Report prepared by:

Elaine Groom and Angela Orozco, QUESTOR Centre, The Queen’s University of Belfast

31st March 2014, Version 1.28, Final

Project part financed through Invest NI by the European Regional Development Fund under the European Sustainable Competitiveness Programme for Northern Ireland.
Contents

Executive Summary........................................................................................................................................... 3
Introduction .................................................................................................................................................. 5
Development of a regional research agenda and action plan........................................................................ 6
  Scope and objectives of the Research Action Plan...................................................................................... 6
  Stakeholders’ role in the Research Action Plan.......................................................................................... 7
Description of the Northern Ireland Region.................................................................................................. 7
  Energy production and demand .................................................................................................................. 8
  Available Organic Resources .................................................................................................................... 12
Research Action Plan .................................................................................................................................. 15
  Development of small scale solutions for biogas production and use ....................................................... 16
  Solutions for improved nutrient management............................................................................................. 19
  Embedding Biogas Use in the Regional Economy....................................................................................... 21
  Future crops and bio-based products.......................................................................................................... 24
Plans for international collaboration.............................................................................................................. 26
Funding instruments targeted for action.......................................................................................................... 27
Conclusions and Recommendations.............................................................................................................. 28
Appendices.................................................................................................................................................... 30
Executive Summary

This Biogas Research Action Plan sets out a strategic research agenda for the Northern Ireland Region and defines the opportunities how they can be implemented. QUESTOR/CASE Energy from Biomass Cluster and its partners and collaborators in the field of biogas production and use have selected the development priorities which are presented herein. The intention in doing so has been to identify and support regional business development, especially the increased growth of companies producing and aiming to export technologies associated with biogas production and the relevant supply chains. An additional aim is to support the region’s targets in avoiding imports of fossil-based energy with their associated costs. The growth and development of this area is considered a means to increase the competitiveness of the whole region. Companies in Northern Ireland consider that the selected development priorities will bring business value-added in global markets.

This Research Action Plan sets out development priorities and targets for 2020 which have been selected by dialogue with stakeholders in the region. These are also summarised in Table 1.

Development of small scale solutions for biogas production and use

Northern Ireland benefits from the large number of small advanced engineering firms developing renewable energy in the region. Such companies, active in the biogas sector, are seeking innovations in the design, production and operation of biogas-related technologies to enable cost reductions, particularly of small scale plant. Small plants are not considered to be financially viable at present but have many advantages as they suit the average farm size locally and in Europe. Companies are also interested in novel technologies for biogas clean up and upgrading that may be economically viable at smaller scale than present technologies. The developing sector also has interested in improved operation and control of biogas plants.

Solutions for improved nutrient management

The nutrient content of digestate has considerable fertiliser value which has the opportunity when used locally to offset imports of (fossil) fertiliser. Slow-release fertilisers produced from digestate are particularly desirable. Phosphorus is a limited resource and, as many Northern Ireland soils do not require additional phosphorus, processes to produce a stabilised product from digestate that is high in phosphorus and can be exported is desirable. There is an additional need to protect watercourses from excess nutrients in run-off and optimise the spreading of digestate across the region.

Embedding biogas use in the rural economy

There is a large potential for alternative uses of biogas in Northern Ireland, over and above its use in electricity production and export to the grid via combined heat and power (CHP). Opportunities include applications in the residential, agriculture, transport, existing gas-fired electricity sectors. Despite this there is poor knowledge within local communities of the benefits of biogas and the involvement and education of local communities through the development of demonstration projects is seen as an opportunity to reduce barriers of social acceptance. An additional barrier to the development of the sector as a whole is the cost of the technology. Many farm-based plants are currently ‘unfundable’ due to a lack of understanding and a common language between the banks and farming sectors and there is a need to the development of financial support services to aid in development of the sector.
Future crops and bio-based products

During the further development of biogas in the farming sector, there are opportunities for co-location of businesses to take advantage of the energy produced. These may take the form of greenhouses to take advantage of the supply of heat, lighting and CO$_2$ and there are opportunities for knowledge transfer and develop in this area. The testing of new annual and perennial crops for biogas production is also desirable. In the longer term, depending upon developments in biomass processing to biochemicals, micro-biorefineries may be practical, associated or co-located with one or more biogas plants. These would produce a limited portfolio of high-value chemicals arising from traditional or novel crops, grown on-demand at small scale.

Table 1. Areas where action is required for implementation of selected development priorities

<table>
<thead>
<tr>
<th>Selected development priorities to 2020</th>
<th>Basic Research</th>
<th>Applied Research</th>
<th>R&amp;D and Demos</th>
<th>Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of small scale solutions for biogas production and use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>❖ Low cost, modular, scalable designs for small capacity biogas plants</td>
<td>-</td>
<td>+++</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>❖ New cost effective techniques for biogas clean-up and removal of trace contaminants</td>
<td>-</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>❖ Proven pre-treatment technologies for increased rate and/or extent of feedstock conversion</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>❖ Advanced monitoring, control, and reporting</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Solutions for improved nutrient management</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>❖ Technologies for the capture and use of nutrients from digestate as fertiliser</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>❖ Logistics of feedstock and digestate movement</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>❖ Technologies for water-course protection</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Embedding Biogas Use in the Regional Economy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>❖ Biogas contribution to Sustainable Energy Communities</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>❖ Integrated supply chains</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>❖ Reduced barriers to public acceptance</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>❖ Control and mitigation of financial risk</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Future crops and bio-based products</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>❖ Knowledge of a range of new crops for bioprocessing to produce biogas or biochemicals</td>
<td>+</td>
<td>+++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>❖ Knowledge of CO$_2$ enriched greenhouse and hydroponics-based cultivation</td>
<td>-</td>
<td>+</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>❖ Emerging knowledge of products suited to small scale biorefinery operation</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Introduction

Northern Ireland regional research clusters seek to strengthen regional development, promote competitiveness and ensure sustainability. In developing this action plan, the QUESTOR-CASE Energy from Biomass Cluster, shared by both QUESTOR and CASE, and described in Appendix 1, sought additional consultation with regional stakeholders to develop a research agenda and actions for innovation in the exploitation of regional biogas resources.

The Research Action Plan 2020 defines the development priorities and tools required for implementing the biogas strategic research agenda for Northern Ireland including its vision and mission.

Vision 2020

Northern Ireland has a target of 40% energy from renewable resources by 2020 and has an increasing international reputation for innovation in renewable energy to contribute to the delivery of this target.¹

> “Within 10 years Northern Ireland will be an internationally recognised exporter of global solutions forged from the development of the lowest cost sustainable energy infrastructure in Europe:
>  
>  • Created by thriving, indigenous businesses;
>  • Exploiting the region’s natural, intellectual and entrepreneurial capital.”

MATRIX Sustainable Energy Horizon Panel, 2013

Knowledge relevant to the delivery of energy via biogas is spread through diverse actors along the bioenergy supply chain. NI companies have gained national and international recognition for their innovation and enhanced business development in the implementation of biogas projects in the period since 2010. This activity covers a wide range of knowledge and expertise in the areas of feedstock production, handling and transformation, improved design, operation and control of digesters, digestate management, and more efficient means of use of biogas. It is supported by research and knowledge transfer from the research providers in the region.

Mission

In keeping with the mission of the QUESTOR and CASE Research Centres, the Energy from Biomass Cluster aims to provide application focussed research to generate knowledge and technologies for the future needs of industry. The activities of the QUESTOR-CASE Energy from Biomass Cluster and its collaborating research partners deliver knowledge, research results, testing services and training for companies, public bodies and other end users. The remit of the Energy from Biomass Cluster covers new approaches for all aspects of biomass feedstocks for production of energy and related value-added products.

The strategic research agenda developed describes the research opportunities in the Northern Ireland Region and outlines the required capacity building needed in the selected research fields related to sustainable production and use of biogas. The agenda supports expertise development

¹ The Matrix Panel is the science industry panel formed to advise Government on the commercial exploitation of Research and Development, science and technology in Northern Ireland)
and cooperation in the regional research-driven cluster. It identifies the focus of research activities in the future and supports the authorities in directing the use of human and financial resources.

The areas of knowledge in which Northern Ireland already has strategic research competence are identified; these are areas which the Energy from Biomass Research Cluster wishes to develop further. The Cluster will also address gaps in regional knowledge and expertise identified by the research agenda by seeking collaboration with regions that can provide complementary expertise.

The strategic research areas in biogas are intended to support the short-to-medium term development of the local biogas (production and use) sector as well as the longer term strategic development of technologies. These are needed to increase local sustainability of biogas use, and underpin and grow the international competitiveness of involved sectors. The strategic research areas identified are:

- Development of small scale solutions for biogas production and use
- Solutions for improved nutrient management
- Knowledge supporting and developing the integration of biogas into the rural economy
- Future crops and bio-based products

These have been developed and defined in terms of the priorities and steps required in the Research Action Plan.

**Development of a regional research agenda and action plan**

This Research Action Plan takes into account selected regional policies in the following areas:

- Use of natural resources
- Energy
- Agriculture and food production
- Environmental protection

These are based on national and EU legislation and strategies as well as regional needs and are summarised in Appendix 2. They set the framework for the action plan, indicating the political drivers. It is considered that the Action Plan should also aim to stimulate growth and employment in rural areas as well as regional competitiveness in the biogas sector.

**Scope and objectives of the Research Action Plan**

The objective of this Research Action Plan is to define priorities for support to regional development, co-operation and knowledge transfer within the region in the field of production and use of biogas in order to realise the following objectives:

- Development of new cost-effective, energy-efficient and sustainable technologies for biogas production and use within energy supply chains
- Development of technologies and services optimising the benefits of biogas for Northern Ireland agriculture, infrastructure and communities
- Provision of research expertise and facilities for manufacturers to commercialise ideas from R&D activities

This Research Action Plan defines specific development priorities, actions needed, required resources, responsible organizations and milestones in order to achieve the set targets by 2020. It
also considers possible funding instruments which might be used to implement the solutions identified.

**Stakeholders’ role in the Research Action Plan**

This Research Action Plan has been developed as a result of consultations with regional stakeholders comprising companies, research actors, regional authorities and public bodies. Workshops presented and discussed the areas of activity required. Four Working Groups (WG) consisting of company representatives and researchers were established:

1. Feedstocks WG (Quantification of feedstocks)
2. Alternative Uses WG (Facts and Figures for alternative uses of Biogas)
3. Financial Support WG (Understanding financial issues)
4. Research Agenda WG (Developing a regional research agenda)

Working Groups compiled data to support the plan and decided the key objectives and implementation activities. Further consultation with stakeholders in the form of a workshop presenting the groups’ interim findings was held in October 2013. Presentations or working papers from each of the groups are presented in Appendix 3 (Outputs from Working Groups). These contain facts and figures aiding the development of the biogas sector in Northern Ireland.

**Description of the Northern Ireland Region**

Northern Ireland, with a land area of 13,852 km$^2$, has a population of 1.8 million people. The labour force is 800,000 with an 8% rate of unemployment. Despite the decline of traditional heavy industries in recent decades, the advanced engineering and agri-food sectors remain strong.

A high proportion - 80% of the land area (11,200 km$^2$) and 35% of the population are defined as being rural. Only 8% of the land area is under forest, one of the lowest proportions in the EU. This is problematic for the desired use of indigenous biomass in heating and renewable energy, and there are plans to increase the planted area.

Agriculture is one of Northern Ireland’s biggest employers. 75% of the land area is devoted to agricultural production, of which 90% is permanent pasture for grazing and silage production. A total labour force (farmers and farmworkers) of 47,000 people is directly involved in agriculture, although the number of farms and farmers has declined steadily over recent decades$^2$.

The Agri-Food Sector is one of the most important contributors to the Northern Ireland economy in terms of revenue (£2.6 billion in 2010) and employment, with 25% of manufactured goods originating from food and drink processing. More than 60% of food produced is exported. The recently published Strategic Action Plan (Agri-Food Strategy Board, Going for Growth Report, 2013) sets ambitious targets for growth in the sector. Greenhouse gas emissions from agriculture and within the food processing supply chain are a concern for the competitiveness of the industry.

---

Accessed 10th January 2014
Energy production and demand

Bioenergy is a key component in the EU long term energy strategy in all sectors, especially transport, with a target contribution of up to 14% of the EU energy mix and up to 10% use in transport by 2020. Biogas has an important contribution to make and AEBIOM\(^3\) estimates there is the potential for production of 500 TWh of primary energy from biogas in Europe, or 1 TWh (3.6 PJ) per million people, derived from agricultural by-products and waste. Biogas generation in Europe is likely to increase from around 36 TWh in 2011 to around 68 TWh in 2020 with Germany continuing to dominate the biogas industry\(^4\).

An Intertrade Ireland report\(^5\) estimated the potential for the anaerobic digestion and composting sectors in Ireland to be up to 2 million tonnes (per annum) of organic resource and requiring an investment of €260-€530 million. It has the potential to create direct employment of 1,500 jobs and support an additional 10,000 persons indirectly within the supply chain.

Biogas, a mixture of methane, carbon dioxide and other gases, is produced by the anaerobic digestion (biological breakdown in absence of air) of organic material such as food waste, energy crops and animal wastes. Biogas has the following benefits:

- It is a flexible renewable energy carrier that can be (i) cleaned and burned directly for heating, (ii) cleaned and used in an engine to generate electricity or for combined heat and power (iii) upgraded to biomethane for injection into gas grids or used in vehicles as a transport fuel.
- Biogas technologies enable recovery of nutrients; residual liquid and solid material (digestate) from the anaerobic digestion process can be recycled to land as a fertiliser.
- Burning biogas produces water and carbon dioxide resulting in reduced emissions of airborne particulates, and savings on greenhouse gas (GHG) emissions from fossil fuel displacement.

This provides both challenges and opportunities in terms of innovation and business connectivity. It also requires a wider understanding of market needs from the point of view of technology integration with existing infrastructure.

The challenge for Northern Ireland is how best to utilise the biogas – as electricity, heat or vehicle fuel, and in what proportions.

Electricity

The NI Strategic Energy Framework sets a target of 40% of electricity consumption from renewable sources by 2020, a target that is matched in the Republic of Ireland since the creation of the Single Electricity Market for the management of electricity generation on an all-island basis in 2007.

---

\(^3\) AEBIOM (European Biomass Association), A Biogas Roadmap for Europe 2009


\(^5\) Foster et al, Market report on the composting and anaerobic digestion sectors, Prepared for Intertrade Ireland, February 2011
The nominal base load capacity of the large generating plant in Northern Ireland is 1564 MW, all from gas-fired power stations; coal/oil provides additional peaking capacity. The forecast peak energy demand for NI in 2020 is 1917 MW. Renewable energy production is predominantly wind; current renewables capacity in Northern Ireland is 489 MW of wind generation and 22 MW of other renewable energy sources. Production from biomass is highly desirable, and, as forest production is low and demand has resulted in the import of woody biomass, biogas has an important contribution to make.

Table 2. Northern Ireland Anaerobic Digestion Planning Applications (at August 2013)

<table>
<thead>
<tr>
<th>Status</th>
<th>Antrim</th>
<th>Armagh</th>
<th>Derry</th>
<th>Down</th>
<th>Fermanagh</th>
<th>Tyrone</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision Pending</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>13</td>
<td>37</td>
</tr>
<tr>
<td>Application Withdrawn</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Permission Granted</td>
<td>19</td>
<td>10</td>
<td>16</td>
<td>9</td>
<td>7</td>
<td>30</td>
<td>91</td>
</tr>
<tr>
<td>Permission Refused</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>19</td>
<td>27</td>
<td>12</td>
<td>8</td>
<td>46</td>
<td>138</td>
</tr>
</tbody>
</table>

Since April 2011, when incentives for generation of electricity from biogas were increased in the region to four ROCs (Renewables Obligation Certificates) for plants <500kW, 91 sites have obtained planning permission (Table 2). Ten plants are operational with a total capacity of just over 4MW; ten additional plants are in commissioning or under construction, including one plant of 3MW.

Heat

The current heat demand in Northern Ireland has been estimated at 17.4 TWh, and the region has set a target of 10% contribution to renewable heat by 2020.

In 2010, the residential sector accounted for 62% of total fossil fuel use for heating in Northern Ireland. This compares to 28% in industry and 5% in commercial uses. The residential sector is almost entirely dependent on imported fossil fuels. Only 1.7% of heat in Northern Ireland is from renewable sources; most of this is from biomass boilers, with a small quantity from heat pumps and solar thermal systems.

The Renewable Heat Incentive (NI) provides a tariff of 3.1 pence per kWh for grid injection of biomethane (all scales) and for biogas combustion (<200kWth). However, due to the greater incentive for electrical generation, biogas utilisation in Northern Ireland has focused on on-site electricity and combined heat and power (CHP) generation. Although CHP plants generally have

---

7 All-Island Generation Capacity Statement 2011-2020, SONI/EirGrid
efficiencies of around 75% (35% electrical and 40% thermal efficiency), a challenge is that there are limited local markets for heat. It can be particularly challenging for rural biogas plants to make full use of the heat which needs to be used close to the generation source. If the heat is not utilised, the overall efficiency of a CHP plant is only around 35%.

Upgraded biogas (biomethane) can be injected into the natural gas grid and used by households as a component in the natural gas supply. Funding for the extension of the gas grid to the West of the region announced by DETI in January 2014 offers an improved means of future distribution. A 2010 study by AECOM/Pöyry (cited in DETI, 2011) estimated that over 15% of Northern Ireland’s heat demand could theoretically be met by biogas produced from waste and grass in Northern Ireland. Thus, indigenous grass and waste biomethane could potentially heat the 15% of households currently with mains gas heating, which is approximately equivalent to the target for 10% renewable heat by 2020.

Transport

The use of renewable fuels for transport is mandated nationally under the Renewable Transport Fuel Obligation (RTFO); biofuel supply currently sits at a level of 4.75% of total road transport fuel supplied by volume. The use of biomethane as a transport fuel is supported in Great Britain under the RTFO by Renewable Transport Fuels Certificates (RTFCs) worth approximately 20p/kg. Support levels are two RTFCs if the feedstock is from waste sources, and one RTFC otherwise. An increased incentive for use of biomethane from waste sources to four RTFCs/kg is under consideration in Europe.

Road traffic currently accounts for 26% of greenhouse gas (GHG) emissions in Northern Ireland. National targets require a reduction of 35% in greenhouse gas source emissions by 2025 from the base year (1990). In Northern Ireland half (17.5%) of this target was achieved by 2011.

Future transport scenarios suggest that oil will continue to play a part in transportation for the foreseeable future. This is a concern for the region, which relies heavily on freight transport of goods including food exports, due to the potential for international energy cost fluctuations. Fuel use statistics (Table 3) show that diesel is the dominant fuel in Northern Ireland, even without accounting for underestimates due to cross-border purchases.

The introduction of electric vehicle (EV) charging points in Northern Ireland is one strategy aimed at encouraging emissions reductions; however, this targets mostly personal cars. In Europe, an increasing role is foreseen for natural gas (CNG and LNG) in transport towards 2050. While natural gas (and biomethane) currently has minor use, by 2030, natural gas is expected to reach a market share of 5% for passenger transport and 13% for freight. Up to 2050 the natural gas market share should increase, reaching 13% and 33% respectively for passenger and freight transport. By 2050 usage in transport is forecast to represent a volume of 33 billion cubic metres, against 1 billion cubic metres currently.

---


10 European Commission, Clean Power for Transport: A European alternative fuels strategy (COM:2013:0017)

The proposed European directive on the deployment of alternative fuels infrastructure\textsuperscript{12} accounts for all transport, including the needs of freight movement, and will require national policy frameworks and binding targets for the build-up of alternative fuel infrastructure. Both locally and nationally there is interest from the freight sector in the use of compressed natural gas (CNG) or liquefied natural gas (LNG). As a fuel this achieves reductions in GHG and particulate emissions compared to diesel; CO\textsubscript{2} emissions reductions are even more attractive when it is blended with a percentage of biomethane. The use of biogas in transport is reviewed in Appendix 3.2.

### Table 3. Fuel usage in Northern Ireland Transport\textsuperscript{13}

<table>
<thead>
<tr>
<th>Data from 2011</th>
<th>Freight</th>
<th>Personal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transport Type:</strong></td>
<td>Diesel HGV</td>
<td>Diesel LGV</td>
</tr>
<tr>
<td>Fuel Use\textsuperscript{1,2} (1000s of tonnes)</td>
<td>278.3</td>
<td>73.3</td>
</tr>
<tr>
<td>Percentages</td>
<td>23.5%</td>
<td>6.2%</td>
</tr>
</tbody>
</table>

\textsuperscript{1} Based on fuel sales recorded for excise duty returns.
\textsuperscript{2} So-called “fuel tourism” in ROI was estimated at a further 300ktoe\textsuperscript{14}. Conversion, based on a split of 25% petrol and 75% diesel for cross-border purchases, adds a further 71,000t for petrol and 223,000t for diesel usage.

### Energy in Agriculture

Agriculture accounted for 26% of Northern Ireland’s greenhouse gas emissions in 2010. The majority of agricultural emissions are from livestock and soils, but a sizeable portion (12%) is from energy use\textsuperscript{6}.

The emissions from energy use in agriculture (Table 4) can be split into:

- Emissions from stationary combustion (e.g. heating of sheds), which account for around 10% of energy related emissions in agriculture;
- Emissions from off-road machinery (e.g. tractors, harvesters and 4x4 vehicles), which account for around 90% of energy related emissions in agriculture.

In NI statistics (2012) 98% of vehicles in the Agricultural Machines taxation class used diesel fuel.

For many farms the costs of fuel is a significant input. In the last ten years domestic diesel prices have doubled, whilst those for agricultural diesel, although lower, have tripled\textsuperscript{15}, and the cost of fuel as a proportion of agricultural production costs is a future concern. The cost of fertiliser, which is closely linked to the cost of energy, is also a major concern and is another driver for the use of digestate as fertiliser.

---

\textsuperscript{12} Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the deployment of alternative fuels infrastructure (COM:2013:0018)
\textsuperscript{14} Energy in Transport: Trends and Influencing Factors. SEAI, 2006
\textsuperscript{15} http://www.dairyco.org.uk/market-information/farm-expenses/monthly-fuel-tracker/monthly-fuel-tracker/#.UtM4HLQvm0Q [accessed 9\textsuperscript{th} January 2014]
Table 4. Energy use in N Ireland agriculture and related greenhouse gas\(^6\).

<table>
<thead>
<tr>
<th>Use</th>
<th>Energy use (GWh)(^3)</th>
<th>% of total agricultural emissions from energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel for vehicles (off-road machinery)</td>
<td>1798</td>
<td>90</td>
</tr>
<tr>
<td>Fuel for heat (stationary combustion)</td>
<td>200</td>
<td>10</td>
</tr>
<tr>
<td>Electricity(^b)</td>
<td>198</td>
<td>-</td>
</tr>
</tbody>
</table>

\(^{a}\) Energy use statistics are for 2010.

\(^{b}\) Emissions from electricity are categorised under ‘energy supply’ rather than under ‘agriculture’.

Available Organic Resources

Estimates of the available quantities of organic resource produced in Northern Ireland have been extremely varied due to differing methodologies and sub-categories used (Figure 1).

Estimates for wastes other than manures (Table 5) show relatively close agreement for the organic fraction of household wastes and sewage sludge only, however more detailed studies adding commercial and industrial wastes estimate the total organic resource at between 347,384 and 496,270 tonnes per annum.

In addition the quantity of animal manures, produced by cattle, pigs and poultry is almost 12 million tonnes per annum (see Appendix 3.1, Table 2).

Figure 1. (right) Categories of organic wastes and materials suitable for biogas production

Grass silage and purpose-grown energy crops are a controversial addition to the available resource. Opinion is divided on the wisdom of an increased use of land for energy production. On one hand energy crops take land away from food production; on the other hand they can provide a valuable alternative income to some farmers. Due to variable grassland productivity and stocking levels, there will be opportunities for some farmers to develop grass silage production for energy use. An estimate of the potential contribution of grass silage to renewable energy calculated that 5% of the grassland area in Northern Ireland (39,000 ha) could contribute 62 MW, equivalent to 39% of the average electricity demand in the region (see Appendix 3.1).
Table 5. Organic waste quantities in NI

<table>
<thead>
<tr>
<th>Waste</th>
<th>Quantity (tonnes/year)</th>
<th>Current Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Source</td>
<td>OES\textsuperscript{16}</td>
<td>WRAP\textsuperscript{17}</td>
</tr>
<tr>
<td><strong>Municipal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household</td>
<td>188,000</td>
<td>169,587</td>
</tr>
<tr>
<td>Sewage Sludge (dry)</td>
<td>39,000</td>
<td>37,700</td>
</tr>
<tr>
<td>Total</td>
<td>227,000</td>
<td>207,287</td>
</tr>
<tr>
<td><strong>Commercial and Industrial</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retail food</td>
<td>35,700</td>
<td>–</td>
</tr>
<tr>
<td>Catering</td>
<td>4,140</td>
<td>–</td>
</tr>
<tr>
<td>Food Processing</td>
<td>26,000</td>
<td>–</td>
</tr>
<tr>
<td>Slaughter House</td>
<td>178,230</td>
<td>–</td>
</tr>
<tr>
<td>Dairy</td>
<td>13,200</td>
<td>–</td>
</tr>
<tr>
<td>Drinks and Distillery</td>
<td>12,000</td>
<td>–</td>
</tr>
<tr>
<td>Animal and vegetables waste</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Total C&amp;I</td>
<td>269,270</td>
<td></td>
</tr>
<tr>
<td>Total Organic Resource</td>
<td>496,270</td>
<td>207,287</td>
</tr>
</tbody>
</table>

Estimates of the potential biogas production from these resources are shown in Table 6 (adapted from Appendix 3.1 Table 4). Since it will not be possible to capture and fully utilise all the waste sources, Figure 2 provides estimates of energy production for capture and transformation of 25%-75% of the available organic resources.


Table 6. Estimates of potential biogas and energy production from available resources.

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Biomethane (m$^3$ CH$_4$/yr millions)</th>
<th>Energy (TJ/yr)</th>
<th>Electrical Energy (GWh$_e$/yr)</th>
<th>Heat Energy (GWh$_h$/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Wastes</td>
<td>9 - 37</td>
<td>324 – 1,315</td>
<td>31 - 128</td>
<td>45 - 183</td>
</tr>
<tr>
<td>Manure</td>
<td>47 - 300</td>
<td>1,680 – 10,658</td>
<td>163 - 1,037</td>
<td>233 - 1,481</td>
</tr>
<tr>
<td>Silage</td>
<td>76 - 247</td>
<td>2,706 – 8,785</td>
<td>263 - 855</td>
<td>376 – 1,221</td>
</tr>
<tr>
<td>Total Potential</td>
<td>133 - 585</td>
<td>4,709 – 20,758</td>
<td>458 – 2,020</td>
<td>655 – 2,885</td>
</tr>
</tbody>
</table>

Depending on the end use of the biogas and therefore the efficiency of conversion, there is the potential to provide up to 2,000 GWh from biogas. In practice this will depend how much of each of the available resources is captured for biogas production.

![Figure 2. Sensitivity analysis of the potential energy production from biogas in Northern Ireland.](image)

The ten anaerobic digestion (AD) plants operational in Northern Ireland in 2013 are estimated to require just over 128,000 tonnes per annum of feedstocks (see Appendix 3.1 Table 1). Table 2 showed 138 AD plants in the Northern Ireland Planning system. If we assume each of these would require 15,500 tonnes per annum of mixed agricultural feedstock (animal manures, slurries and grass silage), the total estimated requirement for 138 plants is just 2,139,000 tpa, which is a small proportion of the estimated resource (12 million tonnes of manures and 5.5 million tonnes of potential silage surplus) even before municipal and commercial wastes are considered.
Research Action Plan

Strategies for sustainability desire increasing local production and use of energy. At the European scale as well as in Northern Ireland there is both a need and a desire for deployment of small-scale distributed energy. This needs to happen without significantly reducing the efficiency of production.

Examination of the opportunities and needs in Northern Ireland, and discussions within the Working Groups and with other stakeholders have developed a strategic research agenda covering the following areas:

1. Development of small scale solutions for biogas production and use
   - Cost-efficient digesters at small scale
   - New technologies for biogas clean up and upgrading to biomethane
   - Improved monitoring and control

2. Solutions for improved nutrient management
   - Technologies for the capture and use of nutrients from digestate as fertiliser
   - Logistics of feedstock and digestate movement
   - Technologies for water-course protection from run-off

3. Embedding biogas use in the rural economy
   - Biogas contribution to Sustainable Energy Communities
   - Developing integrated supply chains for feedstocks, energy, digestate and value-added products
   - Control and mitigation of financial risk
   - Overcoming barriers of public perception and risk

4. Future crops and bio-based products
   - New crops for farm diversification
     - Green-house based crops
     - Crops to produce biogas
     - Crops for bioprocessing and biochemicals
   - Small-scale biorefinery operation and products

The following sections describe the scope and opportunity in each of the areas and set out an estimate of the resources required to meet development needs. The expected impact of the actions and the potential risks are also estimated.
Development of small scale solutions for biogas production and use

There are significant technical challenges required in the optimisation of biogas production and utilisation to enable minimum EU sustainability thresholds to be met. This will also mean wholesale changes in how biogas plants are designed and constructed. In 2006 a European Environment Agency report entitled “How much bioenergy can Europe produce without harming the environment?”\(^{19}\) foresaw the need for development of small, highly efficient and low cost digesters; biogas, particularly from permanent pasture, had one of the most positive bioenergy environmental impact profiles. In Germany the number of biogas plants reached almost 8000 in 2013 (average ~300kW). Now the addition of up to 20,000 smaller plants of 75-100kW scale (or less) is desirable for smaller farms.

In Northern Ireland, partnerships between local companies and European biogas technology providers include several collaborations where continuous innovation is undertaken. Some local companies, notably Williams Industrial Services and B9 Energy, expanding their own technology portfolio, have successfully developed plants without such partnerships, and are actively involved in innovation including collaboration with local research providers.

![Figure 3. Greenville Energy biogas plant in Newtownstewart, developed by Williams Industrial Services.](image)

Local technology providers are seeking innovations in the design, production and operation of biogas-related technologies to enable cost reductions, particularly of small scale plant that can better serve Northern Ireland farms, where the average farm size is 40 hectares, or 81 head of diary cattle. In particular, new designs for small high throughput plant for treatment of manure are desirable. These have many advantages as they suit the average farm size but are not considered to be financially viable at present. The advantages include:

- Smaller plants that fall under “on-farm permitted development” will not require planning approval \(^{20}\)
- Greater acceptability to the public through avoiding perceptible changes to existing farming practice regarding road use, noise etc.
- Grid connection may be more feasible in terms of cost

\(^{19}\) European Environment Agency Report No. 7/2006
Pretreatment systems offer an increase in the rate and/or extent of feedstock conversion and are a means to provide short-term dedicated treatment for parts of feedstocks which resist biological degradation under anaerobic conditions in a biogas plant. Several companies and research providers have evaluated pre-treatment systems and some plant designs now include some sort of pre-treatment as standard even where pasteurisation is not required. There is considerable scope for innovation, cost reduction and improved benefits to plants in this area.

Increased local know-how in plant operation and performance is needed to reduce the risk of process upsets and shorten commissioning times. With this knowledge technology providers will begin to develop interests in detailed monitoring of biochemical and genetic markers for microbial activity to complement innovative plant designs and improved operational efficiency.

While the implementation of sensors in biogas plants has been traditionally low, sensor cost reduction and remote monitoring capabilities are changing this. There is an increasing desire for the inclusion of sensor data within SCADA systems and, as knowledge of biochemical markers of plant performance improves, there is scope for the development of computer learning algorithms and early warning systems to be produced.

There is high interest in alternative uses for biogas, although current incentives favour electricity production. Technologies for biogas clean up and upgrading for grid injection or use in transport applications are commercially mature, but only economically viable at larger scale. There is scope for new methods of trace contaminant removal and separation of CO₂ and water vapour from biogas. Such technologies should also seek to reduce the energy requirement for their use.

**Table 7. Development needs - small scale solutions for biogas production and use**

<table>
<thead>
<tr>
<th>Expertise in 2020</th>
<th>Development Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A range of low cost, modular, scalable designs/technologies for small capacity biogas plants</td>
<td>Simple, novel designs of components for low cost plant</td>
</tr>
</tbody>
</table>
| New cost effective techniques for biogas cleanup and removal of trace contaminants | Development of novel methods of biogas clean up and upgrading based on catalytic and green chemistry for:  
  - CO₂ separation  
  - In-situ removal of problematic materials.  
  - Low cost sulphur/ammonia removal. |
| Proven pre-treatment technologies for increased rate and/or extent of feedstock conversion | Scale up and testing of technologies previously developed at laboratory scale  
  - Pilot scale and on-site testing  
  - Quantification of benefits  
  - Evaluation of costs |
| Advanced monitoring, control, and reporting                                        | Innovative cost-effective, reliable sensors  
  Advanced data processing for internal control loops  
  Development of on-line reporting of regulatory compliance for single plants and groups of plants |
Activities and Key Stakeholders

Activities in this area are expected to be driven by demand from companies and the needs of industrial R&D. This area includes many opportunities for demonstrations.

Innovations in small scale plants are being led by companies in the QUESTOR/CASE Energy from Biomass Cluster. In other specific areas the main actors include:

- Biogas clean up: Queen’s University (QUB), building on its chemical expertise in novel gas treatment, will work with companies to scale up and implement the developed technologies at local plants (in the first instance); South-Waste College (SWC) will continue to assist plant developers in new iterations of more conventional gas cleanup.
- Pre-treatment: interests in this area will be led by companies building on the previous work by QUESTOR, SWC and the Agri-Food and Biosciences Institute (AFBI)
- Advanced monitoring: this will be led by the QUESTOR/CASE Energy from Biomass Cluster.

Assessment of Resources Needed to 2020

The following resources are estimated as a requirement for development in this area

- Human resources: 30 person years for research and industrial R&D
- Costs: £6 million (excl. demonstrations)
- Financing Instruments: EU programmes, national and regional funding (incl. studentships), industry

Expected Impact to 2020

Activities in this area will continue to build on the success of local companies that are developing and building cutting edge plants in Northern Ireland. By 2020 these companies will have early licencing agreements for export of developed technologies to Great Britain, Ireland, Europe and beyond. It is expected that biogas plants in Northern Ireland will be performing well in interregional comparisons enhancing the region’s increasing reputation for innovation.

Risks

The overall rate of development of the sector is a concern, and slow development of biogas plants due to continued difficulties over financing may reduce the demand for plants and may scale back ambitions for smaller scale plants.

Competition for funding of demonstrations may become challenging at a European level where there is a need to prove the novelty of technology underdevelopment due to the high level of maturity of the sector.
Solutions for improved nutrient management

One of the limiting factors for the development of biogas plants is the availability of a sufficient land bank for disposal of digestate. Restrictions on sludge, slurry and digestate spreading under the Nitrates Action Plan for Northern Ireland, and cross compliance regulations ensure the protection of watercourses from excess run-off of nutrients.

The nutrient content of digestate (both solid and liquid fractions) has considerable fertiliser value. Current imports of inorganic (fossil) fertiliser into Northern Ireland are of the order of £80 million per annum and the optimal use of digestate could go a some way to reducing such imports. However, there are additional factors to be considered for digestate and compost use from plants treating MSW, where trace contaminants and other components reduce compliance with end of waste criteria (PAS 110 and Quality Protocol for Digestate (QP)) and limit the end use.

Some nitrogen, as ammonia, is lost volatilised to the atmosphere during and immediately after land spreading of slurry or digestate. The amount lost depends on many factors, such as prevailing weather immediately post application, method of application and the dry matter of the material. Slurry and digestate are likely to contain excessive phosphorus relative to their nitrogen content, and as such are not balanced fertilisers for plant growth. As phosphorus tends to be associated with the suspended solid fraction, it can be differentially partitioned by mechanical separation technologies into a ‘solid’ fraction. Many Northern Ireland soils do not require additional phosphorus for optimal plant growth and, as phosphorus is a limited resource, the mechanical separation of digestate to produce a stabilised product high in phosphorus that can be exported to where the phosphorus is needed is a desirable process.

As the number of operational biogas plants increase, there is potential for an increasing negative impact on surface and groundwater through land spreading of digestate. The development and testing of pollution mitigation measures is desirable, as is the development of advanced fertiliser blends that allow slow release of nutrients. This would be for the benefit of AD plant operators and also help protection of the environment from runoff. Such fertiliser properties would also limit nitrogen losses immediately after land application.

Planning of plant locations in relation to sources of feedstocks and locations for digestate use could benefit from using Geographical Information Systems (GIS) and logistical planning systems. There is also the potential to integrate GIS technology into monitoring and reporting systems for future regulatory requirements.

Activities and Key Stakeholders

Much activity in this area is being led by companies in the QUESTOR/CASE Energy from Biomass Cluster. The main actors in this area include:

- There is extensive expertise in slurry and manure separation and management and related analytical techniques and hygiene issues at AFBI.
- QUB and AFBI working are with local companies on recovery of nutrients from manure and slurry, and developing novel fertilisers.
- AFBI has a long history and reputation in both the growth of short rotation coppicing (SRC) of willow and in the management of phosphorus; this now includes the use of SRC willow in sludge and nutrient management.
This area includes many opportunities for demonstrations and participation and oversight of the regulatory body, the Northern Ireland Environment Agency (NIEA), is anticipated in such actions.

Table 8. Development needs for improved nutrient management

<table>
<thead>
<tr>
<th>Expertise in 2020</th>
<th>Development Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technologies for the capture and use of nutrients from digestate as fertiliser</td>
<td>Testing and evaluation of improved methods of digestate solid/liquid separation</td>
</tr>
<tr>
<td></td>
<td>Techniques for capture and separation of nutrients from the liquid fraction</td>
</tr>
<tr>
<td></td>
<td>Formulations and methods which provide slow release mechanisms for nutrients</td>
</tr>
<tr>
<td></td>
<td>Evaluation of new digestate-fertiliser formulations at field scale</td>
</tr>
<tr>
<td>Increased options for the management of intermediate quality digestates</td>
<td>Development of alternatives to landfill capping for poor quality digestates.</td>
</tr>
<tr>
<td>Logistics of feedstock and digestate movement</td>
<td>Analysis and methodologies contributing to increased planning feedstock and digestate logistics</td>
</tr>
<tr>
<td>Technologies for water-course protection from run-off</td>
<td>Increased monitoring of at-risk areas</td>
</tr>
<tr>
<td></td>
<td>Development of technologies and protection methods and their evaluation in the field</td>
</tr>
</tbody>
</table>

Assessment of Resources Needed

The following resources are estimated as a requirement for development in this area:

- Human resources: 15 person years for research, development and testing
- Costs: £3million (excl. demonstrations)
- Financing Instruments: national and regional funding (incl. studentships), industry; EU programmes for market replication and demonstration

Expected Impacts by 2020

By 2020 it is expected that the region will have a plan for the management of excess nutrients, supported by technologies for the production of slow release fertilisers from manures and digestate. There would be a reduction in the import of (fossil) fertiliser as its use is increasingly supplemented by nutrients from digestate. This activity would also see exchange of know-how with Ireland, Great Britain and Europe and licencing agreements for technologies as well as some export of nutrients.

Risks

There is concern over the environmental impact of a large number of AD plants and the risk that, due to uncertainty, over-stringent environment regulations would limit the growth of the sector. Knowledge of experiences in Germany mitigates this risk to an extent.

Despite efforts at a European scale on nutrient recovery processes, effective technologies have yet to be developed. There is a risk that new processes developed will be insufficiently cost-effective for commercial use.
Embedding Biogas Use in the Regional Economy

There is a large potential for alternative uses of biogas in Northern Ireland, over and above its use in electricity production and export to the grid via combined heat and power (CHP). Opportunities include applications in the residential, agriculture, transport, existing gas-fired electricity sectors, however there is a low awareness of the potential benefits of alternative uses of biogas at a local scale.

The Northern Ireland biogas sector is at an early stage of development stimulated by policy incentives, however the lack of a cohesive policy framework means that the region is being slow to capitalise on the wider benefits of biogas. Current developments are building self-contained plants with relatively few options (Figure 4) considered for use of heat; conditions are not yet favourable for biogas use as biomethane in the gas grid or for transport.

Figure 4. An Integrated approach to rural biogas plants

There is a need for need for education of local communities about what biogas technology is and what it means at a local level. Public understanding of local supply chains and value chains may be a key to acceptance. As concern increases about energy security and the concept of Sustainable Energy Communities is brought forward, there is an appreciation of local sustainable energy supplies. This provides a large opportunity for demonstration projects and smaller projects where there is involvement and ‘buy-in’ from local communities. In particular such projects could include heat recovery processes or energy storage.

The integration of large amounts of intermittent renewable energy to the electricity network means that energy storage is a high priority for the region. Plans for storage of electricity from wind energy are already under development and intend to integrate excess heat from CHP electrical production at farm scale AD plants in the Lecale district of Co. Down with isothermal compressed air energy storage technology. There is also scope to divert excess wind energy into hydrogen production via electrolysis then utilising AD plants to convert hydrogen into readily utilised biogas. This is already

under trial in Germany. Alternatively, during conditions of excess electricity from wind turbines, energy from AD plants could be diverted to production of hydrogen or fuels.

A significant barrier to the introduction of biogas in Northern Ireland (and other European Regions) is the cost of anaerobic digestion (AD) plants. Interviews and analysis by the Finance Working Group (See Appendix 3.3) of site owners that have been awarded planning permission show a very high percentage of plants to be ‘unfundable’ with current development plans and the requirements of the banking and financial sector. The Group concluded that farmers have been ‘sold a dream’ by technology providers, and that the language and structures used by the financial sector are largely incompatible with farmers’ understanding and needs. On a positive note they identified at least four areas falling loosely under ‘innovation in agri-financial services’ where training and development could have a large impact on advancing the development of the biogas sector in Northern Ireland. These areas were:

- Training and support to ensure investment readiness
- Addressing farm inheritance issues associated with the set-up of Special Project Ventures (SPVs) for biogas plants
- Control and mitigation of financial risk
- Alternatives to Conacre

Table 9. Development needs - embedding biogas use in the regional economy

<table>
<thead>
<tr>
<th>Expertise by 2020</th>
<th>Development Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas contribution to Sustainable Energy Communities</td>
<td>The development and application of new technologies for heat storage and distribution. Demonstration of technologies with increased efficiency of heat recovery and use Business models that incorporate the supply and/or use of energy (electricity, heat, fuel) from biogas</td>
</tr>
<tr>
<td>Integrated supply chains</td>
<td>Development of heat value chains and improved means of local supply</td>
</tr>
<tr>
<td>Reduced barriers to public acceptance</td>
<td>Increased public penetration of knowledge Demonstration projects promoting new technologies and reducing misconceptions</td>
</tr>
<tr>
<td>Control and mitigation of financial risk</td>
<td>Development of a range of support services enabling the improved development and operation of plants and projects in local communities</td>
</tr>
</tbody>
</table>

Social opposition is emerging as a potential threat to future technical developments, and in some cases broad public support for aspirational goals often sits alongside fierce local resistance to
projects even where the investment can act as a spur to endogenous growth in local communities. Local actors, having little or no involvement in the development strategy, fail to look for investment opportunities along the renewable energy supply chain. Ultimately, this has a negative impact on the potential for triggering self-employment and entrepreneurship, which are pillars of regional development processes. Much of the technology required is mature – there is simply a low level of local (community-based) knowledge and, consequently, there is a ‘mistrust of the new’.

Activities and Key Stakeholders
The lead activities in this areas is expected to come from communities and public sector actors such as councils who are able to offer site for demonstrations or new applications of technology; some projects have been proposed by QUB through CASE in the areas of collaborative research (technology) for biogas use and efficiency of heat recovery

Assessment of Resources Needed
The following resources are estimated as a requirement for development in this area:

- Human resources: 15 person years for research, development and testing
- Costs: £3million
- Financing Instruments: national and regional funding (incl. studentships), industry; Interreg & other EU programmes

Expected Impact by 2020
By 2020 we would expect to see an increasing number of plants in which good use is made of the heat locally, stimulated initially by the Renewable Heat Incentive. These would include demonstration and installations of improved highly efficient processes, and demonstrations of energy storage and biomethane use for heating and transport.

Public acceptance issues would be reduced and support measures in place would aid in the financial set up and development of plants. These developments would result in an increased contribution to renewable and electricity targets and a reduction in imports of fossil fuels.

Risks
Risk issues include the relative costs of renewable technologies biogas production and use and fossil fuel costs. In particular the cost of natural gas is a future uncertainty, since prices may be kept low by high availability as a result of shale gas exploitation in Europe and worldwide.

The use of biomethane as a transport fuel is hindered by “chicken and egg” issues: without bio-CNG vehicles there is no market demand for the fuel, and without upgrading stations and supply of the fuel there is reason to purchase such vehicles.

Although communities are expected to accept new technological changes over time, this may happen slowly and inhibit the development of the sector.
Future crops and bio-based products

This topic incorporates both immediate and longer-term opportunities that will depend on market development and the success of technical innovations in biorefining, possibly at a European rather than local scale.

A grass biorefinery has been proposed in Ireland and its implementation and location will ultimately depend on the economics of product production and feedstocks logistics and supply. In Northern Ireland very small scale biorefineries (“micro-biorefineries”) may be practical, associated or co-located with one or more biogas plants and able to use the heat and electrical energy. These would depend upon the batch production of a portfolio of high-value chemicals arising from traditional or novel crops, grown on-demand at small scale. Such opportunities would benefit farming directly with demand for innovative crops and would increase the options for crop diversification under the requirements in the revised Common Agricultural Policy. Processing residues would form part of the biogas plant feedstock.

Recent biogas installations have not yet been developed to full advantage within the farming sector. There are opportunities for adjacent or co-location of businesses to take advantage of the energy produced. One possible example is the supply of heat, lighting and CO₂ to greenhouses; supply of digestate to support such operations, perhaps for hydroponic production is an added option.

Near-term opportunities lie in the development of new crops for biogas production with testing and adaptation of methods for the sowing, management, harvesting and processing of both novel annual and perennial crops. Environmental impact effects on biodiversity and soil stabilisation need to be considered. Single harvest crops offer advantages in fuel use reduction over multiple cuts of grass for silage, but this benefit must be balanced against any requirement for annual planting.

Table 10. Development needs - future crops and bio-based products

<table>
<thead>
<tr>
<th>Expertise by 2020</th>
<th>Development Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge of a range of new crops for bioprocessing to produce biogas or biochemical</td>
<td>Establish performance criteria under local conditions</td>
</tr>
<tr>
<td></td>
<td>Testing of individual crops / types</td>
</tr>
<tr>
<td></td>
<td>Develop processing chains and knowledge</td>
</tr>
<tr>
<td>Knowledge of CO₂ enriched greenhouse and hydroponics-based cultivation</td>
<td>Establish performance criteria under local conditions</td>
</tr>
<tr>
<td></td>
<td>Testing of individual crops / types</td>
</tr>
<tr>
<td></td>
<td>Develop processing chains and knowledge</td>
</tr>
<tr>
<td>Emerging knowledge of products suited to small scale biorefinery operation</td>
<td>Chemical and biochemical processes for biomass (small, high-value products)</td>
</tr>
<tr>
<td></td>
<td>Generic plans for microbiorefinery</td>
</tr>
</tbody>
</table>
Activities and Key Stakeholders

This is an area of future opportunity which is expected to be led by research providers working closely with farmers and industry. The main actors are:

- In the areas of new crop development AFBI, including CAFRE and Greenmount College would supply expertise in agronomy and horticulture
- At QUB, CenTACat (Centre for the Theory and Application of Catalysis) has a strong reputation in catalysis biomass transformation, while QUESTOR (microbiology and chemistry staff) has developed commercial precursors from bio-catalytic processes.

Assessment of Resources Needed

The following resources are estimated as a requirement for development in this area:

- Human resources: 20+ person years for research, development and testing (followed by scale up and demonstration)
- Costs: £7+million
- Financing Instruments: national funding (incl. studentships), EU Societal Challenges

Expected Impact

Research and development internationally will drive the bio-based chemicals area, however the development of local knowhow and capacity combined with well-developed and integrated supply chain links would put Northern Ireland in a strong position to take advantage of global knowledge.

Risks

There is an appetite for new crops in Northern Ireland, but they must be suited to the local climate and farm management practises. Conservative attitudes may mean slow adoption of new practices.

Even with suitable sites, farmers may be reluctant to invest in greenhouse crops and, even though such developments would be small in scale, they may be subject to poor acceptance from local communities due to their visual intrusion on the local landscape.

In realistic terms, new crops for food are more likely, with digestion of residues. Although the cultivation of crops for directly extractible high-value compounds, or for biochemical processing is desirable, local companies have limited capacities to engage in this R&D area and ongoing research is largely ‘bioprospecting’.
Plans for international collaboration

Northern Ireland has sought strategic partnerships in other European regions where there is either an already well developed level of activity in biogas R&D, innovation and use, or where there is potential for collaboration due to common regional resources. The primary regions targeted are shown in Figure 5. A number of proposals are already under development with partners in these and other regions.

![Figure 5. Regions targeted for cooperation in biogas R&D.](image)

Northern Ireland has a longstanding relationship with the North Rhine Westphalia Region in Germany – the area around Dusseldorf, Cologne, Essen and Dortmund. This has developed partly through the Enterprise Europe Network (EEN), in which the local services are provided by Invest NI with the assistance of staff in the QUESTOR Centre. A high level of research cooperation has resulted through relationships developed through QUESTOR partnership with the University Duisburg-Essen (UDE) and IWW Wasser Zentrum, and companies in NRW. UDE is a partner in the FP7 ATBEST Project (Advanced Technologies for Biogas Efficiency, Sustainability and Transport). NRW is a region historically known for mining and heavy industry; it has been transformed by structural changes and sustainable development with high levels of renewables and sustainable use of energy.

Located to the Southwest of Stockholm, Linköping is Sweden’s fifth largest city. It is well known for its early adoption of biogas for transport and is widely known as “Biogas City”. Linköping University’s biogas research, built up since the 1980s in collaboration with local industry has recently received formal recognition as a Biogas Research Centre with rolling funding from the Swedish Energy Agency. Linköping University and Scandinavian Biogas Fuels are also partners in the FP7 ATBEST Project. Biogas use in this region is widely accepted. There is widespread production of biomethane from waste and sewage and extensive mature use with continued innovation in all forms of transport.

In Hungary, Észak Alföld, the North Great Plains Region, is a strongly agricultural region dependent on grass based agriculture, which contributes 11% of the regional GDP, double the national average. The regional capital Debrecen is the second city in Hungary and has emerged as a national and international centre both for scientific knowledge and for regional cooperation of Northern and trans-frontier territories. Northern Ireland is exploring cooperation with this region due to the common emphasis on agriculture and food production.
Cooperation with Ireland as a region is beneficial for many reasons, including our common agricultural systems and all-island energy market. University College Cork, TEAGASC and Bord Gáis Networks are partners in the FP7 ATBEST Project.

Cooperation with each of these regions is established through a “triple helix” of actors. As well as research organisations, SMEs and industry and the regional development organisations Invest NI (Northern Ireland), Zenit GmbH (NRW, Germany), Cleantech Östergötland (Sweden) and Innova (Észak Alföld, Hungary)

**Funding instruments targeted for action**

A wide range of options are available to fund the development needs of this Research Action Plan, including both short and long-term development priorities. Options range from locally funded studentships to national competitions offered by the Technology Strategy Board (TSB) and cross-border funding available from Intertrade Ireland. Invest NI and Intertrade Ireland offer funding for travel to consortium-building meetings for the development of proposals.

Under the Horizon 2020 programme for funding from Europe there are several instruments to finance universities and research institutes as well as companies in order to increase the scientific knowledge base and generate new products and services. Figure 6 summarises funding instruments with most potential for the implementation of this Research Action Plan.

---

**Figure 6. Local, National and European sources of funding to be targeted for the development needs of the region in the area of biogas.**
Conclusions and Recommendations

The QUESTOR/CASE Energy from Biomass Cluster and its collaboration partners have already strong cooperation with local companies however developing this action plan has created awareness of the extent of current interactions. All stakeholders have a keen awareness of the need to improve knowledge transfer between research institutions and industry in Northern Ireland to boost the region’s competitiveness. The desire for company participation in knowledge transfer is to improve the exploitation of research results and their uptake by business.

Funding is a key factor in innovation development, and there is a high level of knowledge of funding opportunities Northern Ireland and a wide range of resources to support the development of collaborative proposals and projects. In addition to targeted national funding instruments the emerging Horizon 2020 multi-annual work programmes create both challenges and opportunities for implementation of the priorities.

The human resources and costs for the implementation of the development priorities have been estimated. The estimated total human resources needed for implementing the development priorities are 80 person-years, and the estimated total costs for implementing the action plan are £25 million.

Table 11. Estimated resources required in implementing the development priorities of this Biogas Research Action Plan.

<table>
<thead>
<tr>
<th>Selected Development Priorities</th>
<th>Resources needed</th>
<th>Estimated Costs</th>
<th>Main Actor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of small scale solutions for biogas production and use</td>
<td>30 person years</td>
<td>£6 million</td>
<td>Industry, QUESTOR/CASE EFB Cluster, SW College</td>
</tr>
<tr>
<td>Solutions for improved nutrient management</td>
<td>15 person years</td>
<td>£3 million</td>
<td>Industry, QUESTOR/CASE, EFB Cluster</td>
</tr>
<tr>
<td>Embedding Biogas Use in the Regional Economy</td>
<td>15 person years</td>
<td>£3 million</td>
<td>Industry, CASE, SW College</td>
</tr>
<tr>
<td>Future crops and bio-based products</td>
<td>20+ person years</td>
<td>£7+ million</td>
<td>AFBI, CAFRE (crops), QUB (bio/chemistry)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>80+ person years</td>
<td>£25+ million</td>
<td></td>
</tr>
</tbody>
</table>

The main conclusions and recommendations of the Research Action Plan are as follows:

- The strategic areas and development priorities which should be the focus for activity in the period up to 2020 are intended to build on regional strengths and competences and to optimise the use of the available resources in Northern Ireland. In developing these areas Northern Ireland intended to seek relevant experience and complementary expertise in partner regions.

- The R&D priorities outlined in this document are those in which there is a high interest from Industry and in many cases companies are involved in research activities either through direct collaboration with researchers, or indirectly through influencing the activities of the QUESTOR/CASE Energy from Biomass Cluster. The interests of companies are due to the potential for future business growth in national and global markets.
• Close cooperation between research institutions and companies is essential; this is likely to include cooperation on research and technical aspects, but also in applications for funding, where the greater knowledge may lie with researchers.

• The research activities have been developed from a regional perspective but the results may be applicable to other regions in Europe and elsewhere and funding for cooperation, exchange of knowledge and market replication may be a valuable means to fund local activities.

• The recent investment by Northern Ireland in resources to support European collaboration and project applications provides a means to influence the direction of future funding opportunities within Europe as a result of this action plan.

• The development of this action plan stimulates the development of a cohesive policy framework in the area and aids in influencing EU-level and national policies in order to support regional targets.
Appendices

Appendix 1. QUESTOR and CASE Energy from Biomass Cluster Description

Appendix 2. Summary of policy areas and support mechanisms related to bioenergy

Appendix 3. Description and Remit of the Working Groups

  Appendix 3.1 Working Paper: Quantification of Feedstocks for Anaerobic Digestion
  Appendix 3.2 Alternative Uses of Biogas Group Report
  Appendix 3.3 Financial Support Group Report

Appendix 4. Stakeholders Consulted