Refuelling the Countryside

The prospects for low carbon farm and rural transport fuels
Foreword

There is no doubt that the farm of the future will be very different to that of today. In recent years, agriculture and energy production have become increasingly interlinked with a significant increase in on-farm energy production from wind, solar PV and biomass. Anaerobic digestion has grown as a technology and will become even more important as smaller scale plant and improved processes come on stream.

The farm of the future has the potential to become an important source of renewable fuel and energy, as well as food. One vision could be the farm as the centre of the local community, supplying energy to their neighbours sourced from solar photovoltaic, wind or bioenergy produced on the farm. The ‘energy farm’ might also serve as a local rural vehicle refuelling station delivering renewable fuels.

This report looks briefly at the future and the potential for change as well as an exploration of trends. Government policy and targets and technological change are likely to be key drivers of future change but consumer and community expectations will also be of importance. Already there is movement towards more decentralised energy production and community scale energy projects with farmers and the local community investing in local energy and cooperative projects. Whatever the future, anticipating change and building resilience into farming and rural communities will enable them to thrive.

This study suggests that there will be a benefit to rural communities through the replacement of fossil fuels with renewable alternatives. Engaging local communities in renewable energy production has been shown to overcome local opposition to wind farms, introduce more competition in the energy supply market, and facilitate a better balance of demand and supply measures to reduce transmission losses.

Farms can play a key role in a future sustainable energy system if there can be a better understanding of the barriers to sustainable farm-based energy, the need for good quality financial and performance data and an awareness of the factors and the incentives that make it attractive and profitable for the farmer and investor.

Whilst there will be no single answer suitable for every farm, huge opportunities are available and these will improve as the technologies advance. Renewable energy has a key role to play in the wider rural economy. We hope that this report opens up the debate on the contribution that agriculture and the rural community can make to one important aspect of future energy provision on farms – that of renewable and sustainable transport fuels.

David Gardner
CEO RASE ~ April 2014
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- **Royal Agricultural Society of England (RASE)** – Committed to communicating ground breaking technology for the benefit of agriculture, The Royal Agricultural Society of England has established the ‘Innovation for Agriculture’ initiative. Since 1838, the RASE has played a leading role in the development of British agriculture and a vibrant rural economy through the uptake of good science, the promotion of best practice and a co-ordinated, impartial approach to wide-ranging rural issues. [www.rase.org.uk](http://www.rase.org.uk)

- **Frank Parkinson Agricultural Trust** was incorporated under a Trust Deed in 1943, established by a gift from Frank Parkinson. The main objective as set out in the Trust Deed is the improvement and welfare of British agriculture. The Trust grants financial assistance to improve the education and experience, by working, training, dissemination of information or otherwise, of people working in the agricultural industry. [http://www.afcp.co.uk/search_results/8](http://www.afcp.co.uk/search_results/8)

- **Scotia Gas Networks (SGN)** operates two of the UK’s largest gas networks through 74,000 km of gas mains and services. Scotland is served by Scotland Gas Networks and Southern Gas Networks encompasses the south and south-east of England. The company supplies natural gas to 5.8 million customers and are the second largest gas distribution company in the UK. The company is also involved in biogas distribution. [www.sgn.co.uk](http://www.sgn.co.uk)

- **Greenwatt Technology** is a rural energy consultancy based in South Warwickshire with a main focus upon the design and delivery of farm-based renewable energy, bioenergy and low-carbon transport projects. [www.greenwatt.co.uk](http://www.greenwatt.co.uk)

- **Cenex** is the UK’s Centre of Excellence for low carbon and fuel cell technologies and is a delivery agency, established with support from the Department for Business, Innovation and Skills, to promote UK market development in low carbon and fuel cell technologies for transport applications. Cenex’s principal focus is on catalysing market transformation projects linking technology providers and end users. As part of this work, it runs a number of programmes for UK national and regional government. [www.cenex.co.uk](http://www.cenex.co.uk)

**Authors:** Dr Susan Juned (Editor); Mike Woollacott; Angie Bywater; Ralph Alcock

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Executive Summary

Transport fuels from renewable sources have the potential to reduce UK energy costs, to improve air quality and to address energy security if low carbon vehicle technologies are advanced, if market barriers are adequately addressed and if a supportive investment environment is created to encourage the necessary infrastructure. Farms are ideally placed to exploit the opportunities for fossil fuel replacement both from a supplier and a user perspective and some are beginning to explore the options. Case studies in this report illustrate some of the ingenuity and innovation available – or in development.

Climate change and the need to reduce greenhouse gases, along with the increasing emphasis on energy security and energy efficiency will drive changes in agriculture, as in other industries, over the next decades. This report has looked at a number of likely scenarios for the future and the main drivers of change influencing these scenarios. These are likely to be:

- Government environmental targets and EU compliance
- Commitment to decarbonise the energy, transport and food sectors
- Global supply and demand for transport fuels
- Economic and investment conditions in the UK and overseas
- Advances in transport technologies and fuels
- Consumer and community demand and influence

Whatever the future, anticipating change and building resilience into agriculture and amongst rural communities will be necessary to enable them to adapt and thrive. The progress of change from high carbon fossil fuels to low carbon alternatives will, above all, depend upon the level of Government commitment and ambition.

Several factors will drive technological development including; the need to farm more efficiently and sustainably, the importance of reducing soil compaction, improvements needed to maintain farm productivity and raise farm incomes, and the need to control and reduce the economic and environmental costs of farm transport and CO₂ emissions.

A stable policy environment with a clear and reasonable vision of the sustainability criteria for renewable transport fuels will assist progress. It is noted that a report from the Office for Low Emission Vehicles (OLEV) on future investment policy issued in April 2014 confirms the UK Government’s intention of making the UK a premier location for the design, manufacture and adoption of ultra-low emission vehicles (ULEVs). It also confirms a long term, stable and comprehensive policy framework backed by a significant funding commitment. This report suggests that greater emphasis should be directed towards farm and community scale renewable energy and transport fuel projects. There must be a will to invest in innovative, decentralised, localised supply and demand models for heat, power and transport fuels that make financial as well as environmental sense to farmers and rural communities.
To highlight the prospects and opportunities for farm-produced renewable transport fuels, and the integration with renewable energy and low emission vehicle (LEV) technologies, a funded programme of information exchange and data sharing built around successful case studies is required. This should be complimented by farm tours and study visits to other EU countries to transfer knowledge and build networks. On-farm and rural community-based demonstration plants e.g. at Stoneleigh Park (the home of RASE) and other show grounds, research centres, agricultural colleges and key regional farms would assist in showcasing UK and global renewable energy technology innovations and applications.

RASE has established the ‘Innovation for Agriculture’ initiative (IFA). Regional agricultural societies will work with RASE to establish a new national farm extension service to offer farmers co-ordinated technical support and advice to help farmers ‘raise the bar’ through the early adoption of new technology and techniques including renewable energy.

This study has shown that there is a clear lack of field performance data relating to renewable transport fuels on farms – which means that there is little evidence to demonstrate the real economic and environmental benefits of a shift away from high emission fossil fuels. Coupled with this is the slow entry into the market of ultra low emission vehicles (ULEV) designed and suited to the off-road and on-road requirements of farms and countryside. Such agri-technology developments could offer significant cost savings whilst reducing the carbon footprint of British agriculture.

There is growing interest and investment in the form of community-led and funded renewable energy projects featuring wind turbines, district heating, solar PV and even small scale AD. This could impact upon the potential rural demand and uptake for alternative, farm sourced transport fuels. The UK government’s first ever Community Energy Strategy (January 2014) recognises that community-led action – including working in liaison with farmers and other rural small and medium size enterprises (SMEs) - can often tackle sustainable energy issues more effectively than government alone.

It is hoped that this Report will be of interest to several Government departments and bodies such as the House of Commons Rural Affairs Committee to assist in reducing the carbon footprint of UK food production and improving the resilience of farm and rural businesses. This Report suggests that it would be beneficial to have a government-appointed Defra minister responsible for rural energy generation with the mandate to support and facilitate investment in localised community energy initiatives and renewable transport fuel infrastructure. A ‘Rural Green Energy Task Force’ could implement strategy, build upon local initiatives and coordinate inputs and engagement of rural businesses, community groups, representatives of land-based organisations and other stakeholders.

There would seem to be a case for better coordination of the research and dissemination in the renewable transport fuel sector in the UK and across the EU. Moving forward will require a concerted effort bringing together the farming industry, technology supply chain and research organisations. We hope that this Report will encourage other organisations such as Agriculture and Horticulture Development Board (AHDB), Technology Strategy Board (TSB), Biotechnology and Biological Sciences Research Council (BBSRC), The Country Land and Business Association (CLA), National Farmers Union (NFU) to get involved.
Chapter 1: Introduction

Target audience

The target audience for this study includes farmers and other landowners, rural businesses, technology providers and policy makers at a national and local government level.

The findings of the study will be disseminated through a series of seminars, workshops and demonstrations aimed at policy makers, farmers, landowners and rural communities as well as the agricultural transport and automotive sector.

Purpose of the report

A key aim of this study is to identify the feasibility and viability of farms becoming key players in the production and supply of renewable transport fuels. The study aims to inform those looking to exploit bioenergy and other renewable energy technologies as part of the farm business as well as those involved in rural transport policy development. It utilises case studies drawn from good practice on farms in the UK and elsewhere in the European Union and reviews the options available to farmers - as well as the potential obstacles and challenges that have been revealed.

The study also seeks to raise awareness, engage industry and inform policy around the application of technical innovation in low emission vehicles and the production of more sustainable fuels on farms and in a range of rural situations. It aims to bridge the gap between science and practice, provide a focus for further R&D, highlight policy issues and barriers, and encourage supply chain development. The report identifies the prospects for farms and rural businesses to generate some of their own fuel and energy needs and identifies potential rural user scenarios.

This study does not intend to be an in-depth academic exploration of the subject, but is intended to stimulate debate and innovation and also to provide case studies, sources of information and advice for those wishing to promote, exploit and deploy new technologies and renewable sources of transport fuels.

The current context for this study

Farm incomes

Farm incomes over the past decade have varied by type but income trends have been lower than the peak reached in 1995. After a recovery beginning in 2007, Defra reported in July 2013 that farm incomes dropped between 2011 and 2012. Recent long and dry winters and very wet springs affected cultivations and crop yields and the economic situation was reflected in suppressed commodity prices.

During this period, total income from farming fell by 14 per cent to £4.7 billion. This made a significant impact on individual farm incomes, with average income per farm falling by 14
Reducing the costs of inputs such as farm transport fuels, exploring renewable energy generation, using more efficient cultivation methods and finding new enterprises to maintain and increase farm incomes are of considerable interest to farmers.

**Figure 1: Agricultural industry income trends in the UK (in real terms)**

Source: Defra² November 2013

**Fuel price increases**

Road fuel prices have increased steadily since early 2009³. Petrol prices reached a record monthly high in May 2010, set new records in December 2010 and in each of the following five months - and broke these again in March and April 2012. Since then petrol prices have been in the 131-139 pence per litre range. Diesel prices exceeded their summer 2008 highs in January 2011. New records were set in February, March and April 2012. Although prices fell slightly over summer 2012 they have since been in the 138-145 pence per litre range.

A Defra study⁴ found road fuel prices to be on average slightly higher in rural petrol stations. In June 2010, the average price of unleaded fuel in sparse rural areas was 2.1p per litre more than the national average but also varied depending on remoteness as well as local competition. A study by the Energy Technologies Institute (ETI)⁵ showed that at a time when petrol and diesel prices have more than doubled since 1991, car drivers in rural areas tend to have a higher annual mileage as a result of the distances to local amenities – including to refill their fuel tanks.

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¹ Source: Defra June 2013
² Defra; National Statistics: Total income from farming 2012 – 2nd estimate, United Kingdom published November 2013
⁴ Department for Transport
⁵ Transport –an affordable transition to sustainable and secure energy for light vehicles in the UK. ETI 2012
Prices of red diesel are already on the rise – and the £1/litre may not be too far away! The use of red diesel in ‘exempted vehicles’ (agricultural, horticultural or forestry-related activities) currently enjoys a lower fuel tax than white diesel. Red diesel is taxed at 11.14p/litre, white diesel at 57.95p/litre, and Ultra Low Sulphur diesel at 57.95p/litre. Clearly if UK farmers lose their tax relief for red diesel, as happened in Holland in 2012, this would have a huge knock-on effect on farm costs.

**Sustainable rural transport**

> ‘With 20% of the English population (9.5 million people) living in rural areas, the lack of adequate public transport provision will continue to affect rural communities and businesses. There is a far greater requirement for personal transport – but there is evidence to suggest that low income rural households are often forced into buying and running a car when they cannot really afford to do so.

Rising fossil fuel prices make it even more important to offer a better alternative to car use for these rural households. In addition, the lack of a decent transport service undermines the economies of rural areas, since it is more difficult for people to access jobs and services. It also has environmental consequences, resulting in high levels of car use compared to urban areas, and greater per capita carbon emissions from transport’.

*A New Approach to Rural Transport* (2009) - Integrated Transport Commission

The costs and sustainability of rural transport is becoming an increasing area of concern. The RASE has drawn attention to the falling levels of rural transport provision and has highlighted the cost and availability of road fuel as significant issues in rural communities, particularly in more remote areas. It would be of considerable economic benefit to rural areas if it were possible to both address the causes and find acceptable solutions or alternatives.

In rural areas of the UK, the number of petrol filling stations has been decreasing steadily for many years, with a 29% decrease between 2001 and 2011. There has been an increase in driving times to reach filling stations that is not evenly spread across the country. Rural areas have seen a larger number of closures, with consequent reductions in access and choice. There could be a demand for local alternatives.

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6 RASE Members AgriBulletin ‘Resolving the rural transport challenge’
7 Study of the Petroleum Retail Market, Report for DECC by Deloitte, December 2012
The Department for Transport’s (DfT) National Transport Survey identifies differences in travel behaviour, levels of mobility and access to services between urban and rural areas. People living in the most rural areas travel 53% further than those living in urban areas and a greater percentage of total annual mileage is made using a car in the most rural areas – 58% compared to 49% in urban areas. DfT data on ‘households with good transport access to key services or work’ found the number of households in villages with good transport access had declined from 57% in 2007 to 27% in 2011. This is exacerbated by the rising costs of fuel and reductions in the number of petrol filling stations.

### Agriculture, rural communities and transport fuels

With an increasing demand for food provenance and quality, UK farming is set to maintain its primary role and importance in feeding the nation. However, what is also evident is that the industry can make a significant contribution to the UK renewable energy supply – whether in the form of electricity, heat or transport fuels.

This study examines the potential and opportunity for innovative low carbon transport technologies and renewable transport fuels in rural areas and on farms. The prospect of farmers producing renewable fuels for their own use and for local rural communities is the main focus of this Report. The current reliance of the industry upon fossil fuels (diesel, petrol, and oils), their rising costs and their impact on greenhouse gas emissions (GHGs) is not a situation that can be sustained in the medium to long term. Contingencies need to be in place so that the farming industry can develop more sustainable alternatives that provide energy security, reduced input costs and reduced environmental impact.

In addition, other rural businesses and communities are finding that access to affordable petrol and diesel supplies is an increasing problem. Farmers are able to work with their communities for the wider public good. The prospect of farms supplying renewable fuels – in the form of biomethane, electricity, biofuel and possibly hydrogen in the future – is investigated, using case studies where available from UK and other EU member states. Farmers could become an intrinsic part of the rural transport fuel supply chain widening their existing role in delivering a range of products and services.

Whilst the emphasis of this study is upon the production and supply of renewable transport fuels, the influence of changes to current agricultural practices upon the reduction of input costs and greenhouse gases is also acknowledged. The UK will see an increase in precision farming techniques – using satellite and robot technologies to target crops and ensure more accurate use of equipment and applications. Greater emphasis upon minimum cultivations will improve soil structure and health and reduce the fuel costs of cultivation. Equipment manufacturers are already reducing the weight of machinery to lessen the impact upon soils and working towards technologies with lower emissions and improved automation.

This combination of changes in farming practices, the deployment of farm-based renewable energy technologies, development of new machines and the introduction of non-fossil fuel replacements should result in improved farm incomes, more sustainable food production,

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new farm and rural enterprises and a healthier environment. It is an exciting prospect and one in which the UK could lead the way.

However, as this Report shows, there is much to do to ensure progress. Policy makers and legislators need to be informed and engaged. Targeted and sustained incentives will be needed to stimulate change. Demonstration projects will be required to investigate and disseminate the technical, economic and environmental impacts and benefits of new renewable transport technologies. Machinery manufacturers, fuel suppliers, farmers and rural communities will all need to be involved.

**Building resilience for the future**

Many countries are beginning to look more carefully at the source, supply and sustainability of their transport fuels – developing strategies aimed at building a greater level of resilience as global events continue to provide uncertainties. Scott Garvey from Country Guide⁹, Canada provides a commentary on this:

‘After Oil – farm transport fuels’ – a view from Canada.

‘Efforts to find alternatives to oil are slowly gaining momentum, pushed on by fears about dwindling reserves and global warming. Indeed, sometimes it seems that every newspaper you pick up has a story about one new answer or another, such as biogas, biodiesel or hydrogen among others. Yet no single fuel has emerged as the shining new star to replace gasoline and diesel.

Nor is there likely to be one, predicts Sheldon Hill, manager of the Alternative Energy Development Business Unit at the Saskatchewan Research Council (SRC). “There will be no silver-bullet solution,” Hill says. “There will be no single fuel that allows us to replace fossil fuels.” And he’s not alone in that belief. Other industry experts agree too.

But to be clear, they don’t say it has to be fossil fuels or nothing. In fact, what they’re saying is the exact opposite. The scientific consensus is that there are going to be several alternatives, creating a future energy landscape made up of a patchwork of different fuels and technologies. Then the popularity of each fuel will vary across the country. Hill thinks regions will take advantage of the most cost-effective resources available to them.

So where will that leave farmers? No one knows for sure, at least not yet. But initial indications are that our individual farms could be as diverse on a small scale as the country as a whole is on a much larger scale. A few farms are already making progress down this path, and many of the technologies gaining favour on farms are on the leading edge of what’s happening elsewhere.’

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Chapter 2: Greenhouse gas emissions and agriculture

Impact from agriculture

In 2013, the area of land being used for agriculture in the UK was 17.3 million hectares and, according to Defra, about 296,000 people\(^{10}\) were employed in agricultural production.

The agriculture sector can play a vital part in contributing to meeting the UK Government greenhouse gas emissions target. Agriculture is responsible for about 8% of UK greenhouse gas emissions\(^ {11}\). Although CO\(_2\) is not a major component of the emissions from agriculture, farming has a potentially important role to play in mitigating the effects of climate change. This is because it is able to lock away or sequester CO\(_2\) as biomass or in soil organic matter – a function likely to become even more important in the years ahead.

Emissions from UK agriculture in 2010 were approximately stable at 50.7 million tonnes CO\(_2\)e, compared with 50.2 in 2009, making up 9% of the UK total. The industry remains the main source of methane (44% of the total – largely through livestock production) and of nitrous oxide (80% - largely as a result of use of artificial fertilisers), although emissions have decreased by 20% and 19% respectively since 1990\(^ {12}\).

The UK farming sector will be expected to implement changes to mitigate environmental pollution – as well as taking positive actions to reduce the energy and fuel costs incurred in livestock and arable enterprises. Farms have the potential to be a significant source of renewable energy generation and transport fuel production.

The UK Bioenergy Strategy produced in 2012\(^ {13}\), estimated that in 2009 c.3% of the total yield of UK cereals was used to produce biofuels, generating around 0.6 TWh\(^ {14}\). Other arable crops, such as maize and grass silage, contributed 0.08 TWh of energy from farm scale anaerobic digestion (AD). These figures were predicted to be likely to increase with manures and slurries expected to generate an extra 2TWh by 2020\(^ {15}\).

By 2012, purpose grown crops accounted for 21% of total reported AD feedstocks and manures accounted for just under 17%. Approximately 0.5% of UK arable area was estimated to be used for biofuel crops in 2012\(^ {16}\).

In policy terms, encouraging the potential for agriculture and the rural areas to play a part in the provision of bioenergy for the whole of the country, there has to be consideration of planning, grid connections, financial investment and the diversification of energy generation.


\(^{11}\) Professor Keith Goulding ~ ‘Tackling Agriculture’s greenhouse gas emissions’ (Rothamstead 2011)


\(^{13}\) UK Bioenergy Strategy – April 2012

\(^{14}\) A measure of electrical energy 10\(^{12}\) watt-hours

\(^{15}\) UK Bioenergy Strategy – April 2012

Farm fuels

British agriculture represents around 8% of all UK transport GHG emissions – coming from on- and off-road transport and other fossil-fuel driven machinery\(^\text{17}\). The carbon dioxide produced by agriculture is mainly as a result of the fuel used to power machinery. However, according to Defra, detailed information of the actual volumes and types of fuel being used for all agricultural purposes is not readily available in the necessary detail.

\[\text{"It would be of value to have more detailed information on the actual volume of fuel, as well as the type of fuel (red diesel, LPG, natural gas, fuel oil, petrol, and possibly coal on old horticultural units). It is not clear whether this information is available"}\(^\text{18}\).

A study was carried out for Defra in 2007\(^\text{19}\) by Warwick HRI to quantify the direct energy use in agriculture. At that time, it was estimated that petroleum products made up 56% of direct energy use in agriculture, with oils for mobile operations amounting to 63% of this. Around 36% of direct energy use was gas oil or diesel for field operations, principally by the arable sector for crops (66%).

The study noted that electricity featured most strongly in the dairy, poultry and cereals sector, whilst gas oil or diesel was a large element of the fuel use in field crop sectors and in dairy, beef and sheep. Heating accounted for around 37% of direct energy use, with the majority (61%) used in operations such as greenhouse heating and humidity control and the rest in the rearing of chicks and pigs (24%) or in the provision of hot water in dairying for hygiene purposes (9%) or for the drying, conditioning and storage of grain (9%). Renewables accounted for no more than 0.1% of direct energy use in 2007.

The report concluded that savings could be much higher with the adoption of alternative, low-carbon energy sources and that if all of the barriers to the uptake of alternative fuels were removed, agriculture could ultimately become almost carbon neutral with regards to direct energy use. However, without Government support, the high associated costs are likely to be a considerable barrier to the uptake of such energy sources.

The available information indicates an overall decrease in the fuel being used by agriculture since 1990 whilst output of agricultural product has remained at a similar level\(^\text{20}\). For all farm types, either red diesel or electricity remained the biggest contributors to energy use from fuel\(^\text{21}\). Red diesel accounts for 67% of energy use from fuel on specialist cereal farms.

**On farm renewable energy production: UK trends**

The percentage of farms in the UK reporting to Defra as producing renewable energy in 2010 was, according to Defra statistics, about 5%. These figures were gathered as part of a self-reporting census in 2010 of agricultural and horticultural holdings. Only a very small number of holdings (2%) were producing energy for the commercial market. Most of the renewable energy produced (92%) was used predominantly within farm houses and other on farm residential properties.

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\(^{18}\) Page 75 DEFRA: Agricultural Statistics and Climate Change

\(^{19}\) ‘Direct energy use in agriculture: opportunities for reducing fossil fuel inputs’, 2007 Warwick HRI and FEC Services Ltd

\(^{20}\) Page 75 DEFRA: Agricultural Statistics and Climate Change

\(^{21}\) Defra: Farm Energy Use: Results from the Farm Business Survey: England 2011/12
Since then, farmers and rural communities have made considerable progress in recent years investing in solar PV and small scale wind to provide electricity. A more recent survey\textsuperscript{22} of 700 farmers carried out by the Farmers Weekly in 2013 showed that on-farm renewable energy generation has gained considerable ground since 2010 when Feed-In Tariffs (FITs) were introduced. Thirty-eight per cent of respondents said they currently generated renewable energy. The most popular technology types were solar PV (66%), wind (30%) and biomass for heat (21%). Anaerobic digestion accounted for 7% and biomass/biofuel for 3%.

Overall, the number of small and medium wind turbines deployed in 2012 grew by 21% compared to 2011. The vast majority of these turbines are installed on farms and domestic rural properties, meaning that small and medium wind is playing a major role in revitalising the rural economy\textsuperscript{23}.

Anaerobic digestion (AD) is a technology that is showing a slow but steady increase of farm-based units providing a solution for disposing of livestock slurries and crop residues and an opportunity for income generation. There are reported to be over 20 thousand dairy holdings in the UK, plus 60,000 beef herds, 10,000 pig herds and a total UK manure and slurry arising of about 90 million tonnes in UK agriculture\textsuperscript{24} suitable for AD.

Following the early deployment of sub-200kWe AD plants, more recent trends have been towards the construction of larger (500kWe+) AD plants on those farms and estates with sufficient capital, land and feedstock supply and in industrial situations such as supermarkets and major food processors with access to significant amounts of bio-waste. Of the 120 or so AD plants now in operation across the UK, less than half are reported to be farm based and notably very few are producing biomethane to be used as a transport fuel\textsuperscript{25}.

The slow uptake of this technology on farms to date is considered to be a result of the high capital investment, the limited availability of sub 250kWe units and the typically low returns from the use of slurry and other livestock manures. The UK Government had plans to increase generation from 170MW to about 380-760MW by 2020 (Defra, March 2010), particularly through an increase in farm-based AD. However, the unwelcome FIT degression decisions announced in early 2014 particularly related to sub-250kWe AD plants and the lack of a Feed in Tariff rate for small scale AD below 100kWe will seriously inhibit this ambition.

\textsuperscript{22} Survey carried out by Farmers Weekly, Nottingham Trent University and Forum for the Future, 
\textsuperscript{23} Source: Small and Medium Wind UK Market Report, October 2013
\textsuperscript{24} Meeting the challenge: Greenhouse Gas Action Plan of the Agriculture Industry in England. Progress report April 2012
\textsuperscript{25} UK Biogas website ~ www.biogas-info.co.uk
Chapter 3: Fuelling the Farm – future prospects

What is in it for the farmer and the community?

If farmers and rural communities are to move away from a dependence upon fossil-based transport fuels and a move towards more sustainable, renewable fuel sources, a much stronger case has to be made to stimulate interest, demand and change. It is very easy to adopt the ‘status quo’ attitude – and concerted efforts have to be made to ensure that farmers and other stakeholders understand the drivers and benefits of change. Diesel has been the ‘fuel of choice’ for farmers for many years – and a shift to alternative more sustainable fuel sources will be neither easy nor straightforward. Recognition of their own future transport fuel needs – and those of the rural communities surrounding them – is a key factor in engaging farmers and landowners as future ‘transport fuel producers’. The ‘what is in it for me’ question starts to identify reasons and possible benefits of a change to renewable fuels:

**Arable farmer**
- Can I farm more sustainably?
- Can I use less fuel?
- Can I produce some of my own fuel?
- How will renewable fuels benefit me?
- Will this improve my farm income?
- Can I export / sell renewable fuels to local people?

**Livestock Farmer**
- Can my slurries be turned into a profitable fuel?
- Can I add to my farm income?
- Can I reduce fuel and energy costs?
- Can I reduce environmental impact of farm wastes?

**Biomethane Fuel Producer**
- Is there a marketing and revenue potential?
- Can I maximise the value of anaerobic digestion?
- Can I export biomethane directly to the grid? Is it cost-effective?
- Can I produce my own biomethane for direct vehicle use?

**Local community**
- Can we localise our energy and transport fuel production?
- Can we reduce our bills?
- Are local farmers prepared to work with us to produce renewable fuel and energy?
- What are the prospects for community owned projects?

**Fuelling the farms of the future – technology scenarios**

Throughout this study, the main contenders to replace fossil-based transport fuels on farms and in rural communities are identified. Most of these technologies are already readily available – although often not at a scale to suit many farm situations. To look into the future, a combination of current knowledge and ‘blue sky thinking’ is encouraged.
The three ‘farm of the future’ scenarios below illustrate this process:

**Technology Scenario 1 - The electric farm of the future**

Many farms already produce renewable electricity – from solar panels, wind turbines or anaerobic digesters (AD) through combined heat and power units (CHP). Encouraged by the Feed in Tariff, solar photovoltaics (PV) has become an attractive investment on farmhouses, barns and fields. Some farmers have signed partnership deals with solar park developers providing a guaranteed rent on fields in exchange for a 20-year operational lease. Other farmers have installed wind turbines – and a small number have built AD plants. Many farms, especially arable farms, do not have high daytime electricity demands – unlike schools, factories and hospitals for example. Therefore a high proportion of the renewable electricity is exported back to the grid – for which the farmer receives an export tariff.

In the ‘electric farm of the future’, we will see not only an increase in the amount of renewable electricity produced on farms – but also a greater focus upon how that electricity is used, stored or sold. This will encourage integrated storage solutions such as hydrogen.

Renewable electricity provides a cheaper, cleaner source of power enabling alternative farm enterprises to flourish. Additionally a farmer or group of farmers might become part of an Energy Supply Company (ESCO) or work with local people to form a Cooperative Energy Group – where they can provide decentralised electrical power to local businesses, organisations and individual householders.

Other direct uses of renewable electricity generated on farms will be to battery-charge farm electric vehicles – currently these include all-terrain vehicles (ATVs), quad bikes, electric cars and vans. We will see new designs of lightweight all-purpose vehicles and machines replacing all but the largest tractors leading to reduced farm transport fuel costs, a change towards greater precision farming techniques, and the introduction of on-farm robotics. Rural communities will benefit from a solar or wind-powered electric vehicle recharging.
Technology Scenario 2 - The biogas farm of the future

A small number of farms with access to animal slurries, energy crops and other digestible crop residues have already installed anaerobic digestion (AD) plants. According to the National Farmers Union\(^{26}\), there was a target of around 1000 on-farm AD plants by 2020. However, regression of the Feed in Tariffs, contested by many in the farm-scale AD supply chain, make this forecast seem increasingly unlikely without a major policy change.

Most of the future AD plants will be located on dairy or livestock farms, utilising on-farm wastes and energy crops – but changes to food waste pre-treatments, protocols and legislation could lead to a steady increase in the supply of such high energy feedstocks making on-farm AD plants more economically viable.

Biogas generated from an AD plant has three potential uses:

- to power a CHP unit – with the electricity used on site or exported to the electricity grid, and the heat used on-farm or distributed via district heating schemes to local users e.g. holiday cottages, industrial estates or village buildings.

- to be upgraded to biomethane (with CO\(_2\) and other gases removed) and injected directly into the national gas grid – assuming that the farm is close to a gas grid pipeline. Farms with AD plants producing biogas should see the costs of biomethane upgrading technologies fall, making this a viable option especially on the larger AD plants of >250kWe.

- to be upgraded to biomethane for use as a renewable transport fuel. ‘Biogas’ (biomethane) fuelled tractors are already in operation in Germany, Scandinavia and the US. Other farm vehicles could also benefit through conversions to biomethane /CNG. With the proper authorisation and legislation in place, on-farm biomethane could service local collection/delivery transporters e.g. milk tankers. It could also supply local delivery vehicles, as well as those logistics operators already using ‘dual fuel’ technology (diesel and biomethane) in their HGV motorway fleet.

\(^{26}\) ‘Anaerobic Digestion\^Shared Goals\^ National Farmers Union 2009
Storage of renewable power will receive increasing attention from innovative research and development programmes. With most of the on-farm renewables being dependent upon natural diurnal patterns or variable and uncertain weather conditions e.g. wind, solar – and with national grid demand for electrical power fluctuating at peak times and between day and night time use, hydrogen provides a likely renewable energy storage solution.

This is already happening on more isolated ‘off gas grid’ farms – where wind turbines and solar PVs are replacing stand alone diesel generators, with electricity being stored in DC batteries for later use. In the future, wind and solar energy will be used to power an electrolyser which splits water (H₂O), generating hydrogen and oxygen and stored in secure tanks. The stored hydrogen can then be used in fuel cell powered vehicles for farm transport needs, or converted back to electricity.

Hydrogen will also be used to fuel passenger cars and other gas-fuelled delivery vehicles via a rural CNG-type refuelling station servicing local householders and businesses. Hydrogen will lead to more autonomous farm vehicles (‘tractors of the future’) powered by fuel cells and being used across the farm for arable cultivations and livestock operations.

**Technology scenario summary**

Given the three scenarios above it is clear that integrated variations of each will become the norm over the next decades. Whilst some of these technologies e.g. biogas AD are already ‘main stream’, refinements of these along with innovative new machinery and renewable transport fuel sources will be developed. British farming will certainly respond to and benefit from much closer involvement and engagement in the technology readiness process. Improved cooperation between farmers and research organisations, vehicle and machinery designers and manufacturers, and Government agencies should be encouraged. Building upon the innovative reputation of British farming, the UK could become a global example of a successful transition to a low carbon agricultural economy.
Drivers of change
The main drivers of change influencing these scenarios are likely to be:

- Government targets - for example, the Climate Change Act 2008 introduced a legally binding target to reduce greenhouse gas emissions by at least 80% below the 1990 baseline by 205027. Political uncertainty can delay interventions to meet the targets.
- Economic conditions – for example, a continuing rise in energy prices, slower manufacturing growth, lower consumer spending, global uncertainties.
- Level of national commitment to decarbonise the energy, transport and food sectors.
- Global supply and demand for transport fuels.
- Economic and investment conditions in the UK and overseas.
- Advances in transport technologies and fuels.
- Consumer and community demand and influence.

Government policy and targets and technological change are likely to be the key drivers, but consumer and community expectations will also be of importance. Whatever the future, anticipating change and building resilience into agriculture and rural communities will enable them to thrive.

Government policies and targets towards the achievement of a lower carbon footprint are likely to be along a spectrum of steady progress to ambitious progress. Later in this Report (Chapter 5), economic scenarios are introduced which expands upon the factors influencing change and the technology changes that might be expected:

- The scenario for steady progress assumes that renewable energy and low carbon technologies will be slow to be accepted or to develop. The Government will achieve the carbon reduction it has signed up to for 2020, but may not make later targets.
- The scenario for ambitious progress assumes that all Government declared targets will be met, including an 80% reduction in greenhouse gas emissions by 2050 and 15% of all energy from renewable sources by 2020.

Either scenario will affect the pace of research, rate of acceptance, the incentives and the development of all forms of renewable energy including bioenergy.

Technological development will be driven by several factors - the need to farm more efficiently and sustainably, the importance of reducing soil compaction, the improvements needed to maintain farm productivity and improve farm incomes, and the need to control and reduce the economic and environmental costs of farm transport and CO₂ emissions.

Chapter 4: Renewable transport fuels

Developments in farm machinery in the UK

The use of machinery on British farms since the early 1950’s reads like a version of the transport revolution that has taken place over the last century in other sectors. From the early post-war days of the early tractors, the capacity (usually expressed in terms of horse-power) of farm traction machinery has increased from around 20hp (the Massey Ferguson T20 for example) up to almost 400hp – with a wide range in between to suit different terrains and farm operations.

Tractor manufacturers continue to make improvements to the efficiencies of their vehicles. This includes, for example, the adoption of stop-start technology, piezo-electric injection and other measures. However, there is a theoretical and practical limit to the efficiency improvements that can be made.

The changes in farm machinery have not only been about increased power. A combination of other drivers has included:

- legislation (especially emission controls);
- a move towards precision farming, often requiring less power but more versatility;
- the increasing costs of diesel;
- the damage to soil and the impact on yield production caused by compaction;
- the impact of lease and purchase costs of larger machinery on the farm business;
- demand for improved working conditions and comfort.

Farm fuel and red diesel

Despite the innovations listed above, there has been little change to the fuels used in farm machinery. Diesel dominates the market. In the UK, red diesel is permitted for use in tractors or light agricultural vehicles – including self-propelled harvesters – used for farm operations and on public roads solely for agriculture, horticulture or forestry purposes. The criteria and legislation related to the permitted use of red diesel (actually containing ‘markers’ and a red dye mixed with white diesel) is governed by the Hydrocarbon Oil Duties Act (HODA) – last amended in 2006 with the purpose of “restoring clarity and consistency to the schedule of excepted vehicles entitled to use rebated fuel.”

The premise for tax exemption on red diesel was originally formulated around the fact that many agricultural vehicles never used the public highway – and when road taxes including fuel taxes were expected to pay for the repairs and maintenance of highways, non-use justified exemption. However, with many so called ‘agricultural vehicles’ now having the driving characteristics of other road vehicles and widely in use on the country’s highways, the on-going case for tax exemption using red diesel is more likely to be challenged. The loss of such tax exemption would have a huge impact on the farm business – and indeed may provide some justification for ‘future proofing’ through the use of alternative – and preferably renewable – transport fuels.

28 Piezo injectors are an emerging technology that can allow diesel engineers to perfectly optimize the injection cycle for greater power and lower emissions
Farmers meeting local community transport demands

Farms already have the potential to be a long term provider of renewable energy for rural communities and could become a significant contributor to local grids and the national supply of renewable heat and power. Apart from renewable electricity generation (solar PV, wind, hydro), farms are well-placed to harness bio-energy – producing renewable heat, electricity and bio transport fuels. Farm-based biomass (boilers) and biogas (anaerobic digestion) systems incorporating combined heat and power (CHP) systems should enable farmers and landowners to become key players in the future UK sustainable energy mix. However, the land-based opportunity to exploit renewable and bioenergy systems to produce renewable transport fuels is in its infancy in the UK. Government support is needed to help fill the gap until maturity.

Case Study: Biofuels in Germany

A report produced by FNR[29] in January 2014 outlined the use of biofuels in the German transport sector. Approximately 53 million tonnes of fuel were consumed in Germany in 2012. Of this total, biofuels accounted for 5.7% or 3.8 million tonnes.

There are over 90,000 natural gas powered vehicles on the road in Germany and biomethane is available at approx. 900 natural gas filling stations. The use of biofuels in agriculture is tax-free. Biomethane used pure as a fuel is tax-free until 2015.

![Development of biogas plants](chart.png)

**Number of plants**

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<td>2012</td>
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<td>2013</td>
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**Installed electrical capacity (MWe)**

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Case Study: Lincolnshire County Council gas powered buses

Lincolnshire County Council is the second most rural county in England. It is also an agricultural and food processing area with over 50% of all horticultural crop production within Lincolnshire; over 20% of the national potato crop; over 68% of vegetable production and also large scale intensive livestock especially poultry & pig production within the county.

In September 2013, it was announced that Lincolnshire County Council is to convert eleven Stagecoach buses in Lincoln from dual-fuel technology (diesel and biomethane) to fully gas powered engines to reduce air pollution in the city. Lincolnshire CC was one of 11 local authorities in the country to successfully bid for the Department for Transport’s Clean Bus Technology Fund. Lincolnshire has been awarded £231,000 to fit the buses. The funding will also be used to install a gas fuelling station at the Stagecoach depot on Deacon Road, Lincoln. The Council was the first to operate a fully biomethane bus in 2011.

Renewable fuels – the options

A) Biomethane

This section examines the potential for biomethane in displacing fossil fuels used on the farm and amongst rural businesses and homes. Biomethane, as with other bioenergy sources, extracts the energy potential of a wide range of organic feedstocks derived from animal or plant wastes, or from purpose-grown energy crops. The result is a renewable source of heat, electricity and fuel – with the prospect of powering the countryside.

Farmers can source their AD feedstock from a wide variety of sources, such as:

| Source: FNR |
|-------------|-----------------|
| Dairy cow: 20 m³ slurry/a | 500 Nm³ biogas |
| Pig: 1.5–6 m³ slurry/a | 42–168 Nm³ biogas |
| Cattle: 3–11 t solid manure/a | 240–880 Nm³ biogas |
| Horse: 8 t solid manure/a | 504 Nm³ biogas |
| 100 chickens: 1.8 m³ dry excrement/a | 252 Nm³ biogas |
| Maize silage: 40–60 t FM/ha* | 7,040–10,560 Nm³ biogas |
| Sugar beet: 40–70 t FM/ha | 5,200–9,100 Nm³ biogas |
| Whole grain silage: 30–50 t FM/ha* | 5,016–8,360 Nm³ biogas |
| Grass: 26–43 t FM/ha* (*=12% silo losses) | 4,118–6,811 Nm³ biogas |
| Example – annual substrate requirement biogas plant 350kWelectricity | 5,500 t maize silage (125 ha) |
| | 3,000 t cattle slurry (150 dairy cows) |
| | 1,000 t grain whole plant silage (28.5 ha) |

Press Release: Lincolnshire County Council

Source: FNR, according to KTBL, Guide to Biogas, Fraunhofer-IWES, DBFZ
Biogas produced by anaerobic digestion is a mix of 55-60% methane (CH₄), 40-45% CO₂ with small quantities of sulphur (H₂S) and ammonia (NH₃). It has less energy content than natural gas, typically 98% methane. Biogas can be upgraded to ‘pipeline quality’ biomethane (i.e. a natural gas equivalent) by removing the unwanted gases, as well as water. It can then be pressurised and stored in the same way as compressed stored natural gas (CNG).

This process provides ‘gas-to-grid’ export opportunity where it is practical and cost-effective to access the national or a local gas grid. Alternatively, biomethane could be used directly as a transport fuel usually in the form of a high pressure gas (to reduce volume). Both these processes are becoming established technologies in many countries. In some, these represent large scale industrial processes – in others, they can be much smaller scale and are often located on farms which have installed AD plants for animal slurry treatment.

The capture and upgrading of biogas into biomethane for transport is gathering interest, innovation and investment. Those farms with AD plants already have the option of upgrading some of their biogas into transport and grid quality biomethane ‘side streaming’.

Once OEM manufacturers extend the availability of ‘biogas’ tractors and other farm machinery, farmers will be able to use their own biomethane to replace diesel across the farm. In the future, farmers may be able to sell biomethane directly through a farm or rural filling station (subject to compliance with legal requirements and HMRC Excise Duty payments) - as already happens in parts of Sweden. The success of this however will depend on a significant surge in gas-powered (CNG) vehicles – common in Scandinavia but at a low level in the UK. A more accommodating regulatory landscape in the UK would assist. However it is argued elsewhere in this Report that biomethane when injected into the UK gas grid can be accessed by anyone across the UK if more CNG filling stations are installed.

This issue of scalability and on-farm affordability is significant in determining whether farms should get involved in renewable transport fuel production. Is this a practical and economical option for farms – or will the combination of technology, legislation, health and safety and cost limit farms to the production of biogas – with any further upgrading for grid injection or as a direct transport fuel carried out elsewhere as an industrial process?

The availability of small scale upgrading technology at an affordable cost is a particularly acute issue for farmers who wish to integrate biomethane vehicles into their operations. It is vital that further innovation and R&D takes place to enable suitable technology to be developed at this scale.

An example of this type of work is Evergreen Gas’s project to develop and test a small scale biogas upgrade facility on a farm in Shropshire, under WRAP’s Driving Innovation in AD (DIAD) fund (see case study Chapter 7). This study highlights the results from the first farm-based biomethane transport demonstration project carried out by Evergreen Gas in Shropshire. This represents a valuable first step – however it is vital that further innovation and R&D is in place to determine the future of biogas upgrading technologies on farms.
The Biogas Association of Canada\textsuperscript{32} has provided a useful flow chart to demonstrate the prospect of farm-based AD plants upgrading their biogas to natural gas quality leading to its distribution locally i.e. on farm or via the natural gas grid for other transport users:

The potential of biomethane as a transport fuel has been demonstrated successfully within the heavy goods vehicle (HGV) sector over recent years - advanced through the pioneering efforts of companies such as GasRec\textsuperscript{33} and Hardstaff\textsuperscript{34}, who have combined to develop fuel supply processes and dual fuel engine technologies. Major transport operators have adopted such technologies within their fleet as a part replacement for diesel. A similar process of ‘transfer technology’ could be applied to agricultural and rural transport.

Biomethane is used most extensively in Sweden, Italy and Switzerland. The limiting factors in the UK have been the lack of availability of suitable natural gas-powered vehicles, lack of refuelling stations and infrastructure and limited economic advantage over natural gas.

The transfer of such technology, including the adaptation of farm tractors and other vehicles to run on biomethane, deserves attention. Also the logistics of biomethane production, storage and distribution needs further modelling – and is an objective of Scotia Gas Networks (one of this Report’s sponsors) and the other UK gas grid operators.

\textbf{Case Study: Evergreen Gas – upgrading biogas for vehicle use}

\textsuperscript{32} Courtesy Biogass Association  \textsuperscript{33} www.biogasassociation.ca  \textsuperscript{34} www.hardstaffgroup.co.uk
Evergreen Gas was awarded a grant under the WRAP DIAD (Driving Innovation in AD) programme to evaluate small scale upgrading technologies for vehicle fuel.

Evergreen Gas has developed modular small-scale AD plants for farms and communities and now has a fully operational pilot-prototype biogas plant, allowing the company to carry out research into optimising performance and also to demonstrate the feasibility of small-scale biogas upgrade for vehicle use.

The company is the UK distributor of Metener biogas-to-vehicle fuel upgrade facilities which can be fitted to AD plants and convert biogas flows to useful vehicle fuel. Evergreen Gas uses two VW Caddy Ecofuel CNG vans as company vehicles.

Further details of this case study are included in Chapter 7.

Case Study: RE Hydrogen Ltd - upgrading biogas for vehicle fuel and heating

RE Hydrogen Ltd, based in Surrey has developed a pioneering multi-functional gas compressor which can not only compress the gas but can clean and dry the gas. By combining three functions into one the unit fits into a 3m x 2.5m tall shipping container, reducing the unit footprint by at least 60%. This biogas and landfill gas upgrading system is suitable for farms, dairies, breweries, crops growers, fruit juice makers from very small to very large scale. RE Hydrogen fills a gap in the market with their smallest unit, sized at 4Nm3/h biogas upgrader, but scalable to a 100Nm3/h (6m container). Upgraders are capable of producing 95% biomethane from raw biogas. The clean gas can be further pressurised to 220bar for refuelling tractors, cars, vans and for storing the energy for CHP and other heat usage.

Using biohydrogen to speed up AD decomposition

Using the bacteria naturally present in waste water to produce biohydrogen can speed up the process of decomposition of organic matter and enhance the production of high energy biogas. One innovative example of this is shown in the case study below:
Case Study: H^2AD - using microbial fuel cell technology

H^2AD, part of the Lindhurst Innovation Engineers group based in Sutton-in-Ashfield, specialises in the application of Microbial Fuel Cell technology to anaerobic digestion plants.

Their modular system uses a semi-continuous flow process to reduce the time, footprint and temperature needed in the AD process. Material remains in the tank for less than 48 hours, produces renewable energy within 2-3 days and cleans the waste water to a high standard. The construction CAPEX costs are reduced compared with traditional AD.

The system has been operating on farm for more than a year treating cow slurry manure, cleaning the waste stream and achieving high yields of biogas with a minimum input of energy required. It does not require addition of crops to enhance the biogas production and is built, commissioned and tested in factory requiring only one day to be installed to a farm.

According to the company, the main innovative advantages are a fast rate novel AD system utilising low cost Microbial Fuel Cell technology which produces green energy recovery from waste and reduces CO_2 emissions. The technology has a small footprint, is modular, scalable with low maintenance costs, has remote monitoring and produces an attractive return on CAPEX.

AD and biomethane vehicles on farms – an industry perspective

Diversification into AD can help the farming community support traditional farming practices and food production. AD recycles farm wastes and crops to generate ultra-low carbon biogas, which can be used to produce heat and electricity through CHP, cleaned up for use as a vehicle fuel or injected into the gas grid, as well as digestate biofertiliser, a replacement for carbon intensive oil based fertilisers. Crops for AD can be excellent options for break and cover crops, and when grown in food crop rotations can improve food crop yields, reduce the need for costly pesticides and support biodiversity.

Biomethane vehicles can play a particularly important role in helping farmers cut their costs – if farms can generate their own fuel source, they will no longer be dependent on price-volatile petrol or diesel. By treating wastes and slurries generated on farms through AD, and using at least some of the resultant biogas to fuel farm vehicles and using the digestate to replace synthetic fertiliser, the carbon footprint of the farm is also significantly reduced.

The use of AD is viable at a variety of scales, from small dairy units to larger arable farms under current incentives. Given farmers will typically have a reliable supply of feedstock; AD is an option at nearly all scales to generate on-site energy and their own fertiliser. There may also be opportunities for farms to pool their resources and knowledge to invest in AD technology and share the products and revenue. (Anaerobic Digestion and Biogas Association)
Biogas (biomethane) farm vehicles on the market

Several authors\textsuperscript{35} have predicted that farms will become increasingly important producers of energy in the future and that biogas could, possibly, become more important than wind and solar power.

Biogas has a strong potential as a tractor fuel, particularly since it could be produced on farm from the anaerobic digestion of livestock manures and plant materials providing a buffer against the rising cost of fossil fuels. In theory, every farm with an anaerobic digester and biogas upgrade plant could become self-sufficient in fuel.

Tractor manufacturers including Steyr, New Holland and Valtra, have developed biogas prototypes (details of these can be found in Annex 1). In Sweden a research programme has been testing dual fuel technology\textsuperscript{36}.

Valtra’s first test tractor – a four-cylinder N111 HiTech – was presented in summer 2010. The biogas N111 is to be further developed and adapted for use in other tractor models.

The Steyr tractor is the Profi 4135 Natural Power with a special gas burning engine from Fiat Powertrain Technologies. The 3 litre engine has 136hp rated output.

New Holland T6.140 uses a 3-litre 135hp engine with methane stored at high pressure in steel tanks, with a 50kg capacity (0.5 day operation) and a 15 litre diesel back up tank with auto-switch mechanism. It is said to have low emissions and fuel cost saving of 25-40\% over diesel (NH).

However there is a distinct lack of information relating to the performance and efficiency of such tractors as compared with traditional diesel fuelled alternatives. Data drawn from independent UK farm-based trials will be required to make the business case for investment in alternative fuelled farm machinery and encourage change.

Biomethane re-fuelling stations

According to the Official Information Portal on Anaerobic Digestion (biogas-info.co.uk) there are only around 15 CNG or LNG refuelling sites in the UK compared to around 800 in Germany. There are fewer biomethane or CNG vehicles in the UK and infrastructure to supply biomethane road fuel is sparse compared to other countries such as Sweden or Germany which have invested heavily in infrastructure and have supportive Government strategies.

\textsuperscript{35} Mike Williams, Sunday 18 March 2012 Farmers Weekly, Scott Garvey Feb 1st 2011 http://www.agcanada.com/countryguidewest/contributor/scott-garvey

\textsuperscript{36} The MEKA Biogas Tractor Project
The first public access bio-LNG / CNG station opened by Gasrec at Daventry (DIRFT) in May 2013 can refuel up to 250 trucks per day, with plans to increase that capacity to around 700 vehicles per day. Further stations around the country are planned.

Whilst no single data source is available to determine current numbers and distribution of methane gas-fuelled vehicles in the UK the low Emission HGV Task Force\(^37\) uses figures from a study carried out by the LowCVP\(^1\) indicating that there were around 500 gas HGVs operating in the UK in 2012.

**Case Study - Biomethane filling stations in Sweden**

Biogas Ost (East) is a regional cooperation organisation that works to actively influence and improve the conditions for biogas in east central Sweden. In 2008/9 Biogas Ost undertook a study of five biomethane filling stations in Sweden.

**Uppsala:**
One of the first biomethane filling stations in Sweden was built in 1996 in the city of Uppsala using biogas from the treatment of organic household waste. The filling station fuelled ten buses and the light transport vehicles of the local authority. The station has been reconstructed several times since 1996 and by 2008 it served 54 buses, 2 lorries and 10-20 cars on a daily basis. By 2013 a second filling station had been built.

**Vasteras:**
In Vasteras, biomethane production is part of a partnership between a local energy company, a regional solid waste company, the national federation of farmers and 17 farmers near to the town. Together they have formed a company called Svensk Vaxtkraft AB which operates a plant for the production of biogas from organic waste and ley crops. The company operates an upgrading plant and filling stations for buses and refuse lorries, as well as members of the public. The plant started in summer 2005 and has been fully operational since 2006. Annually, the plant can treat about 14 000 tonnes of biodegradable waste including organic waste from households and restaurants, about 4,000 tons of sludge from grease traps and approximately 5,000 tons of forage crops. This produces approximately 2.3 million gallons of fuel per year.

**B) Biofuels for farm machinery**

Biofuels were used by farm machinery before the introduction of fossil fuels. Steam powered traction engines were superseded by the first ‘gasoline’ powered tractors built in the USA in the late 1800’s. Peanut oil was used by Rudolf Diesel in 1900 as the fuel source for his diesel engine and Henry Ford had expected that his Model T car would run on ethanol from corn (maize). Both fuels were subsequently replaced by the cheaper petroleum-based alternatives, diesel oil and petrol.

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\(^{37}\) Low Emission HGV Task Force ‘Recommendations on the use of methane and biomethane in HGVs’, March 2014
There has been periodic interest in the re-introduction of biofuels and significant interest in recent years in developing biofuels capable of being used in modern engines. The process of trans-esterification to produce less viscous vegetable oils, first developed in Belgium in the late 1930’s, has allowed the use of vegetable oils in modern, high speed diesel engines.

Recent years have seen further advancements in alternative fuels as well as major adjustments to conventional fuels and engines reducing levels of fossil-based transport fuels. Two particular biofuels are being offered in the UK - bioethanol and biodiesel.

Biodiesel is manufactured from oil seed rape, waste cooking oil and palm oil. Production of biodiesel from used cooking oil is well developed in the UK. Rape oil methyl ester (RME) has been used without modification but is more generally used in a mix with diesel fuel.

**Case Study: NISP: The opportunity to recover biofuels from biowastes**

The National Industrial Symbiosis Programme\(^{38}\) is a Government sponsored programme owned by International Synergies Ltd that works to support businesses recover and reuse unused or undervalued resources moving them up the value chain and the waste hierarchy away from being treated as a waste. A number of their case studies have involved production of bio-diesel from used cooking oils and International Synergies offers a feedstock mapping analysis service.

**Case Study: Cottage Farm, Cornwall – 100% biodiesel**

Cottage Farm\(^{39}\) is an organic, sustainable, carbon neutral farm powered by renewable energy with near zero use of fossil fuels, one of the first in the country. Cottage Farm does not use fossil fuels, but still uses machinery and energy. Home produced 100% bio-diesel from waste vegetable oil powers a car, Land Rover and the farm tractor, and is used to deliver meat boxes to customers.

**Case Study – Hemp as an energy crop for fuel**

The concept of using vegetable oil as an engine fuel dates back to 1895 when Dr. Rudolf Diesel developed the first diesel engine to run on vegetable oil. Hemp (Cannabis sativa) grows in relatively poor soils, making it easier to produce commercially viable crop yields in otherwise unproductive areas. Hemp seed when pressed can produce oil for biodiesel whilst the fermented stalk of the plant produces hemp ethanol or methanol. Scientists at York University\(^{40}\) have successfully used conventional plant breeding techniques to increase the content of oleic acid in hemp, creating a viable alternative to rapeseed and olive oil. The new product is useful not just as an improved cooking oil, but in potentially more high temperature industrial processes, such as a transport biofuel. With this added value opportunity, hemp could replace other break crops on UK farms e.g. oil seed rape - which itself faces declining yields and increasing attacks from pest and disease. However hemp currently faces restrictions as a commercial crop in the UK. Growers must apply for a licence from the Home Office [https://www.gov.uk/hemp-growing-licence](https://www.gov.uk/hemp-growing-licence)

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\(^{38}\) [http://www.nispnetwork.com](http://www.nispnetwork.com)

\(^{39}\) [Paul.Sousek@tiscali.co.uk](mailto:Paul.Sousek@tiscali.co.uk)

\(^{40}\) NextGen Energy Week February 2014
Case Study: Fyne Futures – biodiesel from cooking oil

Established in 2004, Fyne Futures is a subsidiary company of Fyne Homes, a Registered Social Landlord managing houses in Bute, Cowal, Mid Argyll and Kintyre.

Fyne Futures produced biodiesel from used cooking oil for four years from their own biodiesel processing plant with support from Highlands and Islands Enterprise (HIE) and Third Sector Enterprise. Beginning with a two year pilot project, the charity committed to expanding the operation from 170 litres production vessels to 400 litre production vessels. To be sustainable, 400 litres had to be produced each week. The biodiesel produced was of high quality and has been used to operate recycling vehicles without fault for 4 years and has, until recently, been fuelling Bute Produce agricultural vehicles and a collection vehicle.

Over four years the enterprise produced 10 – 11k litres a year and fuelled two 7.5 tonne vehicles, a transit van and a Volkswagen Caddy with 100% biodiesel for their own enterprise and also supplied other community enterprises on the island with biodiesel which has provided a 50:50 mix of biodiesel and diesel to a car club vehicle and a 12-seater minibus.

The decision has now been taken to close production of biodiesel due to the challenges of sourcing sufficient used vegetable oil at a commercial price, rises in taxation and the balance of production costs compared to commercial diesel costs.

Bioethanol

Bioethanol is widely used as a fuel additive in petrol to improve the octane rating and produce a reduction in CO₂ emissions. It is of interest to farmers, as the biorefinery process takes grains such as maize, wheat, sugar beet and other agricultural feedstocks and produces high protein animal feed.

Since 2008, the Renewable Transport Fuels obligation (RTFO), has legally obliged fuel companies to mix 5% bioethanol with 95% petrol and 5% biodiesel with 95% conventional diesel. At these concentrations, there will be no damage to fuel systems, nor should internal combustion engines require any adjustments. Biodiesel and bioethanol have become standard ingredients of road transport fuel.

The Renewable Energies Directive (European Parliament, 2009) requires a mandatory blending of 10% in the transport sector by 2020, by which date, the consumption of bioethanol in the EU is expected to rise to 15 billion litres.

Bioethanol process

The process used breaks down the starch stored in each grain to sugars. These sugars are then fermented into alcohol and carbon dioxide. The protein and other parts of the grain are converted into a high protein animal feed.

The three co-product streams are:

- Bioethanol for petrol substitution
- Carbon dioxide, captured for use in the food, beverage, and horticultural industries
- Animal feed (DDGS), a high-protein ingredient for cattle, pig and poultry diets
Case Study: Bioethanol processing

The largest bioethanol plant in the UK is the Vivergo plant in Hull which aims to process feed wheat (over 1m tonnes per year) and produces 420m litres of bioethanol. Frontier Agriculture, the UK’s largest crop and grain marketing business, jointly owned by Associated British Foods and Cargill, is the sole supplier of wheat to the plant.

The £350m Vivergo bioethanol plant in Hull was officially opened in August 2013 and is a joint venture between AB Sugar, BP, and DuPont. The facility has a full-time staff of 80. As well as producing 420m litres of renewable transport fuel every year, it is also set to become the UK’s largest single-source supplier of livestock feed. The plant uses locally sourced feed grade wheat to produce 420 million litres of bioethanol a year at full capacity, equivalent to a third of the UK’s current demand. It will also produce 500,000 tonnes a year of protein-rich animal feed for the UK market.

A second bioethanol plant is that of Ensus on Teeside, now owned by the German bioethanol producer CropEnergies. Producing about 400 to 450 million litres, the plant has recently restarted after market uncertainties halted previous production.

Future Capital partners are raising capital for a renewable transport fuel refinery in Grimsby and British Sugar has a facility producing ethanol from sugar beet and wheat.

Recent research carried out by Nottingham Trent University and AB Agri, the agricultural division of Associated British Foods, has shown that a Yeast Protein Concentrate (YPC) can be separated from fibrous cereal matter to become a cost-competitive substitute for imported soya-based and similar high-value protein feeds for chickens bred for meat.

On a global scale, bioethanol production has risen steadily, from 40 billion m$^3$ in 2005 to a demand in excess of 100 billion litres in 2012. About 84% is used for fuel ethanol and the rest is non-fuel (food and beverage, industry and cosmetics and pharmaceuticals). In the EU, production has grown from 560 million litres in 2004 to over 4.3 billion litres in 2011, 18% of which is produced in Germany.

Feasibility studies into the use of woody or ligno-cellulosic sources, such as crop residues, forestry residues and waste wood have been undertaken with a view to finding alternatives to using agricultural crops as the feedstock. It is already clear that there will be increased research to explore this as an option in the future.

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Case Study: Advanced biofuels from wood wastes

Bioenergy plays an important role in the Finnish energy system and, in 2009, the country was considered to be one of the world leaders in utilisation of bioenergy with almost 20% of total primary energy consumption met in this way\(^\text{42}\).

In the summer of 2012 UPM Biofuels began construction of a biorefinery to produce advanced biofuels from crude tall oil. Tall oil or ‘tallol’ is a viscous, odorous liquid obtained as the by-product of wood (mainly coniferous) pulp manufactured using the Kraft process. Construction is expected to be complete in 2014 and the plant is expected to produce the equivalent of 120 million litres of renewable diesel a year.

In April 2013, UPM reported a partnership with VTT and VV-Auto Group to start fleet tests of renewable domestic diesel and collect and analyse data. The model chosen for the test drive is a Volkswagen Golf 1.6 TDI.

The company received an award (Sustainable Biofuels Award) for innovation for the process in Rotterdam in 2013. Further research is being continued by VTT Technical Research Centre to improve efficiency.

Potential for Biofuels

Gathering data to determine the difference in performance of biofuels has been hard to source. However, reports published by Fachagentur Nachwachsende Rohstoffe\(^\text{43}\) from Germany cover a wide range of biofuel applications and illustrations. One example is provided below:

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43 www.fnr.de
A study carried out by AEA concluded that sustainable biofuels potentially have an important future role to play in decarbonising the transport sector between now and 2020 and that they can be used to control greenhouse gas emissions from road transport.

The study noted that a number of barriers would need to be overcome before the predicted quantities of fuels can be delivered and used in road transport. For the farmer there are currently limited options - other than growing crops for the marketplace, which might be for biofuel production, unless on-farm or near-farm biofuel refinery processes become available or machinery becomes available that can run on crude plant oils.

The NNFCC (National Non-Food Crops Centre) is a useful source of information on biofuels and bioenergy and publishes regular market reviews for their members. They have produced a number of reports including ‘Advanced Biofuels: The Potential for a UK Industry’, published in November 2011.

**The biofuels versus food issue**

Including biofuels in petrol and diesel mixes begins to reduce the UK’s reliance on fossil fuels. Already, a proportion of the cereals, sugar beet, oilseed rape grown in the UK is mixed with imported materials to make up the proportion of biofuels in petrol and diesel required by Government.

Greenhouse gas emissions and savings from biofuel cultivation in the UK have been calculated. The greatest emissions from crop cultivation arose from (in order of significance) N₂O from soil, the manufacture of fertilizer, fuel used to power machinery during cultivation and harvest and from crop residues.

It is recognised that the UK does not have sufficient land to grow enough crops for all its food and fuel requirements but that other countries with larger land areas could grow crops for both food and fuel. However, diverting crops grown for food into biofuels is the subject of debate as consumers’ question how the UK’s farmland should be used, now and in the future, and the risk of global deforestation that might result.

The question of land use for food crops or biofuels was discussed in the European Parliament in a debate on the EU Biofuels directive in 2013. Dr Phil Bennion, an MEP and farmer from the West Midlands argued that a rational and informed energy and land use debate was needed and that, whilst there is a need to consider the possible impacts of biofuels on food prices, efficient biofuels have a vital role to play in fighting climate change. “Bio-ethanol produced from feed quality wheat leaves a much higher protein feedstuff as a by-product, which can then replace soya imported from countries where forest clearance for agriculture is a real threat to the climate”, he said. “The EU does have a continuing responsibility to foster efficient and sustainable food production, both in the EU and globally, but that does not mean that any support for non-food crops is a bad thing”.

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44 AEA study AEA Ref: Scenarios for the cost effective deployment of biofuel in the UK road transport sector in 2020
45 http://www.nnfcc.co.uk/
47 http://www.theparliament.com/policy-focus/agriculture/agriculture-article/newsarticle/sustainable-energy-week-phil-bennion/
C) Electricity-fuelled farm machinery and transport

The gradual introduction of electric cars and light commercial vans (EVs) has provided another option for rural drivers and commuters. Range (miles travelled on a single re-charge) can (but not always) be a bigger issue in more isolated areas compared with the much shorter journey cycles found in urban areas. Battery technology is rapidly improving and the recharging network is growing.

Farmers owning solar photovoltaic arrays and wind turbines, and proximate to rural market towns and villages, have the potential to provide electricity recharging points on their farms selling ‘electricity fuel’ to local drivers at a price per kilowatt hour (kWh) licence lower than the cost of domestic recharging, yet higher than the export tariff rate that farmers can earn through the Feed in Tariff scheme. However, there are currently legal restrictions affecting the ability to sell electricity as a transport fuel rather than for own use.

PV panels or wind turbines are established technologies producing renewable electricity with the potential to fuel electric vehicles (EVs). Farmers with large solar PV arrays on barns and fields are well-placed to utilise this form of renewable energy as an alternative transport fuel. Currently there is an increasing range of EVs (cars and vans) on the market with some pioneering projects (some featured in this Report) already operating designed to demonstrate the opportunities of ‘driving on electric’. The development of electricity-fuelled farm vehicles has already begun. Farmers are using electrically powered harvesting vehicles and all-terrain vehicles (ATVs). More research and demonstration projects are needed to identify where electrically-powered transport can replace traditional fossil-fuelled vehicles on the farm and in other rural businesses. Larger heavy duty tractors are unlikely to be displaced by electricity powered units.

Recently, tractors that use electrical energy to power auxiliary services have been developed and are now in limited production. These include:

- The Belarus diesel-electric tractor has a 170 kW six cylinder diesel engine which drives a generator set in addition to powering the tractor. The electrical energy is used to power auxiliaries and the front power take-off (PTO).
- John Deere ‘E’ series tractors based on their ‘7030’ models which have a built in generator and flywheel that provides 3-phase as well as DC electrical power to drive auxiliaries, replacing the conventional hydraulic and mechanical drives.
- Rigitrac, a Swiss firm, has developed a 90 kW four cylinder diesel tractor that drives an 85kW generator which powers four electric wheel motors as well as powering the auxiliary services. This design has no axles or conventional transmission, producing a much better overall efficiency for the drive system.
- Valtra are developing an electric tractor which will either be a hybrid design or full electric drive.
“RE-fuelling the Countryside”

- Other companies, such as Deutz, Agritech and Fendt are reportedly considering similar developments.
- The Tektu T100 is a purpose designed all-electric strawberry harvesting system which can operate inside polytunnels, as well as outside, with zero in-field emissions.

**Case Study: Tektu electric strawberry harvester**

The Tektu electronic strawberry harvester, designed and manufactured by Tech2Reality in Warwickshire, is an example of farm machinery design and propulsion moving towards low emission systems.

This company set out to design a strawberry harvester that could work outdoors and in polytunnels in all weathers, temperatures, gradients and ground conditions. It had to be fuel-efficient, eco-friendly and allow pickers to influence the machine’s speed depending on the density of the fruit.

In the summer of 2008, the first production version of the TEKTU T100 all-electric strawberry harvester went into service and several units have been sold. Typical TEKTU T100 costs are around 10 per cent of those to run an internal combustion engine equivalent.

http://www.tech2reality.com

**Case Study: Electric farm quad bikes**

Shropshire Quads is pioneering the deployment of electric All-Terrain Vehicles (ATVs) on farms across the UK. British made and manufactured by EcoCharger in Devon, the 4x4 quad bike offers farmers and landowners the opportunity to utilise the renewable energy generated on the farm from wind, solar and AD for a wide range of transport purposes. The EcoCharger has a top speed of 35mph and comes as road registered (it attracts no road fund tax as an electric vehicle). Its range is 30 miles, dependent upon conditions, and Shropshire Quads indicate a cost per mile of around 1.1p, providing considerable fuel savings.

Shropshire Quads also distribute a fully electric 4-wheel drive utility vehicle called the eBear which is a fully electric four wheel drive utility vehicle manufactured in the U.K. by Avid Vehicles. The maximum range of the eBear is 60 miles depending on conditions. In addition running costs are very low at as little as 1p per mile. The eBear is supplied fully road legal and can be registered as a concessionary vehicle if used for the purposes of farming, forestry or horticulture. http://shropshirequads.co.uk
Case Study: Land Rover E-Defender

The Land Rover has been popular on UK farms for more than 60 years.

The Land Rover Electric Defender is a pioneering research project into the electrification of an all-terrain vehicle (ATV). The project forms part of Land Rover's overall sustainability objectives. The innovative 4x4 is a rolling laboratory to develop new ideas and investigate electrification in a real-world environment. Prototypes have converted standard Defender diesel vehicles, replacing the engine and gearbox with an electric motor and battery.

The E-Defender may not be a production vehicle, but it may soon have the potential for retro-fitting in existing Land Rover vehicles. The prospect of driving on farm-generated solar or wind renewable electricity provides an added incentive to deploy electric vehicles (EVs).

The Electric Defender demonstrates full all-terrain capability, with permanent 4 wheel drive 94bhp and a top speed of 70mph. It is also fully waterproofed with a ‘wade depth’ of 800mm (compared with 500mm on the standard Land Rover). Land Rover indicates a range between charging is 50miles, although usage dictates this. Trials indicate that, in off-road use, the charge should last for around eight hours, given regenerative braking and the relatively low speeds involved. Recharge time is 10 hours, or 4 hours with a fast-charger.

The first Electric Defender started work at the Eden Project near St Austell in Cornwall in 2013.

Case Study: Aylesmore Farm – electric ATV and solar panels

Partners Richard and Bill Cheney of Aylesmore Farm, Warwickshire, use a Polaris electric all-terrain vehicle for general farm use, travelling around the farm to inspect fencing.

The buggy is used for spot weed spraying on the 8 metre grass headlands. Although the farm no longer has livestock, they believe that it would be a very useful vehicle for stock checks.

The farm has a 54 panel, 10KWP solar array on a barn roof. If the vehicle is charged on a sunny day there is no mains electricity used, so no cost is incurred. It is estimated that the farm should see a payback for their costs after 3 or 4 years, but that they will also have to replace the batteries after this time.
Case Study: Wyke Farms – electric cars, PV and anaerobic digestion

In 2013, Wyke Farms, the UK’s largest independent cheese producer and milk processor based in Bruton, Somerset, became 100% self-sufficient in green energy.

The company is switching to electric Nissan Leaf vehicles for its delivery services. The vehicles will be charged using the solar panelling on Wyke’s dairy farm buildings. The initiative will enable Wyke Farms to save on their CO₂ emissions and will also reduce associated fuel costs.

The company has an anaerobic digester based biogas plant of three 4,600 cubic metre digester vessels which converts 75,000 tonnes of biodegradable waste materials per year, mainly cow manure, from the farm and dairy into energy. The plant will enable Wyke Farms to save more than four million kg of carbon dioxide per year and provide the capacity to source all electricity and gas from solar and biogas and export power to the National Grid.

Source: Wyke Farms

Case Study - Mitsubishi Outlander Plug in Hybrid Electric Vehicle (PHEV)

With the Outlander, the UK will see the first plug-in hybrid (PHEV) sport utility vehicle (SUV) on sale in the UK. The Outlander will appeal to farmers and landowners who are looking for a low emission vehicle that can utilise solar generated electricity and can cope with both off-road and on-road situations. The hybrid powertrain favours running on electricity only with the petrol engine being used mostly as an electricity generator.

The Outlander provides a four-wheel-drive, with 5-seater capacity and can run on electricity for 32 miles. It has a large-capacity battery and a pair of electric motors – one on each axle to provide four-wheel drive – that generate a combined 161bhp. When the 2.0-litre 4-cylinder petrol engine is included, it has a total of 204bhp. The PHEV has a top speed of 106mph and, according to Mitsubishi, has a combined fuel economy of 148mpg and CO₂ emissions of 44g/km.

With a full battery and fuel tank, Mitsubishi claim that the Outlander PHEV can travel 560 miles without stopping. Charging takes about five hours from a domestic socket (32 amp), or with a rapid charge (e.g. motorway service stations) an 80% charge can be achieved in 30 minutes. According to AutoExpress, the anticipated on-road price (after the Government grant of £5,000), will be around £30,000.
Case Study: Warwickshire GP Electric Vehicle Project (GPEV)

The Warwickshire General Practitioner Electric Vehicle (GPEV) Project is a pilot scheme to establish and monitor a small network of EVs and charging points located at GP surgeries and health care centres across rural Warwickshire. This is part of a wider commitment from Warwickshire County Council towards a more sustainable transport infrastructure for rural businesses and communities.

Health centres are a hub of rural and market town communities and use short vehicle journeys for home visits, prescription deliveries and other health services. They provide a focal point for information and are trusted organisations in the community. They are also businesses and have to make decisions based upon sound economic as well as social and environmental factors.

The electric vehicles being used for home visits, prescription deliveries and on-call activities have been provided with the assistance of Peugeot UK and the necessary charge point infrastructure has been funded by British Gas. Project management of the trial is provided by Warwickshire-based low carbon project consultants Greenwatt Technology.

Case Study: Fetlar - Shetland, Scotland – a rural community EV scheme

The Community of Fetlar secured funding to purchase a Smith electric minibus based on a Ford Transit which is planned to be charged by linked wind turbines. The minibus provides a “dial a ride” service on the island, as well as being used for community transport.

The vehicle is expected to meet the transport needs of islanders and, potentially, replace up to two diesel powered vehicles. The minibus was delivered in Spring 2013, with plans for 2 x 20kw turbines to provide charging for the electric minibus and a micro district heating solution for Fetlar primary school and a private house. The plans for the turbine have been affected by the Government’s degression review of Feed-In Tariffs, as external funding is required.

Plans for community supported renewable energy take time to develop, particularly if negotiations and consultation has to be undertaken with other bodies. They are particularly susceptible to changes in Government policy and incentives such as the FIT regime. Small communities may lack access to capital and finance and changes in policy can affect decisions at critical points.
Case Study: The Eco Travel Network (ETN) – electric vehicles for tourism

ETN operates a fleet of low energy electric vehicles (Twizys) in the Brecon Beacons National Park. The vehicles are hosted, used and hired out by ETN members across the Park.

The Eco Travel Network is not-for-profit and is about:-
- Having fun.
- Using much less energy to move around.
- Exploiting local energy sources - sun, rain, wind.
- And benefiting networks of residents, visitors, businesses and communities.

The ETN works through loose social networks of residents, businesses and visitors. The members are currently tourism businesses and local residents who use the Twizys themselves for their everyday travel and hire them out to their visiting customers and sometimes share them with members of their local community. The Network has developed over 40 volunteer Twizy charge points across the Park – these are pubs, cafes, visitor attractions and activity providers who offer access to a 13amp socket for visiting Twizys. They co-promote the ETN whilst also benefitting from featuring as Twizy destinations for visitors.  

www.ecotravelnetwork.co.uk

Case Study: Talybont-on-Usk Energy (a not-for-profit community venture)

Talybont Energy owns and operates a 36kW hydroelectric turbine that has been running since 2006. It sells the electricity to Good Energy and invests the income in energy projects in the Talybont community.

In 2010, Talybont Energy decided to see if it could set up a zero carbon car share scheme in the village of Talybont-on-Usk in the Brecon Beacons National Park. With help from the Brecon Beacons Sustainable Development Fund, Talybont Energy purchased two cars: a second hand Skoda Octavia which could run on recycled vegetable oil, a 500 litre bunded tank to hold the recycled vegetable oil and a Mega City electric car with a range of 30 miles.

The scheme was launched in February 2010 with 10 member households. Members pay £25/year to belong to the scheme. They provide copies of their driving licences and sign a standard rental form. They are then instructed in use of the vehicles. The Electric car was replaced in May 2013 by a Kangoo ZE electric van/5 seater.

The 2013 scheme has 15 member households – only 6 of these are from the original 10. Running a rural car share scheme has proved logistically straightforward but economically challenging. A full report is available at:  
D) Hydrogen and fuel cell technology

Hydrogen - the transport fuel of the future? A viewpoint from Canada

‘In transport terms, many believe that the characteristics of hydrogen - its zero emission and high energy density qualities - offer a real prospect for it to become ‘the fuel of the future’. The development of highly efficient fuel cells – twice as efficient as internal combustion engines - maximises the energy potential of hydrogen and reduces fuel consumption. Fuel cells are not new technology – in fact they were first invented in the 19th century but came to prominence as part of the NASA space programme in the 1960’s. Hydrogen fuel cell demonstration vehicles have been released and under test by most of the major car manufacturers. The expectation is that fuel cell cars will be widely available by 2020. Other applications have been developed in buses, tractors, submarines and even a canal barge!

Farms have plenty of wide open spaces ideal for erecting solar panels or power-generating wind turbines that could take advantage of natural resources to create electricity, which can be converted to hydrogen. Producing it that way would create a no-cost fuel, aside from the infrastructure costs. Hydrogen fuel cells would allow for electric drivelines on a pickup truck or tractor and would eliminate the need for large battery banks, thereby increasing a vehicle’s effective range.

Although fuel cell technology is very efficient, hydrogen can also be ignited in a regular internal combustion engine, just like gasoline. That would allow farmers to use hydrogen in existing equipment with only some minor modification. But there is a major hurdle yet to be overcome with hydrogen systems. The technology does not yet exist to store it in large enough quantities to give vehicles a range comparable to current gasoline engines.

While hydrogen research continues, another group of scientists believes they know a better alternative. It happens to be one already familiar to farmers, anhydrous ammonia. The same gas that benefits crops as a nitrogen fertilizer may be one of the best alternatives as a fuel.

Icom, a US-based company already specializing in propane conversions for gasoline engines, will offer a dual-fuel ammonia conversion kit to consumers, allowing an engine to run on an ammonia-gasoline, LPG or CNG mix. It will be designed for fuel-injected gasoline engines. Later, the company expects to offer a mono-fuel ammonia conversion eliminating the need for regular gasoline entirely.

All of this means farmers may have more options than anyone when it comes to their future fuel. Increasingly farmers will be the producers of their own energy... in one form or another’.

Research organisations such as Birmingham University have been working for several years on hydrogen fuel cell technologies for transport. Costs and safety remain key issues preventing commercialisation at this stage. But further investment will surely bring hydrogen forward both as a source of renewable energy storage and as an alternative to electricity and biomethane as a renewable transport fuel. Again, farms could provide an

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ideal location for hydrogen systems – and for direct usage. In this context, New Holland are setting the scene and provide a valuable insight into how hydrogen fuelled tractors might power farms as part of their ‘Energy Independent Farm’ initiative.\(^{49}\)

Hydrogen will gradually develop as an efficient means of converting and storing energy generated from renewable sources i.e. solar, wind, hydro and bioenergy and transporting to power demand applications such as transport and buildings. As such, hydrogen should be seen not as an energy source in itself but rather as an ‘energy carrier’.

Hydrogen can be produced using a process of electrolysis – using renewable electricity to split water into its base components of hydrogen and oxygen. However, the handling, processing and storage of hydrogen is neither simple nor cheap. The idea of ‘power to gas’ units being located on farms for example may not be a viable proposition unless the economics, safety and transmission all stack up. An alternative idea is to utilise hydrogen within a process of producing synthetic gas (‘syngas’) with the capability of replacing natural gas and of utilising the natural gas grid network as a national storage and transmission grid. This ‘power to gas’ technology addresses the problem of surplus energy reserves from renewable energy sources – and would go some way to balancing the peaks and troughs of production found particularly in solar and wind power.

**Bio-hydrogen for electricity and transport fuel as a product of AD**

Hydrogen can also be produced from microbial activity – biohydrogen. This is hydrogen produced through the action of living organisms resulting in an ‘advanced or third generation biofuel’. Bioreactors provide the ideal conditions for microbes to grow – light, nutrients, CO\(_2\) – resulting in a continuous production of biohydrogen which can then be stored and used as a biofuel.

Bio-hydrogen offers an attractive alternative to first and second generation biofuels in that it does not compete with food production for land area. It has also a highly efficient solar capture capability and has the potential to produce large volumes of transport biofuels on a commercial scale.

A feasibility report funded by the WRAP DIAD Programme\(^{50}\) has looked at doubling power from waste by adding sunlight to the anaerobic digestion process. The technology produces ‘Biosolar hydrogen’ by the conversion of volatile fatty acids, produced during anaerobic digestion. Hydrogen is produced via a photosynthetic reaction and enhances energy from wastes by working in concert with anaerobic digestion (AD). The authors conclude that the process could be applied, cost effectively, wherever AD is applied at scale, including waste AD, sewage sludge AD, food waste, energy crop, and co-digestion.

The report considers the feasibility of transport fuel from a process that could co-exist with farming. However, the work is at an early stage and requires large scale testing for both the mechanics and the relevant legislation. The primary application for the hydrogen is thought


by the report authors to be electricity generation and therefore excise duty would not apply. However, one potential future application for bio-hydrogen is as a vehicle fuel and this would require compliance with HMRC Excise Duty payments.

**Case Study: Hydrogen powered vehicles trialled in Scotland**

A light goods vehicle trial was conducted in Stornoway, Outer Hebrides, Scotland in July-August 2010. The trial involved the use of a demonstration Ford Transit converted by Revolve Technologies to a bi-fuel petrol/hydrogen internal combustion engine (HICE) vehicle operated by Royal Mail on two delivery routes out of its Stornoway delivery office over a six week period.

Hydrogen fuel was provided by Comhairle nan Eilean Siar (Western Isles Council) via its H2seed facility. H2seed generates renewable hydrogen by feeding electricity generated by a biogas engine to an electrolyser. The trial sought to examine the reliability, ease of fuelling and usability of the vehicle and fuelling regime, and the suitability of the HICE vehicle in fleet operation. (CENEX Stornoway Hydrogen Vehicle Trial)

**Hydrogen-fuelled tractors**

New Holland Agriculture exhibited a fuel-cell powered tractor the NH²™ at the SIMA show in 2009 (shown left, courtesy NH). It uses a hydrogen tank and fuel cells that generate electricity to run the electric motors, which power the machine and any implements. A total replacement for diesel, the NH²™ offers a zero emissions future for farming activities producing just a little water. New Holland Agriculture claim that the NH²™ is ‘The world’s cleanest tractor’.

John Deere had earlier developed a prototype in 2002. The fuel cell may well be the power source for the next generation of farm tractors and other machines.

Fuel cell powered machines have some distinct advantages over diesel and other transport systems:

- no pollution
- quiet
- efficient electrical drive
- non-fossil based fuel source
- little or no waste disposal issues
- fewer moving parts.

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51 Cenex Stornoway Hydrogen Vehicle Trial
http://www.cenex.co.uk/LinkClick.aspx?fileticket=sSD7Pbd9IUs%3D&tabid=119&mid=695
However, there are also some disadvantages:

- expensive to produce (no current scaling benefits from mass production)
- no infrastructure, currently, for supplying hydrogen fuel
- hydrogen gas is a less convenient energy source than liquid fuels
- industry standards for hydrogen liquefaction and storage are still being developed

**A hydrogen-fuelled transport strategy for the UK**

The UK H₂Mobility Project⁵² is a partnership of UK industry leaders and Government working to make hydrogen-fuelled transport a reality. The key findings of Phase 1 of the Project (March 2013), were that 1.6 million hydrogen fuelled vehicles could be on UK roads by 2030 with an initial UK network of 65 hydrogen refuelling stations (HRS) by 2020.

Also, the project estimated that by 2025 there could be 330 refuelling stations providing close-to-home hydrogen refuelling for 50% of the UK population, with up to 50% of transport hydrogen to come from renewables.

An on-line map of UK Hydrogen Capabilities⁵³ has now been produced that maps hydrogen refuelling stations, production plants, research facilities and funded demonstration projects. In addition to its potential as a fossil fuel technology replacement, hydrogen technology has potential as a renewable energy storage facility.

**Case Study: Five hydrogen refuelling sites approved for the Isle of Wight**

ITM Power, the energy storage and clean fuel company, has received planning permission for five hydrogen refuelling sites on the Isle of Wight. The permission is for an 80kg/day hydrogen refuelling station at four locations and at one for a 15kg/day marine refuelling station.

ITM has chosen two of these sites to take forward for installation of hydrogen refuellers ready for operation in November 2014, as part of the EcoIsland Hydrogen Vehicle Refueller project on the Isle of Wight, supported by funding from the UK’s innovation agency, the Technology Strategy Board.

The approvals process involved several stages including the identification of candidate sites prior to conducting a detailed survey, preparation of plans together with a Design and Access Planning Statement and liaison with stakeholders including the Isle of Wight Council and the Environment Agency. The sites surveyed included two owned by Vestas; one being their R&D centre at Stag Lane and the other Monks Brook, one operated by Scotia Gas Networks in East Cowes, and one at the St Cross Business Park, Newport. ITM Power has decided to proceed with the site owned by Scotia Gas Networks, providing an opportunity to further develop commercial links. For further information: chp@itm-power.com.

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⁵² [www.ukh2mobility.co.uk](http://www.ukh2mobility.co.uk)
⁵³ Energy, Generation and Supply KTN (Knowledge Transfer Network)
Case Study: Hydrogen fuel cells in Denmark

Electricity generated by wind turbines cannot be stored for use at a later stage unless large banks of acid batteries are deployed. This is a particular problem in areas where a grid connection is not possible.

A Danish consortium, Dansk Mikrovarme⁵⁴, has been involved in a 6 year project in Vestenskov, a village of 540 people on the south eastern Danish island of Lolland to test the potential of storing wind energy by converting it to hydrogen and using fuel cells to generate electricity and heat. The island produces 50% more wind energy than it consumes and has to use fossil fuels when there is no wind. By using a fuel cell, hydrogen can be stored to supply homes and transport with electricity as well as heat when needed to replace oil and gas.

Hydrogen has to be subjected to electrolysis to release energy from water to which it is bound. Separation is via an electrical charge which can be from wind or solar energy. Once separated, it can be used in a fuel cell and turned into electric power and heat, with water as the waste product.

E) Pyrolysis and gasification

Renewable transport fuels and oils can also be sourced from other processes such as pyrolysis and gasification. Research institutions such as Aston University (European Bioenergy Research Institute)⁵⁵ are developing technologies to treat a wider range and form of biomaterials and wastes including agricultural residues using high temperature thermo-chemical processes to produce low carbon oils, as well as biochar residues (suitable as a fertiliser and soil improver).

Pyrolysis oils could be refined to the necessary transport fuel standards and again used in farm and rural transport situations as a fossil fuel replacement. Pyrolysis is a sealed process that has no emissions. With biowaste treated at temperatures of around 400°C and in anaerobic conditions, a wide range of waste and residues can be processed. These include sewage sludge, husk from rice, wheat, barley, oil pressing cake from rape, soy bean, cocoa butter, olive, sunflower, straw from rape, wheat, rice, miscanthus, wood, algae, corn residue, dried anaerobic residues, meat and bone meal, residues from composting, grass and green clippings, and spent brewers grain. The wide range of material able to be treated through novel reactors such as the Pyroformer™ currently being developed and tested by EBRI means the process is not vulnerable to fluctuations in biomass feedstock prices.

⁵⁵ http://bioenergy-midlands.org/
Following dewatering or drying down to <30% moisture by weight (for example in most farm feedstock such as slurries and digestate) there is no need for feedstock to be pre-processed – they can be in any form and size ranging from powder to chips. The overall process is not just carbon neutral, it is actually carbon negative - as up to 25% of carbon can be saved as biochar and sequesters and returned to the soil in the form of fertilizer. The Pyroformer™ offers the potential for carbon negative heat and power generation using biowastes.

As with anaerobic digestion and biogas upgrading, more R&D is required to render such processes viable and at a scale suitable for smaller, on-farm applications. EBRI is investigating the use of mobile pyrolysis units to provide a lower-cost biowaste and crop residue solution for farms and rural communities. Already, EBRI is leading a pioneering mobile pyrolysis project in India utilising rice and wheat straw harvest residues in the Punjab region and helping to prevent open field burning.

56 ‘Transforming life in rural India ~ biomass conversion and pyrolysis’ ~ www.aston.ac.uk/ebri
Chapter 5: Future Farm Transport Scenarios

The use of farm energy scenarios

Scenarios are a valid method used to present a range of plausible possibilities for the future. They allow for an exploration of trends and can be used to identify and prioritise risks and opportunities.

The UK energy sector has the challenge of providing or securing reliable, affordable and resilient supplies of energy now and in the future. Agriculture has to plan for rising energy costs and to decarbonise production whilst continuing to provide affordable food and other non-food products. There is considerable uncertainty about future costs and technologies, but scenarios help those interested to visualise and plan for the future by considering the drivers and potential solutions. Scenarios are not forecasts nor are they predictions, but rather present a picture of the technical possibilities, their integration and their impacts.

The steady or near-term scenario (within 5 -10 years)

Tractors and self-propelled farm vehicles

There is already a move towards alternative fuel sources and associated engine/vehicle designs, either in conjunction with conventional fossil fuels (petrol and diesel) or as vehicles fuelled entirely by sustainable fuels. This is alongside the developments being required under new Tier 4 emission regulations required for tractors and other machinery.

In the near-term, greater use will be made of electrically powered drive systems and auxiliaries for tractors and self-propelled farm machinery and there will be wide-spread use of renewable and sustainable fuels.

Examples of diesel-electric powered tractors include the John Deere ‘E’ series, and the Belarus, which have a diesel engine driving an electric generator and electric motor for the tractor’s auxiliary services and power take off (PTO). A design being developed by Rigitrac has a diesel powered engine and generator powering electric motors at each drive wheel as well as an electric motor for the auxiliaries. AGCO is developing a diesel-electric self-propelled sprayer. These diesel-electric designs are to be introduced by a number of manufacturers in the next 5-10 years. Their advantages are a more efficient operating system, as well as the potential to use sustainable fuels for the diesel engine.

A number of manufacturers are developing, or have developed, tractor engines that use alternative fuels. The current 5% biodiesel approved for use in most diesel engines (B5) may have an increased component of biodiesel in the near-term. The oil source for bio-diesel is likely to be rape seed with trans-esterification taking place by commercial organisations.

Dual-fuel tractors are likely to become more widely used, with compressed natural gas (CNG) or compressed biogas (CBG) being used in conjunction with diesel fuel – as is happening with the HGV transport fleet. The bio-gas will be sourced from large-scale anaerobic digesters with on-farm or near farm upgrading to ‘pipe-line’ quality.
There will also be tractors designed to run on diesel with ethanol injection in the inlet manifold. Companies such as AGCO are already developing tractors principally for the South American market where ethanol from sugar cane is currently widely used for spark-ignition engines. In many cases, these developments will offer the potential for the greater use of alternative fuels sources with bio-diesel and CNG/CBG being the main fuel options.

It is clear that there will be a range of innovative tractor and engine designs in use in the near-term.

Light commercial transport and personal vehicles (near-term)

In addition to vehicles fuelled by biodiesel, ethanol will continue to be used to improve the octane rating of petrol.

There will also be a number of vehicles powered by CNG/CBG, ranging from small delivery trucks to cars powered by CNG/CBG such as the Honda Civic GX and the VW Bio-bug. These engines can operate at higher compression ratios because of the higher octane rating of natural gas/bio-gas. The cost of running vehicles of this type is around two-thirds of a conventionally fuelled engine. The widespread use of CNG will require a more extensive network of CNG/CBG filling stations and a corresponding network of pipeline supplies.

There will be a significant growth in hybrid vehicles using battery power in conjunction with conventionally fuelled engines. Examples of manufacturers of these types include Toyota, Mercedes, etc. There will also be battery powered vehicles for small cars, such as the Nissan Leaf, and for small dedicated vehicles such as ATVs. Solar photovoltaics (PVs) offer the potential for supplementing the electrical recharging requirements of these vehicles.

Currently, Tesco and Sainsbury’s amongst other hauliers use a mix of liquefied natural and biogas on some of their large delivery trucks. The fuel is a blend of biomethane from land-fill and natural gas, liquefied by cooling to −162 °C. Currently, one company (GasRec) is supplying the fuel for these fleets with their biomethane processing plants utilising biogas largely from landfill sites. It is likely that this approach will become more widespread and that the larger farm vehicles could be fuelled by upgraded biogas from large-scale ADs, possibly supplemented by natural gas.

The implications for farmers and land-owners of these developments, and the continued demand for sustainable energy are:

- **Biogas**: Farm produced biogas from anaerobic digestion will be upgraded to pipe-line quality and compressed on-site prior to off-site injection to the grid or to vehicle fuel quality biomethane quality.
- **Biodiesel**: This will continue to be an important fuel for diesel engines with an increased component of biodiesel in the fuel mix. Expansion of oil crop cultivation, such as rape seed, which will be sold to commercial biodiesel processors.
- **Solar photovoltaics**: PVs will be used more extensively for recharging of battery powered vehicles, as well as meeting an element of the on-farm electrical energy requirement.
Wind turbines: Turbines of various sizes will be used to provide electrical energy back to the grid and to power other services such as on-farm electrical demand, and recharging of battery powered and hybrid vehicles.

Solar thermal panels: These have an application for domestic hot water and on-farm hot water requirements e.g. dairy farms, particularly off-grid.

Combined Heat and Power plants: CHPs will be used increasingly on a local basis to provide electrical energy and supplementary heat. These plants will be powered by a range of fuel sources, such as biomass, CBG, CNG, biodiesel, etc.

Heat pumps: Ground, air and water source heat pumps will find wider application on farms for heating and cooling needs.

Gas grid supplies: Large farms will be suppliers to the natural gas grid and may also be regional distributors of CBG.

Shale gas: Although a fossil fuel and therefore not renewable, farmers and land owners may be consulting with government and industry on the extraction of shale gas and the potential this offers as a supplement to biogas generated on site.

Other near-term developments related to farm sustainability
- Changing farming practices (direct drilling/ minimum tillage, site-specific precision farming, geographic information systems (GIS), controlled traffic operations, self-activated gantries, drones, hydroponics)
- Management of flood plains and river catchments
- Changing requirements of the supply chain e.g. supermarkets, consumers
- Contract co-operative and community energy schemes working with farmers
- A move towards more energy efficiency and energy independence on farms

The energy independent farm

The energy efficient and energy independent farm of the future is likely to:
- Use efficient production systems; e.g. precision agriculture, knowledge based systems, GIS, site-specific management tools, etc.
- Use or plan to use dual-fuelled tractors, battery powered transport vehicles and fuel cell powered vehicles, as and when available.
- Use bio-fuels and bio-gas from farm crops/wastes to power vehicles and generators
- Use biomass fuelled boilers
- Use wind turbines and PV to supply electrical energy for their own use and to export to the grid, and/or to battery storage to power local electric vehicles.
- Constantly monitor on-farm energy production and uses scenarios as a tool.

EFFICIENT20 is a European funded initiative to help farmers and foresters to reduce their fuel usage by 20%. Fuel used in farming machinery represents more than 50% of the energy consumed in agriculture, so introducing fuel saving measures brings significant cost savings to farming businesses. A pilot study was established in 2010 with 22 groups of farmers and 3 groups of foresters across Europe and the UK who monitored their operations.

The pilot groups implemented two types of measurements:
- Day to day measures of their fuel consumption with different implements
- Comparative tests to assess the possible fuel savings capacity on chosen operations.
Each group established an action plan for further fuel reduction. This data would be of interest to a wide range of farming businesses and could be used to provide a base line comparison for alternatives. For details see: http://uk.efficient20.eu/

The ambitious progress or long-term scenario (10-20 years)

Technological change has been a major factor shaping agriculture in the past and climate change, the requirements of CO₂ reduction and growing populations will continue to produce pressure for change.

Liquid fuels are likely to remain important to the long-term energy mix. However, the development and deployment of advanced biofuels, coupled with increased vehicle efficiency and performance will be essential if the European transport sector is to cut greenhouse gas emissions and meet its decarbonisation targets.

In the long-term, the developments and implications will continue, as for the short-term, with the likely addition of:

- Wide-spread adoption of fuel-cell hydrogen-powered tractors. Developments are currently underway with the New Holland NH2 fuel cell tractor, research at AGCO, and John Deere.
- Wide-spread adoption of electric vehicles and fuel-cell technology for cars and commercial vehicles with Hyundai and others currently planning for the introduction of production fuel-cell cars and trucks.
- Hydrogen production from biomass.
- Biogas storage stations and filling points developed adjacent to large-scale anaerobic digestion units and contracts to supply to major trucking firms.

Case Study: Smartseeder robotic tractor

A robotic tractor and seeding machine has been developed by the SmartSeeder Team at the University of New South Wales, Australia partnered with the Grains Research and Development Corporation (GRDC).

The ambition is to increase precision and improve productivity with an autonomous robotic vehicle and enable cropping on more land by reducing soil compaction on crop lines. The tractor is designed to be also used for weeding, fertilising and growth monitoring. The research team behind the invention were finalists in the 2012 Eureka Prize for Innovative Use of Technology sponsored by the Australian Museum. The team are now working with the GRDC to pursue further development and commercial production.

57 http://tv.unsw.edu.au/video/smart-seeder
**Case Study: Intrepid Minds; Developing slurry as a source of energy and nutrients**

Intrepid Minds are a R&D and professional services company operating in rural Warwickshire in the UK and Tauranga, Bay of Plenty in New Zealand. The company has started to develop a range of technologies which effectively move energy from one source to another. One of the technologies under development removes different types of energy from slurry.

A three stage process extracts a range of gases and liquid nutrients from slurry using an automated machine; the tertiary output is a dry log which can be used for burning. Outputs are being tested on a range of equipment that would allow a farm to power all LPG converted machines and produce organic nutrient concentrates.

Initially the slurry is heated to allow the gases to rise into a series of chambers developed to extract each gas at a point and hold within a low pressure container. The second stage of the process cleans the slurry. Using a special organic mixture a high concentration of natural minerals are extracted and then containerised to boost crop production. The last stage of the process dries the remainder of the slurry with the primary function of generating ‘dry logs’ for fuel.

[www.intrepidminds.co.uk](http://www.intrepidminds.co.uk)
Chapter 6: Policy and Incentives

UK Government renewable energy policy

The UK has to meet its low-carbon objectives by 2050. The Government has a number of targets including the 2020 Renewables Target which aims to achieve 15% of its energy consumption from renewable sources by 2020. The Climate Change Act 2008 establishes a long-term framework to tackle climate change and encourage the transition to a low-carbon economy in the UK.

Under the Climate Change Act 2008, the UK Government is legally required to achieve an overall 80% reduction in greenhouse gas (GHG) emissions from 1990 levels across the UK economy by 2050. Government policy has developed to meet the need for energy security and to reach climate change goals and recognises that bioenergy has an important role to play if the UK is to meet its low-carbon objectives by 2050, provided it is sustainable and affordable.

The Scottish Government has set an ambition to generate as much renewable energy as it uses on an annual basis by 2020. To achieve this goal, the intention is that half of all electricity generated in Scotland will come from renewable sources by 2020. Scotland has also banned the disposal of food waste to Landfill from January 2014.

The Government’s Bioenergy Strategy states that only sustainable deployment will be acceptable in the UK and calculates that around a tenth of UK total primary energy supply could be provided by bioenergy by 2050. The Strategy defines a set of low-risk sustainable energy deployment pathways that could allow a bioenergy sector to develop that contributes towards longer term decarbonisation targets and the 2020 renewable objectives.

In summary, these are:

- Wastes: use of end-of-life materials for energy where it maximises carbon and cost effectiveness and where it is consistent with the waste hierarchy;
- Heat: use of biomass to provide low carbon heat for buildings and industry (process heating), through either biomass boilers, through use of biomethane or from recoverable waste heat.
- Transport: some biofuels, provided that sustainability can be assured and while fossil fuels continue to be used in transport.
- Electricity: Combined heat and power generation as an efficient use of biomass resources.

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58 DECC, 2050 pathways analysis
59 DECC, 2050 pathways analysis. DATE?
60 UK Bioenergy Strategy – April 2012
Low Emission Transport Strategy

Transport is a major source of greenhouse gas emissions. Around a quarter of domestic carbon (CO₂) and other greenhouse gas (GHG) emissions in the UK come from transport. A number of UK and EU legislations apply, including the European Renewable Energy Directive (RED) which sets a target of 20% of EU energy to come from renewable sources by 2020, with a sub-target for the transport sector of 10% of the final energy consumption to come from renewable sources. At a UK level, a clear strategy has not yet been developed. The Renewable Transport Fuel Obligation (RTFO) sets a target of 5% biofuel blending by volume, but a 10% blend could be an option.

Ultra-low emission vehicles and UK Government policy.

The Office for Low Emission vehicles (OLEV) has outlined key elements of the Government’s proposed package of support for ultra-low emission vehicles (ULEVs) in the period 2015–20, which include £4m to ensure the UK has an initial network of gas refuelling stations to support freight and logistics operators, at least £30m from 2015 to clean up bus fleets and a positioning of the UK to be a lead market for the introduction of hydrogen fuel cell vehicles.

This report indicates that the next step should be to assist agriculture and the rural sector to achieve low emission standards.

The rising costs of raw material costs has led to a rethink of renewable energy and the role of alternative non-fossil fuels and to research on vehicle technologies able to use alternative fuels. It is useful to look at the influence that the internal combustion engine has had over the last century – and the extract below from the Government Office of Low Emission Vehicles (OLEV) suggests that change is on its way:

‘At the beginning of the 20th century a dizzying array of different technologies was available for the discerning purchaser of a motorcar. These included steam power, petrol/gasoline power, electric drive, gas power and even gas/electric hybrids. Some vehicles had two or even four engines. This was a period when innovation was rampant as companies looked to find better ways of giving people the greater mobility they craved. Over time a dominant technology – the internal combustion engine – emerged as the pre-eminent way of powering vehicles ...That pre-eminence has remained in place to the present day.

Internal combustion engines will continue to dominate in the global market for vehicles for years to come. But it is already clear that we have begun another era of significant change, much like the early 20th century. Rapid innovation is delivering a variety of different ways of powering our vehicles. Manufacturers are investing billions of pounds into the research, development and production of alternative powertrains, which are now being introduced to the market. By 2020 it is extremely unlikely that vehicles powered solely by the internal combustion engine will remain the only realistic choice for consumers in all vehicle segments’.

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62 Investing in ultra low emission vehicles in the UK, 2015 to 2020, OLEV April 2014
63 ‘Driving the Future Today; A strategy for ultra low emission vehicles in the UK’. Office for Low Emission Vehicles, September 2013
Current studies on the links between transport and the environment focus upon urban transport and the need to reduce emissions in our cities and major towns. For example, a study carried out in 2011\textsuperscript{64} quantified and modelled the costs for different fleet operations of switching from diesel to dedicated and dual fuel vehicles, specifically in Heavy Goods Vehicle (HGV) fleets. The study also identified barriers to uptake and reviewed the incentives, forecast CO\textsubscript{2} reductions and concluded that there are significant potential benefits of developing a larger UK gas vehicle sector fuelled by biomethane and that operating heavy commercial vehicles on gas can lead to lower costs compared to operating on diesel for an important sector of the UK economy.

Another recent study\textsuperscript{65} looked at the potential for the UK to develop ultra-low emission vehicles (ULEVs) and the necessary conditions to support hybrid vehicles, plug-in hybrid electric vehicles (PHEVs), pure electric vehicles (PEVs) and extended range electric vehicles (E-REVs) in the market and in the near future, fuel cell electric vehicles (FCEVs), but did not address the particular concerns of the rural market.

The agricultural sector covers approximately 75\% of the land area of the UK\textsuperscript{66}. The prospect of running farm, commercial (HGV) and passenger vehicles on renewable electricity (wind, solar), on biomethane (AD biogas upgrading), on biofuels (biodiesel, bioethanol) and from biomass processes (using gasification and pyrolysis) could have a direct impact upon the farm and rural economy as well as the environment. Few studies have been carried out in the UK that fully embrace the environmental, social, technical and economic transport issues and opportunities from a rural perspective.

**Actions to promote renewable transport fuels**

Bioenergy and other sources of renewable transport fuels have the potential to reduce UK energy costs and address energy security if innovation and market barriers are adequately addressed and investment is channelled to ensure delivery. Farms are ideally placed to exploit the opportunities.

A more stable policy environment is required, with a clear and reasonable vision of the sustainability criteria for renewable transport fuels. The incentives - current and future - need to take into account the time needed for projects to develop and commercialise. The machinery and renewable fuel supply chain needs to be engaged. Emphasis needs to be directed towards farm and community scale renewable energy and transport fuel projects.

As has been done in urban areas to tackle air pollution (through for example the Clean Bus Technology Fund), the government could offer similar support for on-farm deployment of low emission vehicles, as well as supporting refuelling infrastructure initiatives in rural areas. In 2013 WRAP announced £3m support for the development of small-scale on-farm AD plants\textsuperscript{67}, and it would greatly boost the biomethane vehicle sector if similar support mechanisms could provide direct backing for biomethane vehicle use and infrastructure.

\textsuperscript{64} Biomethane for Transport- HGV cost modelling, Report Prepared for LowCVP by Transport and Travel Research Ltd
\textsuperscript{65} http://www.lowcvp.org.uk/assets/reports/IPPR_Leading-the-charge_ULEVs_Apr2013_10620.pdf
\textsuperscript{66} Defra
\textsuperscript{67} http://www.wrap.org.uk/content/farm-ad-fund
With biomethane currently representing the most realistic alternative fuel for farm and rural transport, Government could do more to support the uptake of smaller-scale AD in general. At the time of this Report, support under the Feed-in-Tariff (FIT) for electricity generation from AD projects under 500kWe and under 250kWe had been cut by 20% (in April 2014) which will hamper the economic viability of a significant number of sub-500kWe on-farm projects.

Although the FIT supports electricity generation rather than biogas, it is vital to the development and viability of technology at the smaller scale, which will ultimately help develop the industry as a whole. Using biomethane as a vehicle fuel needs to make financial as well as environmental sense, and the Government could identify a suitable funding support programme.

It is also important that the non-energy benefits of AD and other technologies to farming are recognised, such as the huge cut in greenhouse gas emissions (mainly methane) that arise from treating animal slurry through AD and the spreading of digestate to land as an organic replacement for artificial fertiliser. However, the rules that prevent locally available wastes and residues being processed into energy at the point where they are generated – i.e. on farms, in businesses and within residential communities – and often used locally through decentralised systems deserve further study – and, where necessary, challenge.

There are important benefits that can be delivered from integrating purpose grown energy crops as ‘break crops’ into an agricultural rotation - increasing soil organic matter, improving soil structure, reducing soil degradation and ultimately resulting in greater long-term farm profitability through higher yields.

RASE could consider working with organisations such as DEFRA and NNFCC to set up a data base of farm and rural energy projects to see where they are located. Such case studies could serve as a location for farm tours, complimented by study visits to other EU countries.

On farm and other rural demonstration plants at Stoneleigh Park (the home of RASE) and other show grounds, research centres, agricultural colleges and key regional farms would assist in showcasing UK and global technology development. It will also be important to ensure that rural energy generation is studied and demonstrated at agricultural universities and colleges coupled with scholarships and renewable energy champions.

At Government level, it would be beneficial to have a Defra Minister responsible for rural energy generation and facilitating investment in decentralised systems not only of renewable transport fuels but all renewable energy opportunities on farms. A rural green energy task force could be established to take the lead and bring on board industry and other commercial stakeholders.

It is hoped that this Report will be of interest to other influential bodies such as the House of Commons Rural Affairs Committee to assist them in their efforts towards the reduction in the carbon footprint of UK food production. There is a case for better coordination of the research and dissemination in this sector both in the UK and across the EU and RASE along with other stakeholder groups should seek to raise the profile of rural LCV transport.
Prospects for Community Energy

By the end of 2010, ‘community energy’ made up 40% of Germany’s total renewable energy capacity, largely through private citizens investing in energy cooperatives. A further 11% was owned by farmers and 14% by project developers, with the ‘Big Four’ utility companies only controlling a 13.5% share of the market. Community and shared ownership of wind turbines and increasingly solar PV installations are the most common forms.

In Denmark, the majority of wind turbines are wholly or jointly owned by citizens, communities, landowners and farmers. 150,000 households in Denmark owned or held shares in wind farm projects as far back as 2001.

Denmark and renewable energy and transport fuel strategy on farms:

‘The Danish Government has a goal of making the country independent of fossil fuels by 2050 as a response to rising greenhouse gas concerns, prices and energy security. The goal is also expected to create opportunities for economic and green growth. Part of the strategy is an ambition to increase biogas production and recharging stations for electric vehicles. Agriculture is covered in the strategy, with an aim for up to 50% of livestock manure to be used for energy purposes by 2020.

The Danish vision captures some of the opportunities to use hydrogen as the ‘bridge’ from power to heat and transport, and also importantly in conversion processes to produce liquid transport fuels. One of the strengths is ‘whole energy systems thinking’. This ‘whole system’ approach may be a key enabler to achieve the full potential from renewables, and also to maximise the commercial opportunities.

The Denmark vision fits well with the development of UK hydrogen policy for opportunities around: Integrating sustainable transport more fully into the energy system (with energy storage benefits), more distributed generation using renewables & high efficiency micro-CHP Hydrogen injection to the existing gas grid for partial decarbonisation linked to renewables load balancing, creation of stand-alone ‘hydrogen grids’ for Renewable Heat in town locations without gas grid and use of advanced gasification in ‘energy from waste’ process, such as Air Products in Teesside.

The vision for Denmark in 2050 considers all of the energy inputs and all of the energy outputs, but emphasises the multi-layered and integrated energy networks that enable the energy flows to be delivered in practice to the users as transport, heat, etc. The vision has a clear ‘whole system’ mind set which cuts through the traditional distinctions between energy, transport, heat etc. The driver for future change will be based on economic priorities. In particular, some of the conclusions about fuels for the transport sector and extensive use of electrolysers for ‘load-demand balancing’ and production of clean transport fuels such as methanol and dimethyl ether (DME) are relevant.’

‘Denmark 2020 Vision’ ~ Dr Nigel Holmes, CEO Scottish Hydrogen and Fuel Cell Association

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In the UK, the progress of small scale community projects such as wind turbines and solar PV has been affected by the Government’s degression review of FITs, particularly where external funding is required.

Plans for community supported renewable energy take time to develop if negotiation and consultation has to be undertaken with other bodies and planning permissions sought. They are particularly susceptible to changes in Government policy and incentives such as the FIT regime. The UK government’s first ever Community Energy Strategy (January 2014) recognises that community-led action can often tackle difficult issues more effectively than government alone.
Chapter 7: Prospects for AD

In a previous report\(^70\), RASE highlighted the role that anaerobic digestion – and specifically on-farm AD - could play in reducing greenhouse gas emissions, assisting more sustainable farming and noted the barriers and challenges that limited the take up of the technology. With biomethane being the most likely near-term renewable fuel alternative to diesel-fuelled tractors and farm machinery, AD deserves a separate chapter to inform, update and present opportunities for further investment in the technology and biomethane processing.

In 2010, the Agricultural and Horticultural Development Board (AHDB) produced ‘The Greenhouse Gas Action Plan (GHGAP) Framework for Action’\(^71\) which further emphasised the potential for AD to deliver multiple environmental benefits, including low-carbon energy, abatement of greenhouse gas emissions and stimulation of good nutrient recycling. The Plan reported that AD has a critical role in potentially delivering one-fifth of the abatement (by capturing methane lost from manures and slurries) required of the industry by 2020, if there is a widespread uptake of AD technologies.

The GHGAP reported that total UK manure and slurry arisings are about 90 million tonnes. The present processing capacity represents <5% of the UK’s potentially digestible waste (Defra, March 2010) and the UK Government had plans to increase generation from 170 MW to about 380-760 MW by 2020 (Defra, March 2010), particularly through the installation of farm-scale AD. However, processing a realistic proportion through anaerobic digestion may not be realisable unless a number of obstacles are overcome to justify the capital costs to individual farmers.

The anaerobic digestion (AD) sector can make a huge contribution to the low carbon economy, with the potential to meet over 10% of domestic gas requirements while creating 35,000 jobs, largely in manufacturing and engineering, and an industry worth around £2-3 billion to the UK economy.

AD integrates well into the farming sector, reducing methane emissions from slurry management and giving farmers an alternative revenue stream both through the energy they produce and from growing more valuable break crops. The digestate produced can be applied straight to farmland, enhancing the nutrient value over raw slurry, and reducing the need for artificial fertilisers. Artificial fertilisers currently contribute 1.1% of UK greenhouse gas emissions, making this another area where AD can deliver significant environmental benefits for Britain.

Source: *Anaerobic Digestion and Biogas Association ADBA, 2013*

Support for AD came from the Coalition Government Agreement issued in 2010 which stated that, “The coalition government has pledged to be the greenest ever, and anaerobic digestion can help us achieve this goal. We’re getting straight to work with industry, farmers, the financial sector and other experts who can help make it a reality.”\(^72\)

\(^{70}\) ‘A Review of Anaerobic Digestion Plants on UK Farms’ RASE; A Bywater


\(^{72}\) Lord Henley at the Anaerobic Digestion Round Table (July 2010)
The RASE report\textsuperscript{73} ‘Review of Anaerobic Digestion Plants on UK Farms’ produced by one of the authors of this current report made extensive use of case studies and concluded that smaller scale robust and simple AD plants with direct use of the biogas from the process might be the simplest and most cost effective option for most farmers. Many of the current AD plants are limited by economies of scale to larger farms or groups of farms and they need to show a good energy performance in order to justify their capital cost.

The Report includes detailed case studies of more than 20 operational farm-based plants. None of the studies indicated that any use was being made of biogas for transport use. The older farm digesters were adopted to improve slurry handling and some used heat for the dairy and farmhouse.

Co-digestion of agricultural residues such as manures, together with high-energy feedstocks such as food waste or silage is recognised as a way forward, but the growth of on-farm AD in Britain is held back by a number of factors. Amongst the obstacles have been finance, planning application delays and refusals, regulatory issues, connections to the grid networks for gas or electricity and clear and consistent Government incentive policies.

Biogas energy from AD is more established in mainland Europe, with over 5000 plants in Germany\textsuperscript{74} and substantial numbers in Austria and Sweden. However, the data for farm based anaerobic digestion in the UK varies according to source. The Official Information Portal on Anaerobic Digestion (biogas-info.co.uk) states that there were 78 AD in operation in the UK in July 2012 and that this figure had risen to 106 by March 2013, with more than 12 more under construction. Nearly half were reported to be ‘community’ digesters using predominantly food waste from multiple sources, 30\% used ‘agricultural’ feedstocks and the rest were ‘industrial’. The ‘agricultural’ category covered anaerobic digesters using slurries, manures and crop residues produced on-farm. In September 2013, the portal included 125 AD sites, of which 52 were agricultural CHP sites and 2 were Biomethane to Grid plants. None are upgrading to biomethane for transport use.

Rainbarrow Farm, Poundbury, Dorset opened in November 2012 and was the first fully operational commercial scale AD plant in the UK to inject biomethane directly into the gas grid on site. The supplier was Future Biogas Ltd/Agraferm Technologies. One of this Report’s sponsors, Scotia Gas Networks, is a major stakeholder in the project.\textsuperscript{75} This case study is expanded later in this Report. A further Biomethane to Grid plant at Springhill Nurseries Ltd with Vale Green Energy in Worcestershire was commissioned in 2013.

\textsuperscript{73} ‘A Review of Anaerobic Digestion Plants on UK Farms’ RASE; A Bywater
\textsuperscript{74} (Renewables 2010 Global Status Report)
\textsuperscript{75} http://www.princeofwales.gov.uk/media/press-releases
Biogas upgrading

Whilst there is both documented and undocumented evidence of biogas being used as a vehicle fuel during the war, there has been very little sustained or commercial effort at upgrading the biogas until relatively recently.

In the late ’70s and early ’80s, Farmgas, the UK’s largest anaerobic digester technology providers of that era decided to look at upgrading technologies in New Zealand. At the time, New Zealand had a nascent, but thriving program of anaerobic digester building and gas use technologies, with much of the drive behind this coming from Dr David J Stewart at the Invermay Agricultural Research Centre in Mosgiel.

Based on the knowledge obtained from New Zealand by Tim Clarke, Farmgas engineer James Murcott built a water scrubbing system in 1985 using biogas from the Bishop’s Castle abattoir digester and successfully ran his converted Renault 9 on the gas until the site had to be cleared for expansion of the factory. He built two further similar systems in the early 2000’s.

Avonmouth (Wessex Water’s Bristol sewage treatment works) now produces around 18 million cubic meters of biogas, producing 40GWh a year of electricity. Geneco, the company set up to effect Wessex Water’s aspiration to be carbon neutral by 2020, also started to take food waste into the AD plant at the end of 2012. They are now running a converted VW Beetle, the ’Bio-Bug’ on upgraded biomethane, demonstrating that the vehicle can run for a whole year on the sewage waste from just 70 homes.

The opportunity to look further into the technology and practicality of upgrading biogas into biomethane for direct use into a light commercial van has been provided through a WRAP Driving Innovation in AD (DIAD) award to Evergreen Gas in 2013.

Biogas upgrading methods

Currently, there are a number of commercially available methods used to upgrade biogas, each of which has different operational considerations and costs. These include:

- Amine scrubbing
- Pressure swing adsorption (PSA)
- Scrubbing using membranes
- Organic scrubbing
- Water scrubbing

A recent WRAP DIAD report (see below) assessed three of the different upgrading technologies that are currently available. Two of the processes employ water scrubbing and the third uses a variant of pressure swing adsorption. While upgrading biogas to biomethane for grid injection can benefit from an economy of scale in regard to energy and capital cost, a purpose-built unit for production of vehicle fuel might be an attractive option to a farm-scale AD installation.

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**DIAD Small Scale Gas-to-Vehicle Case Study (Evergreen Gas)**

In 2011, Michael Chesshire and Will Llewellyn founded Evergreen Gas in order to develop a range of small modular farm anaerobic digester systems. They are one of a small but growing number of companies investigating the prospects for ‘gas-to-vehicle’ solutions.

As part of the first WRAP DIAD (Waste Resources Action Program Developing Innovation in Anaerobic Digestion) programme, Evergreen Gas assessed three different biogas upgrading technologies from Finland, the UK and India. These systems were from Metener Oy, Chesterfield Biogas and Green Brick Eco Solutions (GBES), respectively.

The Finnish system was selected, with the demonstration upgrade plant processing a biogas flow rate of 10m³/hr and costing in the region of £135K. This plant is installed at the Barrett’s Mill Anaerobic Digester (BMAD), Evergreen Gas’s 50m³ small-scale anaerobic digestion demonstration plant near Ludlow in Shropshire. Evergreen Gas are selling Metener upgrade units under license in the UK and Ireland.

Anaerobic digesters need heat and electricity to operate so the Evergreen Gas feasibility study found that it was most cost-effective to use the majority of biogas produced to run a CHP to provide the digester heat and electricity for export, with a small amount of gas being ‘side-streamed’ to the upgrading plant to produce vehicle fuel.

They concluded that, if done properly, the economics of upgrading could work well, even with a small farm biogas plant. Where excess biogas is produced by a larger plant which borders a FIT band (i.e. 249kWe or 499kWe), it may very well make economic sense to side-stream and upgrade this gas, instead of purchasing a larger CHP, a second CHP or simply flaring it. This economic case can be further strengthened where a gate fee is involved, since side-streaming both maximises the value of this excess gas and maintains the plant feeding rate and thereby, the gate fee income.

**Biomethane upgrading – system and process**

The Metener upgrading system arrives in a 6.5m container, complete with scrubbing columns, high pressure compressor, storage cylinders and a vehicle refuelling system. A limited amount of assembly is required on site, mainly for the tall scrubbing columns. The system is available in single or 3 phase configuration, and just needs to be connected to water, biogas and electricity supplies. The space in the container provides a reasonable amount of work space for servicing and maintaining components. The process is automated, but the operator can change a number of parameters, such as the percentage of methane in the upgraded gas.

The system used by Evergreen Gas can upgrade 10m³/hr of raw biogas, but it can easily be expanded to 30m³/hr. 10m³/hr of biogas equates to approximately 5m³/hr of vehicle fuel, depending upon the methane content of the biogas. Overall, approximately 90kg of biomethane can be produced per day. The digester is a 50m³ demonstrator which is fed with a combination of pig slurry and grass silage. It has a comparatively large 100m³ gas holder, in order to provide maximum operational flexibility for the plant. There is also a 7kWe CHP on-site, so that biogas can be used for electricity generation and digester heating, with gas being ‘side-streamed’ as necessary in order to provide vehicle fuel.
The Metener “Low pressure” upgrade process uses standard low-pressure water scrubbing technology centred on a pair of water scrubbing columns that alternate between filling and discharging phases. The columns, which are filled with a packing media, are pressurised using widely-available components for ease of maintenance. The water used does not have to be mains water; for example, recycled rain water can be used to top up the system. A 1m$^3$ International Bulk Container (IBC) acts as a buffer in order to recirculate some of the water used in the upgrading process. Repeated re-use of this water apparently reduces its efficacy and part of the Evergreen optimisation programme is to try to ascertain how often the water can be re-used. As the water is re-used in the upgrading process, it becomes very slightly acidic, so should be discharged according to local regulations.

Raw biogas is compressed to between 4 and 10 bar and enters the bottom of the first scrubbing column, which also has water being sprayed in from the top of the column. This continuous counter-flow of water and biogas continues, with purified biogas continuously flowing out from the top of the column. The water enters a flash column where any dissolved gases are desorbed when the pressure is reduced, with the methane preferentially being released back into the front end of the system, leaving the carbon dioxide and hydrogen sulphide in the water. Once de-pressurised, the water flows back into the IBC buffer tank. It is cooled before it is returned to the scrubbing cycle.

The methane flowing from the top of the scrubbing column can optionally go for further upgrading into a second scrubbing column but, in any case, will finally be passed through a desiccation cylinder in order to remove moisture. It can also be passed through a bio-filter to remove as much residual hydrogen sulphide as possible. Finally, the gas is compressed to 250 bar and will either go directly into a vehicle or into storage tanks.

**Illustrative economics of biomethane upgrading**

Whilst water scrubbing can be built to any size, the Metener low pressure upgrading system is available in two sizes: one which can upgrade 10m$^3$ of biogas per hour and one which can take 30m$^3$/hour, sizes which should suit a wide variety of farm situations.

When the macro economics of biogas use are considered, unless the CHP heat can be beneficially used, only about 28% to 42% of the energy will be converted to electricity, depending upon the size and electrical efficiency of the CHP.
This means that up to 72% of the energy potential of the biogas can be wasted, if the heat is not used. If the waste heat from the plant is not used and needs to be dumped, this adds an extra expense. Part of the CHP heat is used to heat the digester; however, it could be argued that any biogas over and above that used for digester heating could more profitably be redirected or ‘side-streamed’ for biomethane upgrading.

In terms of feedstock, the ‘side-streamed’ biogas required to run a 10m$^3$/hour upgrading plant could be produced from the daily slurry production from around 200 dairy cows or slightly over 1.1 tonnes per day of a feedstock such as maize. For the purposes of comparison, the following illustration assumes that a CHP would run 8000 hours a year, as would the biomethane upgrading plant although, in practice, the operational up-time of the biomethane plant would depend upon a number of factors, including the available storage capacity and the vehicle usage patterns.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Fuel usage</th>
<th>Weekly Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercedes Sprinter Van</td>
<td>7 miles/kg</td>
<td>4,549 miles/week</td>
</tr>
<tr>
<td>VW Caddy Van</td>
<td>10 miles/kg</td>
<td>6,499 miles/week</td>
</tr>
<tr>
<td>Valtra N101 dual fuel tractor</td>
<td>8 kg/hr biogas + 2.2 l/hr diesel @70%-80% loading</td>
<td>~81 hrs/week</td>
</tr>
</tbody>
</table>

Table 1 - Weekly vehicle usage from a 10m$^3$/hr upgrading plant

Table 1 lists the number of miles which could potentially be driven on the biomethane from a 10m$^3$/hr upgrading plant. The figures are calculated on the assumption that the biogas is 60% methane, such as that coming from cattle slurry. Should the percentage methane content per cubic metre of the biogas be lower, as is usually typical from feedstocks such as maize, the mileage which could be driven would be commensurately reduced. Nevertheless, assuming that a VW Caddy, for example, is driven every day of the week, the daily mileage would be about of 928 miles, an impressive distance. Should this same quantity of biogas be used in a small CHP, approximately 20kWe of electricity would be produced on a continuous basis, depending upon the efficiency of the CHP. Bearing in mind that the smallest anaerobic digestion Feed-In Tariff band is for <250kWe CHP, one could perceive that, in relative terms, hardly any electricity is being produced when compared with the large mileage which could be driven using the same amount of fuel. For example, the Evergreen Gas ‘rule of thumb’ is that the gas from 1 tonne of cattle slurry can fuel a vehicle such as a VW Caddy for 100 miles.
Illustrative Economics – Biomethane Upgrading (DIAD Evergreen Gas)

<table>
<thead>
<tr>
<th>Cost of fuel (petrol/diesel)</th>
<th>£/litre</th>
<th>£1.40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles driven</td>
<td>miles/yr</td>
<td>337,928</td>
</tr>
<tr>
<td>Fuel costs saved</td>
<td>£/yr</td>
<td>£67,002</td>
</tr>
<tr>
<td>LESS HMRC duty</td>
<td>£/kg</td>
<td>£0.3445</td>
</tr>
<tr>
<td>Total HMRC duty</td>
<td>£/yr</td>
<td>£11,641</td>
</tr>
<tr>
<td>Total fuel costs saved less HMRC duty</td>
<td>£/yr</td>
<td>£55,360</td>
</tr>
</tbody>
</table>

Table 2 - Illustrative economics of biomethane upgrading on the 10m³ system

In Table 2, it can be seen that a vehicle such as a VW Caddy Van could use the 650kg of biomethane produced every week by the 10m³ system in order to drive nearly 338K miles a year, saving a gross figure of slightly over £67,000. However, unlike biodiesel production, where a certain amount can be produced free of tax, and electricity, which is not taxed as a fuel, biomethane attracts duty from the moment it is produced. The effects of this are illustrated above. It should be noted that, as this is a relatively new technology for HMRC, it can be quite challenging trying to ascertain how the remittance process works.

As already noted, the quantity of the biogas being side-streamed would be roughly equivalent to 20kWe on a continuous production basis. It can be seen from Table 3 that the FIT income for this quantity of biogas would be in the region of £31,456, assuming a CHP efficiency of approximately 34% This illustration also assumes that the electricity would have been exported – if the electricity were used on-site, the savings would be higher: if the electricity replaced cost £0.10/kWh, the value received/saved would be slightly more than £40,000.

<table>
<thead>
<tr>
<th>CHP size</th>
<th>kWe</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP up time %</td>
<td>%</td>
<td>91%</td>
</tr>
<tr>
<td>FIT value</td>
<td>£/kWh</td>
<td>0.1516</td>
</tr>
<tr>
<td>Export tariff</td>
<td>£/kWh</td>
<td>0.045</td>
</tr>
<tr>
<td>FIT income</td>
<td>£/yr</td>
<td>£31,456</td>
</tr>
</tbody>
</table>

Table 3 - Equivalent FIT income from biomethane upgrading

There is, however, an operational cost for biomethane upgrading in terms of electricity and water used by the process. Table 4 looks at the potential costs for these. The electricity usage of the Metener high pressure biogas upgrading system is 0.9 - 1.0 kWh/kg of gas upgraded and pressurised, requiring water of about 0.02 - 0.03 m³/kg of gas produced. The maintenance costs for that system are in the region of £0.033 – 0.066 Euros/kg of upgraded and pressurised gas. It can be seen that the figures below are on the conservative side, but part of the Evergreen Gas DIAD initiative aim is to reduce these operating costs as much as possible by optimising both electricity and water usage.
For the purposes of simplicity, Table 4 uses an electricity cost of £0.10, with the water cost being taken from Thames Water metered charges of £1.2843/m³ plus £0.7041/m³ for the waste water: the effect of fixed charges has not been taken into account.

<table>
<thead>
<tr>
<th>Potential Yearly Operating Expenditure of a 10m³/hr biogas plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity consumption per kg upgraded</td>
</tr>
<tr>
<td>Electricity cost</td>
</tr>
<tr>
<td>Total electricity cost</td>
</tr>
<tr>
<td>Water consumption per kg upgraded gas</td>
</tr>
<tr>
<td>Yearly water consumption per kg upgraded biogas</td>
</tr>
<tr>
<td>Water cost</td>
</tr>
<tr>
<td>Total water cost</td>
</tr>
<tr>
<td>Misc operating and maintenance costs</td>
</tr>
<tr>
<td>Total yearly operating costs</td>
</tr>
</tbody>
</table>

Table 4- Potential yearly operating expenditure for a 10m³/hr biogas upgrading plant

A simple payback is calculated in Table 5, which simply divides the income into the capital expenditure. Again, it assumes that the vehicle used is the VW Caddy which, at 10m/kg fuel economy, makes a nice comparator. The first two lines of Table 5 ignore the effect of the operational expenses (gross income), with the second two lines including these operating expenses in the calculation (net income). It can be seen that the largest effect is due to tax which, at the proposed capital expenditure of £150,000, adds nearly a year onto the payback period.

| Simple payback no opex, no HMRC                                | yrs | 2.24 |
| Simple payback no opex, incl HMRC                             | yrs | 2.71 |
| Simple payback incl opex, no HMRC                             | yrs | 2.95 |
| Simple payback incl opex, incl HMRC                           | yrs | 3.82 |

Table 5- Calculation of simple payback for 10m³/hr biogas upgrading plant

As this system is in its infancy in the UK, the capital cost may vary, as units are sold and engineering efficiencies made. In addition to capital cost, the economics of such systems are based on the background fossil fuel prices that the biomethane replaces. In the graph below, the red lines show the effect of replacing fuel at £1.20, with the green and blue lines illustrating the effect of fuel at £1.40 and £1.60, respectively. Taking just the tax paid figures into account, the shortest payback of just over 2 years is for a £100,000 upgrading system take against background fuel prices of £1.60/l, with the longest payback not surprisingly found on a high capex £200K system against low fuel price of £1.20: 6.74 years.
However, it should be remembered that the biogas to be upgraded comes from side-streaming the gas from an AD plant and that this analysis does not take into account the capital expenditure of that original biogas plant. Therefore, any individual economic assessment would need to take into account these further costs. There is no doubt that this is a capital intensive operation but, especially where slurries, manures, food waste and other organic by-products and co-products are used in the process, the larger value of anaerobic digestion to GHG reduction, nutrient recycling and pollution mitigation makes this a unique and valuable contribution to the range of renewable energy technologies.

### Biogas networks – the potential for ‘Gas-to-Grid’

In addition to being compressed and used as a vehicle fuel, biomethane can also be injected directly into a gas grid (‘Biomethane-to-grid’ BtG). The gas grid can be part of the national natural gas network or part of a local gas network. Once in such a network, the gas can be easily transported from where it is produced to where its energy potential can be used – for heating, power generation or as transport fuel.

Currently the Renewable Heat Incentive (RHI) is the key driver for grid injection, although this scheme is at an early stage and regulations are developing rapidly. The RHI rewards developers for each kWh of renewable gas injected (7.5p/kWh April 2014). A green gas certification scheme[^77] can also add value as a corporate reporting point of view for the industry.

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[^77]: [www.greengas.org.uk](http://www.greengas.org.uk)
Green Gas Certificates

The Green Gas Certification Scheme (GGCS)\(^{78}\) was set up by CNG Services Ltd along with six other companies including National Grid, Eon, Centrica and Bio Group. The scheme is run by the Renewable Energy Assurance Ltd (REAL), a subsidiary of the Renewable Energy Association and works on the basis that each unit of green gas injected into the grid displaces a unit of fossil-derived natural gas. The GGCS tracks each unit of green gas from its injection into the gas grid to its sale to a consumer. It monitors the contractual rather than physical flows to ensure there is no double-counting of the gas.

The Biomethane Certification Scheme (BMCS). Green Gas Trading Limited (‘GGT’) was set up by ADBA\(^{79}\), ADBA members and other environmental investors to provide a credible process for certificating biomethane but most importantly to facilitate the trading of certificates to ensure producers get maximum value for their biomethane. The BMCS scheme, based on the EU’s most widely used certification system, allows biomethane producers to evidence their “green gas” production, whether they are injecting it into the gas grid or simply compressing it for direct use as a transport fuel, for example on farms. GGT’s easy to use web-based trading platform allows producers to sell their certificates into a wide marketplace of interested buyers. For more information visit [www.greengastrading.co.uk](http://www.greengastrading.co.uk), call 07951 240728 or email info@greengastrading.co.uk.

Biomethane – Grid or Transport Fuel?

The concept of ‘closed loop’ systems for use of biomethane directly as a transport fuel is technically possible but unlikely to be a viable option for most situations including farms, according to John Baldwin, MD of CNG Services Ltd. John advocates a ‘biomethane-to-grid’ option where biogas upgraded to CNG quality is injected into the gas grid from where it can be used as a transport fuel at any CNG filling station in the UK. This is likely to happen for large biogas producers with direct access to the grid pipeline, working in association with gas grid companies to facilitate and manage connection. In a recent interview by the National Non Food Crop Centre (NNFCC)\(^{80}\), John responded as follows:

“Using biomethane directly in trucks is not practical in most cases. The trucks are not located at the AD plant and even if they were, trucks need a ‘lumpy’ supply of gas, not well suited to a natural process like AD. So in the UK, as well as in all other countries apart from Sweden (which does not have much of a gas grid), biomethane will be used via the REAL Green Gas Certification Scheme. Already CNG is sold at the UK’s largest station in Crewe with a Green Gas Certificate.

In Germany, which has gone down the CNG for cars route, there are 950 CNG filling stations, more than half sell biomethane via certificiates. There are very few vehicles that actually run on biomethane.

The Lille biomethane buses are famous – 350 of them – but the biomethane goes into the grid and comes out 300m away. Another practical reason is that the gas grid never fails to supply so buses, which need 100% reliable gas, have to connect to that and cannot rely on biomethane which will be down for maintenance at times.”

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\(^{78}\) CNG Services Ltd.  
\(^{79}\) ADBA farm consultancy service [http://adbiogas.co.uk/about-adba/third-party-services/farmers-consultancy-service](http://adbiogas.co.uk/about-adba/third-party-services/farmers-consultancy-service)  
\(^{80}\) NNFCC Newsletter 31 Spring 2014
Do you see biomethane to grid as a viable option for farm scale anaerobic digestion in the future only in comparison to electricity only?

“At present, it is generally uneconomic to utilise biogas to-grid (BtG) for AD plants operating at a biogas flow rate of below 400m3/hr.

However, work is underway to reduce all the costs associated with biomethane upgrading and it could be possible for this process to be economic at 200m3/hr of biogas, equivalent to that of a 400kWe AD plant.

If further changes are made by OFGEM to recue the cost of energy measurement it may even be possible for plants operating at 50m3/hr to be viable.”

For those AD plant operators located some way from an accessible gas grid pipeline – as is the case with many farm situations – then other options may be developed involving collection of biogas from farms with centralised gas clean up and grid injection – as outlined in the Scotia Gas Network’s illustration below:

**Case Study: Scotia Gas Networks**

Scotia Gas Networks (SGN) is one of the country’s leading authorities in so-called 'green gas' and biogas development, acting as both the regulated gas network transporting gas and also through a commercial business to provide the services and manage the process of treating biogas and injecting it into the network.

SGN’s long term strategy is to increase the volume of 'green gas’ entering the network from many different sources, including sewage, food waste and energy crops. SGN is part of the group of companies that worked together to inject the first green gas into the UK gas network at Didcot in Oxfordshire. This project used biogas from a waste water treatment works. The company is undertaking innovative works on a number other green gas projects.
The concept of a biogas network where access to centralised biogas upgrading and biomethane injection facilities, or more favourably centralised CHP facilities, exists in the Netherlands and Sweden and could be used in the UK to enable a greater number of biogas producers to make more efficient use of biogas.

**Case Study: Greener for Life in Cornwall**

Greener for Life is a specialist company created by farmers and other associated partners. The GFL management team has recognised the business potential of on-farm AD with the added value of clusters and gas grid injection.

Greener for Life has had a project approved to construct a biomethane and electricity to grid anaerobic digestion facility in Fraddon, Cornwall which is expected to produce enough gas and electricity to supply the equivalent of over 2,500 homes each year.

The plant will convert organic materials including local food waste and agricultural waste, into gas and electricity to be injected into the gas grid and also potentially be available for vehicle fuel in a highly rural area.

Further AD cluster projects are being planned to provide a gas to grid pipeline within Cornwall.

**Case Study: National Grid**

National Grid has commissioned its first commercial biogas plant, linking an £8m anaerobic digestion scheme near Doncaster to the network.

The facility by biomass operator Future Biogas will ferment 35,000 tonnes of farming break-crops including maize and grass per annum to produce biomethane. Its output is now being injected into the gas grid in South Yorkshire.

**Case Study: Rainbarrow Farm, biogas to grid**

Rainbarrow Farm, Poundbury, Dorset opened in November 2012 and is the first fully operational commercial scale AD plant in the UK to inject biomethane directly into the gas grid on site.

The 5 MW anaerobic digestion plant is owned and operated by J V Energen as a joint venture between local farmers and the Duchy of Cornwall. The plant will use 41,000 tonnes per year of maize, grass silage, potato waste and organic waste provided by local farms and businesses to produce around 400 m³/hr of 96 per cent pure methane. The biogas is cleaned, mixed with propane and an odoriser and injected into the local gas grid.

Biogas production began in March 2012 with the commissioning of the CHP plant and injection to the gas grid (approximately 1.5 km away) began in October 2012. The plant is a joint venture – JV Energen LLP – between JV Farming Ltd, the Duchy of Cornwall and ABP Ltd. The AD provider was Agraferm. The Grid Entry Unit supplier was Scotia Gas Networks.

A video link explains the scheme: [https://www.sgn.co.uk/Greening-the-gas/](https://www.sgn.co.uk/Greening-the-gas/)

81 http://www.princeofwales.gov.uk/media/press-releases
Innovative thinking on the challenges of small scale biogas production and ensuring economic scale and viability, including the development of Biogas Energy Centres, has begun. A feasibility report\(^\text{82}\) on the potential for biogas networks was submitted to WRAP in November 2013\(^\text{83}\). A funding application followed for a demonstration project to demonstrate the business case of establishing biogas networks. This involved a number of biogas generating sites including dairy farms in the North West of England connected via a network of biogas pipelines to a centralised upgrading or combustion facility.

Although the concept is proven in the Netherlands and Sweden, the feasibility report states that different regulatory and political conditions within the UK mean that a specific feasibility assessment is required here, in order to understand the potential scale and impact of the biogas network concept, and any regulatory or technical issues that may arise.

**AD and nutrient recycling of food waste to farmland**

In a circular economy, the aim should be to recycle nutrients from food wastes, food processing residues and other organic by-products in urban areas back to farmland in order to grow more food. However, whilst the theoretical return of nutrients back to growing land is easy, in practice, a number of obstacles present themselves. Contamination with materials not suitable for anaerobic digestion require expensive sorting, segregation and pre-conditioning equipment which is beyond the budget and operating remit of the average farm digester.

There is also a requirement to macerate and pasteurise the organics, in order to comply with Animal By-Product (ABP) regulations. If these nutrients are to be returned to farms, this pre-treatment could be carried out at a central Hub, with the organics being taken to farm digesters (PoD - Point of Digestion) for energy recovery and, ultimately, the return of nutrients and carbon to the farmland. This is known as Hub and PoD anaerobic digestion.

In this model, anaerobic digesters in rural areas surrounding cities are not only able to effectively recycle food nutrients back to land, they are also able to supplement existing farm feedstocks such as slurries, manures and other residues. This improves digester economics and produces energy which can be used in a variety of ways. If the AD owner decides to upgrade the biogas to biomethane, there are a number of options for the energy use, if the biomethane cannot be injected into the local gas grid.

On many such sites, biogas could be upgraded to biomethane and used to re-fuel compressed natural gas (CNG) vehicles. As outlined earlier in this Report, these vehicles could be farm vehicles, such as tractors and trucks, they could be vehicles owned by rural communities or they could be vehicles which regularly visit the farm, such as those which transport milk or other farm products. The challenge with this scenario is balancing fuel production with fuel use, especially as the latter can be variable and dependent upon a number of factors. Two similar solutions are being trialled and are described in the case studies in this report.

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\(^{82}\) NNFCC with CNG Services Ltd

\(^{83}\) Potential for biogas networks in the UK, funded by the WRAP Driving Innovation in AD round II programme

Project code: OIN001-010 Research date: Jan - May 2013 Date: November 2013
The research carried out by Evergreen Gas and referred to earlier in this Chapter, uses a small biomethane upgrading plant in conjunction with a combined heat and power (CHP) plant in order to provide maximum flexibility of gas use. Other companies are now beginning to emerge in this sector.

Another case study referred to earlier, the Scotia Gas Network’s Portsdown Hill hub, builds on this scenario. In this instance, one or more CHP plants are installed on farm AD plants, with a proportion of biomethane upgraded and compressed into large tanks. Using this model, more biomethane can be side-streamed by shutting down one or more CHPs and redirecting the gas to the biomethane upgrading unit. The use of multiple CHPs on their own is becoming increasingly common, as it has a number of advantages, not least of which is the ability to still produce energy should a CHP require shutting down for maintenance. The use of a biomethane upgrading plant also means that energy could still be captured for use should a CHP be down for maintenance.

However, the Bio Collectors/SGN case study actually illustrates what is effectively a double Hub and PoD system: an organics treatment Hub to Point of Digestion coupled with a biomethane Hub to Point of Deployment, since upgraded biomethane from several facilities can be taken to a central hub. Here, the biomethane can then be injected into the gas main which is a cost-effective and flexible energy transport mechanism.

Biomethane produced on a farm, say in Sussex can be flexibly deployed anywhere in the network: from home heating by a household in Edinburgh, to vehicle fuel in a transport firm in Andover or even to a home vehicle re-fuelling compressor in Weymouth. In this scenario, the gas supply and demand control systems are then carried out by existing technology inherent within the gas network.

A further variation on the “farm-AD / rural energy” relationship can be illustrated by a third case study, the ‘virtual gas pipeline’.

Many rural areas do not have access to relatively cheap natural gas and therefore need to buy a more expensive form of energy, usually fuel oil. In the virtual pipeline model, biomethane or natural gas can be compressed into large trailers or ‘cassettes’ which can be delivered to an individual customer or even to another kind of hub, which provides a source of gas for a standalone rural gas network. The third case study describes the virtual pipeline that CNG Services Ltd has created at their Crewe CNG filling station.

This system is flexible. As biomethane can be produced at one or more farm AD plants within a reasonable distance of each other and transported or piped to the standalone hub or supply point for the rural off-grid network. In the case of over-production of biomethane, cassettes can be removed and taken to a mains injection point such as Portsdown Hill; if local demand is in danger of exceeding biomethane supply, such as during winter cold spells, a natural gas cassette can be “plugged in” to supplement the supply.

The economics of such systems described above depends on a number of variables. The Hub and PoD model is dependent upon the value of the product being transported (pasteurised organics or biomethane) versus the distance it needs to be transported.

**Case Study – Bio Collectors and Scotia Gas Networks double Hub and Pod**

Bio Collectors provide a low cost food waste collection service from London, Greater London, Surrey, Croydon and Essex, informing customers of the quantities collected, so that they are able to reduce wastage by both reducing their bill for purchasing the food and the charge for disposing of the waste.

These organics are taken to a 70,000 tonne/year Autothermal Thermophilic Aerobic Digestion (ATAD) plant located at Mitcham in Surrey where any necessary de-packaging takes place, along with removal of any inorganic materials. The material, suitably macerated, is then put through the ATAD treatment process, effectively pasteurising the material which ends up as a liquid product, suitable for further treatment at the plant. However, it is also potentially a very good feedstock which could be taken from the Mitcham hub to a number of biogas pods within a reasonable travelling distance, in order to return the nutrients to land via the farm AD plants.

This Hub feedstock (“Hubstock”) is advantageous from the farmers’ point of view, as they are not as exposed to the cost or risk associated with purpose grown crops. Additionally, their anaerobic digester system design can be farm-based and extra capital investment in expensive pasteurisation, de-packaging and maceration equipment does not have to be made, since the product has been sufficiently treated in order to both remove this expense from the pod and to satisfy potential biosecurity issues.
The ATAD feedstock has a dry matter content of between 12 and 14% with 88-89% volatile solids and is capable of generating 80m$^3$ biogas per tonne of dry solids. A number of studies have shown that co-digestion of food waste and slurries provides a good, stable digestion process and better gas production than mono-digestion of any feedstock (particularly food waste), which often lacks micro-nutrients essential to the process.

Farm AD plants relatively local to the Mitcham organics treatment hub could use their biogas in any number of ways; however, in March 2013, following on from their innovative biomethane injection facility at Poundbury, Scotia Gas Networks (SGN) signed a contract with Crouchland Biogas Ltd. This plant, potentially four times the size of Poundbury, and relatively local to Mitcham, will be producing biomethane which will be transported to SGN’s new biomethane injection hub, located at Portsdown Hill near Portsmouth.

At Portsdown Hill, the biomethane will be blended with mains gas and injected directly into the local gas distribution network, using environmentally-friendly, cost-effective, pioneering technology which removes the need to add fossil-based propane during the process. SGN assert that biomethane to grid efficiency is at least 50% more favourable than electricity and that such a project has a positive effect in helping the UK meet its 2020 carbon reduction targets.

In addition, they have identified a number of further benefits, including:

- removing the need for such AD units to be near a suitably large gas network, with all the potential associated planning difficulties and costs
- allowing ‘off-grid’ AD plants to access a biomethane injection Hub, but without the associated capital and operational expenditure of biomethane injection, thereby providing a realistic alternative to CHP in terms of cost-effectiveness
- the ability to optimise operational gas network flexibility and availability by retaining control of the injection process
- developing a specification and design to support virtual pipeline transmission.

Whilst the initial contract is with one biogas plant, the biomethane injection Hub is designed to take upgraded biogas, compressed to 250 bar and transported in Class 1 high pressure trailers, from a network of off-grid or connection constrained anaerobic digesters and inject it into the gas network at 28 bar.

This double hub and pod model, with its organics treatment hub at the front end, a biomethane injection hub at the back end and a network of digesters in the middle is an effective demonstration of how nutrients from urban organic concentrations can be effectively recycled back to farmland through farm anaerobic digesters, with the energy being returned to a flexible distribution network in a cost effective way.

**Anaerobic digestion – options for the food industry**

There is increasing potential for smaller-scale Anaerobic Digestion (AD), both on-site for food businesses and at smaller-scale “merchant” AD sites located around the country. The latter will enable more businesses to send their food residues to a local site, particularly in more remote areas. Also, larger businesses could benefit from building their own plant.
Businesses in the food processing and catering sectors are being urged to reduce energy use, their carbon footprint, water consumption and their wider environmental impact. Anaerobic Digestion (AD) can help address these issues but many food businesses are unaware of the potential benefits.

DEFRA and bodies such as WRAP are taking a greater interest in the potential for smaller scale AD plants installed where bio-waste is generated - on farms, in communities and on industrial sites. Smaller plants offer an alternative to large scale “merchant” AD sites that are less suited to handling liquid feedstocks and can involve transporting residues to distant locations, exporting energy value.

**Case Study: BV Dairy – Onsite AD food industry demonstration plant**

Dorset-based BV Dairy processes milk from local farms into yoghurt and soft cheese and supplies food manufacturers and food service customers across the UK. In 2012, BV Dairy supplied dairy products to the Olympics. Clearfleau’s on-site anaerobic digestion (AD) facility was supported by a WRAP fund to stimulate investment in innovative anaerobic digestion.

**Key Features:**
- Limited footprint / on-site installation
- Bio-secure – treats site feedstocks
- Biogas energy for production process

**Benefits for Dairy Sector:**
- Generation of renewable energy
- Lower waste treatment charges
- Reduced energy consumption

**Low carbon transport Implications:**
- Farms could supply biogas to factory
- Fuel for milk collection ‘closed loop’
- Bio-methane for on-site vehicles

Although smaller scale digestion may not generate large volumes of energy, they offer other benefits, including cutting green-house gas emissions and more efficient handling of residues. Also, smaller businesses can supply residues to local AD plants or even work with others to develop shared facilities. British companies are developing smaller plants to digest food residues and other feedstocks. In Scotland, by 2016, all food residues will be excluded from landfill.

**Opportunities for Food Service and Catering**

Food service companies, caterers and pub and coffee shop chains, as well as SME food processors and restaurants, cafes or pubs produce residues with excellent biogas potential. There are a number of initiatives, involving British companies, developing solutions that should help meet the needs of this sector. These include various off-site and on-site applications for smaller scale digestion.
Companies like Olleco have developed regular collection of smaller volumes of degradable wastes. This could be combined with smaller AD solutions, particularly in rural areas. With Scotland banning food waste to landfill from smaller businesses by 2016, more effort must be made to develop local solutions - working with British AD technology providers. An interesting model for smaller community based “merchant” AD has been developed at Llangadog in west Wales, where a local waste site now has a small scale AD plant.

**Case Study: Olleco food and catering collection – small-scale merchant**

<table>
<thead>
<tr>
<th>Key Features:</th>
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<tbody>
<tr>
<td>- Collection of all degradable waste</td>
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<tr>
<td>- Dedicated collection trucks</td>
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<td>- Renewable energy generated</td>
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<tr>
<th>Customer benefits:</th>
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<tr>
<td>- Guarantee not to use landfill</td>
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<tr>
<td>- Cost effective and sustainable solution</td>
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<td>- Access to AD and carbon reduction</td>
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<table>
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<tr>
<th>Low carbon transport Implications:</th>
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<tr>
<td>- Collection vehicles driven on biogas</td>
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<tr>
<td>- Small gas converter on merchant sites</td>
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<tr>
<td>- CO$_2$ reduction of collection system</td>
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Some on-farm AD plants are capable of taking food waste from the local area, but it is hard to permit them for food residues. The “Hub & PoD (point of digestion)” approach offers centralised pasteurisation, prior to farm delivery of feedstock. But, in more remote areas, direct waste supply would be more efficient. Another option is installation of pre-digestion “homogenisation” units on retail and catering sites, so that pre-treated feedstock can be uplifted and supplied to a local AD plant.

On-site AD provides a number of benefits for food businesses, apart from lower energy and treatment costs but will not suit all sites. Clearfleau is one company developing a modular approach to on-site AD, with smaller capacity units able to handle under 60m$^3$ per day of liquid residues and supply biogas to a boiler or micro CHP unit. This approach could involve collaboration with feedstock collection partners.

Local, smaller scale and on-site solutions deserve wider recognition in the food and drink industry, also within government and from regulatory bodies, as changes are needed to facilitate local treatment of bio-degradable residues. With the ability to convert biogas into bio-methane this offers another option for use of the biogas from food sector AD plants.
**Case Study: Nestlé Confectionery, Fawdon, Newcastle – On-site Industrial**

Clearfleau’s on-site AD plant converts wash waters and confectionery production residues into biogas, used to generate renewable electricity for the factory. Power output is 300 kW and the recently completed facility is located on the edge of the factory’s car park. This is an urban site but other factories are located in rural areas and transport fuel may be an option.

<table>
<thead>
<tr>
<th>Key Features:</th>
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<tbody>
<tr>
<td>- Limited footprint / on-site installation</td>
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<tr>
<td>- Closed loop system – avoids odour</td>
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<td>- Integral solids dissolution process</td>
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<tr>
<th>Benefits for Food Processors:</th>
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<tr>
<td>- Revenue from renewable incentives</td>
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<td>- Lower residue disposal and energy costs</td>
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<td>- Reduced carbon footprint for the site</td>
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<tr>
<th>LCV Transport Implications:</th>
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<tbody>
<tr>
<td>- Major carbon reduction exercise on site</td>
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<tr>
<td>- Could fuel vehicles with bio-methane</td>
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<tr>
<td>- Power for on-site electric vehicles</td>
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Annex 1: Technical information ~ farm tractors and ATVs

Valtra: 85

The Valtra T133 Dual Fuel is reported to be the first tractor to combine the use of biogas with clean SCR (Selective Catalytic Reduction) technology. The new tractor is a continuation of Valtra’s biogas project. The first test tractor – a four-cylinder N111 HiTech – was presented in summer 2010. The biogas N111 is to be further developed and adapted for use in other tractor models.

However, according to Alan Sanderson AGCO/Valtra UK Sales Support Manager, a combination of bureaucratic challenges in terms of vehicle dual fuel classification, the new focus upon meeting new emission regulations across the whole farm machinery fleet and the additional costs of dual fuel technology design and deployment (adding £15-£20k on 110hp tractor), farmers are unlikely to see Valtra biogas tractors in the UK market for some time yet.

The range of biogas tractors developed and tested by Valtra since 2010 are based upon Tier 3 vehicle emission requirements. Engine technologies are continually improving to meet more stringent global emission standards. The current legislation requires tractor technologies that reduce particulate matter or smoke by 90% and nitrogen oxides by 50%.

Currently much of Agco/Valtra’s R&D work and costs are aimed at upgrading their main diesel tractor fleet up to Interim Tier 4 and working towards full Tier 4 compliance by 2015 – with very low particulates – requiring some major changes in tractor engine design.

AGCO acknowledge that there is an R&D Challenge for major tractor manufacturers – “to develop solutions that will bring farm input costs down, allow an increase in power levels and lower fuel consumption — all while offering reliable emissions reduction technology” (Matt Rushing, AGCO Product Management, Global Electronics and Global Engines).

Valtra’s T133 and N111 biogas tractors are similar to standard tractors in terms of characteristics, equipment and performance. The fuel cost of biogas tractors is approximately 10 to 40% lower than that of standard tractors. The storage containers for the gas are positioned in a safe location within the tractor frame. The containers can hold 170 litres of gas at 200 bars of pressure. This amount corresponds to approximately 30 litres of diesel and is sufficient for 3 to 5 hours of work. Additional storage tanks can easily be fitted to the system if needed. The tractors can also carry 165 litres of diesel and 27 litres of AdBlue, as on standard tractors. (Source: Information from Valtra).

85 Information from Valtra
Steyr biogas tractor

Early in 2009, Austrian tractor manufacturer Steyr, a subsidiary of CNH Global (to which New Holland Agriculture also belongs), released a model designed to make use of farm-produced biogas. The tractor runs on a 50-50 blend of biogas and diesel. It will also run on a mix of diesel and natural gas or diesel alone. The biogas tractor is still under trial conditions.

The Steyr tractor is the Profi 4135 Natural Power with a special gas burning engine from Fiat Powertrain Technologies. The 3 litre engine has 136hp rated output. New Holland has the T6.140 model.

Battery Powered ATVs

A number of companies are manufacturing and distributing battery powered ATVs.

Battery powered ATVs are typically powered by a 15 kW DC motor powered by deep discharge lead-acid or lithium ion batteries.

Advantages:
- Cheap to run
- Easily charged, off-peak, 13A supply
- Zero emissions
- Excellent torque and operating speed

Disadvantages:
- Limited range (approx. 50 km, versus 500 km for diesel equivalent)
- Replacement cost of battery pack (around £1000)
- About 15-20% greater initial cost over diesel

Cost comparisons ~ E-ATV with an equivalent sized diesel engine ATV

A battery powered ATV will have a running cost of £50 for 6000 km. A conventional powered ATV would have a running cost of £1200 over the same distance. However, the battery pack would be replaced at the end of this distance, at a cost of around £1000. On this basis, the cost of a battery powered ATV is only about £150 cheaper over a similar distance. However, these calculations do not consider the reductions in costs associated with being able to power via a solar PV array if this already exists.

What is the energy content of biogas?

The energy value correlates with the methane content of biogas. This can range from 50–75% depending on input substrate and process characteristic. One cubic metre of methane has an energy value of about 10 kilowatt-hours (9.97 kWh), so biogas with a content of 55% methane has an energy content of about 5.5 kWh per cubic metre.
Annex 2: Agri-technology development and funding

**Innovation for Agriculture (IFA)**

The Royal Agricultural Society of England (RASE) is one of four founding members of ‘Innovation for Agriculture’.

A consortium of English Agricultural Societies are coming together to set up a new national extension service. The aim is to offer farmers co-ordinated technical support and advice to help speed up adoption of technology and best practice across the country.

The independent network is planned to consist of centres of excellence in different areas such as soils, dairy, cereals or renewable energy, in order to help farmers raise the bar through the early adoption of new technology and techniques.

“The initiative would address some gaps in providing knowledge to farmers, which has seen the UK fall behind other nations,” said project co-ordinator and RASE CEO David Gardner.

“One of the key weaknesses of UK research and development is that it is horribly fragmented. We used to have centres of excellence but now research is scattered across a wide group. None have got enough to make a story out of their research and there is no one pulling it all together,” he said.

‘Agricultural societies are perfectly placed to deliver this as they not only have a strong, wide-reaching network of agricultural showgrounds and members, but they are also trusted by farmers’.

For further information, contact project co-ordinator David Gardner at davidg@rase.org.uk

**Agri-Tech Catalyst**

The Technology Strategy Board (TSB) has launched an ‘Agri-Tech Catalyst’ with investment of £70m from Government to help businesses and researchers develop innovative solutions for the agricultural sector.

The Catalyst will deliver the vision of the Government’s UK strategy for agricultural technologies to make the UK a world leader in agricultural technology, innovation and sustainability. Non-food uses of arable crops (for example, for biomass) will be covered by the scheme.

Also announced in January 2014 was a competition of up to £11m to help UK companies develop localised energy solutions which involve generating, storing and using energy at the local scale, including transport. Such funded agri-technology programmes could make a significant difference to the way we power our farms.

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86 Technology Strategy Board
One example of innovative R&D is given below:

Harper Adams University launched an Agricultural Engineering Innovation Centre (AEIC) in 2013. The AEIC is home to the National Centre for Precision Farming (NCPF), which aims to promote and evaluate the use of technology as a vital aspect of precision agriculture and provide a focal point for the industry. NCPF’s facilities include an electronics/mechatronics lab, hydraulics lab and a research lab for tractors and machines. [www.harper-adams.ac.uk](http://www.harper-adams.ac.uk)

It is hoped that this Study and Report will stimulate further investment in research and near market deployment of alternative farm machinery and vehicles for rural applications using renewable transport fuels.

**Funding sources, projects and HMRC information**

**WRAP – On Farm AD Fund**
To encourage the uptake of small scale on farm AD in the UK, WRAP has developed a programme to help farms access finance, provide case studies and demonstration information plus provide support for farmers who want to use AD on their farm.

The scheme is split into two parts:
- Stage 1: The first part is a business plant grant up to £10,000 to investigate the environmental and economic potential of building an AD plant on the farm.
- Stage 2: The second part is a capital loan up to £400,000 (or a maximum of 50% of the project cost). This is available for AD plants producing up to 250kWe of power.

The scheme is open to applications from farmers in England who have access to slurries or manures; and who wish to build AD plants producing up to 250kWe of power. For more information: [http://www.wrap.org.uk/node/16778](http://www.wrap.org.uk/node/16778)

**EU Biogas projects**
The BioEnergy Farm project was funded by Intelligent Energy Europe project and ran from the 1st of June 2010 until the 30th of April 2013. The objective of this project was to increase in the use and production of bioenergy and biofuels by farmers in Italy, Poland, Estonia, Belgium, Germany and the Netherlands. At the start of the project, the final goal was set to increase the capacity of bioenergy with 40 MW, three years after the end of the project. At the end of the project, 19 plans for 18MW were realised.

**Farm Power**
A complementary, but wider study of rural energy alternatives, is being carried out by Forum for the Future in partnership with Farmers Weekly and Nottingham Trent University. Their project is called ‘Farm Power: Putting Agriculture on the Grid’. [87](http://www.forumforthefuture.org/project/farm-power-putting-agriculture-grid/overview?goback=%2Egde_4274075_member_5795552845478518786#%21)

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87 [http://www.forumforthefuture.org/project/farm-power-putting-agriculture-grid/overview?goback=%2Egde_4274075_member_5795552845478518786#%21](http://www.forumforthefuture.org/project/farm-power-putting-agriculture-grid/overview?goback=%2Egde_4274075_member_5795552845478518786#%21)
Farm Power has received start-up funding from The Ashden Trust and has recently completed a scoping phase (culminating in a workshop in July 2013). During the pilot phase, research was conducted into the key sustainability questions surrounding farm-based energy systems; interviews were undertaken with a selection of key stakeholders and a survey of the readership of Farmers Weekly was undertaken to learn from farmers’ on-the-ground experiences with energy.

The Farm Power project aims to develop a set of tools that help farmers find, and act on, the best options and advice and explore the development of a mapping system that enables stakeholders to quickly determine their local options/barriers.

**HMRC and red diesel**

Red diesel can only be used for vehicles specifically exempted by legislation. Exempted vehicles have to be agricultural, horticultural or forestry related and be engaged in such activities. Farmers Weekly carried an article on red diesel in February 2014 ([www.fwi.co.uk/reddiesel](http://www.fwi.co.uk/reddiesel)). (For more information, contact HMRC on 0845 010 9000).
Glossary

Anaerobic digestion (AD): a naturally occurring process which can be harnessed to produce a renewable gas (biogas) and a biofertiliser (digestate). The process is fuelled most commonly by household food and garden waste, farm slurries, waste from food processing plants and supermarkets, and crops grown on farms. These feedstocks react with microorganisms to produce a biogas, and digestate, which can be applied to farmland to reduce the need for artificial fertilisers.

Bioenergy: a form of renewable energy. Derived from biomass it is used to generate electricity or heat or used to produce liquid transport fuels.

Bio-ETB: EuroTransBio is an EU funding initiative to foster initiatives in biotechnology

Biofuel: In this report, the term biofuel refers to liquid and gaseous fuels produced from organic matter derived from plants or animals.

- **Conventional biofuels** are fossil fuel substitutes. They can be made from a range of agricultural crops, including bioethanol derived from sugar and starch rich crops such as wheat or sugar beet, biodiesel from oil crops such as rape and used cooking oils, and biomethane derived through anaerobic digestion and biogas upgrading. By-products and wastes such as used cooking oil (mentioned above), tallow and municipal solid waste MSW can also be used to produce biofuels.

- **Second generation biofuels**: A second generation or advanced biofuel is one which is derived from waste products. These waste products may be highly ligno-cellulosic, consisting of the essential part of woody cell walls and are typically agricultural and forestry residues, such as wheat straw or wood base biomass, non-food crops such as miscanthus or algae or industrial waste and residues. They should have low CO₂ emissions or the ability to reduce greenhouse gases and have a low or zero ILUC (Indirect Land Use Change) impact.

Biofuel categories:

- Ethanol 1G – first generation from barley, corn, sugar beet, sugar cane, wheat
- Ethanol 2G – second generation from agricultural residues, forestry residues, non-food cellulosic and ligno-cellulosic materials - miscanthus and short rotation coppice
- FAME – (Fatty acid methyl esters) food based – oilseed rape, palm, soy
- FAME – non-food – used cooking oil and tallow
- BTL Biogas to liquid – wood energy crops, agricultural residues, municipal wastes
- Biomethane - Biogas

Biogas: produced through the decomposition of organic materials in the absence of oxygen in a process known as anaerobic digestion. Anaerobic digestion occurs in nature in the bottom of ponds and lakes, in bogs and in the digestive tract of ruminants such as cows, but the process can also be carried out in tanks, whereby the biogas can be effectively harnessed. Biogas typically consists of 50%-65% biomethane (CH₄), with the remainder being comprised mainly of carbon dioxide (CO₂), with small amounts of water vapour and other gases, including hydrogen sulphide (H₂S).
**Biomass**: any organic matter of recently living plant or animal origin. It is available in many forms including agricultural and forestry products and municipal and other wastes.

**Biomethane**: methane obtained from organic materials; in the context of this report, it refers to the methane component obtained through the anaerobic digestion process, a renewable energy technology.

**CBG**: Compressed biogas

**FAME**: fatty acid methyl ester

**FT diesel**: synthetic fuel produced using the Fischer-Tropsch process

**FQD**: EU Fuel Quality Directive

**GHG**: greenhouse gases

**GIS**: geographic information systems

**Intermediate pyrolysis**: Pyrolysis is the thermal decomposition of organic matter in the absence of oxygen. Intermediate pyrolysis occurs at a temperature of approximately 450°C under moderate heating rates (25-100°C/min) and solid residence times (10-30 minutes).

**RED**: European Renewable Energy Directive

**Renewables Obligation (RO)**: provides incentives for large-scale renewable electricity generation by making UK suppliers source a proportion of their electricity from eligible renewable sources.

**Feed-in Tariffs (FITs) scheme**: pays energy users who invest in small-scale, low-carbon electricity generation systems for the electricity they generate and use, and for a percentage of unused electricity they export back to the grid.

**Renewable Heat Incentive (RHI)**: pays commercial, industrial, public, not-for-profit and community generators of renewable heat for a 20-year period.

**Renewable Heat Premium Payment (RHPP)**: gives one-off payments to householders, communities and social housing landlords to help them buy renewable heating technologies like solar thermal panels, heat pumps and biomass boilers.

**Renewable Transport Fuel Obligation (RTFO)**: makes companies that supply more than 450,000 litres of fuel per year source a percentage from renewable sources.

**RME**: Rape oil methyl ester

**UK Renewable Energy Roadmap**: sets out a plan for accelerating the use of onshore wind, offshore wind, marine energy, solar PV, biomass electricity and heat, ground source and air source heat pumps, and renewable transport.

**ULEVs**: ultra-low emission vehicles:
- PHEVs - plug-in hybrid electric vehicles (PHEVs)
- PEVs pure electric vehicles (PEVs)
- E-REVs extended range electric vehicles (E-REVs)
- FCEVs fuel cell electric vehicles
Editorial contact:

Greenwatt Technology
Minerva Mill Innovation Centre
Station Road
Alcester
Warwickshire
B49 5ET

Tel: 01789 761367
Mob: 07901 916694
Email: mike@greenwatt.co.uk
Web: www.greenwatt.co.uk