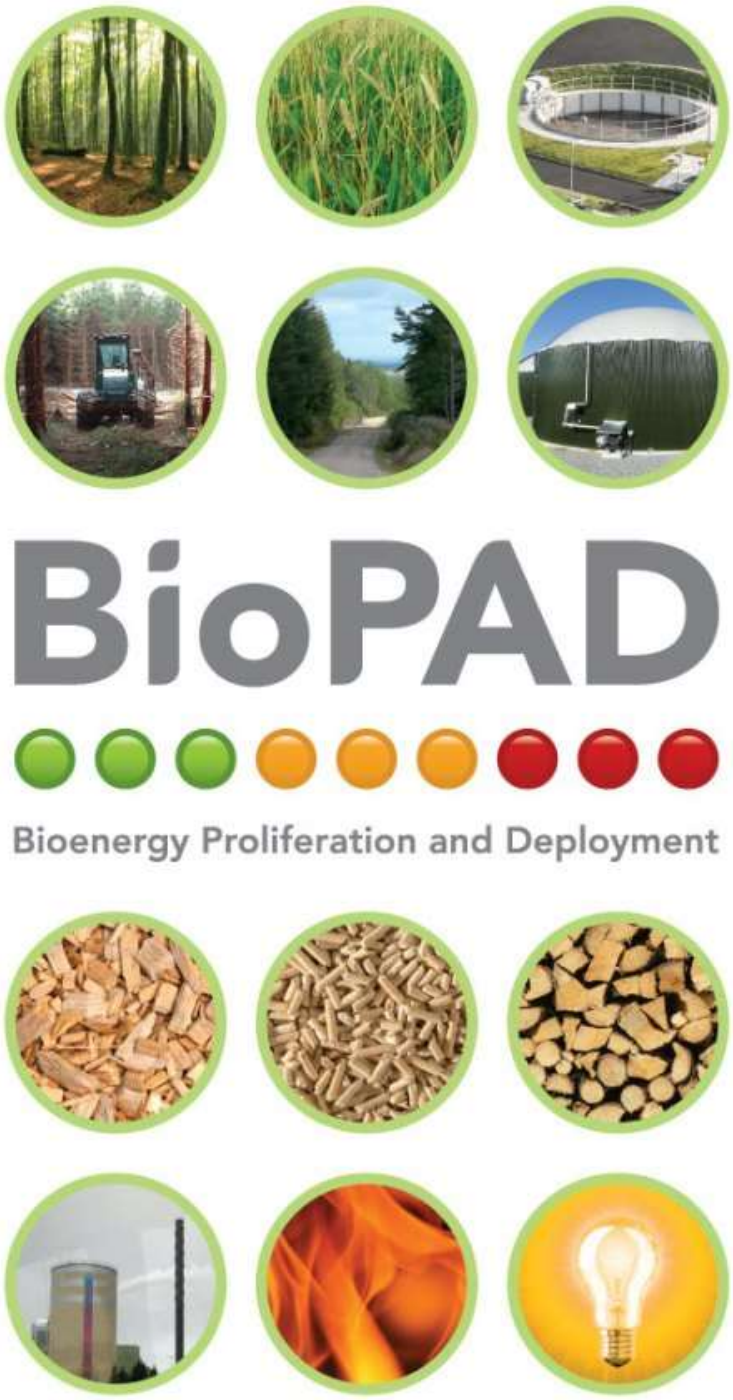
Energy Flows and Carbon Emissions: Anaerobic Digestion



BioPAD

Bioenergy Proliferation and Deployment

Northern Periphery Programme 2007–2013

Innovatively investing in Europe's Northern Periphery for a sustainable and prosperous future

European Union
European Regional Development Fund

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Preface

Completed by Dr Kenny Boyd (Environmental Research Institute, North Highland College UHI, Scotland) for BioPAD, a project of the Northern Periphery Programme.

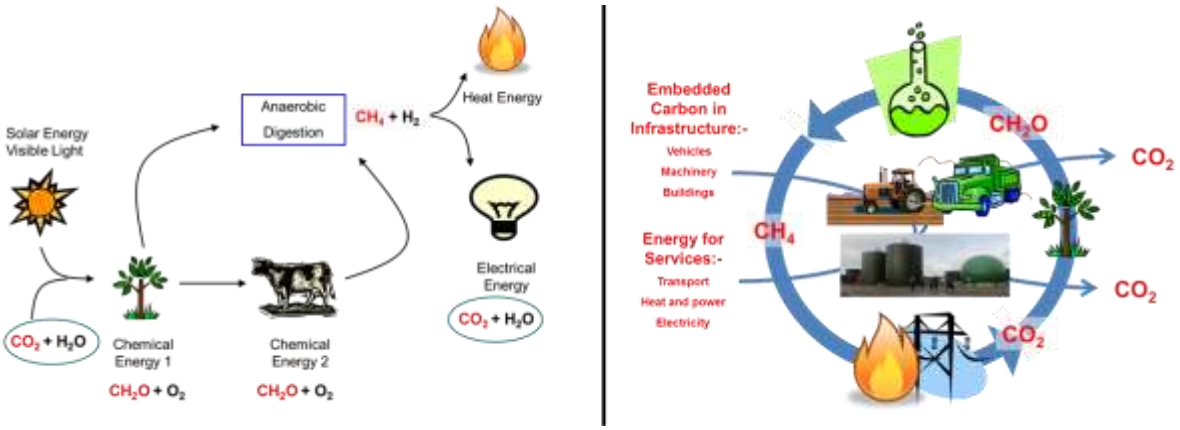
The BioPAD project aims to improve our understanding of the links between supply and demand by looking at supply chains for a variety of bioenergy fuels and different ways of converting these fuels into sustainable energy. Understanding the supply chains and the ways bioenergy moves from fuel source to energy provision will help the establishment of robust and efficient supply services which can match local demand.

BioPAD is led by the Western Development Commission www.wdc.ie (Ireland) and is funded under the ERDF Interreg IVB Northern Periphery Programme (NPP) http://www.northernperiphery.eu. It has partners in Scotland (Environmental Research Institute, UHI http://www.eri.ac.uk/), Northern Ireland (Action Renewables http://www.actionrenewables.org/) and Finland (Finnish Forest Research Institute, Metla http://www.metla.fi/).

Energy Flows and Carbon Emissions: Anaerobic Digestion

Synopsis

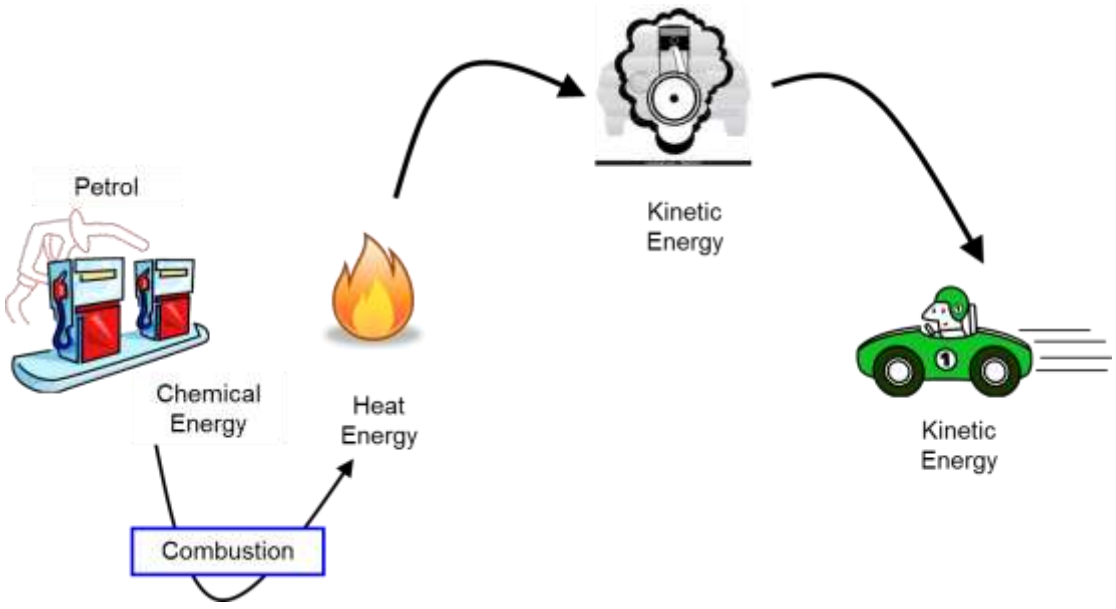
In the production of energy using anaerobic digestion (AD) both energy and carbon "flow" through the entire process. Initially carbon dioxide, from the atmosphere, is utilised by plants to build complex carbon based molecules, predominantly carbohydrates. Plants can be harvested and fed into the AD process, or can be used to feed animals. Feeding animals results in the production of slurry which can also be used as a feedstock for AD systems. During the AD process itself methane and hydrogen are produced from the complex molecules that make up the feedstock. This gas mixture is then burned to produce heat and/or electricity and carbon is released back into the atmosphere as carbon dioxide. Plants therefore act as energy and carbon accumulators absorbing energy from sunlight and carbon dioxide from the atmosphere. The production of energy using AD can therefore be considered carbon neutral as it is a closed carbon loop. However other operations in the AD supply chain which emit carbon dioxide, such as the production of vehicles and buildings and the use of fuel for transport and energy requiring processes, normally result in the emission of some carbon dioxide to the atmosphere.



Introduction – Conservation of Energy

Before we consider the carbon emissions and energy transfer steps involved in the anaerobic digestion supply chain it is important to remember that energy can neither be created nor destroyed but can be converted from one form to another. As an example we can consider the energy transformations which take place in order for us to drive a petrol powered car.

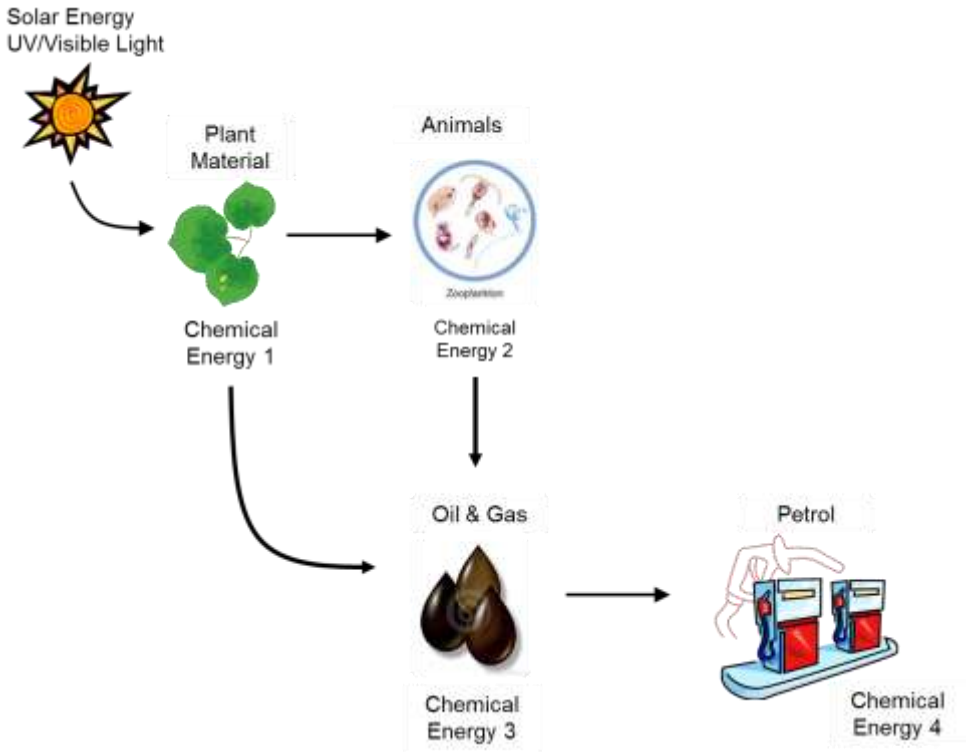
When we drive a petrol powered car we are releasing the chemical energy stored in the molecules that make up petrol to first produce thermal energy, by combustion of the fuel, which is converted into kinetic energy, a rapidly expanding gas, which drives the moving parts of the engine and the car itself.



Energy transformations taking place when burning petrol to power a car.

The energy which is stored in the petrol has its origins in the sun. The sun provides energy directly for the growth of plants which transform this energy into chemical energy, stored in complex molecules such as carbohydrates, fats and proteins. The plants can in turn be eaten by animals which act as another store of chemical energy. The decomposition of animal and plant material over long periods of time produces oil and gas which are themselves a store of chemical energy. Petrol is

then produced by processing the crude oil to give a product with properties that allow it to be utilised in an internal combustion engine. Petrol is another form of stored chemical energy.

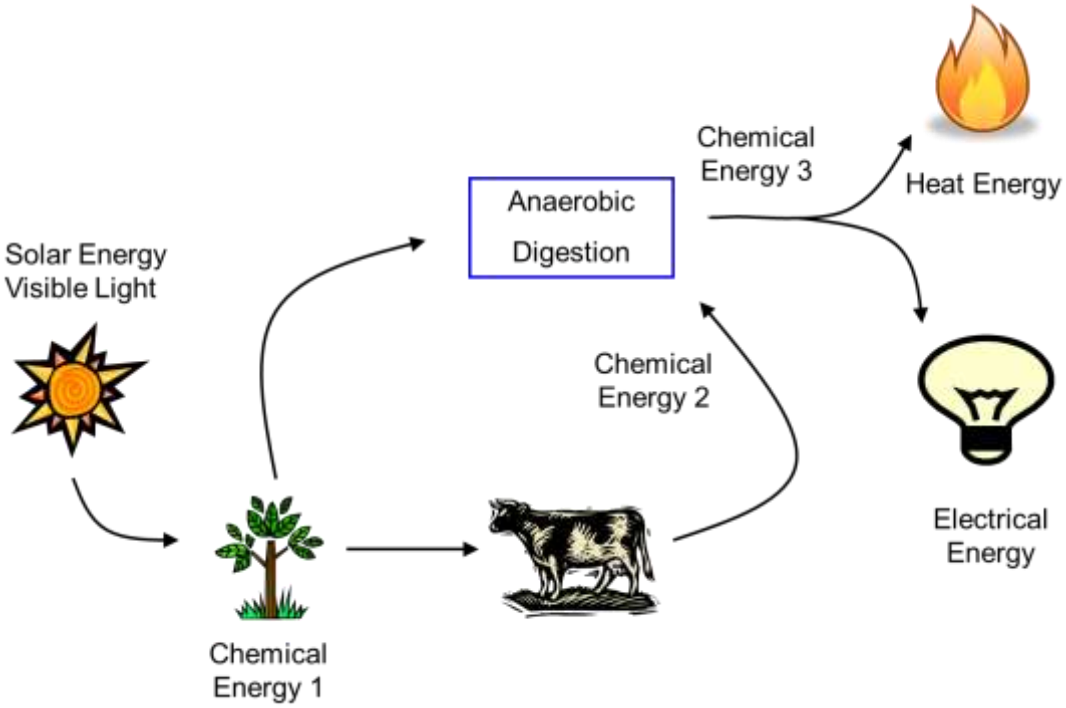


Energy transformations taking place in the formation of oil and gas and in the production of petrol.

Energy and Carbon Flows Associated with Anaerobic Digestion

If we examine the energy flows associated with the anaerobic digestion we can see that the energy stored within plants was originally supplied by the sun. The sun provides the energy to drive photosynthesis, building plant material and storing the energy as chemical energy which holds together the atoms within the complex molecules, which make up plants. Where plants are used directly as a feedstock for AD the plant material is then modified to form a product suitable for transportation, which acts as another store of chemical energy. If the plant material is used to feed animals, the animals use up some of the energy stored in the plant material to build animal biomass and fuel respiration. However animals, such as cows, produce a

large amount of faeces (slurry) which is essentially modified plant material which can be used as a feedstock for anaerobic digestion. The AD process itself produces methane and hydrogen, rich in chemical energy which can be burned to produce heat and/or electrical energy.



Energy flow associated with the anaerobic digestion of energy crops and agricultural residues. We can see that biomass acts as an energy accumulator absorbing energy from sunlight. The AD process converts complex molecules into a combustible gas which is used to generate heat and/or electrical energy.

As well as energy flowing through the process carbon also flows through the system. In the case of the carbon, carbon dioxide is utilised by plant materials during photosynthesis to build complex molecules, predominantly carbohydrates, as follows.

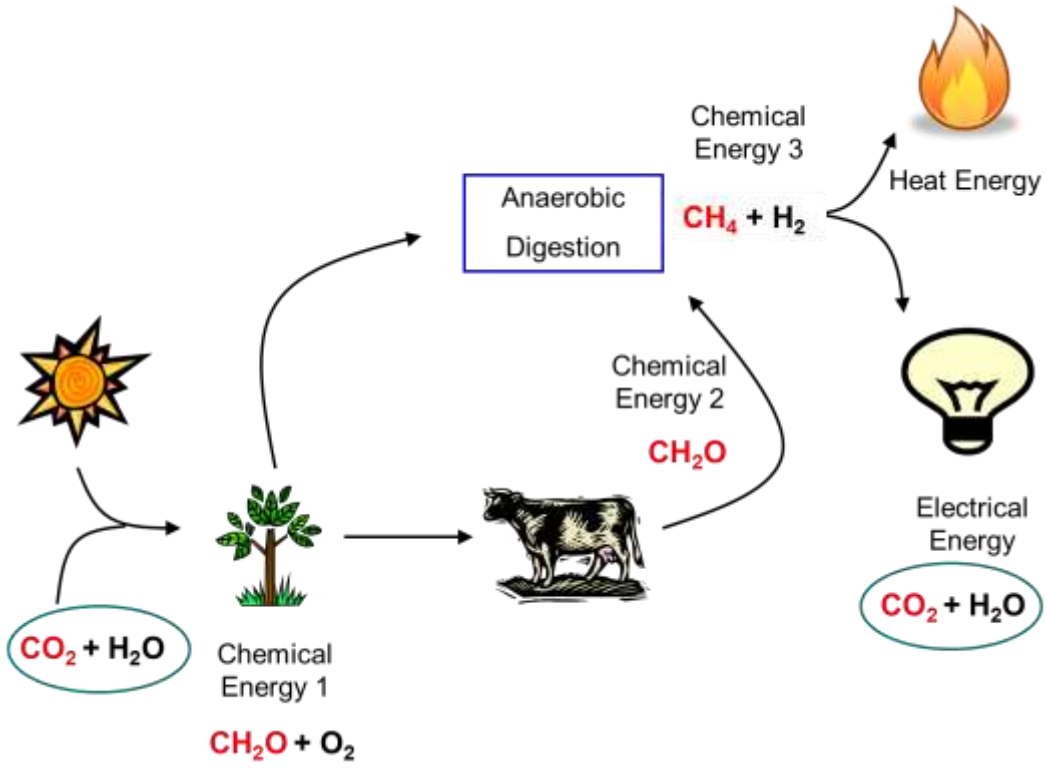
$$nC0_2 + nH_20 \rightarrow (CH_2O)_n + nO_2$$

The plant material can also be utilised by higher organisms to build animal biomass. The complex molecules, making up plant and/or animal biomass or waste products such as slurry, can be used in anaerobic digestion to produce methane and

hydrogen. When burned carbon is released as carbon dioxide according to the following equation.

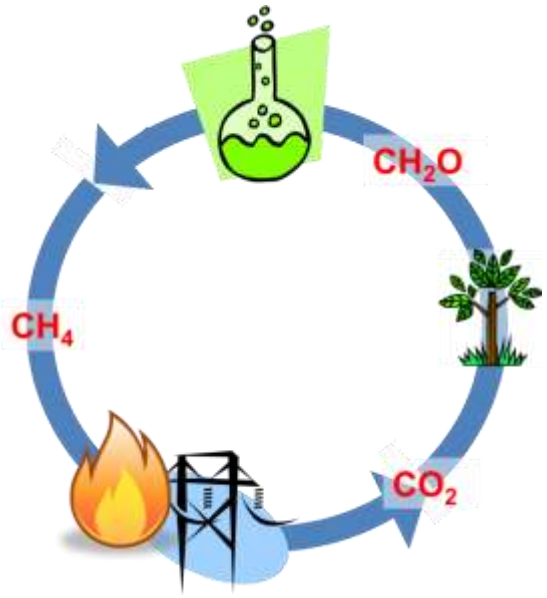
$$CH_4 + H_2 \xrightarrow{O_2} nCO_2 + nH_2O$$

The overall flow of carbon within this system is therefore as depicted as follows.



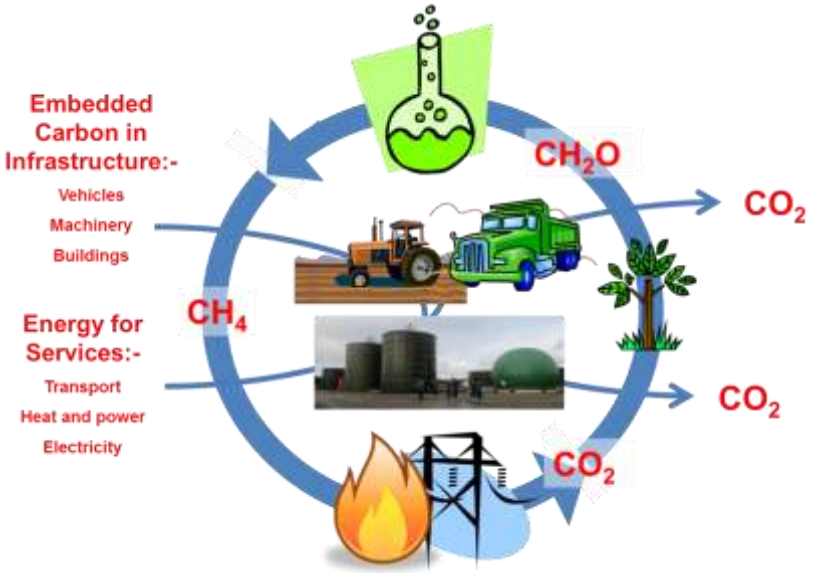
Energy and carbon flows associated with anaerobic digestion.

The production of useful energy by anaerobic digestion is considered renewable as it is a closed carbon loop in which carbon dioxide is continually cycled through plants and animals.



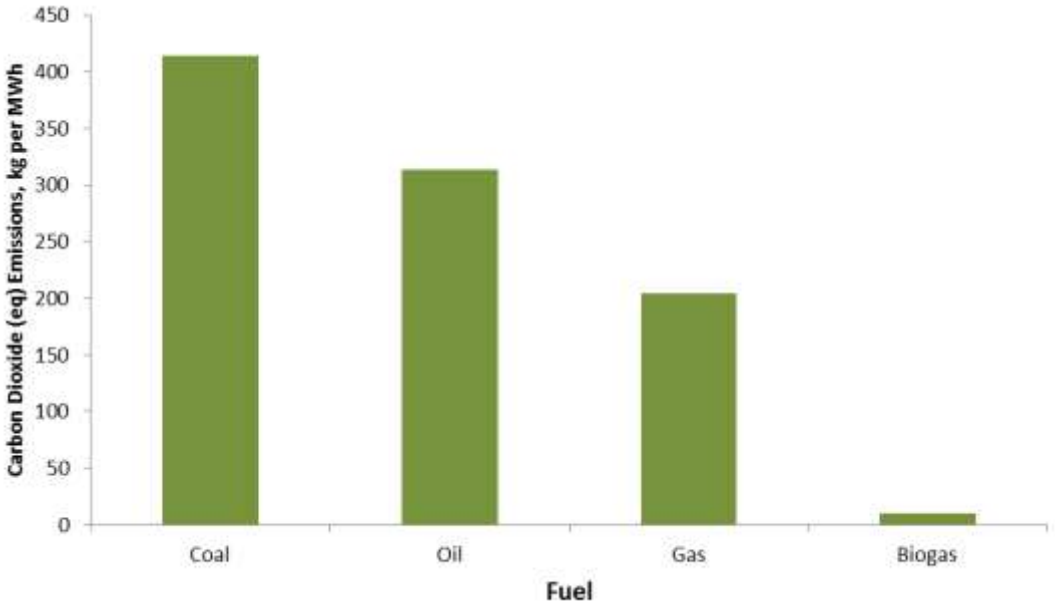
The closed carbon loop, associated with anaerobic digestion

Processing operations in the AD supply chain (planting, harvesting, transportation, shredding etc.) can result in the emission of carbon dioxide to the atmosphere. This can be from the direct use of fossil fuels for transportation or providing heat. The use of electricity within the supply chain can also be responsible for carbon dioxide emissions where electricity production relies on fossil fuels. The fabrication of the physical resources needed for the supply chain (vehicles, harvesting equipment, storage facilities, computers etc.) is also likely to be a source of carbon dioxide emissions which are attributable to the supply chain.



Additional carbon emissions from the supply chain

The production of useful energy from biomass using AD can therefore be sustainable but does result in the emission of carbon dioxide, especially where electricity generation is not decarbonised. However, compared to other energy sources emissions are much reduced.



Emissions of carbon dioxide associated with the combustion of different fuel types. From 2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting.

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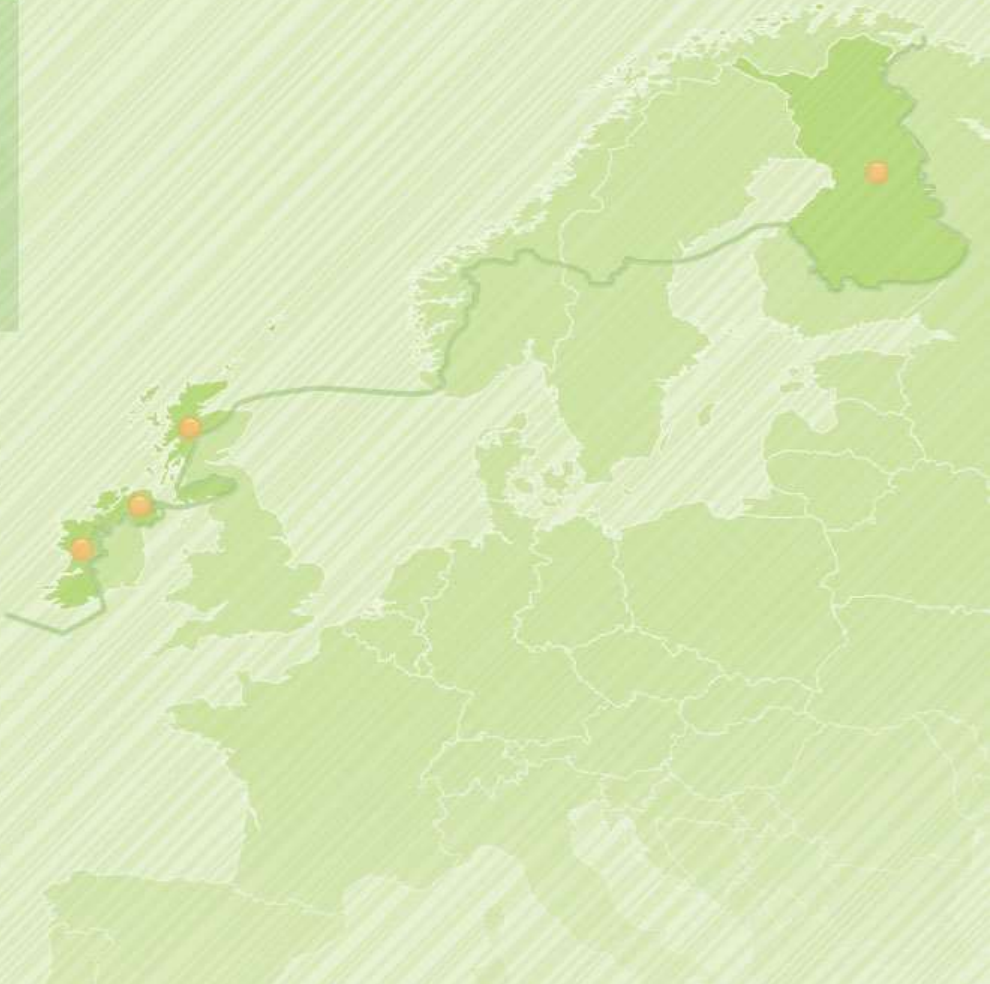

BioPAD is promoting the wider use of bioenergy and developing applications targeting the whole process from supplying fuel to producing energy.

The project is led by the Western Development Commission (Republic of Ireland) and brings together partners from Northern Ireland (Action Renewables), Scotland (Environmental Research Institute) and Finland (Finnish Forest Research Institute, Metla).

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