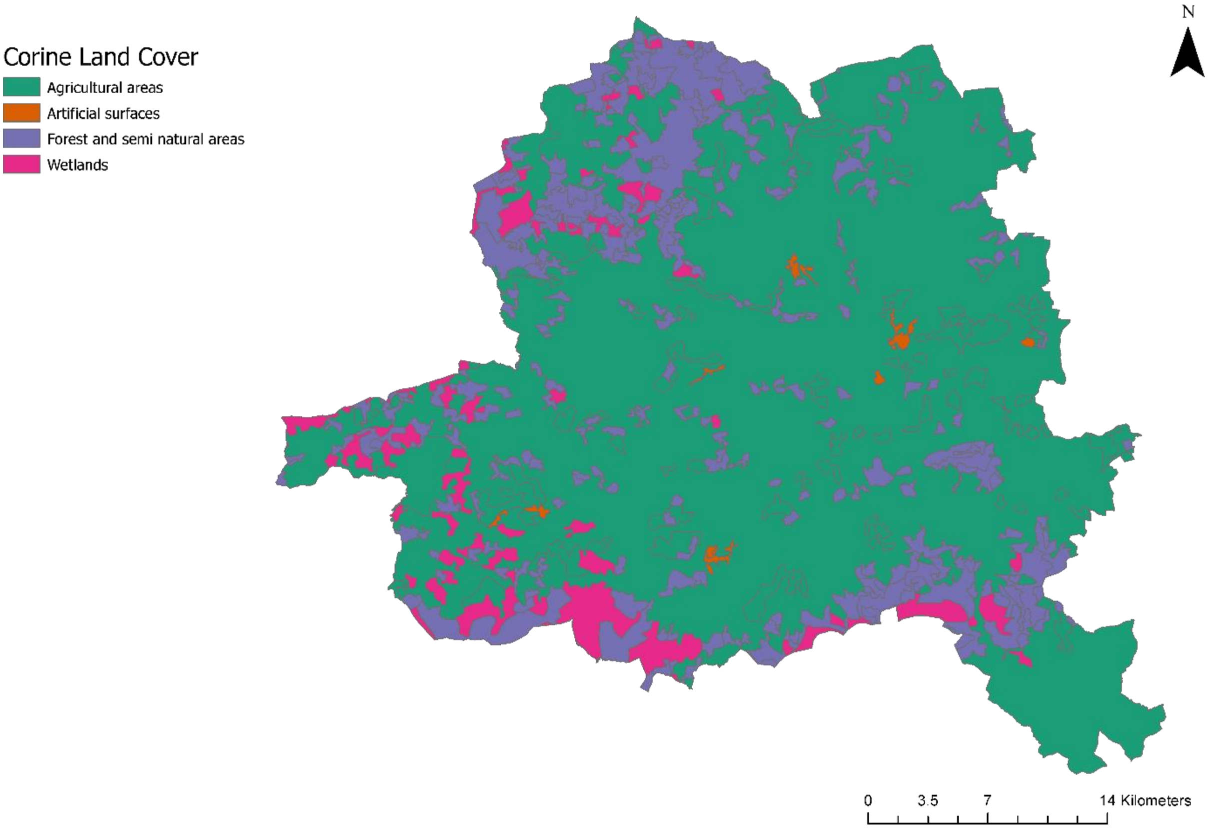


Figure 7: Land cover in the study area. Data source: Copernicus Land Monitoring Service (2018)

6. Proximity to major roads

Proximity to major roads was also considered in the analysis to capture the ease of transport of the feedstocks. A raster cost path layer was produced using the road network inside the study area as inputs. This layer represents the proximity of major roads, to all locations on the study area. The values for this layer were normalised to a scale of 0 – 255 for the MCA analysis. The same procedure was applied to the roads layer (fig. 10).

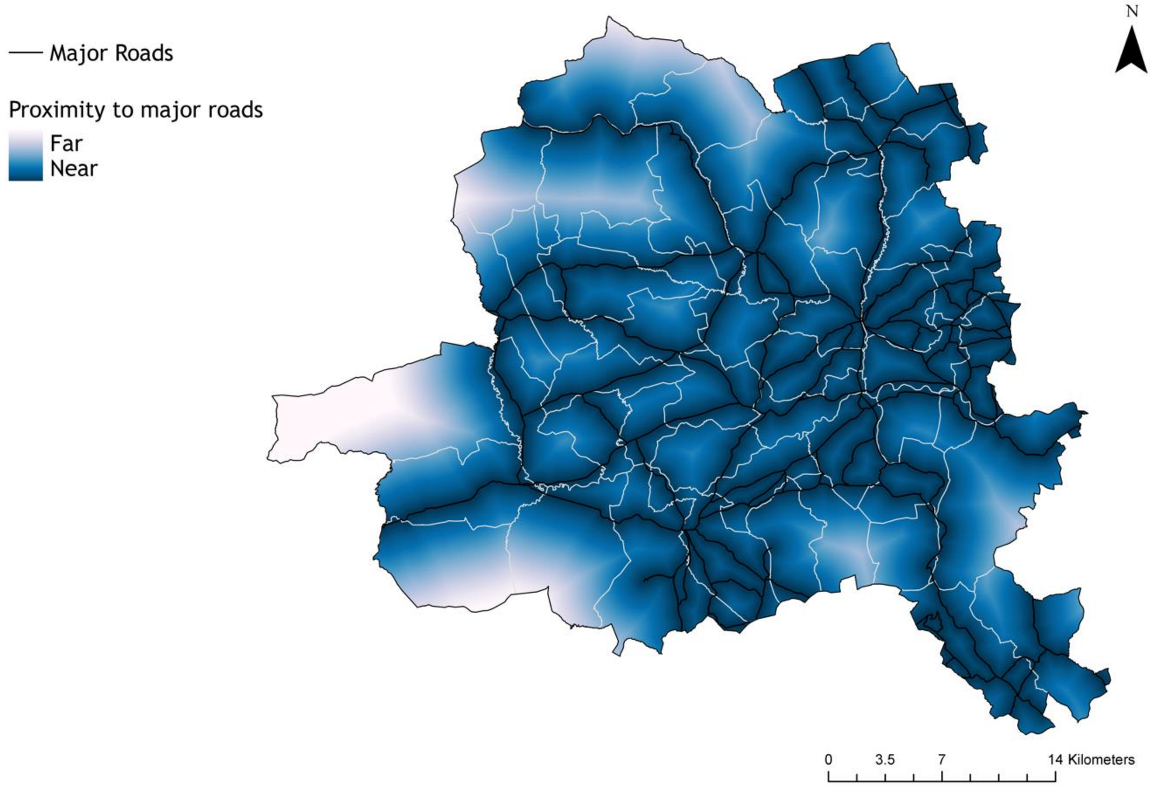


Figure 8: Raster cost path layer illustrating proximity to the major roads

D. Protected Sites

Protected sites including special areas of conservation (SACs) and special protected areas (SPAs) were mapped from data obtained from the NPWS for 2019, see Figure 9. While development is not necessarily prohibited in these areas, applying and securing planning is more difficult. As such, the area *outside* of these areas may be considered more desirable for development. A data layer was produced representing the areas *outside* of designated sites. When performing MCA, only areas outside of the designated sites were analysed.

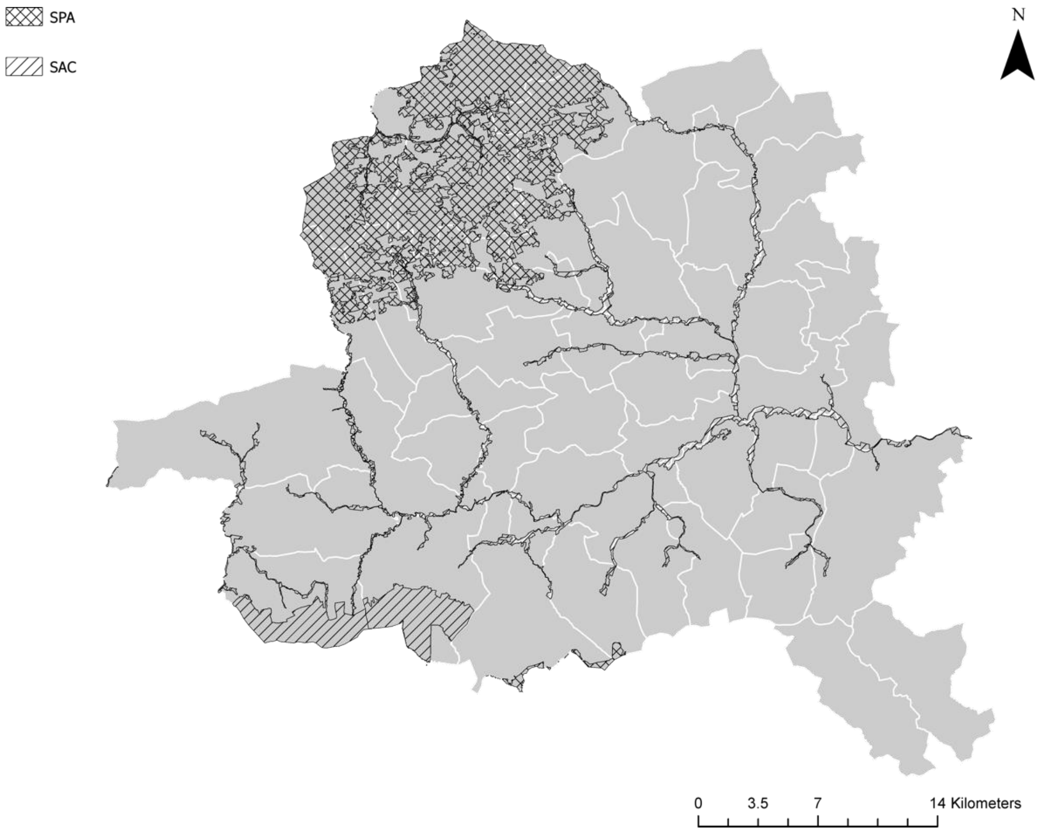


Figure 9: Protected sites. Data source: NPWS (2019)

E. Constraints

A constraints layer was produced to eliminate categorically unsuitable areas from the spatial MCA. This layer included the features shown in table 2. The total geo-mapped area outside the constraint area was used for the MCA analysis, see Figure 10.

Feature	Layer from which these were extracted
Coniferous forest	Land cover
Mixed forest	Land cover
Beaches, dunes, sands	Land cover
Intertidal flats	Land cover
Sea and ocean	Land cover
Estuaries	Land cover
Water bodies	Land cover
Salt marshes	Land cover
Burnt areas	Land cover
Sport and leisure facilities	Land cover
Inland marshes	Land cover
Transitional woodland-shrub	Land cover
Prime special amenity areas	Zoned land
Settlements + 250m buffer (after Thompson *et al.*, 2013)	Settlements
Land with slope >14 degrees (after Thompson *et al.*, 2013)	Slope

Table 4 Constraints – features that were considered categorically unsuitable areas for AD development.

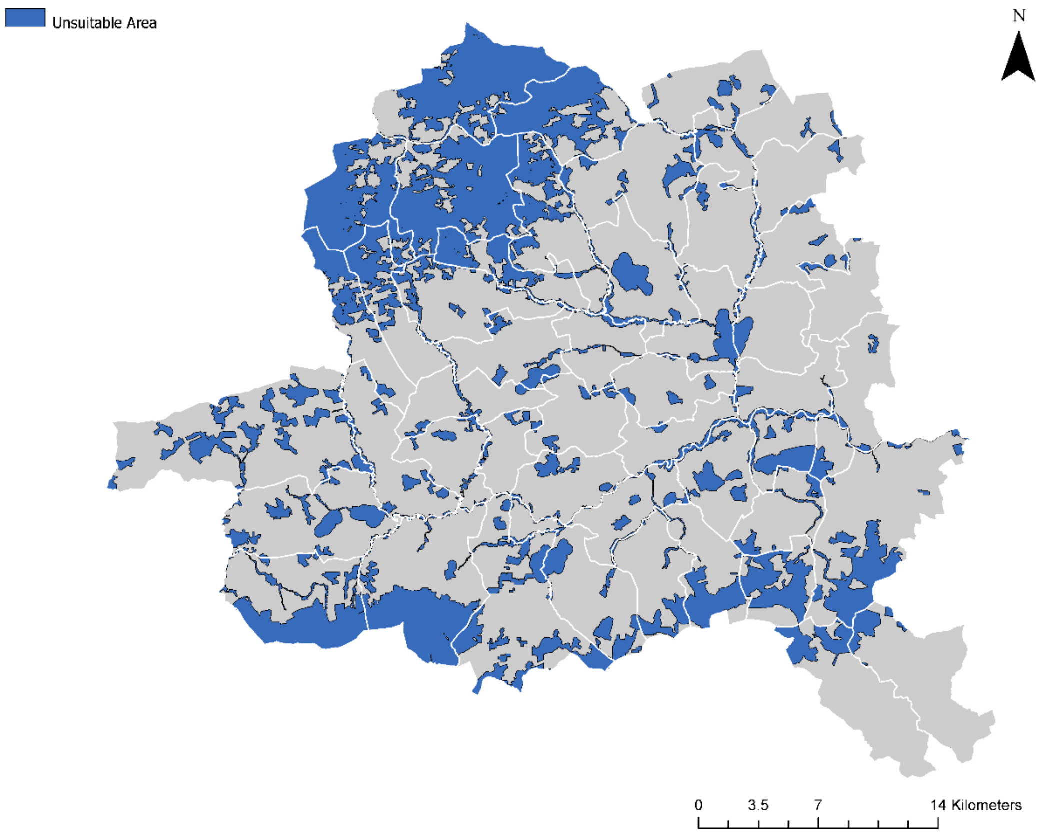


Figure 10: Constraint areas (areas excluded from spatial MCA).

F. Performing the MCA

Using the raster calculator, the factor layers (Silage, Slurry and Landcover) were aggregated using a weighted linear combination, described mathematically as follows:

$S = \Sigma w_i x_i x$ where:
S = is the composite suitability score
w_i = weights assigned to each factor
x_i = factor scores (0-255)
Σ = sum of weighted factors

The composite suitability score is unitless, with the highest values representing highest levels of desirability. The weights for different layers were decided based on the relative importance of the layers for planning of an AD site. We have chosen 0.35 for the silage layer, 0.15 for the slurry layer, 0.1 for the landcover layer and 0.1 for distance to major roads as weights. Next, point data layer for EPA licensed sites and the heat density layers were superimposed on the suitability map to demarcate areas that are:

a) highly suitable with respect to potential feedstocks (silage, slurry, food waste) and landcover.
b) have high municipal/organic waste potential.
c) have high heat demand density.
d) are not considered unsuitable.

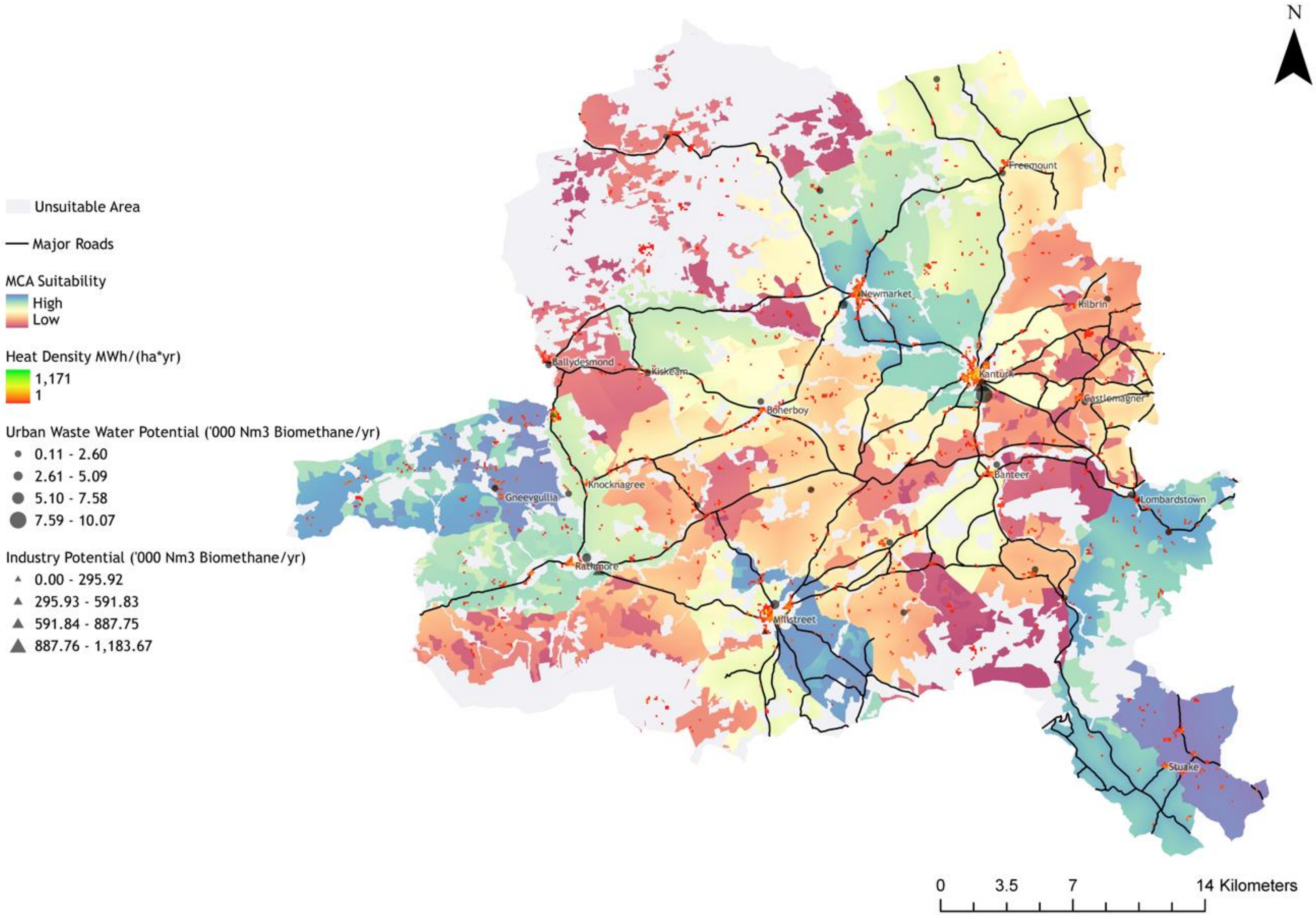


Figure 11: Site suitability map for an AD development.

G. Interpretation of the MCA results

This spatial analysis indicates that the south-ern EDs of the IRD Duhallow region, in the Gowlane and Drishane ED in particular, have a high degree of suitability due to a conjunction of highly productive grassland and organic waste from municipal sources. Areas around Kanturk and further North/Northeast region around Newmarket also present a high degree of suitability, again with highly productive grassland and the availability of organic waste feedstocks from urban wastewater and industrial feedstocks. At the south of the study area, Milstreet stands out in terms of availability of organic waste feedstocks (wastewater treatment sludge), energy demand and availability of grass silage and cattle slurry in the surrounding EDs. There are also potential opportunities around Gneevgulia in terms of industrial organic wastes and agricultural feedstocks (silage and cattle slurry).

The Northern side of the study appear less suitable for AD development, with a lower concentration of feedstocks. However, there could be opportunities for smaller, farm-based AD plants sited in conjunction with local industrial activities, such as milk and meat processing plants. Another potential AD location of interest is Rathmore region with availability of organic waste from an industrial facility and moderate availability of agricultural feedstocks nearby.

The siting of an AD plant is a very sensitive matter that will require detailed spatial and environmental planning, and careful stakeholder engagement and consultation with the community. The spatial analysis conducted above provides a basis of knowledge and data to support exploring the issues concerned and potential locations. The next steps in the feasibility study in terms of spatial analysis will be to assess potential locations identified from the MCA above, with a view to review, at a higher resolution:

- The factors and constraints mapped during the MCA.
- The AD feedstocks available within an appropriate distance from the potential AD locations selected.
- Capacity to connect to nearby energy users, energy networks (electricity grid, gas grid, district heating, etc.), or potential refuelling points for vehicles.
- Access and the logistics of transporting the feedstocks to the proposed plants.
- Access and the logistics of transporting the biomethane produced by the plant to a distant user or injection point to the gras grid, as well as of distributing secondary products (digestate, compost, CO2, etc.).

This will be done following the technical and financial assessment of different AD pathways (Chapter 5), in conjunction with the preliminary design and detailed financial feasibility study of selected 'case study' projects (chapter 5).

Chapter 4. Key Considerations About the Sustainability of Developing Anaerobic Digestion in IRD Duhallow

With a minimum of 1.6 TWh of biomethane likely to be developed by 2030, in line with the Government's National Energy and Climate Plan 2021-2030, Climate Action Plan and the Renewable Heat Obligation consultation, this could see the development of up to 80 medium-scale AD plants (with an average of 20 GWh/yr biomethane output).

In this chapter, we review key considerations for the sustainable development of AD in the study area, with a focus on the agri-based AD model utilising grass and slurry as primary feedstocks. Sustainability concerns relating to this model pertains to three key issues: feedstock procurement, nutrients management and greenhouse gas emissions. The associated regulatory and compliance framework associated with these issues will also be discussed.

A. Sourcing AD feedstock sustainably

1. Grass silage

Grass silage is considered as the primary feedstock for AD development in the study area (and in Ireland) due to its wide availability and suitability for biogas production. As discussed in the feedstock assessment in Chapter 2.B, it is foreseen that grass silage would be primarily derived by increasing yields from existing grassland by an average of 4 tDM/ha/year. This is deemed achievable by implementing the correct management techniques.

In the short term (approximately five years), more fertiliser and lime inputs will be needed to **build soil fertility to optimum levels**. Farmers will likely apply additional lime to correct pH as well as increase phosphorus and potassium fertiliser applications to build indices in a targeted manner (target index three). On average, increasing soil fertility levels requires between 35-50% more phosphorus and potassium fertiliser use. However once soils have reached optimum fertility, only maintenance fertiliser will be required at higher productivity rates. Digestate, the by-product of AD can be used as a biofertiliser to displace chemical fertiliser use and if it has sufficient nutrient quality and availability, it may be suitable as a maintenance fertiliser.

Ongoing work into **Multi-Species Swards (MSS)**[7] has showed promising results for feedstock production at reduced artificial fertilisers input, significantly improving the environmental impact of silage production and the sustainability of grass-based AD. In trials conducted by Devenish, nitrogen use was reduced by 58% and phosphorus use declined by 42% when optimal conditions were reached (after approximately 5 years), whilst improving yields by 2-3t DM/ha. Additional work from Dowth shows an increase in 300% of the earthworm population (an indicator species for soil health and biodiversity) under MSS compared to monoculture ryegrass, while MSS requires less pesticides and fertiliser than ryegrass.

2. Slurry

As discussed in Chapter 2, slurry is an important AD feedstock first because its readily available as a 'by-product' of beef or dairy farming in the study area. However, most of the slurry is only available during the cattle-housing period (3-4 months per year), and it has low dry matter content and **low energy density** (biogas potential per tonne of fresh

[7] Multi-species swards refer to a mixture of three or more species whose growth characteristics complement each other resulting in improved productivity compared to the typical ryegrass monoculture. Perennial ryegrass and timothy provide strong early-season growth and quality while legumes like white and red clover feed the sward with nitrogen fixed from the atmosphere and boost protein. As well as providing excellent quality, mineral-rich forage in the summer months, deep-rooting herbs like ribwort plantain and chicory are extremely drought tolerant which is an increasing concern for many Irish farmers (source: https://www.dlfseeds.ie/multi-species-r-d)

weight). This has serious implications in terms of digester size (and the associated capital cost) as well transport requirements in terms of cost, traffic and fuel use.

On the plus side, the **treatment of slurry with AD** and application of the digestate as an organic fertiliser to land[8] has a number of positive environmental impacts, compared to spreading raw slurry (KPMG Sustainable Futures, 2021):

- It reduces the pathogen load to the environment compared with the spreading of raw slurry.
- The digestate contains significantly less volatile organic acids and therefore less odour emissions.
- The digestion process organic nitrogen (N) is released as ammonium (NH4+), with more N available to plants[9].
- The digestion of slurry reduces significantly GHG emissions compared to raw slurry storage in typically open tanks and application to land.

3. Sustainability Criteria of the Revised Renewable Energy Directive

For biomethane gas from AD plants to be classified as a zero-carbon renewable fuel, plants must be able to achieve strict sustainability criteria as outlined within the EU Renewable Energy Directive II ("RED II") and future RED III criteria. The RED II criteria stipulates that biomass fuels produced from agricultural biomass cannot be derived from raw material obtained from (1) land that was formerly peatland; (2) lands with a high biodiversity value; and (3) lands with a high carbon stock. In addition, RED II requires that all biomass fuels used for electricity, heating and cooling must achieve at least a 70% GHG emission saving, increasing to 80% for installations that start operating from 2026.

Capturing methane from slurry prevents it from being released to the atmosphere, thereby having the effect of being carbon negative and improving the overall GHG savings of the AD facility. Analysis has demonstrated that it will be possible for Irish AD plants using grass silage as its primary feedstock to produce biomethane which meets RED II sustainability criteria if slurry is included as a co-feedstock. The proportion of slurry required ranges from 40-55% to meet the 2026 (80% GHG emission savings) RED II Sustainability Criteria.

4. Animal By-Products Regulations

The EU Animal By-products regulation classifies livestock wastes such as cattle slurry and manure, as Class 2 Animal By-products (ABP). Use of these feedstocks in a biogas plant is subject to several constraints including thermal treatment, size reduction, validation, storage, plant layout, plant management, monitoring, recording and reporting; all of which have substantial capital and operating cost implications. The implications of complying with the ABP regulations require a step change in the complexity of the plant. There is only one exception: small volumes of slurry from a single farm (< 5,000 tFM/year) can be processed by an on-farm biogas plant without conforming to the ABP conditions above, provided that the digestate is recycled to land of the same farm

For the AD pathways considered in Chapter 5, agri-based AD plants will require very significant volumes of cattle slurry in addition to grass silage to meet the RED II Sustainability Criteria, which will have to be sourced from a number of farms. Compliance with the ABP regulations will be applied by default in the AD pathways considered.

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[8] Digestate is a nutrient-rich substance which consists of the organic products of digestion, left over indigestible material, live and dead micro-organisms. All the nitrogen, phosphorous and potassium present in the AD plant's feedstock will remain in the digestate. However, the nutrients are more available to plant growth than the original material.

[9] Ammonium is ionized and has the formula NH_4^+.

B. Nutrients Management

1. AD digestate as an organic fertiliser

While digestate is a by-product of AD, it will play an important role in the industry. Digestate will supply sustainable quantities of the nutritional requirements of the plants forage feedstocks by being land spread at targeted stages in the crop's development cycle. As fossil-based fertilisers become more expensive, good management of the nutrient content of digestates will become important as a cost-saving measure for farms. Digestate is also packed with trace elements and potential animal and plant pathogens are significantly reduced, and in most cases are eradicated, due to the requirement to pasteurise the feedstock as required by the ABP regulations.

Spreading digestate falls under the Nitrates Action Programme and must adhere to strict conditions. The nutritional value of digestate varies depending on the AD plant's diet. Farm based digestate values, which is based on slurry and forage, has a higher dry matter but lower total and available N (3.6kg N/t and 2.8kg N/t respectively). Typical P values are higher at 1.7kg/t while K comes in much higher at 4.4kg/t. Food-based digestate (unseparated) could have a total N value of 4.8kg/t with around 3.8kg/t of this readily available; typical P values comes in at 1.1 kg/t while K comes in at 2.4kg/t with typical dry matter of 3.8%.

Managing the digestate is an important aspect of an AD project development and establishing a nutrient management plan in conjunction with farmers in the vicinity of the plant is an essential part of planning the project. Applying the digestate as an organic fertiliser to the grassland producing the grass silage used by the proposed AD plant will not only help close the nutrient cycle in the project catchment area, but also play an important role in improving the sustainability of the agricultural system underlying it.

A review conducted by KPMG, Devenish and Gas Network Ireland (2021) of best agronomic practices in Europe for nutrient management with AD highlights a number of key principles:

- Adherence to the Water Framework Directive as a minimum standard.
- The submission of a detailed nutrient management plan that addresses soil nutrient status, the nutrient value of the digestate and the nutrient requirements of the crop that is grown.
- Application techniques that minimise the risk of nutrient run-off and ammonia emissions are industry best practice and should be followed (see section 3 below).
- The provision of enough storage capacity at the AD facility and the facility's farms is of fundamental importance. All European countries have closed periods where no application is allowed.

2. Nutrients Recovery

Value of digestate depends on NPK content and nutrient availability, which can vary significantly with the feedstocks used, processing technology, application method and soil quality where is it applied. Nutrient recovery technologies aim to increase the availability of nutrients in the digestate and process it into a more concentrated form. The nutrients harvested from these processes can help improve the commercialisation of the digestate. As fossil-based fertilisers become more expensive, good management of the nutrient content of digestates will become important as a cost-saving measure for farms.

There are different nutrient recovery solutions commercially available in well-established markets such as France, Germany and the UK, and we refer to the work done in the framework of the Project Clover for recommended solutions and the associated business case (KPMG Sustainable Futures, 2021). In this feasibility study, the only digestate treatment considered is the separation of the solid fraction from the digestate and its composting to provide a horticulture grade compost to be commercialised as part of the proposed AD projects.

3. Impact of digestate on other farm emissions & eutrophication of waterways

While the AD digestate provides organic nitrogen more readily available to plants, there are concerns relating to the potential increase in ammonia (NH_3)[10] and nitrogen oxide emissions (NO_2) when applying straight digestate compared to animal slurries. This is because the AD process increases the pH of digestate (pH 7-7.5). However, mitigation strategies such as covered storage, trailing hoses/shoes, direct injection into soils and ammonia harvesting technologies will be standard on many plants.

Nitrous oxide (N_2O) is a naturally occurring GHG released from soils. Excess N_2O is released when nitrogen fertilisers are added to soils. However, the use of digestate from AD has been shown to reduce N_2O emissions. Research has demonstrated that the use of digestate can reduce N_2O emissions to 0.25 g per kg N applied as slurry and digestate - compared with 1.49 g of N_2O per kg Calcium Ammonium Nitrate ("CAN").

A major environmental concern with land application of digestate is the potential contamination of surface and ground waters with excess nitrogen and phosphorus. In terms of nutrient leaching, digestate is deemed to have at least a similar impact on water bodies as slurry. However, AD reduces the Biochemical Oxygen Demand (BOD) by circa 40% compared to slurries, and in turn the potential for water pollution. The nutrient leaching potential following the application of digestate depends on factors such as fertilisation strategies, soil texture, topography, precipitation and cropping systems.

Best management practices that mitigate nutrient leaching include nutrient management planning to predict the nutrient supply for the crop grown and the use of soil tests. Recommended digestate application techniques should follow Low Emission Slurry Spreading advice provided by Teagasc.

[10] Ammonia is un-ionized and has the formula NH3. The major factor that determines the proportion of ammonia or ammonium in water is water pH.

Chapter 5. Technological Pathways Analysis

A. Introduction

In this chapter, the methodology and results of the AD technological pathways analysis are reviewed. The objectives of the analysis were to:

- Map out AD technological pathways with a potential to become effective solutions for the IRD Duhallow region, identifying key elements of their value chain from feedstock harvesting to final energy distribution.
- Determine key inputs and outputs of selected technological pathways along their entire value chain, in terms of feedstocks quality and quantity, AD technologies' energy outputs as well as non-energy products (digestate, compost and CO_2).
- Conduct a high-level techno-economic modelling of selected AD technological pathways to identify viable pathways and key factors impacting on their viability.
- Conduct a SWOT analysis and compare selected technological pathways, using modelling outputs.

B. Technical assessment of AD pathways

There were two primary considerations used when shortlisting the AD pathways to be analysed: a) the nature of the feedstocks used and b) how the biogas is used to produce useful energy.

1. Pathway Selection - Feedstocks

There are a number of key considerations when selecting an AD technical pathway in terms of feedstock: availability within a reasonable transport distance, biomethane potential, pre-treatment, plant design and operation, supply costs, environmental impacts and regulatory requirements.

The feedstock pathways presented in this report reflect the implications of the ABP regulations. Four principal pathways were considered in this analysis:

- The first represents a medium-sized farm-based AD plant (20 GWh/yr energy output), using grass silage and slurry.
- The second represents a medium-size AD plant (20 GWh biomethane output) co-located with a food processing operation, primarily accepting on-site feedstocks and grass silage.
- The third represents a large AD plant (40 GWh biomethane output) co-located with a food processing operation, accepting a range of organic wastes from industrial, municipal and agricultural sources, as well as grass silage.

2. Pathway Selection - Processes

Figure 12 provides a general view of the various process pathways that may be implemented for AD, considering different variations around the core anaerobic digestion process itself:

- **Compressed biomethane (CBM) production:** the biogas is cleaned, its CO_2 content is removed (between 40-50% of the biogas content by volume) along with other contaminants and compressed to a high pressure. The compressed biomethane can be stored and used locally or shipped by tanker to an injection point at an appropriate distance (up to 50 km). The biomethane can be used to fuel heating plants, CHP plants or as a vehicle fuel. The upgrading/compression plant produces heat which contributes to the AD plant thermal requirements.
- **Carbon dioxide**, a by-product of the biogas upgrade to biomethane, can be compressed, stored at high pressure in steel containers and sold in horticulture or industry. Certain biogas upgrade technologies can produce high concentration CO_2, with virtually no contaminants, which can be used in the food & drinks industry and attract a high price.
- **Combined Heat and Power:** the biogas produced by the digester is cleaned and injected into a gas engine driving an electricity generator, with heat recovery from the exhaust gas and engine cooling. This is referred to as a combined heat and power (CHP) plant. The main CHP application foreseen in the pathways reviewed is to supply the electricity and heat required by the AD plant and its processes. If there is excess heat available, it can be exported to heat nearby buildings or industrial processes.

- **Digestate & compost:** the volume of digestate will be around 90-95% of what was fed into the digester. The solid fraction of the digestate (15-20%), separated by a screw press and composted to provide a very valuable soil fertiliser and enhancer for use in gardening and horticulture.

As we will see in the cost/benefit analysis of the different pathways, valorising potential by-products (heat, CO2, compost, etc.) can play an important role in the financial viability of the proposed AD projects.

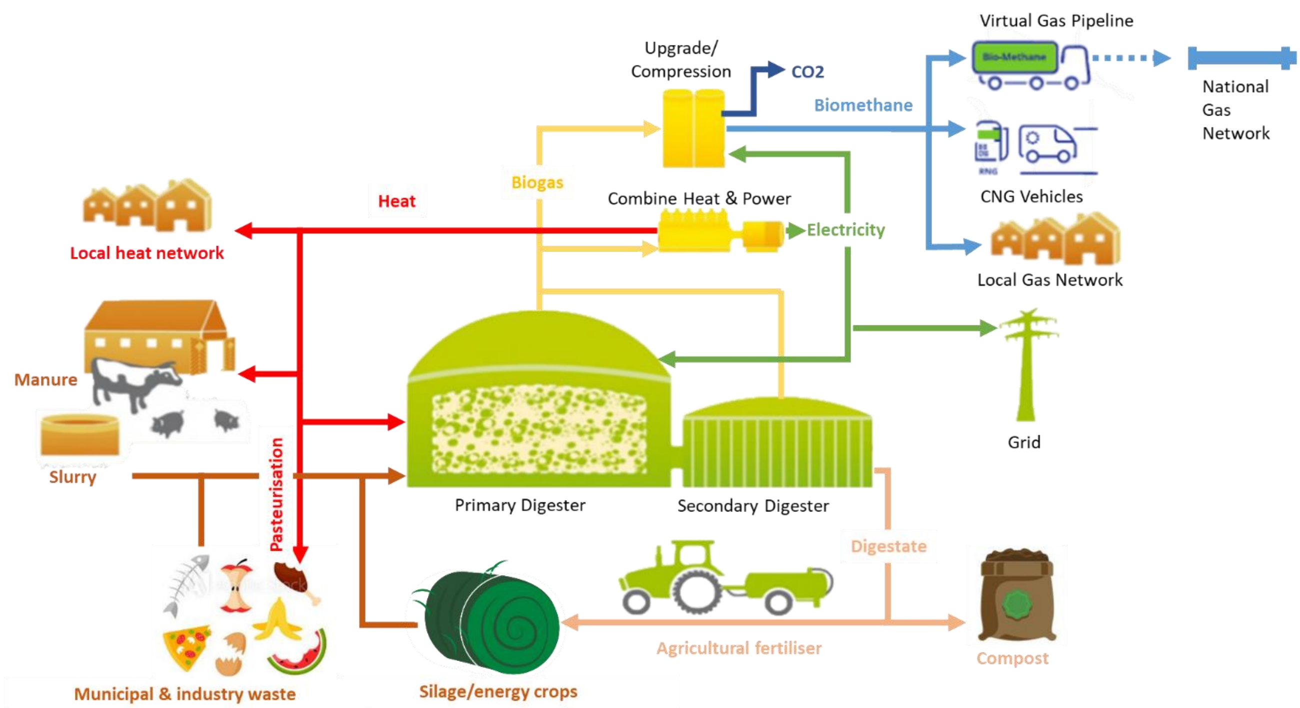

Figure 12: Overview of the AD pathways analysed. Source: XDC

3. Summary of pathways analysed

The following table summarises the pathway options investigated:

Table 5: Summary of pathways analysed.

Pathway Name	Feedstocks		Processes & energy systems					
	Agricultural feedstocks	Organic Waste	Pasteurisation	CHP	CBM used on site	CBM sold to local user	CBM injected to Grid	CO2
1) Medium – Multiple Farms – CBM	V		V			V		
2) Medium – Multiple Farms – CBM + CO2	V		V			V		V
3) Medium – Multiple Farms – CBM + CO2 + CHP	V		V	V		V		V
4) Medium – Co-located – CBM	V	V					V	
5) Medium – Co-located – CBM + CO2	V	V					V	V
6) Medium – Co-located – CBM + CO2 + CHP	V	V		V			V	V
7) Large – Co-located – CBM	V	V	V		V	V		
8) Large – Co-located – CBM + CO2	V	V	V	V	V	V		V
9) Large – Co-located – CBM + CO2 + CHP	V	V	V		V	V		V

4. Key technical parameters used

The following assumptions were taken in relation to the feedstocks' biomethane potential, delivered cost or gate fees:

Table 6: Feedstocks' biomethane potential and costs.

	DS (%FM)	VS (%FM)	VS/DS (%)	Methane Yield (LCH4/ kgDS)	Methane Yield (LCH4/ kgVS)	CH4/ biogas (%)	Biogas yield (Lbiogas/ kgVS)	Biogas yield m3/tFM	Costs/Gate Fees €/tFM
Grass Silage	23	20.9	0.85	340	400	60%	667	130	30
Cow Slurry	8	6.0	0.75	107	143	60%	238	14	5
Farmyard Manure	20		0.85	232	273	60%	455	77	5
Food Waste	30.6	27.1	0.88	242	274	60%	457	124	-70
WWTP sludge (dewatered)	17		0.65		200	60%	333	37	-60
Food processing plant sludge	14.5	10.3	0.71	202	284	84%	338	35	-

Other technical assumptions made about different elements of the AD pathways systems are outlined hereafter. These are based on typical industry standards and technical specifications received from technology suppliers:

- Electricity usage:
  - Digester: 0.438 kWh per m^3 of digester volume
  - Biogas upgrading: 0.3 kWh/Nm^3 biogas
  - Biomethane compression: 0.3 kWh/Nm^3 biogas
  - CO_2 liquefaction: 1.4 kWh/Nm^3 CO_2
- Heating requirement:
  - Biodigester: 15% of gross energy output (biogas)
  - Pasteurisation: 10% of gross energy output (biogas)
- Heat output:
  - CHP: 39% of gross energy input (biogas)
  - Biogas upgrading: 0.25 kWh/Nm^3 biogas
  - Biomethane compression for storage: 0.25 kWh/Nm^3 biogas
  - CO_2 liquefaction: 1.4 kWh/Nm^3 CO_2
- Average annual operating times:
  - Biodigester: 8760 hours
  - CHP unit: 8000 hours
  - Biogas upgrade and CBM compression plant: 8000 hours

C. Financial assessment of the different pathways analysed

1. Methodology and assumptions

A preliminary financial analysis was conducted for each pathway to assess the financial operating balance (effectively a profit and loss account) on a typical year of operation of the associated AD systems. This analysis considers the following variables:

- **The capital expenditure** required to build and commission the AD system:
  Turnkey (supply/install/commission) budget costs were sourced for the ***biogas plant***[11], the biogas ***upgrade/compression*** and CO_2 ***liquefaction*** plants[12]. Cost estimates for the supply and install of ***CHP plants*** were taken from previous projects.
- The annual operating cost including:
  - Cost of acquiring ***feedstocks*** including production (in particular silage) and transport costs, considering gate fees for municipal & industrial organic waste, taken from the feedstock analysis undertaken in WP2.
  - ***Energy*** costs (electricity, biomass fuels, etc.) taken from SEAI's Commercial Fuel Costs publication or actual energy costs for a given user when available.
  - Cost of disposing of ***the digestate*** at the end of the process, based on transport and application to land costs of €2/tonne.

[11] Preliminary quotations provided in 2021 by Tank Storage Systems of Ireland, and Host-Bioenergy, UK
[12] Preliminary quotations in 2021 by Bright Biomethane

    - ***Repairs and maintenance*** costs, based on information provided by suppliers and general biogas plant operating costs relative to plant capital costs
    - Plant operators, management, administrative ***staff costs based on typical biogas plant operational requirements, plus*** overheads (30% of staff cost) and ***insurance*** (based on 1% of total capital cost).
    - Cost **of biomethane delivery and injection** into natural gas grid (GNI, 2019):
        - Biomethane haulage: €0.055/MWh,km (round trip of 70 km).
        - Biomethane injection: assumed to be borne by gas network operator.
    - The cost of ***financing*** the capital expenditure above, based on debt-to-equity ratio of 80:20, interest rate of 4.5%, loan repayment period of 10 years.
    - Depreciation based on ***straight-line depreciation*** over 15 years for machinery (CHP, pumps, compressors, upgrading plants, etc.) and 20 years for buildings, digesters and other non-mechanical plant.
- The potential revenues derived from:
    - Production of energy including:
        - ***Electricity*** produced by biogas CHP to replace on-site electricity use (€0.12/kWh) or exported to the grid or co-located user (€0.15/kWh)
        - ***Surplus heat*** available for export (sum of outputs from CHP, biogas upgrading, compression and CO_2 liquefaction, minus digesters and pasteurisation heating requirements). Heat has been valued at €0.05/kWh to allow for additional cost of heat distribution (assume €0.03) and remain competitive with pre-existing heating costs (oil and LPG). A renewable heat subsidy in line with the SSRH was assumed.
        - ***Compressed biomethane*** (CBM) used on site or exported to the gas grid. The biomethane is priced in each pathway analysed to achieve an Internal Rate of Return of 9% for the AD developer and provide a profit margin of 20% for the plant operator.
    - The sale of food grade CO_2 as a by-product of the biogas upgrade process, taken as €0.3/m^3.
    - The sale of the ***compost*** produced at €25 per tonne (sale in bulk).

The following key performance indicators (KPIs) were derived from the cost/benefit analysis of the pathways analysed above:

- **Profit & Loss (P/L) account** for an average year of operation, **before tax**, including total revenues, operational expenditure, depreciation and interest payments (for mid-repayment period year).
- **Return on Capital (ROC, %)** as a measure of the profitability and value-creating potential of companies relative to the amount of capital invested by shareholders and other debtholders. The ROC is calculated by dividing the sum of [initial capital expenditure and interest payment] by the P/L value.
- **Net Present Value (NPV):** Difference between the present value of cash inflows and the present value of cash outflows over the project timeline. It applies the discount rate to account for the time value of money.
- **Internal Rate of Return (IRR):** A discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. It measures the rate return on the investment made.

The CBM value calculated to achieve an IRR of 9% + 20% profit margin is compared to equivalent fossil fuels such as heating oil, LPG or natural gas in order to establish its competitiveness against incumbent energy sources. It is also compared to the anticipated CBM value of c€8.5/kWh mentioned by Gas Network Ireland in the framework of the Renewable Heat Obligation[13] scheme to be introduced in Ireland.

2. Results of the financial analysis of the AD pathways analysed

Table 7 below summarises the results of the financial analysis of the 3 sets of pathways selected above, for a 20 GWh/yr farm-based plant (1-3) exporting its CBM for injection in the gas grid; a 20 GWh/yr plant collocated with a food processing plant (4-6) and a 40 GWh/yr plant co-located with a food processing plant (7-9) where the CBM produced is used on site.

[13] The Renewable Heat Obligation (RHO) scheme is to be introduced in Ireland as a key measure of the Climate Action Plan 2021. It would require the suppliers of energy used in the heat sector in Ireland to ensure that a certain proportion of the energy supplied is renewable. A consultation was undertaken on the RHO by DECC at the end of October 2021; further details are available here.

Table 7: Financial Analysis of Selected AD Pathways

Financial Assessment		(1) Medium – Multiple Farms – CBM Grid injected	(2) Medium – Multiple Farms – CBM + CO2 Grid	(3) Medium – Multiple Farms – CBM + CO2 + CHP Grid injected	(4) Medium – Co-located CBM sold locally	(5) Medium – Co-located – CBM sold locally + CO2	(6) Medium – Co-located – CBM sold locally + CO2 + CHP	(7) Large – Co-located – CBM Sold locally	(8) Large – Co-located – CBM sold locally + CO2	(9) Large – Co-located – CBM sold locally + CO2 + CHP
CAPEX	Mio€	5,039,543	5,560,000	5,850,695	4,839,177	5,360,000	7,200,695	8,885,759	9,260,000	9,868,888
Total Revenue	€/y	2,036,752	2,067,179	2,134,814	1,308,602	1,336,402	1,570,325	2,895,911	2,885,030	3,075,967
Total OPEX	"	1,567,381	1,547,535	1,588,070	855,240	835,459	897,745	2,065,985	2,019,800	2,153,682
Depreciation	"	228,803	263,500	282,880	218,778	253,500	345,880	428,217	453,167	493,759
Loan Interest	"	120,949	133,440	140,417	116,140	128,640	172,817	213,258	222,240	236,853
Price of biomethane for IRR 9% + 20% margin	**€/MWh**	**110**	**89**	**89**	**64**	**41**	**47**	**75**	**50**	**45**
Profit/Loss	**"**	**119,619**	**122,704**	**123,448**	**118,443**	**118,803**	**153,883**	**188,450**	**189,823**	**191,672**
Return on Capital	**%**	**4.9%**	**4.7%**	**4.6%**	**5.0%**	**4.7%**	**4.6%**	**4.6%**	**4.5%**	**4.4%**
NPV	**€/2021**	**366,575**	**423,723**	**445,140**	**380,445**	**408,386**	**544,411**	**671,303**	**703,331**	**751,317**

The key parameter to consider in the outline results presented above is the price of biomethane necessary to achieve a 9% IRR in the different pathways analysed, as compared to existing fuel alternatives[14] and the anticipated RHO CBM value. Figure 13 below indicates that in collocated AD plants (pathways 4-9), CBM is competitive with gasoil and LPG, the predominant heating fuels for commercial energy users in the study area. However, CBM is significantly more expensive than natural gas for large users on the gas grid. These pathways would be able to profitably supply CBM at the anticipated CBM value in the framework of the RHO scheme.

Commercialising CBM as an alternative, renewable transport fuel should also be considered carefully. It would be ideally suited as a substitute to diesel for captive fleets of heavy goods vehicles in the study area, serviced by CBM refuelling stations adjacent to the AD plant or located at the client's site. There are several reasons CBM for HGVs should be considered:

- CBM can be readily competitive with transport diesel. The cost of diesel including Carbon Tax and NORA, excluding Excise Duty & VAT is taken as 88 cents per litre, or 8.5 cents per kWh – similar to the RHO CBM value envisaged above. There is a strong argument that CBM should not be subject to excise duty (currently 4.9 cents/kWh) which would make it even more competitive compared to diesel. Moreover, carbon taxes currently at €33.5/tCO_2 (for 2021) have been raised to €44/tCO_2 in budget 2022 and are anticipated to grow to €100/tCO_2 by 2030. This will add another 18 cents per litre of diesel before VAT, further compelling the financial case for CBM as an alternative fuel.
- Transport, and freight in particular, represent a significant aspect of our Ireland's energy use (respectively 34% and 6.5% of the total national final energy consumption). Decarbonising HGV is particularly difficult and CBM represents a practical solution. CNG (compressed natural gas) trucks are available commercially in Ireland, or existing ICE trucks can be converted. HGV fleet operators in the study area would be key stakeholders to consider as part of developing a local market for locally produced CBM.

A central reason for the relatively good financial performance of these co-located AD plants is that co-digesting agricultural feedstocks with organic wastes, significantly reduce their feedstock costs by attracting gate fees for the treatment of organic wastes or by using their own organic wastes at no cost. By comparison farm-based AD plants using silage and slurry exclusively and exporting their CBM for grid injection struggle to be competitive.

[14] Based on SEAI Commercial Fuel Cost Comparison tables, October 2021. Prices are without VAT. Rebates larger users could secure (up to 20-25% according to SEAI) have not been factored in.

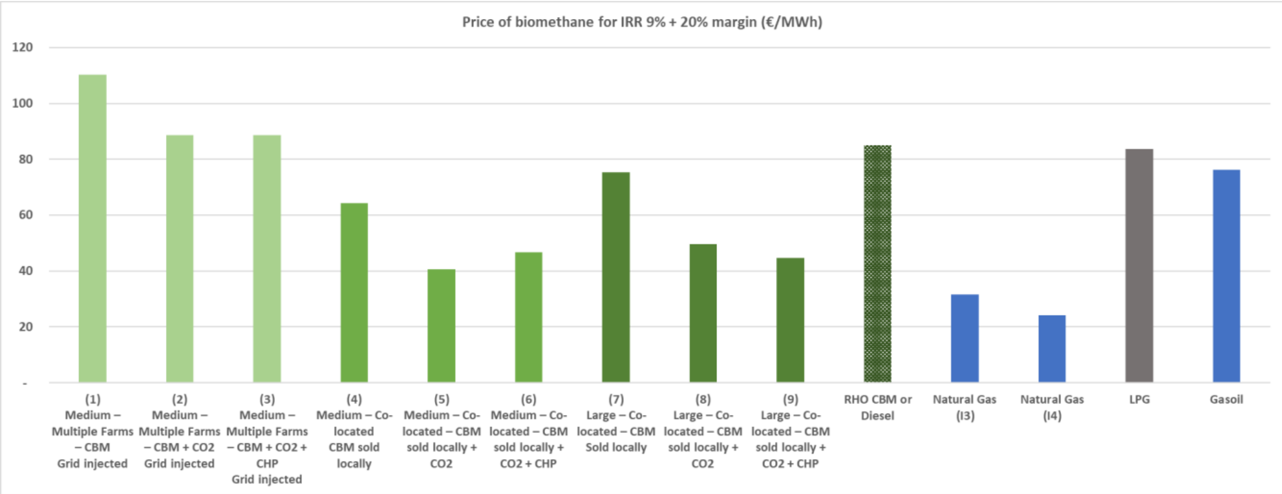

Figure 13: Comparison of CBM value required to achieve 9% IRR with a 20% profit margin, against existing fuels.

A number of other observations can also be made on the results of this pathway analysis:

- The extraction and liquefaction of CO_2 for sale in the food industry significantly increases revenues and profitability[15]. The sale of compost and to a smaller degree heat also make a useful contribution in that regard.
- The economies of scale anticipated in the large co-located plant (pathways 7-9) do not materialise in noticeable increases in return on investment. While revenues double compared to the medium-sized AD plant, operational costs increase commensurately; the higher proportion of silage in the feedstock mix pushes input costs up disproportionately despite income from gate fees for the organic waste processed.
- Energy costs of operating the plant (electricity and heat) are a significant part of the operational costs (around 30%). Electricity use by the biogas upgrading and compressing system as well as the CO_2 recovery plant represents 15% of the gross energy output of the AD plant. The addition of a CHP system can improve profitability (pathway 9) by reducing energy costs on site. However, the operation of a CHP unit requires additional biogas production, leading to increased feedstocks cost and the need for a larger digester – this can in turn counterbalance energy savings (pathway 6).
- Heat recovery from the CO_2 production process contributes to meeting the heating requirement of the digester. If there is a CHP unit on site, there is excess heat available which can be exported to a nearby heat user (e.g. industrial plant or district heating system) and generate an additional revenue (5-10% of total revenues in pathways 5,6 and 8,9).

Following this broad pathway analysis, a more detailed technical and financial assessment of selected pathways has been undertaken, with the results presented in Chapter 6.

[15] This value is likely to be conservative in the context of significant increases in CO_2 price in recent months.

Chapter 6. AD Case Study Projects, Preliminary System Design Life Cycle Cost-Benefit Analysis

In the chapter, we revisit the spatial multi-criteria analysis to shortlist three potential areas for the development of AD projects in the study area, each a specific use case in terms of plant design and biomethane valorisation. These 'case study' projects are then subject to a preliminary design and more detailed lifecycle cost analysis.

A. Strategic areas and AD Use Cases

Having considered the results of the spatial multi-criteria analysis conducted in Chapter 3, three strategic areas for AD project development were retained and a concept for the associated 'use case' AD projects was adopted in consultation with the feasibility study steering committee. The three strategic areas selected, as illustrated in Figure 14, are:

1. The area in and around **Drishane ED** scores high in the spatial MCA, primarily due to the concentration of agricultural feedstocks available within a suitable radius (10 km for grass silage and 5 km for slurry), sufficient to service the needs of one agri-based 20 GWh/yr AD plant. The proximity to Millstreet and to a large energy user near Rathmore lends to an AD plant dedicated to producing biomethane for export to local energy users, using high-pressure storage tanks mounted on a trailer for transport and stationary tanks at the user sites. Local CBM use can include producing heat, electricity and be used as a transport fuel.
2. The area in and around **Kilshannig ED** also scores high in the spatial MCA, again due to the concentration of agricultural feedstocks available in the area, sufficient for at least one if not two 20 GWh/yr AD plants. There are also no obvious planning contraindications for development, and adequate road network for the logistics requirement of the plant. The use case for the biomethane produced here would be to haul the CBM to Mitchelstown for injection into the gas grid.
3. The area in and around the **Newmarket and Kanturk EDs** also score high in the MCA, due to the availability of agricultural feedstocks but also organic waste from local agri-food processors and food waste in the local towns. Here the proposed use case is for AD plants to be co-located with the food processing plants whereby the biomethane produced is used to meet (part of) the energy requirements of these plants and contribute to the decarbonisation of their operation.

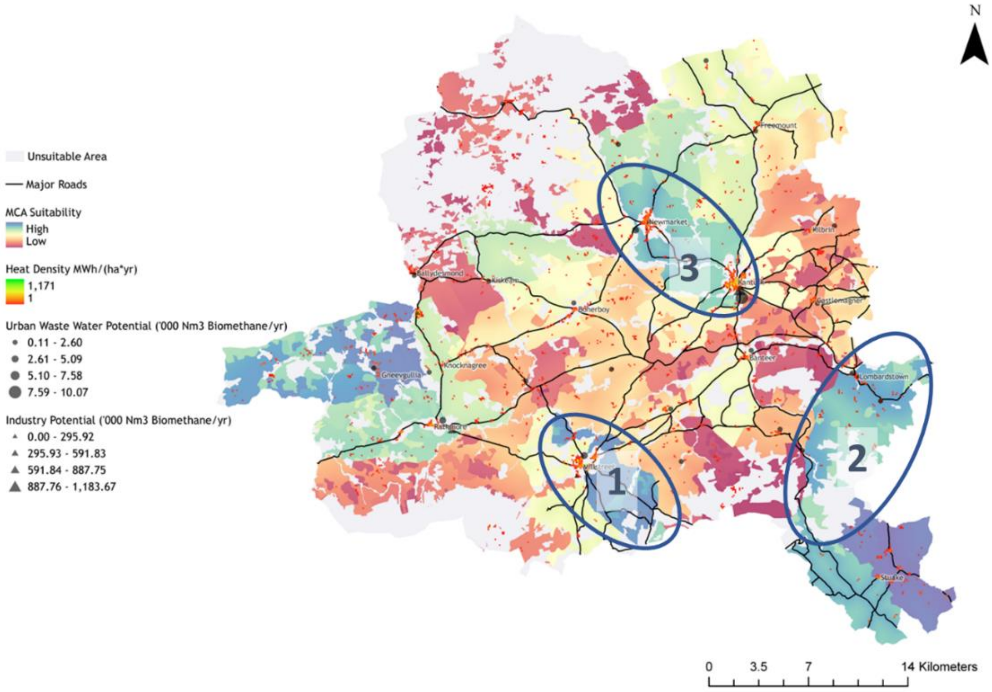

Figure 14: Spatial MCA map with strategic areas for AD development selected for further analysis.

B. Preliminary Design

This chapter builds on the AD pathways review and cost/benefit analysis undertaken in Chapter 5 and explores in more detail the design of two specific AD systems:

1. A farm-based AD plant digesting a combination of grass silage and slurry. The biogas produced is primarily upgraded to biomethane before it is exported via a 'virtual pipeline' to a grid injection facility (Mitchelstown) or to a remote user site. The biogas upgrade plant is combined with a CO_2 liquefication unit which produces a high-quality food grade CO_2 for commercialisation. Some of the biogas is used to fire a combined heat & power unit dedicated to meeting the energy requirements of the AD plant, in particular the electricity needs of the biogas upgrade and CO2 liquification systems. The AD system also includes pasteurisation to treat the slurry in compliance with the ABP regulations.
2. An AD system collocated with a dairy processing plant, digesting a combination of grass silage, slurry and dairy wastewater treatment sludges, sized to produce approximately 20 GWh of biogas per year. The biogas is upgraded into compressed biomethane (CBM) which is then used to meet the energy requirement of the dairy plant. The plant also includes CO_2 liquification and commercialisation. The AD system also includes pasteurisation to treat the slurry in compliance with the ABP regulations.

The following sections outlines the typical design of both AD systems.

1. Farm-based AD system for CBM export, with CHP

Here is a functional description of the plant:

a) **Feedstocks reception:** In this plant layout design, two plant entrances have been included; one for ABP feedstock reception, and the other for non ABP feedstocks and activities. Grass silage is stored in large clamps sufficiently large for day-to-day operation all year (average of 85 tFM/day; 31,000 tonnes per year). A front-end loader operated by the plant manager, feeds silage into a large 20-tonne feed-hopper which is equipped with weigh-cells; allowing a controlled amount of silage and sludges to be fed into the digester every day. The slurry (70 tFM/day, 21,600 tFM/year) is stored primarily on farms before it is brought to the AD plant and received in liquids storage tank, from where it is pumped into the digester.

b) **Pasteurisation:** the feedstocks subject to ABP regulations are pasteurised before being fed into the digester to eliminate potential pathogens.

c) **Digester:** In this design, the digester has a total capacity of 7000 m3 made, divided in two insulated tanks in which the feedstocks are heated and mixed continuously. The two tanks can operate in parallel (one-stage digestion process) or in series (two-stage process). The digesters' roof is a double-membrane system in which the inner membrane rises and falls to allow for gas storage. The biogas produced (c.13,000 m3/day) is cleaned before being supplied to the upgrading plant or the CHP unit.

d) **Digestate processing & storage:** The digestate flowing out of the digesters is stored into a large covered tank onsite, sized to be able to hold the digestate produced during the period during which it cannot be applied to land. The solid fraction of the digestate is extracted with a screw press and composted for commercialisation as compost for horticulture (10,200 tonnes per year).

e) **CHP unit:** A CHP unit of approximately 500 kWe capacity provides the electricity requirement of the AD plant, the biogas upgrade system and CO_2 liquefaction plant. The CHP unit, together with the biogas upgrade system and the CO_2 liquification plant produce a large amount of heat, which is used to pasteurise the ABP feedstocks and heat the digester (c. 8,000 MWh/yr), leaving excess heat to be dissipated or valorised locally (e.g. for pig or poultry farming, greenhouse gases, nearby buildings, etc.).

a) **Upgrading biogas to biomethane:** The biogas produced comprises mainly methane (60% average content) with most of the balance being carbon dioxide and some water. It also has trace compounds of which the most important is the corrosive gas hydrogen sulphide. After it has been cleaned of contaminants, biogas is processed semi-continuously by an upgrading facility that produces biomethane (2 million Nm3/yr).

b) **CO_2 liquefaction:** High purity carbon dioxide is produced by the upgrading facility (2,500 tonnes per year). Instead of releasing this CO_2 to the atmosphere, it is compressed and stored for sale as food-grade CO_2 for industrial applications. The compression of carbon dioxide also produces heat which can be recovered for use by the digester.

c) **Biomethane storage and shipping:** The biomethane produced is stored in high-pressure tanks mounted on a trailer. Each trailer would have a capacity of circa 9,000 Nm3 of CBM at 250 bar working pressure. A typical operation would have two trailers, with one at the AD plant being filled and the other one being transported with a truck to a gas grid injection point (in Mitchelstown presumably as per Use Case 2 above) and/or to a local user site (as per Use Case 1 above). The user site would have its own CBM storage (this can be a CBM tanks trailer too) and dispensing system (e.g. HGV filling station).

2. Co-located AD system for onsite CBM use

This AD system is an upscaled version of the previous one, collocated with a food processing plant and supplying CBM to meet part of its large year-round energy usage (Use Case 3 described above). Here is a functional description of this larger, more complex system:

a) **Feedstock reception:** The feedstock reception area can manage solid (silage, possibly food waste, manure) and liquid feedstocks (sludges and slurry), with a total annual capacity of 330 tFM/day flow through (89,000 tonnes per year). Reception facilities include weighbridge, liquid feedstocks storage tanks, solid feedstock clamps. In addition, an enclosed building accommodates the food waste reception and processing system.
b) **Digester feeding:** A front-end loader operated by the plant manager, feeds silage into a large 20-tonne feed-hopper which is equipped with weigh-cells; allowing a controlled amount of silage to be fed into the digester every day. Liquid feedstocks are pumped to the digesters from their holding tanks.
c) **Pasteurisation:** the feedstocks subject to ABP regulations are pasteurised before being fed into the digester to eliminate potential pathogens.
d) **Digester:** Four 3,500 digesters with a similar design to the above, produce a total of 18,500 Nm3/day of biogas.
e) **CHP unit:** A CHP unit meets the electricity requirement of the AD plant, the biogas upgrade system and CO_2 liquefaction plant (900 kWe average output). Additional CHP capacity could also be provided to meet the food processor's WWTP plant if AD system is located on the same site. The CHP unit, together with the biogas upgrade system and the CO_2 liquification plant produce a large amount of heat, which is used to pasteurise the ABP feedstocks and heat the digester, leaving a significant amount of surplus heat (circa 4,300 MWh/yr) which should recovered to meet the thermal requirements of the food processing plant[16].
f) **Upgrading biogas to biomethane:** The upgrading plant produces over 4 million Nm3 CBM per year which is piped to the food processing plant, to be used gas boilers or CHP systems. If possible, existing systems can be adapted to use CBM, if not new boilers or CHP plant will need to be installed.
g) **CO_2 liquefaction:** High purity carbon dioxide is produced by the upgrading facility (5,000 tonnes per year), stored in high pressure tanks before being commercialised (unless there is use for it on the collocated industrial site).
h) **Digestate and products**: A total of c. 22,000 tFM/yr of high-quality compost is produced. The liquid fraction of the digestate (100,000 tFM/yr) is stored onsite temporarily and then spread on agricultural land.

3. AD System Process Flow Diagram and Plant Layout

Figure 15 below presents a process flow diagram for the AD system underlying Use Cases 1,2 and 3.

[16] The energy supply to the AD system needs to be considered carefully specifically for each project, considering possible integrations with the energy system of the adjacent industrial plant. In some case, the industrial site might have spare CHP capacity to produce the electricity required by the AD systems.

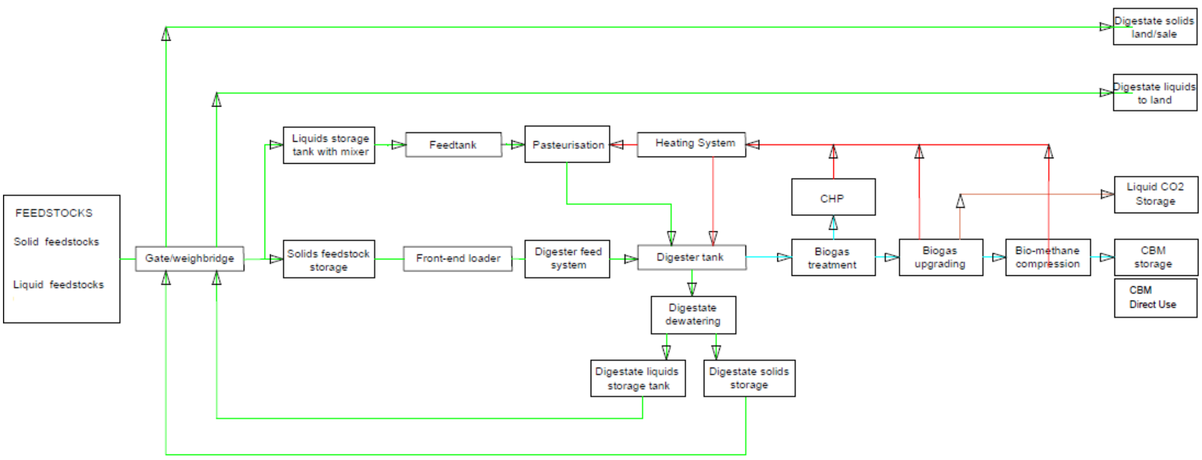

Figure 15: Process flow diagram of AD + CHP + CBM + CO2 pathway.

Figure 16 presents a generic plant layout for the Use Case Projects 1 and 2. The land requirement is approximately 1.5 hectares.

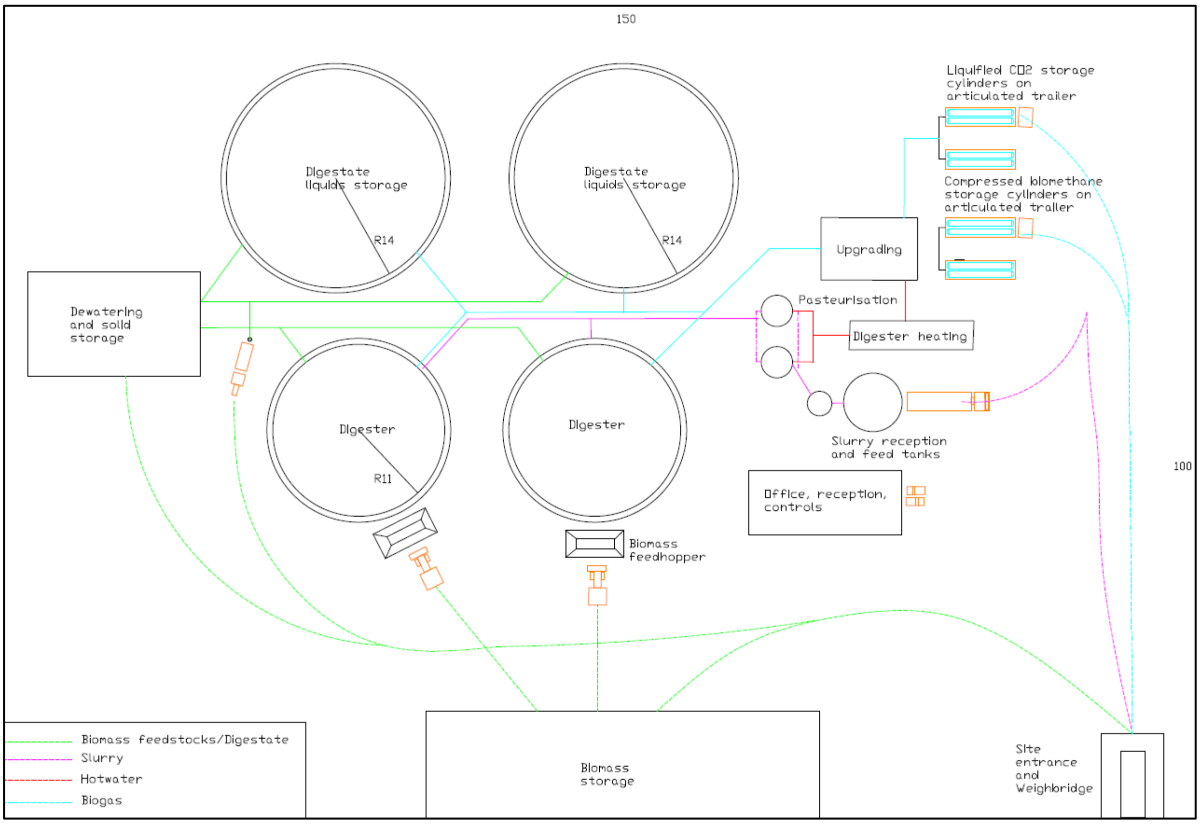

Figure 16: Farm-based AD Plant Layout - 20 GWh/yr biogas capacity, CHP, CBM, CO_2.

Figure 17 presents a generic plant layout for the Use Case Project 3. The land requirement is approximately 2.5 hectares.

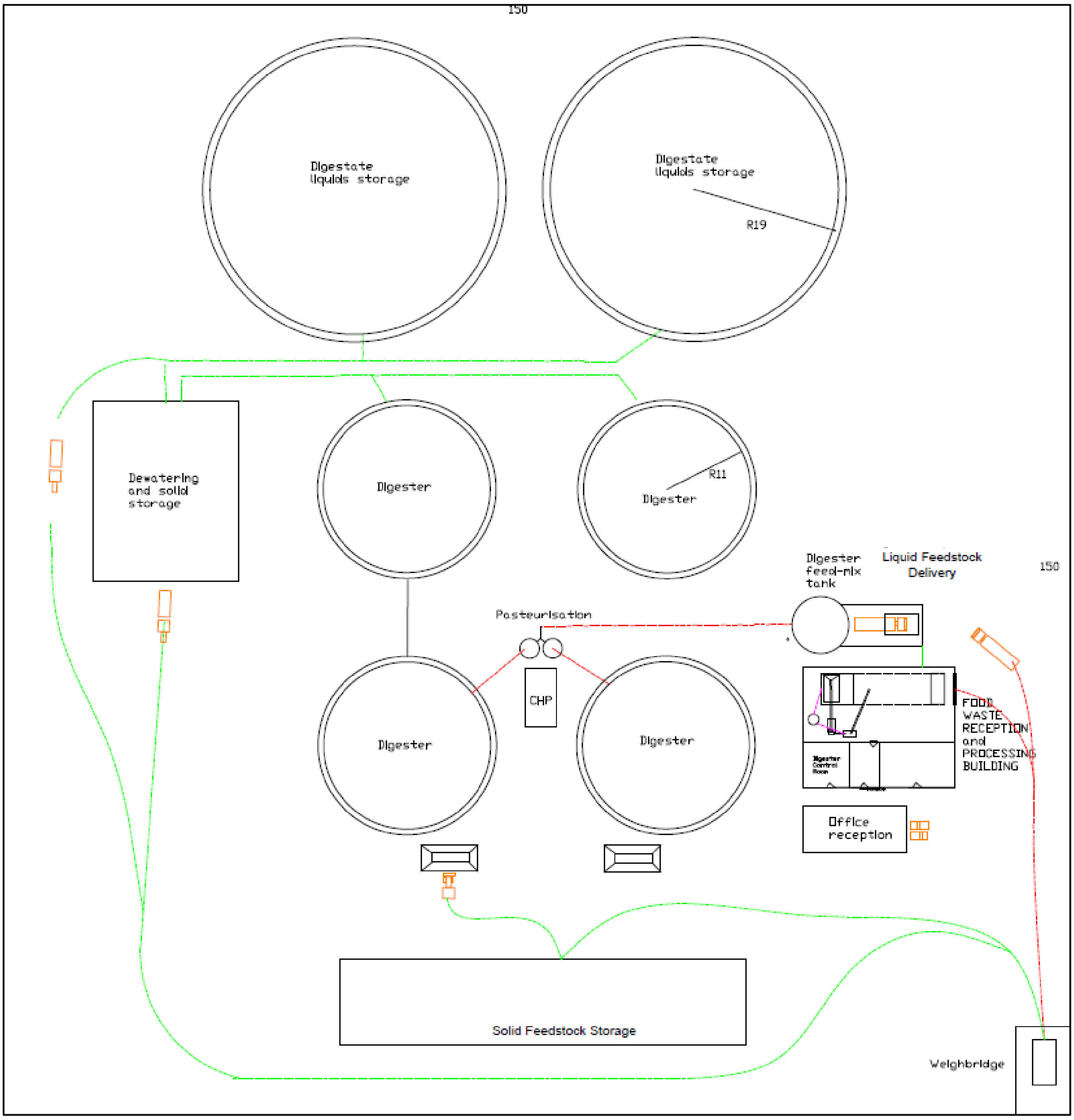

Figure 17: Plant layout for 40 GWh/yr AD plant with ABP treatment, CHP and CBM for onsite use.

C. Life Cycle Cost Analysis

The life cycle cost analysis uses the data and assumptions applied in the AD pathways cost/benefit analysis to determine the cash flow of each project over a 20-year lifetime. The annual cash flows are discounted with a rate of 8%, assumed to be the weighted average cost of capital[17] for such a project (Ricardo Energy & Environment, 2017). Inflation is not considered in the discounted cash flow analysis as it is assumed that inflation on costs will be reflected in the value of the outputs.

[17] The weighted average cost of capital (WACC) represents a firm's average cost of capital from all sources, including common stock, preferred stock, bonds, and other forms of debt. The weighted average cost of capital is a common way to determine required rate of return because it expresses, in a single number, the return that both bondholders and shareholders demand to provide the company with capital. Source: Investopedia.

The following key performance indicators of financial performance are used for the lifecycle cost analysis:

- **Net Present Value (NPV):** Difference between the present value of cash inflows and the present value of cash outflows over a period of time. It applies the discount rate to account for the time value of money.
- **Internal Rate of Return (IRR):** A discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. It measures the rate return on the investment made.

The NPV and IRR are calculated for the project cash flows before tax.

In this analysis, a biomethane value of c€ 8.5/kWh has been applied to Use Cases 1 and 2 (biomethane injected to the grid or used locally), and c€ 6/kWh for Use Case 3 for biomethane being competitive with LPG or gasoil at a food processing plant. The full value of the initial capital investment has been applied as a negative cash flow on year 0 (no loan repayment and finance costs) so that the IRR values obtained indicate the potential return on investment from the perspective of the equity investor or institutional lender. The results of the discounted cash flow analysis for the AD systems proposed above are presented hereafter. The discounted cash flow analysis considers the replacement cost of some of the machinery on year 15 and end-of-life value for the plant and associated infrastructure (including land).

The analysis, summarised in Table 8,shows that for all three AD Use Cases envisaged, the projects are profitable and generate a healthy return on investment with IRRs before tax of 16%, 14% and 20% respectively. The NPVs of the project is €4 million, €2.6 million and €10.4 million respectively. These results indicate that:

a) Use Case 3 is the most profitable project whereby the biomethane produced is used on site, which simplifies the infrastructure required and helps reduce operating costs (less storage and logistics costs, and reduced feedstock costs due to the treatment of organic wastes).
b) Use Case 2 is less profitable than Use Case 1 because of the increase operational costs of having to transport and inject biomethane into the natural gas grid at a considerable distance.
c) These two Use Cases use agricultural feedstocks only, with grass silage representing a very significant operating cost, which reduces the level of return on investment compared to Use Case 3 benefitting from reduced feedstock costs.
d) By-products from the CBM production (CO_2, compost and to a lesser extent heat) play a very important role in the viability of the projects, without these revenue streams they have a negative return on investment.

It is also worth noting that the capital expenditure estimates date from early 2021 and recent inflationary pressures on construction costs, in particular on materials, has not been factored in the analysis. While it is hard to predict how this is going to involve in the next 2-3 years, **a sensitivity analysis** shows that increasing these by 20% reduces the IRR of these projects by 3 to 4% percentage points. Should CAPEX increase more than 60% above our current assumptions, the viability of Use Case 1 and 2 projects is seriously compromised (Use Case 3 is more resilient from that point of view).

Table 8: Lifecycle Cost Analysis – Discounted Cash Flow

Pathway Analysis	units	(Use Case 1) 20 GWh/yr Farm-based AD plant - CBM sold locally + CO2 + CHP	(Use Case 2) 20 GWh/yr Farm-based AD - CBM grid injected + CO2 + CHP	(Use Case 3) 40 GWh/yr co-located AD – CBM used onsite + CO2 + CHP
Feedstock Input				
Grass Silage	tFM/day	85.0	85.0	152.0
Cattle Slurry	tFM/day	70.0	70.0	121.0
Domestic Food Waste	tFM/day	0.0	0.0	3.4
Commercial Food Waste	tFM/day	0.0	0.0	1.2
Food processing WWTP sludge	tFM/day	0.0	0.0	53.7
Total	**tFM/day**	**155.0**	**155.0**	**331.3**
Capital Expenditure				
Planning/project approvals	€	80,000	80,000	80,000
Project management	€	80,000	80,000	80,000
Digester turn-key	€	1,800,000	1,800,000	3,600,000
Electrical and controls	€	200,000	200,000	400,000
Feed system	€	330,000	330,000	660,000
Digestate system (press+store)	€	70,000	70,000	90,000
Digestate liquid storage	€	360,000	360,000	720,000
Civils	€	360,000	360,000	720,000
Grid connection	€	80,000	80,000	80,000
ABP reception + pretreatment	€	250,000	250,000	250,000
Site CHP plant and gas conditioning	€	290,695	290,695	608,888
Biogas-to-CBM upgrading plant	€	750,000	750,000	1,400,000
Biogas-to-CBM compression plant	€	100,000	100,000	200,000
CBM storage	€	160,000	80,000	160,000
CO2 recovery and storage	€	670,000	670,000	670,000
Gas Grid Connection	€	-	200,000	-
Total Build Cost	**€**	**5,580,695**	**5,700,695**	**9,718,888**
Site acquisition	€	150,000	150,000	250,000
Cost of Finance				
Debt to Equity Ratio	%	80%	80%	80%
Amount Borrowed	€	4,584,556	4,680,556	7,975,111
Interest Rate	%	6%	6%	6%
Loan Repayment Period	years	10	10	10
Annual Loan Repayment	**€/year**	**622,894**	**635,938**	**1,083,562**

Pathway Analysis	units	(Use Case 1) 20 GWh/yr Farm-based AD plant - CBM sold locally + CO2 + CHP	(Use Case 2) 20 GWh/yr Farm-based AD - CBM grid injected + CO2 + CHP	(Use Case 3) 40 GWh/yr co-located AD – CBM used onsite + CO2 + CHP
Revenues				
Sale of Electricity	€/y	-	-	25,626
Sale of Heat	€/y	-	-	218,309
Sale of CBM	€/y	1,710,259	1,710,259	2,458,679
CBM Subsidies	€/y	-	-	-
Sale of CO2	€/y	392,929	392,929	786,681
Sale of Compost	€/y	254,588	254,588	544,160
Total	*€/y*	**2,357,776**	**2,357,776**	**4,033,455**
Operational Expenditure				
Feedstock Costs/Income				
Grass Silage	€/y	930,750	930,750	1,664,400
Cattle Slurry	"	127,750	127,750	220,825
Domestic Food Waste	"	-	-	(86,870)
Commercial Food Waste	"	-	-	(30,660)
Food processing WWTP sludge	"	-	-	(401,934)
Net feedstock costs	€/y	1,058,500	1,058,500	1,365,761
Digestate Disposal	€/y	92,783	92,783	198,316
Cost of CBM Haulage & Injection	€/y	17,504	132,995	-
Energy Costs	€/y	6,383	6,383	-
Labour, Insurance, Overheads	€/y	197,487	198,687	400,018
Maintenance and Repairs	€/y	94,722	98,722	189,587
Total OPEX	**€/y**	**1,783,478**	**2,024,860**	**2,743,294**
Depreciation				
Buildings	€/y	111,500	121,500	220,500
Machinery	€/y	166,713	161,380	273,259
Total Depreciation	€/y	**278,213**	**282,880**	**493,759**

Pathway Analysis	units	(Use Case 1) 20 GWh/yr Farm-based AD plant - CBM sold locally + CO2 + CHP	(Use Case 2) 20 GWh/yr Farm-based AD - CBM grid injected + CO2 + CHP	(Use Case 3) 40 GWh/yr co-located AD – CBM used onsite + CO2 + CHP
Annual Profit and Loss				
CAPEX	*Mio€*	5,730,695	5,850,695	9,968,888
Total Revenue	€/y	2,357,776	2,357,776	4,033,455
Total OPEX	"	1,467,379	1,588,070	2,153,682
Depreciation	"	278,213	282,880	493,759
Loan Interest	"	137,537	140,417	239,253
Profit/Loss	"	474,647	346,409	1,146,761
Return on Capital	%	11.0%	8.5%	14.3%
Discounted Cash Flow Analysis				
Year 0		- 5,730,695	- 5,850,695	- 9,968,888
Year 1		890,397	769,706	1,879,773
Year 2		890,397	769,706	1,879,773
Year 3		890,397	769,706	1,879,773
Year 4		890,397	769,706	1,879,773
Year 5		890,397	769,706	1,879,773
Year 6		890,397	769,706	1,879,773
Year 7		890,397	769,706	1,879,773
Year 8		890,397	769,706	1,879,773
Year 9		890,397	769,706	1,879,773
Year 10		890,397	769,706	1,879,773
Year 11		890,397	769,706	1,879,773
Year 12		890,397	769,706	1,879,773
Year 13		890,397	769,706	1,879,773
Year 14		890,397	769,706	1,879,773
Year 15		- 225,742	- 370,433	- 64,004
Year 16		890,397	769,706	1,879,773
Year 17		890,397	769,706	1,879,773
Year 18		890,397	769,706	1,879,773
Year 19		890,397	769,706	1,879,773
Year 20		1,281,045	1,168,754	2,560,095
FINANCIAL KPIs				
IRR	%	14%	11%	18%
NPV	€/2021	2,540,103	1,326,468	7,426,115

Chapter 7. Community-ownership Models for the Development of Anaerobic Digestion Projects

The objective of this chapter of the study is to review business and financing models appropriate for community participation in the development of anaerobic digestion in the IRD Duhallow region, in consultation with key stakeholders. Models of community ownership promote wide participation in ownership and management, engender local support, are inclusive and deliver tangible and intangible local benefits, particularly for individuals that do not have sufficient funds to invest.

A. Ownership & Organisational Model

There are two possible structures to raise equity in the framework of a community-owned project: a limited company or a co-operative, also known as an Industrial and Provident Society (I&Ps). These two organisational structures are governed by separate legislation but subject to broadly similar requirements.

Both types of organisations provide 'limited liability', which means that members/ shareholders cannot be sued for more money than they have invested in the organisation. This protection is important for any group but particularly for community ventures. The organisation becomes a 'legal person' that has its own identity and can enter into contracts of various sorts including owning property, buying and selling. If things go horribly wrong, the organisation 'dies' and members lose the money they have invested but there is no recourse to individuals' personal wealth.

The main differences that impinge on this project are the governance, the number of members and requirements regarding share offers. Some other differences regarding shares may also be relevant in terms of ensuring a truly community enterprise.

1. Governance & Membership

Both companies and I&P societies are managed on a day-to-day basis by a board of directors, elected by general meetings of the shareholders. Both need to have a governing document that is registered with the Company Registration Office. Both need to report annually to the CRO. Both can raise share capital, and both can make payments to shareholders.

Companies are controlled by their members (or shareholders) and controlled on the basis of share ownership; those who hold more shares wield more votes and exercise greater control over the company. The maximum number of members that a company can have is 100. This could be a major limiting factor as community projects aim to have hundreds of members.

Co-operatives are controlled by their members, who are also the shareholders. Each member has one vote, regardless of how many shares they hold. This prevents a small number of members from seizing control. There is no limit to the number of members that a Co-op can have.

2. Share Raising

Companies raise capital by selling shares, which they can do on an informal basis with small numbers of engaged people but if they issue a public share offer, they will need to comply with detailed legislation that will require lawyers and accountants at significant expense. European Securities and Markets Authority (ESMA) list all European share prospectuses.

Co-ops can issue a share offer without great expense and raise the required capital. Interest can be paid on this to incentivise investment although the rate paid should only be sufficient to obtain and retain the investment. The finances should be sufficient to pay an average (IRR) of about 6% and be sufficiently attractive to raise the equity necessary.

3. Registering an I&Ps

Co-ops or I&Ps are governed by Rules and the Irish Co-operative Organisation Society (ICOS) has Model Rules that can be used as a basis for many new societies. They have helped a dozen energy co-ops to register, using bespoke Rules. This is the advised route and ICOS would be supporting the group to develop the necessary Rules. There are plenty of useful documents on the ICOS website, including a guide to starting a new co-op.

I&Ps are registered with the Registry of Friendly Societies, which is held by Companies Registration Office (CRO). They charge €100 to register a new society.

The following table provides a summary and comparison of the key characteristics of Co-operative and Company legal structures.

Table 9: key characteristics of Co-operative and Company legal structures

	I&Ps/Co-operative	Company
number of members	7 to unlimited	1 to 100
governing document	Rules	Memorandum and Articles of Association
registration	Registrar of Friendly Societies (RFS)	Companies Registration Office
can raise shares	✔	✔
requirements	share offers >€30k must have the intention registered with RFS	share prospectus >€1M must comply with the new Prospectus Regulation
returns	interest and dividends	dividends
taxable	interest no; dividends yes	yes
pros	Model Rules available good support from co-operative organisations inexpensive registration process lightweight reporting requirements interest to members is an allowable expense secure community ownership possible with 'asset lock' can raise equity and loans simply from its members simple share offer document that ordinary people can understand	well recognised organisational form Mem' & Art's can be written to permit anything [legal] can invest in other enterprises can be junior partner in a joint venture can invest for profit
cons	community shares not well understood by many interest payments limited must be in control of its own trade—cannot be a junior partner in a joint venture	shareholder membership is limited to 100 for private limited companies onerous reporting requirements share prospectus expensive to develop

4. Co-operative principles

An Industrial and Provident Society embraces the co-operative principles set out by the International Co-operative Alliance. The seven core principles of co-ops are:

- voluntary and open membership.
- democratic member control—one member, one vote.
- member economic participation.

- autonomy and independence—never owned as a subsidiary.
- education, training and information.
- co-operation among co-operatives.
- concern for community.

It is clear that these principles fit easily with the values of community-based organisations and provide a good structure for carrying out a business enterprise for the benefit of the community.

B. Financing A Community Owned Anaerobic Digestion Project

There are various types of agreement that can be used to secure the required capital for an anaerobic digestion project. Broadly, these can be classified as debt and equity. Debt involves money from a creditor or 'lender', who will expect to be repaid with interest and this can be in the form of a loan, bond or debenture. Equity means ownership and it is typically expressed as shares, with each person owning one or several shares of the total project being an 'investor'.

Debt carries higher risk for the lender, who in turn demands greater returns. Generally speaking, interest payments on debt is an allowable expense for tax purposes but dividends to shareholders is paid from the after-tax profits. The exception is community shares where interest on shares is an allowable expense for tax purposes.

The amount borrowed or invested is termed 'capital' or 'principal'; the extra payments made to the lender or investor are 'interest', 'returns', 'coupon rate' or 'dividend' (although this is technically distinct). Some terms are used interchangeably but the following are descriptions of the main distinctives as generally understood.

1. The specificities of financing a community renewable energy project

Research into the experience of community owned renewable energy projects in securing finance has indicated a number of commonalities (Ricardo Energy & Environment, IEA-RETD Operating Agent, 2016). Debt financing is often expensive for communities due to the risks perceived by commercial investors such as banks and pension funds. Co-operatives might have a reputation to offer lower investment returns, and the corresponding cultural acceptance of community RES projects with lenders and investors, creates barriers to securing financing. Debt is also often more expensive for smaller community RES projects because lenders are not offered a portfolio of many projects to spread their risk. In a larger, more diversified investment portfolio, the risk of default on the entire principal is much lower.

Development costs include feasibility analysis, project management, securing financing, planning, and advisory fees. There are issues with availability and cost of debt financing for communities, especially for the planning and development stage of projects. Cash poor, and general risk averse communities, will have much less cash available. In addition, small RES projects are unable to leverage economies of scale for construction and developmental costs. Shared ownership models that required complex agreements or community-owned projects that did not have previous experience had a greater need for advisory support by the community.

However, there are plenty of positives:

- Community projects inevitably use volunteer time from the member base at different stages of the project. If volunteer labour is used during the construction phase it can help reduce installation costs.
- Communities also usually have personal relationships with various local businesses and stakeholders, which can enable them to get good deals, for example on equipment rentals or leases on land.
- Community RES projects can sometimes be seen as a demonstration project and can attract discounts on equipment, donations of materials, and funding.
- Various grants and additional funding are available for the development of community projects, especially for feasibility assessments as a critical component of on-going community energy planning projects.
- On the other hand, community consultation costs may be small or negligible for community-owned or shared community projects depending on the level of engagement of the community. However, the process may often be protracted.
- Complete community ownership of the project can then be seen as an even greater participation with the benefits and challenges of such projects and if there is capacity and commitment within the community to embrace this, they will be the richer for it.

2. Financing instrument options

Developing a community-owned project typically involves a combination of equity, generally 20 to 30% of the investment, and the balance is financed by debt. We review hereafter the common financing instruments available for renewable energy projects such as anaerobic digestion plants:

a) **Loans**

Loans are the most familiar type of borrowing arrangement. The lender offers money, and the borrower commits to repaying the capital and interest. In this case, the loan is likely to be taken with a bank or other financial institution and be secured in that it is backed by some form of collateral. Loans are generally not tradable.

b) **Bonds**

Bonds are certificates of debt that are issued specifically to raise funds. They should be secured against the assets of the company. Some people refer to unsecured bonds, but these are better described as debentures. There will be a clear repayment schedule for the interest and capital is generally repaid 'on maturity', i.e., at the end of the loan term. Bonds will have the same terms and conditions for all bondholders of that particular bond. They can generally be traded.

c) **Debentures**

Debenture is a general term for bespoke debt instruments used to raise capital for an enterprise. They are generally unsecured (against assets of the company) but may include some type of security arrangement in case problems arise. As with all debt mechanisms, they do not give any ownership of the company. There will be a detailed offer document that explains the terms and conditions of the agreement. Debentures may be allowed to be traded. The rate of interest can sometimes be referred to as the coupon rate and may be fixed at the outset or variable according to the performance of the enterprise.

d) **Shares**

Companies can raise capital by offering a stake in the enterprise. Investors become linked to the fortunes and misfortunes of the company. If the company does well, they will be paid a dividend and the value of the shares may increase above the price paid for them. This 'capital gain' is only realised when the shares are sold. Conversely, if the company does poorly, there may be no return on the investment and the value of the shares may reduce, even to zero. If the company is liquidated, the shareholders get a slice of the residual value once all other liabilities have been fulfilled. Shares can be bought and sold and may appear on public trading platforms like Euronext Dublin.

e) **Community Shares**

When an I&Ps issues shares, different rules apply. The shares still give a part-ownership of the enterprise, but the value of the shares can never increase above the face value, referred to as 'par value'. The shares cannot be freely traded, and all transfers of ownership must be managed by the society's board. They can also transfer the shares back to the society whereupon they are cancelled. These mechanisms prevent the financial speculation that can happen with company shares. Both interest (in proportion to investment) and dividends (in proportion to interactions with the society) can be paid. Interest is an allowable expenditure for tax purposes, but dividends are generally paid from taxed profits.

Community shares are often referred to as 'patient capital' as the investors are not out to make 'a quick buck' but are keen to support a community enterprise and are willing to let their money be used for this over an extended period of time.

3. Community buy-in to commercial projects

There may be some cases where a commercial developer will offer communities a stake in a renewable energy development and communities should look carefully at all such offers. The main advantage of such a scheme is that an experienced developer has carried out the hard work of investigating the potential and developing the business case; they have taken the risk and secured the various permissions necessary. In addition, partnering with commercial developers makes access to affordable debt easier, but often decreases the share owned by the community, and hence the benefits. Partnering also imposes new challenges in terms of framing the partnership and engaging on an equitable footing with better-resourced and more-experienced commercial developers and financiers.

It is difficult to find good models for such part-ownership and the terms and conditions of the offer will need to be assessed on their own merit. Wholly owned community projects are of more benefit to communities but require much more work.

When a community has ownership in a renewable energy project, there is an income stream that can pay interest to the local investors and, depending on the energy distribution arrangements (e.g. heat distribution, transport fuel, etc.), there may be benefits in terms of reduced energy costs in the community. It has been well demonstrated that when people have a stake in a development, they are much less focussed on any downsides and much more conscious of the benefits that arise. There is also better engagement with the underlying issues that the development addresses, be it climate change, fuel poverty or community enterprise when individuals in the local community are members of the organisation and own part of the development.

All investment carries risk and with community schemes, the risk is mainly carried by the members. If something goes wrong or if the generator does not perform as expected, the investor members may not receive the returns that they expect and may need to dip further into their pockets to rectify problems that become evident. It is at least theoretically possible that the investors could lose all their investment.

When things go according to plan and when a well-researched scheme is implemented, local people benefit financially from their local energy resources and that in turn translates into more money in the local economy for purchases and other investments. Depending how the co-op is set up, there could be explicit funding for local community projects as part of the designed outcomes. Communities have gone on to build various community facilities where there is such an established income stream.

Where a commercial developer offers a share of the project to a community group, they will have factored that into their business model and unless the pay-outs are linked to performance, the income that comes to the community may be minimal because the developer will need to give some type of commitment to pay a certain amount and that will therefore be at the lower end of the range of what they can afford so that years of poor performance do not bankrupt the project. It is therefore expedient to negotiate a true equity stake where the community share in the fortunes (and misfortunes) of the project.

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