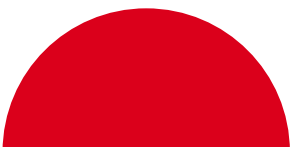
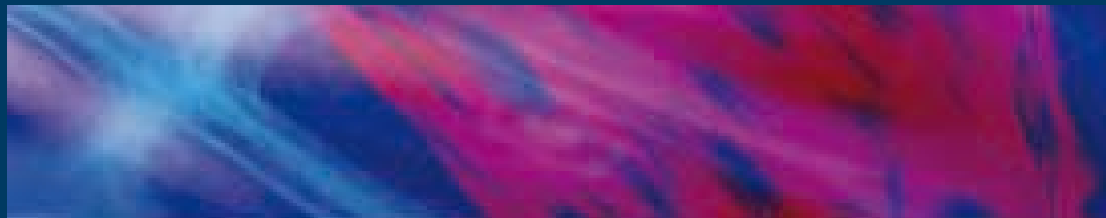


The Improvement Service

WORKBOOK

# Low and zero carbon development





# Contents

Introduction	3
Why are energy efficiency and low carbon energy generation important?	4
Introduction to low and zero carbon development	7
Planning policy context	9
Understanding energy profiles	12
Measuring carbon and energy	17
Energy efficiency	22
Energy generation	26
Micro-wind turbines	30
Large scale wind turbines	33
Photovoltaic panels	36
Solar thermal hot water	38
Biomass	40
Ground source heat pumps	43
Combined heat and power	45
Hydro power	48
Marine renewable technology - waves and tidal	50
Energy from waste - anaerobic digestion	53
Energy from waste - thermal treatment	57
Exercise	61



# Introduction

In the planning and design of sustainable places and buildings, it is essential that energy demand is firstly reduced through energy efficiency measures, then opportunities for renewable and low carbon energy generation are sought to achieve additional carbon savings.

This workbook provides a range of information to help planners understand this complex and interdisciplinary set of issues. Firstly this workbook focuses on how the planning system is responding to these challenges. It then goes into greater detail on the planning context relating to low and zero carbon development before looking as to how energy is used within developments in 'Understanding Energy Profiles'. The following section to that, 'Measuring Energy and Carbon' looks at how zero carbon development is defined and provides example planning policies. The remainder of the document examines the areas where planning can have most impact, 'Energy Efficiency' and 'Energy Generation', where participants will develop an understanding of the individual low and zero carbon technologies

This workbook was created by AECOM in 2009 and has been updated by the Improvement Service in 2011.

## Why are energy efficiency and low carbon energy generation important?

Climate change is generally regarded as the greatest global threat. It is caused by a proliferation of certain gases in the atmosphere that trap the sun's heat, known as the greenhouse effect. The trapped heat causes changes in the global weather patterns that will affect Scotland, nationally and regionally. Expected changes to 2050 and beyond are summarised below:

- Temperature - mean annual temperatures will rise by 1-1.5°C across Scotland. Regional variations include 1.5-2°C increases in autumn and 1.5-2°C increases in east Scotland in summer. Variation in summer and autumn temperatures will also be more frequent.
- Precipitation - although annual rainfall is likely to be similar to present levels, winters (particularly along the east coast) are likely to be 10% wetter and summers 10% dryer. Rainfall and dry-spells are likely to be more intense with greater risk from more extreme weather events (i.e. severe winter gales).
- Wind speed - typical wind speeds are set to increase by 2-4% by 2080.
- Sea levels - by 2080 sea levels are set to increase by 15-28cm with an increase in average tidal surges and waves.

The greenhouse gases - carbon dioxide (CO<sub>2</sub>), methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride - are naturally occurring, but have been chronically exacerbated by human activities, such as energy generation from fossil fuels (coal, oil and gas). The International Energy Association's World Energy Outlook 2008 concluded that current energy trends are patently unsustainable - socially, environmentally and economically. Although oil will remain the leading energy source in the near future, the era of cheap oil is over due to oilfield output decline with growing global demands and to avoid abrupt and irreversible climate change, we need a major decarbonisation of the world's energy system.

Although Scotland only produced 0.2% of global greenhouse gases in 2009-10 there is a collective responsibility for all nations to reduce their contribution. The European Union targets for overall EU energy policy are to:

- Reduce greenhouse gas emissions by 20% by 2020;
- Improve energy efficiency by 20% by 2020; and
- Provide 20% of energy from renewable energy sources by 2020.

### What this means for the UK and Scotland

The UK Government's current energy policy is explained in the Annual Energy Statement 2010. The overall policy is to support the transition to a secure, safe, low carbon, affordable energy system in the UK and to mobilise commitment to ambitious action on climate change internationally. The UK Government's programme has four key areas:

- Saving energy through the Green Deal and supporting vulnerable consumers;
- Delivering secure energy on the way to a low carbon energy future;

- Managing our energy legacy responsibly and cost effectively;
- Driving ambitious action on climate change at home and abroad.

The UK Government's targets, set through the Climate Change Act 2008, are to reduce CO<sub>2</sub> emissions by 34% by 2020 and 80% by 2050 against the 1990 baseline.

The UK government's Committee on Climate Change reports concluded that Scotland's share of UK emissions reductions should be approximately 9% of the UK total in 2008, with emissions reductions from the following key sectors:

- Emission from existing residential and non-residential buildings could be reduced by up to 3.2 MtCO<sub>2</sub> in 2020.
- In industry, there is likely to be considerable scope to reduce emissions from electrical engineering and food and drink sectors in Scotland. Total emissions reductions in industry could be 0.5 MtCO<sub>2</sub> in 2020
- Road transport has emissions reduction potential of 1.5 MtCO<sub>2</sub> in 2020
- In power generation there is likely to be considerable scope to deploy renewables in Scotland where 30% of Britain's onshore wind potential lies.
- Emissions from agriculture, land use and forestry and waste management sectors could be reduced by up to 1.7 MtCO<sub>2</sub>e in 2020.

The Climate Change (Scotland) Act was passed in 2009 and contains targets for reducing greenhouse emissions by 42% by 2020 and 80% by 2050. The Act also places climate change duties on Scottish public bodies. Section 44 of the Act requires all public bodies to act in the way best calculated to contribute to the delivery of the emissions targets in the Act, in the way best calculated to help deliver the Government's climate change adaptation programme, and in a way that it considers is most sustainable.

The Scottish Government published the Climate Change Adaptation Framework in 2009 (<http://www.scotland.gov.uk/Topics/Environment/climatechange/scotlands-action/adaptation/AdaptationFramework/TheFramework>). The Framework presents a national, coordinated approach to ensure that Scotland understands the risks and opportunities climate change presents and is adapting in a sustainable way. It sets out the overarching model for adapting to climate change in Scotland.

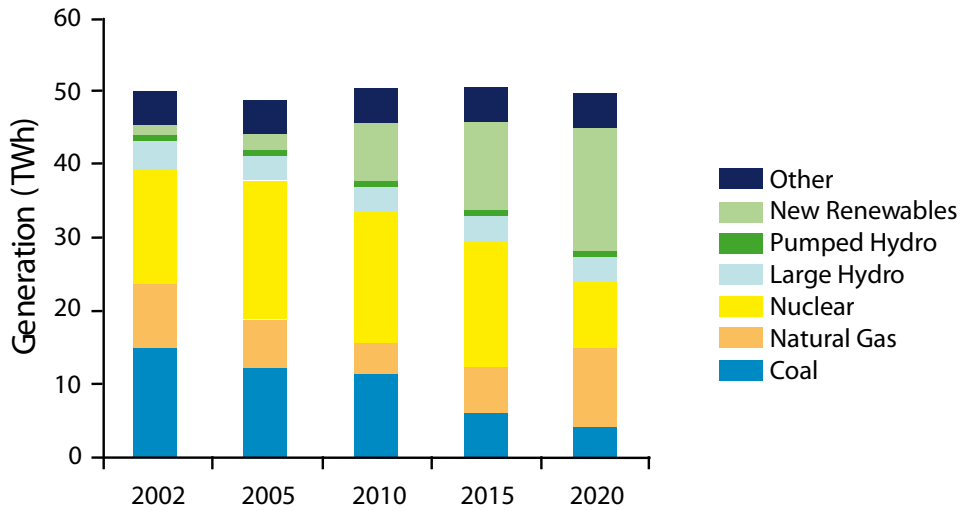
The Scottish Government has also set the target of generating 80% of electricity from renewable sources by 2020, with an interim target of 31% by 2011. An additional target is to generate 20% of Scotland's total energy use from renewable sources by 2020. The Renewables Action Plan was published in 2009 and updated in 2010 (<http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Energy-sources/19185/Resources/20801/RAPCONS>).

The Renewables Action Plan identifies collective actions by government, its agencies and partners, to ensure at least a fifth of Scotland's energy comes from renewables by 2020. The Plan will:

- Kick start a renewable heat industry to massively increase take up;
- Identify necessary infrastructure projects and options to deliver them;

- Get the skills mix right to maximise potential and attract investment.

Electricity generation by fuel type in Scotland to 2020 (GWh)



Source: Scottish Government, 2008

# Introduction to low and zero carbon development

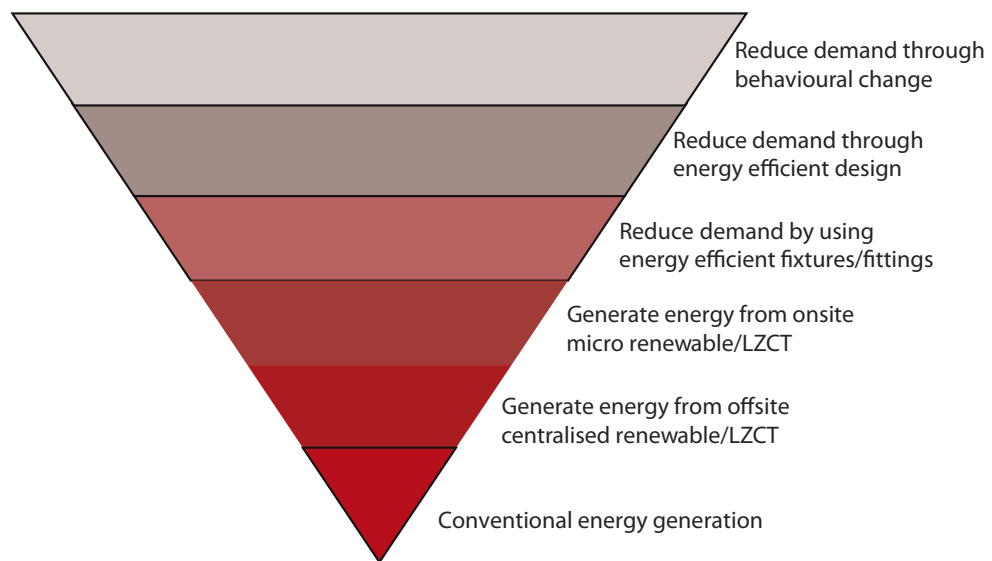
Over half of the CO<sub>2</sub> emissions generated in the UK come from processes related to generating electricity, heating homes and businesses and for industrial processes. Tackling the demand for these energy uses will play a significant role in achieving the targets set out in the previous section. Overall the Scottish Government has set a target of reducing final energy consumption by 12% by 2020. The way in which development is located, arranged, constructed and finished all contribute to reducing energy demands for electricity and heating.

Developments that achieve significant energy demand reductions, and therefore lower the amount of resulting CO<sub>2</sub> are known as low carbon developments. Developments that have no net energy requirements, i.e. they do not use more energy that they generate, are known as zero carbon developments. These definitions are not universally agreed and there is more detailed discussion on the definitions of zero carbon development in the section on 'Measuring Carbon and Energy'.

## Energy hierarchy

There are a number of ways in which developments can help reduce energy demands and CO<sub>2</sub>. Ideally behavioural change will lead to a reduction in demand. However, behavioural change is uncertain and difficult to enforce. The planning system can have a greater impact in helping reduce energy by ensuring that buildings are sited and designed to maximise passive gains to reduce heating cooling and lighting demands. Further reductions will be achieved through specifying energy efficient fixtures and fittings.

Energy efficiency measures encouraged through the planning system cannot, however, eliminate all energy demand, such as the residual energy demand from appliances. Once opportunities to reduce energy demand have been exhausted through efficiency measures, opportunities to utilise onsite or local renewable and low and zero carbon technologies (LZCT) to generate heat and electricity should be explored. Small scale energy generation is not always technically or economically feasible; these shortfalls will need to be backed up by larger scale centralised renewable and LZCT energy generation. Following this preferred sequence of policy priorities is known as the energy hierarchy.



## Relationship with the planning system

As energy demand and development are linked, the planning system has an important role to play in the reduction of CO<sub>2</sub> emissions. This is highlighted in the Low Carbon Economic Strategy for Scotland which was published by the Scottish Government in November 2010 (<http://www.scotland.gov.uk/Publications/2010/11/15085756/0>).

In the planning and design of sustainable places and buildings, it is essential that energy demand is firstly reduced through energy efficiency measures, then opportunities for renewable and low carbon energy generation are sought to achieve additional carbon savings. This workbook provides a range of information to help planners and others understand this complex and interdisciplinary set of issues. The next section focuses in greater detail on how the planning system is responding to these challenges. The next section provides more information on the planning context relating to low and zero carbon development before looking in greater detail as to how energy is used within developments in 'Understanding Energy Profiles'. The following section, 'Measuring Energy and Carbon' look in more detail at how zero carbon development is defined and provides example planning policies. The remainder of the document looks in greater detail at the areas where the planning system can have most impact, 'Energy Efficiency' and 'Energy Generation'.

# Planning Policy Context

## The role of the planning system

In shaping the pattern of development and controlling the nature and quality of development, effective planning plays a fundamental role in tackling climate change. By controlling the spatial arrangement of development, the planning system can reduce the need to travel and capitalise on public transport to reduce associated emissions. In locating development, the planning system can help identify opportunities and deliver centralised low and zero carbon power generators and ensure communities are adequately powered. Through development management the planning system can encourage energy efficient buildings and on-site/micro-renewable energy generation.

Working at a wide scale, planning policy and guidance sets out the strategic plans for an area, providing a framework to guide future development. This is done both nationally, across Scotland, and locally by each of Scotland's 34 planning authorities and four strategic development planning authorities. Decisions on applications are made through the development management process. There is also the legislative requirement to conform to Building Regulations, which set the minimum build specification requirements.

## National planning policy and advice

The Planning etc. (Scotland) Act 2006 requires that functions relating to the preparation of the National Planning Framework and development planning should be exercised with the objective of contributing to sustainable development.

Under section 72 of the Climate Change (Scotland) Act 2009, local development plans must require all new buildings to be designed to avoid a specified and rising proportion of the projected greenhouse gas emissions from their use through the installation and operation of low and zero carbon generating technologies.

National planning policy in Scotland is set out in the National Planning Framework 2 (NPF2) and the Scottish Planning Policy (SPP).

Scottish Planning Policy - renewable energy section explains that planning authorities should support the development of a diverse range of renewable energy technologies, guide development to appropriate locations and provide clarity on the issues that will be taken into account when specific proposals are assessed. The policy is that development plans should support all scales of development associated with the generation of energy and heat from renewable sources, ensuring that an area's renewable energy potential is realised and optimised in a way that takes account of relevant economic, social, environmental and transport issues and maximises benefits. It also states that when planning authorities are preparing policies under section 72 of the Climate Change (Scotland) Act 2009, planning authorities should take account of technical constraints which may exist including the availability of effective and appropriate technology and its practical application to different scales of development.

PAN 45: Renewable Energy Technology (2005) sets out how the planning system should encourage incorporating renewable energy technology into developments. It includes two annexes. Annex 1: Planning for Micro Renewables (2006) explains how the planning system can support the micro-renewables industry in the rollout of the technology to support on-site low and zero carbon energy generation. Annex 2: Spatial Frameworks and Supplementary Planning Guidance for Wind Farms (2008) provides advice to planning authorities on supplementary planning guidance for wind farms, particularly on the process of preparing spatial frameworks for wind farms over 20 megawatts capacity.

## Local planning

Scotland's planning authorities are required to prepare local development plans. This provides an opportunity for the authorities to review and update policies on energy generation and efficiency based on the recent national updates. The section 'Measuring Carbon and Energy' provides more details on developing policies to reduce the CO<sub>2</sub> emissions from developments.

Planning authorities can also produce Supplementary Guidance to help interpret and implement policy requirements. For example, Scottish Borders Council has developed supplementary guidance on renewable energy to help developers, households and community groups considering utilising LZCT.

## Development Management

Section 75 of the Town and Country Planning (Scotland) Act 1997 sets out arrangements for legal agreements between a planning authority and applicants to ensure that certain extra works related to the development can be undertaken. These agreements could be used to help deliver a range of sustainability criteria such as contributing to district heating schemes.

Conditions can also be applied to planning permissions to ensure schemes are developed in a way that meets the local authority's requirements. Conditions have to comply with Circular 4/1998, being 'necessary, relevant to planning, relevant to the development to be permitted, enforceable, precise and reasonable in all other respects'.

## Building Regulations

The Building (Scotland) Act 2003 sets out provision for Scottish Ministers to make building regulations. In addition to protecting health and safety of people, the key purposes of the regulations are 'to help furthering the conservation of fuel and power', and 'furthering the achievement of sustainable development'. The regulations set out minimum performance specifications for a wider variety of domestic and non-domestic building types.

Section 6 of the Regulations deals specifically with energy standards and covers a range of energy related issues including CO<sub>2</sub> emissions and covers regulated energy systems. Details of the regulations can be found in the 2010 Technical Handbook on the Scottish Building Standards (SBS) website - <http://www.scotland.gov.uk/Topics/Built-Environment/Building/Building-standards>.

Building on the report by SBS Policy into Practice - New Buildings (2007) which highlights the potential of building regulations to deliver more energy efficient development, the regulations were substantially revised and updated in 2007. Further iterations have also been incorporated into the 2010 Technical Handbook to take account of the Energy Performance of Buildings (Scotland) Regulations 2008 which sets out requirements for assessing energy performance and providing certificates for buildings.

In addition to the requirements set out in the building regulations, Scottish Ministers set up an advisory panel to investigate realistic measures for the development of a low carbon building standards strategy to increase energy efficiency and reduce carbon emissions. The panel published 'A Low Carbon Building Standards Strategy for Scotland (2007)' also known as 'The Sullivan Report' which set out 56 recommendations, including:

- The 2013 change in energy standards for new non-domestic buildings should deliver carbon dioxide savings of 75% more than 2007 standards.
- The 2013 change in energy standards for new domestic buildings should deliver carbon dioxide savings of 60% more than 2007 standards.
- Net zero carbon new buildings (i.e. space and water heating, lighting and ventilation) by 2016/2017, if practical.
- The ambition of total-life zero carbon new buildings by 2030.
- The report also recommended that energy efficiency through backstop levels of U-values and airtightness for building fabric should be improved in 2010 to match those of Nordic countries.

Although these standards remain aspirational for the time being, they are likely to be incorporated into building regulations in the future.

The section 'Measuring Carbon and Energy' provides more details on how building regulations are used to measure energy efficiency.

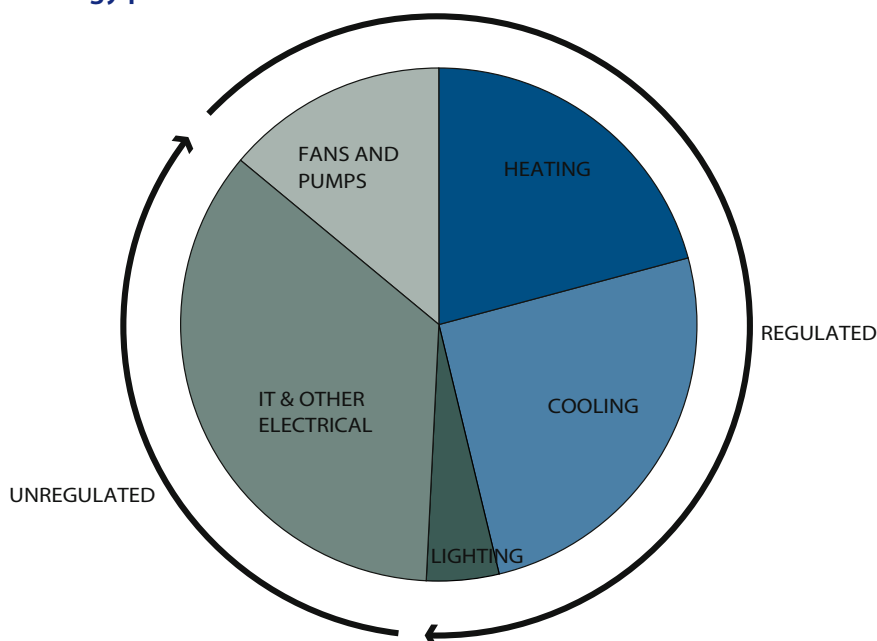
## Understanding energy profiles

A building's energy use falls into two broad categories - regulated and unregulated. The regulated portion includes energy uses such as heating and lighting which are controlled through building regulations and can be directly influenced through planning standards. The unregulated portion, which includes appliances and uses that the occupant controls, is harder to predict and control. The layout of a site and the design of a building can, however, have a significant impact on the energy efficiency of a development. This section looks in more detail at how energy is used within developments.

### Building energy profiles

In order to assist with understanding how energy can be saved and best supplied, it is important to understand how it is used. The following energy profile pie charts give a breakdown of energy use and resulting carbon emissions for a variety of building types. Comparing the charts show the opportunities and limitations of different strategies for reducing energy and CO<sub>2</sub> generation.

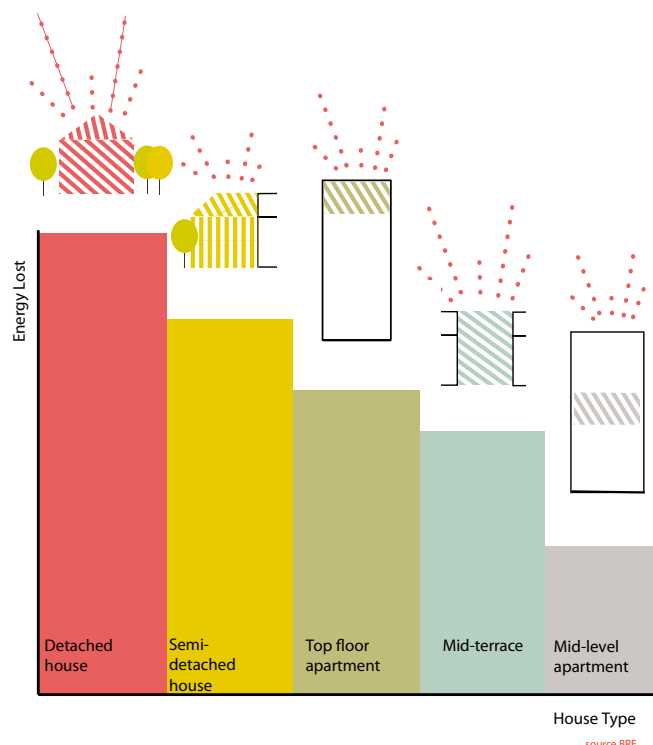
Energy pie chart



### Residential buildings

As with all buildings, the built form a house takes will affect its energy efficiency. The diagram below, 'Energy lost by house type' shows how different residential forms lose energy. Heat energy is lost through external walls and, as heat rises, particularly roof spaces. Detached properties are more likely to be less energy efficient as there is a higher surface area of external walls and roof space through which energy can be lost. Mid-level apartments are more energy efficient as heat rising from one level will help to keep the level above warm, before it is finally lost out of the roof. It is also likely that there are less external walls.

### Energy lost by house type



Due to these differing energy efficiencies, different residential built forms use energy in different ways. This set of energy profile pie charts compare different building types (flats with detached houses) and build specification (Buildings regulations (2007) section 6 with Code for Sustainable Homes level 6) alter the profile of energy use within the home.

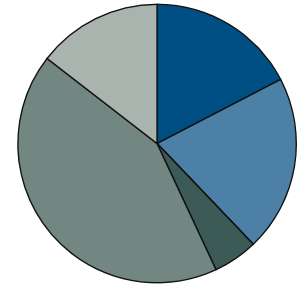
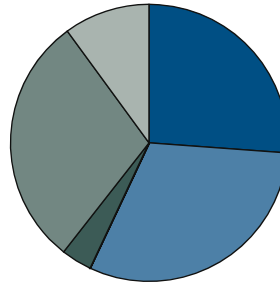
The energy profile pie charts (overleaf) show that for a standard 3 bed detached house the highest energy requirements are for heating. Reducing the building envelope (such as in a flat) or increasing the insulation and air tightness (as in the Code for Sustainable Homes example) can dramatically reduce the proportion of energy required for heating with IT and other electrical equipment (white goods) becoming more important. This shows us that energy efficiency measures can dramatically reduce the regulated energy requirements of buildings, but are limited in reach when it comes to the use of unregulated appliances and equipment brought into homes. As such, more sustainable low carbon means of generating energy need to be explored as energy efficiency becomes limited.

**Graphs showing energy use breakdown:**

**Graphs showing CO<sub>2</sub> emission breakdown:**

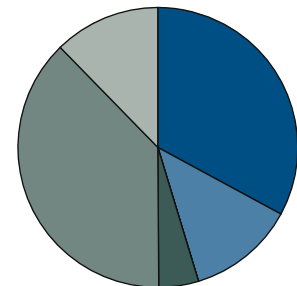
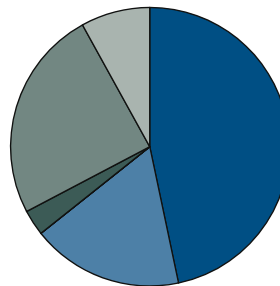
1bed flat to Section 6 2007

1bed flat to Section 6 2007



3 bed detached house to Section 6 2007

3 bed detached house to Section 6 2007



**Key:  
energy use breakdown**

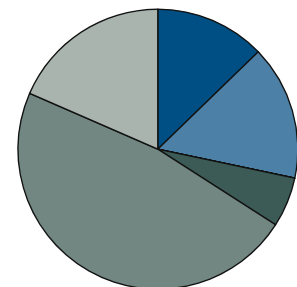
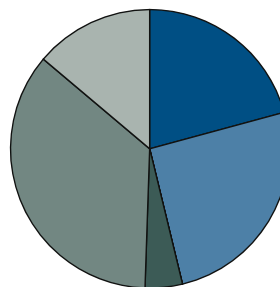
- Heating (kWh/annum)
- HotWater (kWh/annum)
- Cooling (kWh/annum)
- Lighting (kWh/annum)
- IT & other electrical (kWh/annum)
- Fans & Pumps (kWh/annum)

**Key:  
CO<sub>2</sub> emission breakdown**

- Heating (kgCO<sub>2</sub>/annum)
- HotWater (kgCO<sub>2</sub>/annum)
- Cooling (kgCO<sub>2</sub>/annum)
- Lighting (kgCO<sub>2</sub>/annum)
- IT & other electrical (kgCO<sub>2</sub>/annum)
- Fans & Pumps (kgCO<sub>2</sub>/annum)

3 bed detached house to CfSH 6

3 bed detached house to CfSH 6



**Non-domestic buildings**

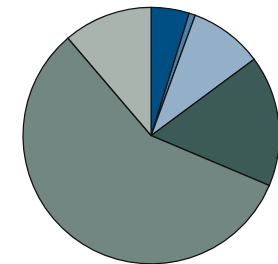
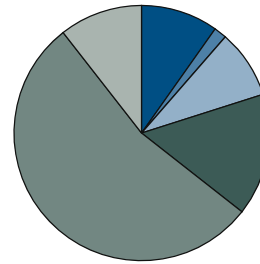
In non-domestic buildings, heating and hot water demand are usually a small proportion of energy use (the exceptions being schools, hospitals, hotels, etc). In new commercial buildings energy use is dominated by IT and other electrical use (such as appliances). In high density new build offices and data centres, cooling becomes a key energy use. With external conditions rarely exceeding internal cooling setpoints, the opportunities for low energy cooling in Scotland is very high and should be exploited.

Graphs showing energy use breakdown:

Graphs showing CO<sub>2</sub> emission breakdown:

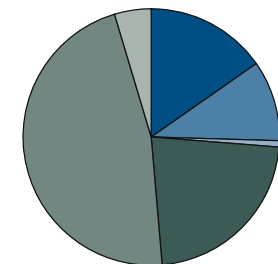
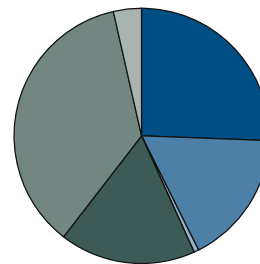
New Build Office

New Build Office



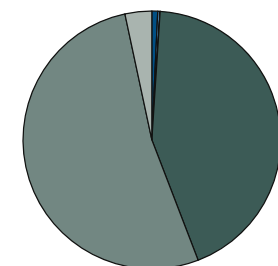
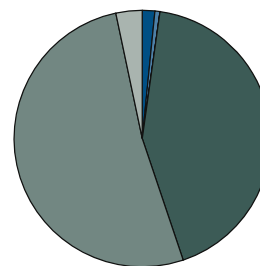
New Build Secondary School

New Build Secondary School



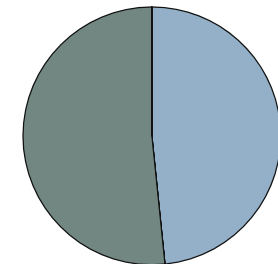
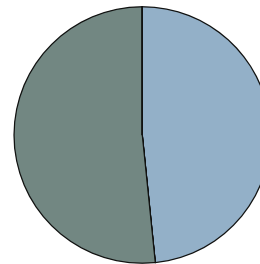
New Build Retail Warehouse

New Build Retail Warehouse



New Build traditional Data Centre

New Build traditional Data Centre



**Key:**

**energy use breakdown**

- Heating (kWh/annum)
- Hot Water (kWh/annum)
- Cooling (kWh/annum)
- Lighting (kWh/annum)
- IT & other electrical (kWh/annum)
- Fans & Pumps (kWh/annum)

**Key:**

**CO<sub>2</sub> emission breakdown**

- Heating (kgCO<sub>2</sub>/annum)
- Hot Water (kgCO<sub>2</sub>/annum)
- Cooling (kgCO<sub>2</sub>/annum)
- Lighting (kgCO<sub>2</sub>/annum)
- IT & other electrical (kgCO<sub>2</sub>/annum)
- Fans & Pumps (kgCO<sub>2</sub>/annum)

## Changes in energy use over time

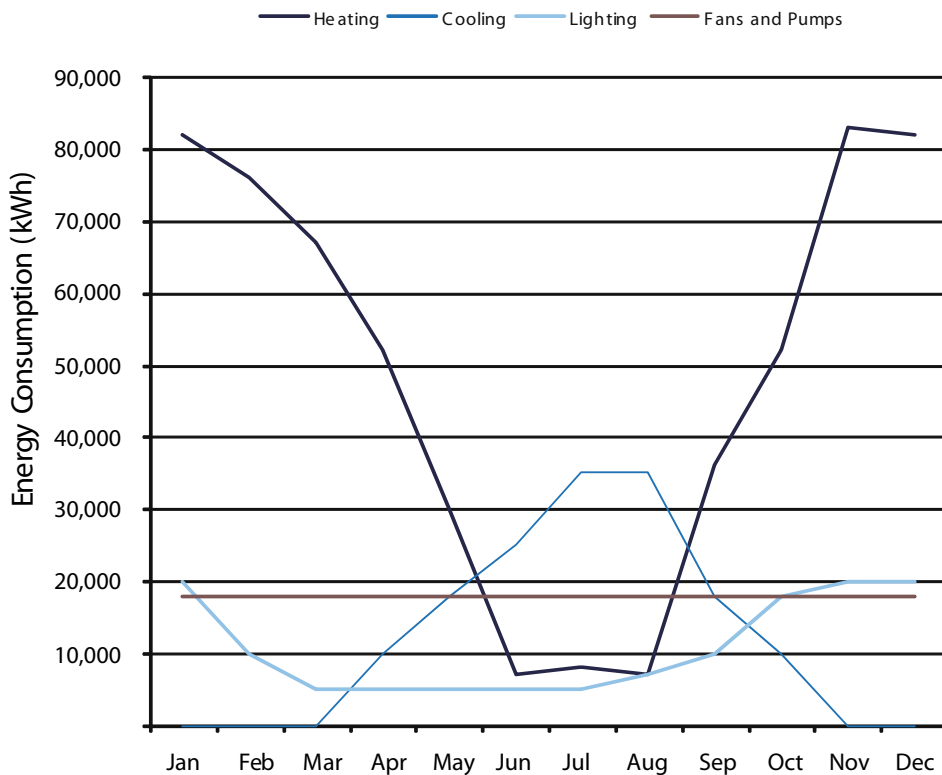
Just as energy use changes with different building functions, energy use changes over time. Throughout the day residential energy use peaks in the morning and evening as people get up and come home from work. Likewise, commercial and industrial processes also have peaks and troughs in energy demand. Similarly, variations in energy consumption occur across the year, particularly in heating and cooling demands as the seasons change. The graph below shows a typical energy use profile for an existing office over a year (note that some electrical energy uses such as computers and appliances are not shown but are relatively constant over the year).

Changes in energy demands need to be met with a supply that can cope with the variations in load. Conversely, different energy generation technologies vary in the way in which they

produce energy. For example, many low carbon and renewable energy systems give variable outputs with climatic conditions (such as wind turbines, photovoltaic solar electric panels and solar thermal how water panels) whereas others, such as combined heat and power units and biomass boilers, prefer to run at near full power continuously. This can cause problems when looking at energy needs over the year as well as on a smaller hourly scale as energy demand can vary greatly with time. This is one of the issues of running a combined heat and power plant (which likes to run continuously) for a single office; the heat demand varies considerably over the year and in summer months in very low (just providing hot water to taps and shower). Similarly, photovoltaics or wind are unlikely to provide a reliable significant supply at peak times.

In addition, number of building types are linked together such as in a mixed use development, the variations in energy use over time are “flattened out” (homes and restaurants requiring heat and power in the evening when offices and shops require little). This can lead to savings in the size of equipment required for a development as well as providing better financial returns and performance due to the more predictable, constant demand profile.

### Energy Load profiles



## Measuring carbon and energy

There are significant policy requirements for energy use and carbon dioxide emissions from new developments in Scotland to be considerably reduced, moving towards zero carbon buildings. These policies and targets are only going to increase in the future. In order to turn these policies and targets into specific requirements for individual buildings to meet, a clear methodology for measuring energy use and carbon emissions is required.

There is much debate as to how energy and CO<sub>2</sub> emissions should be measured and the method currently used by Scottish Building Standards has issues to resolve as we move towards zero carbon new buildings. Therefore, this section explores the definition of zero carbon development and the various methods of measuring carbon, including the method currently used by Scottish Building Standards.

In summary, however, there are a several overarching issues surrounding the definition and measurement of zero carbon:

- Whether all emissions from energy used in buildings should be considered, including cooking, computers and other electrical equipment?
- Whether embodied energy and associated emissions used in the construction, maintenance, operation (including transport and water) and demolition of the building should be included?
- What carbon emission factors should be used (the assumed carbon output of the national grid electricity supply varies depending on power station fuel breakdown)?
- Should the target also require minimum energy efficiency levels?
- Should, and if so how should, offsite renewable energy systems (such as offshore wind farms) be allowed to contribute to carbon emissions reductions?
- Should, and if so how should, carbon offsetting (such as funding energy efficiency or overseas renewable energy) be allowed to contribute to carbon emissions reductions?

### Examples of definitions of zero carbon

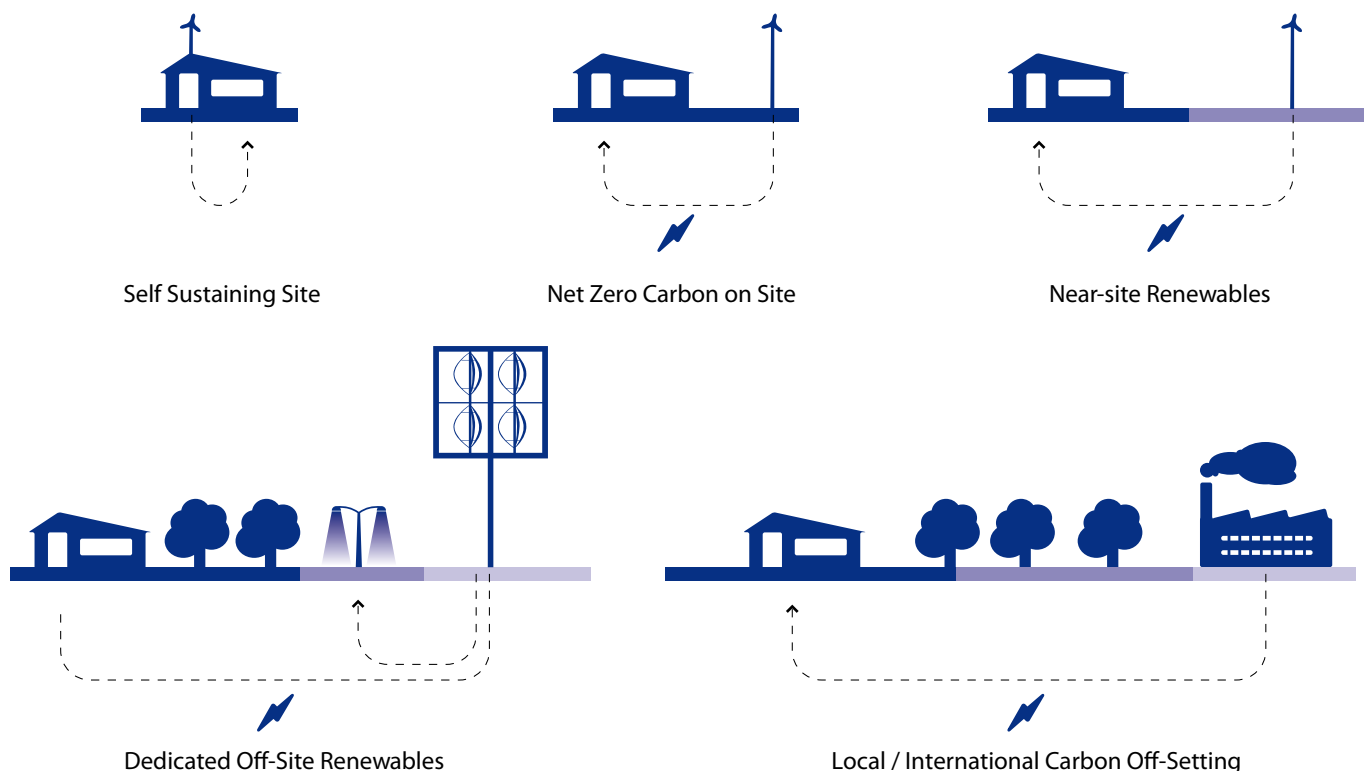
- A self sustaining site i.e. a site that only uses zero carbon energy generated on the site (all energy from renewable technologies such as wind, hydro, PV etc. and there is no mains gas or electricity connection).
- A (onsite) net zero carbon site. The buildings produce and export sufficient zero carbon electricity (or possibly gas in the future) over the year to compensate for the carbon emissions resulting from all electricity and other fuels used on the site.

These three definitions are all currently accepted methods of achieving net zero carbon emissions for the purposes of Scottish Building Standards, Energy Performance Certificates (EPCs), BREEAM and the Code for Sustainable Homes (CfSH).

A key element in defining zero carbon is what emissions are included. Most current definitions are limited to operational energy use. Scottish Building Standards, EPCs and CfSH level 5 only require regulated carbon emissions to be included (heating, hot water, cooling,

ventilation, lighting, fans and pumps). For BREEAM’s “true zero carbon” definition and for CfSH level 6, non-regulated emissions (such as small power, lifts, appliances, etc) should be included in the calculation making zero carbon a much harder target to meet.

- Similar to option 3 but dedicated offsite renewables provide electricity via a special “green” tariff which guarantees Renewable Obligation Certificates (ROCs) are retired, ensuring carbon reductions are additional to other policy requirements. This route may be allowed in the future.
- The use of local or international carbon offsetting to achieve a carbon neutral buildings. Offsetting involves funding projects which save carbon in a very economic way such as planting trees. You buy the offsets you need to balance your emissions on an annual basis. The UK government estate has committed to being carbon neutral in this way by 2012.
- The Sullivan Report sets an aspiration that new Scottish buildings should achieve “Total Life Zero Carbon” emissions by 2030. This definition of zero carbon includes the embodied emissions required to build, maintain, operate (including, water and transport emissions as well as energy) and demolish the building. This will require buildings to be highly carbon negative in operation to “pay-back” the emissions from construction and maintenance of the building.



## Current Scottish Building Standards methodology

In response to the European Energy Performance of Buildings 2002/91/EC Directive, revisions to Scottish Building Standards in 2007 required that calculations are undertaken to predicted carbon dioxide emission from new buildings. New Buildings must demonstrate that their carbon dioxide emissions (Building Emission Rate (BER)) are less than a target level (Target Emission Rate (TER)).

The Building Emission Rate (BER) or Dwelling Emission Rate (DER) must be calculated using recommended software such as SAP or NHER for Dwellings and i-SBEM, IES or TAS for non-domestic buildings. A building's CO<sub>2</sub> emissions are calculated from simulation of energy use from heating, cooling, ventilation, hot water and lighting over a typical year.

The Target Emission Rate (TER) is defined by the software as a 20% to 28% improvement (depending on building types and building services solution) over the actual building if it were built with fabric and building services plant to previous Section 6 minimum Building Standards. Energy Performance Certificates are now also required at construction, sale and rent of new and existing buildings. The A to G rating is based upon a building's carbon dioxide emissions in a similar manner to Building Standards.

In summary:

- Only emissions from energy used in heating, cooling, ventilation, lighting and generating hot water in buildings are included.
- Embodied energy and associated emissions are not included.
- The carbon emission factors are defined in Building Standards Section 6 and are fixed in the compliance software.
- There is no target for energy efficiency although minimum backstop performance standards for fabric and plant are defined in Building Standards Section 6
- Only onsite or directly connected near site renewable energy systems are allowed to contribute to CO<sub>2</sub> emission reductions
- Carbon offsetting is not currently allowed to contribute to carbon emissions reductions

## Measuring carbon - good policy practices in setting targets

As demonstrated above, the definition of targets for energy and carbon dioxide emissions is not straightforward. Notwithstanding the debate over the definition of zero carbon and measuring energy and carbon, the methodology currently used by Building Standards Section 6 is relatively clear, consistent and fairly well understood by the construction industry.

However, planning policies across local authorities vary considerably. Some set targets for reductions of carbon dioxide emissions beyond building regulations while others require minimum targets for renewable energy. The renewable energy target also varies between authorities; some requiring a 10% reduction in energy use from renewables and others a 10% reduction in carbon dioxide emissions.

One of the first planning authorities to require a minimum amount of energy be produced on site through renewable energy was Merton Borough Council, London and its policy is now well known as the "Merton Rule". Merton Borough Council developed the rule and adopted it in 2003. Its impact was so great that the Mayor of London and the majority of English councils have since implemented it, while many councils in Scotland and Wales have developed their own versions of it.

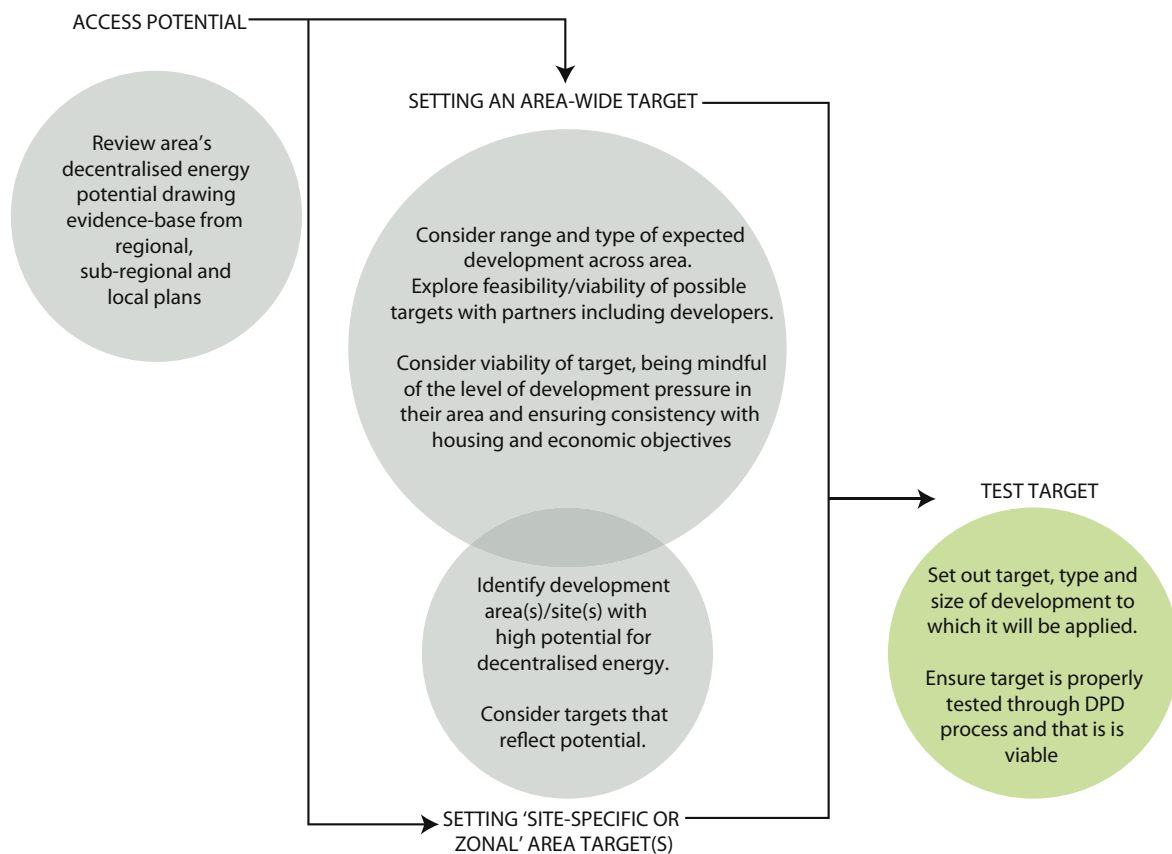
Over the past few years, Merton Borough council has been working closely with other authorities, professions and industry to embed the Merton Rule. This work is not only leading to

big CO<sub>2</sub> reductions, but it is helping to create an industry that can respond to the needs for affordable renewable energy.

Merton Core Strategy Policy

*“The Merton Rule stipulates any new development must generate at least 10% of its energy needs from on-site renewable energy equipment.”*

However, this type of policy is seen by many as a “one size fits all” policy target which is not suitable for many sites in a local authority. The requirement to install renewable energy is seen by many as being restrictive and that there are other potentially more effective and cheaper ways to reduce carbon emissions through measures such as fabric improvements. This needs to be balanced against the need to change the way our energy is generated and as we move towards zero carbon buildings the use of low and zero carbon energy sources will be required. Many renewable energy installations do work and are cost effective and should be encouraged in appropriate locations. As a result, the following route to setting targets has been used successfully by many local authorities:



Targets should cover:

- Area wide targets relating to local potential i.e. targets should be justified using the evidence base;
- Areas with higher potential (such as near a proposed district heating main, with a wind resource or part of a large mixed use development) should have higher targets.

It is very important when setting targets to define compliance precisely as well as providing an easy and consistent way of presenting the necessary evidence (such as a submission template).

Key issues include:

- Defining what energy uses should be included within calculations (regulated and unregulated? Embodied, operational, etc).
- Defining how energy use should be calculated - e.g. using Section 6 calculations for regulated energy use and a fixed methodology for non-regulated emissions (as per the Code for Sustainable Homes).
- Defining your units, a 10% saving in energy use is different from a 10% saving in carbon emissions (due to carbon emission factors of different fuels).

An interesting example is Southampton City Council's policy which also requires buildings to link into the existing CHP district heating systems:

*“All developments, either new build or conversion, with a floorspace of 500m<sup>2</sup>, or one or more residential units (based on the size of the final development footprint), will be required to incorporate decentralized and renewable or low-carbon energy equipment to reduce predicted CO<sub>2</sub> emissions by at least the percentage values for each type of development stated in the ‘Requirements for reductions in CO<sub>2</sub> emissions’ table’. Where specific opportunities exist, development will be required to connect to existing Combined Heat and Power (CHP) systems or make equivalent CO<sub>2</sub> savings through other on-site renewable or low-carbon energy measures.”*

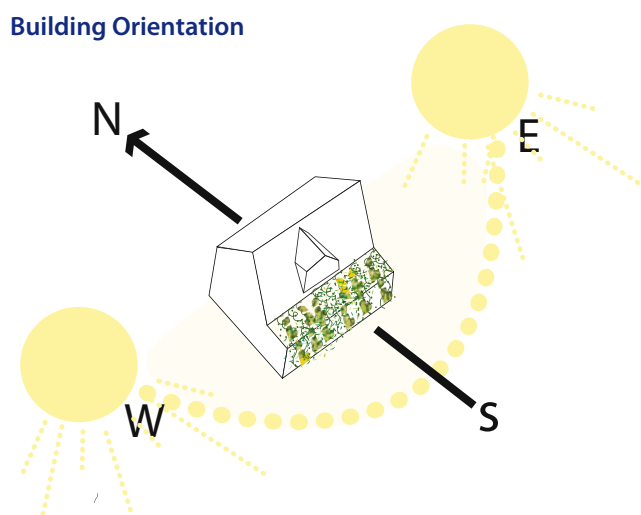
## Energy efficiency

Energy efficiency relates to how much energy is used for a particular process. The more energy efficient a process is, the less man-generated energy is required to achieve the same output.

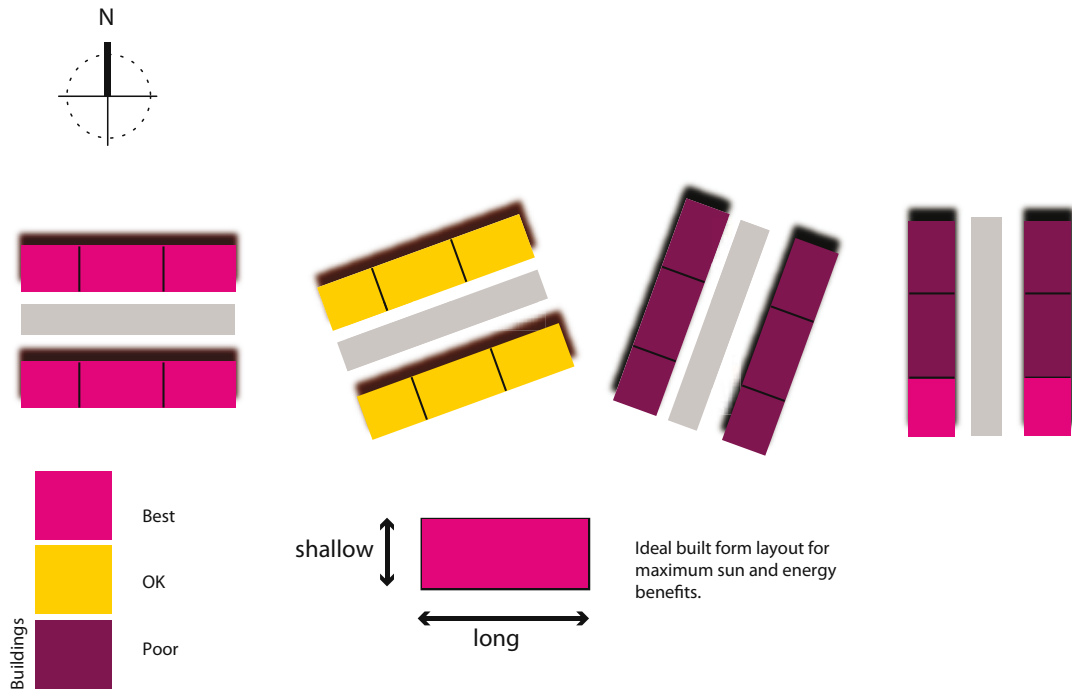
In the case of heating, a more energy efficient building would be one that reaches and maintains thermal comfort with minimal energy input. Different measures can be incorporated into developments to increase their energy efficiency, such as insulation or passive design in the heating example. The following section explores some of the measures used at both a site level and a building scale to improve the energy efficiency of a development.

### Energy efficiency - site scale

The masterplanning of a development will also have an impact on its energy demands. Orientation and shelter can be used to improve the energy performance of buildings to reduce the amount of energy needed for heating, ventilation and lighting. The ideal orientation of buildings is with the longest face of the building orientated towards the south. Correct orientation will reduce space heating needs and also increase natural daylight levels. Orientation is also vital to the use of solar technologies for energy generation. Photovoltaics and solar water heating units should be used on roof tops that are angled within 15 degrees of south. As good urban design principles demand that buildings face onto the street, especially in medium-high density areas, street layout has a significant impact on energy efficiency. Utilising natural light and heat to minimise the need for additional man-generated in this way is known as passive design.

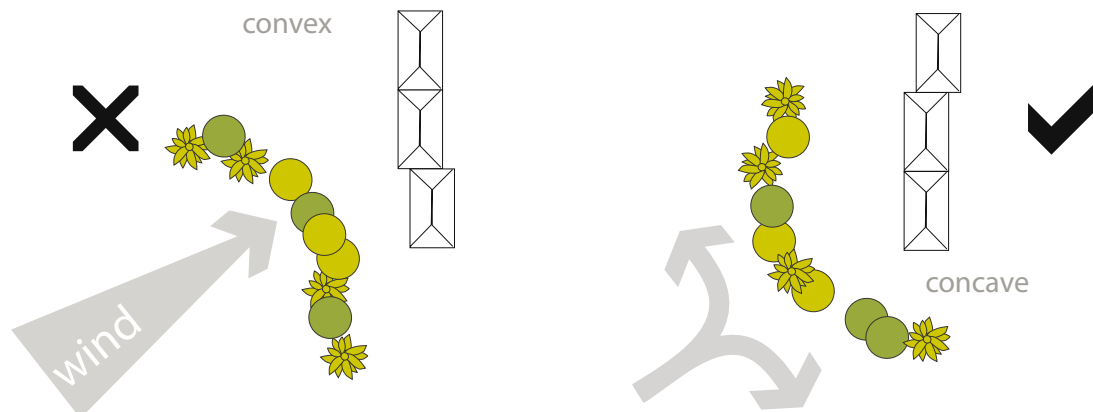


Orientation: Good sun locations



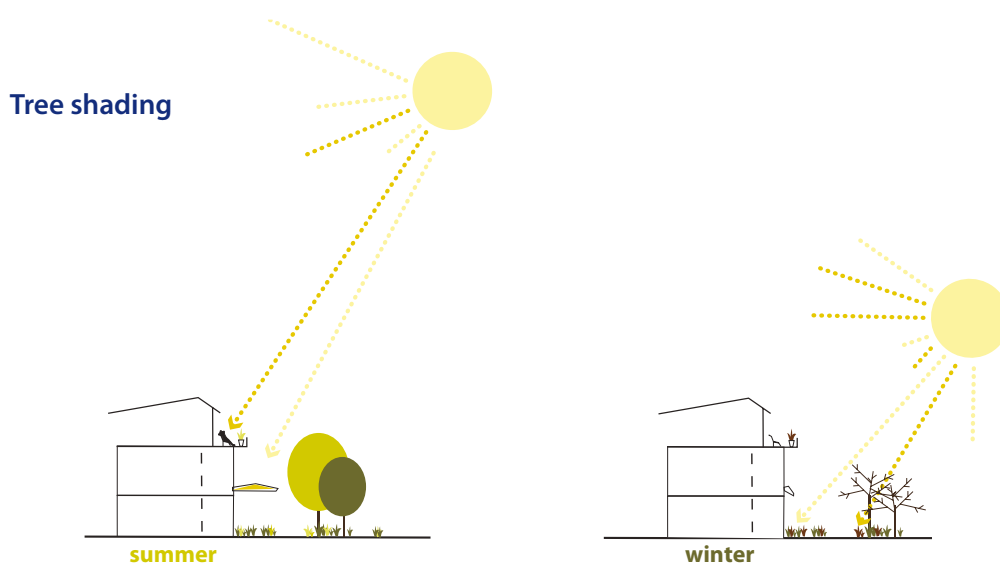
Landscaping and urban form can also have an impact on energy efficiency. Ensure that buildings and open spaces are not overshadowed where possible. Street widths and building placement should ensure that there is good daylight exposure to building frontages and key public spaces. Wider east-west streets will expose south-facing buildings, allowing for good daylighting and natural heating. Deciduous trees can be planted near buildings to shade in the summer, while letting heat and light through in the winter. Wind should also be considered in site layout. Exposure to wind results in heat loss from buildings and the creation of unpleasant spaces and streets. Shelter belts can be planted on the edge of sites to shield from prevailing winds and cold northerly winds. With good design breezes can also be used to assist energy efficiency, providing natural ventilation in buildings. ‘Wind cowls’ can be placed on the roof of buildings which respond to breezes and circulate air through the building.

Shelterbelt



## Energy efficiency - building scale

Various strategies can be taken to reduce energy demand in a building. Heat demand can be reduced through good insulation, efficient boilers, good orientation and external shading balance, careful consideration of glazing and the use of sun collection areas or sun spaces. Green roofs increase energy efficiency by increasing roof insulation and regulating heat gain and heat loss in a building. The Passivhaus standard is commonly specified in sustainable exemplars as a building standard that reduces heating demand to a minimal amount. Passivhaus utilises thick concrete walls and very high insulation standards. To reduce electricity demand, efficient appliances and lighting should be specified and good orientation along with the use of light wells and carefully placed glazing should be included in design to maximise natural daylight.



The following list sets out commonly used energy efficiency measures and typical energy savings:

- Improved wall, roof and floor insulation performance - reduced heating energy use by up to 20-30% depending on insulation levels.
- Improved glazing insulation performance - reduced heating energy use by up to 20-30% depending on insulation levels.
- Reduced areas of glazing - reduced heating energy use by up to 20-30% depending on areas. Care needs to be taken not to increase lighting energy use.
- Increased areas of glazing - reduced lighting energy use by up to 20-30% depending on areas. Care needs to be taken not to increase heating energy use.
- Improved building air leakage - reduced heating energy use by up to 10-20% depending on insulation levels.
- High efficiency heating systems - reduced heating and hot water energy use by up to 5-10% depending on efficiencies.
- Heat recovery on ventilation systems - reduced air heating energy use by up to 50-60% depending on efficiencies.
- Heating system controls - reduced heating and hot water energy use by up to 5-10% depending on controls.

- High efficiency appliances - reduced electrical energy use by up to 10-20% depending on efficiencies.
- High efficiency lighting - reduced lighting energy use by up to 20-70% depending on efficiencies.
- Lighting controls - reduced lighting energy use by up to 10-30% depending on controls.
- Greater use of natural ventilation - reduced ventilation and cooling energy use by up to 100% depending on systems, location and use.
- Introduction of rooflights - reduced lighting energy use by up to 20-30% depending on areas. Care needs to be taken not to increase heating energy use.
- Thermal mass and night cooling - reduced cooling energy use by up to 100% depending on systems, location and use. Care needs to be taken not to increase heating energy use.
- Solar shading or solar control glass - reduced cooling energy use by up to 100% depending on systems, location and use. Care needs to be taken not to increase heating energy use.

It is important to note that some of the above measures are expensive to implement and the use of low and zero carbon technologies may be a cheaper way of achieving emission reductions targets. However, many of the above measures are “in for the life of the building” such as insulation and won’t break down. Although energy efficiency measures can dramatically improve the energy performance of a development, there will inevitably be some demand for energy remaining. To be as sustainable as possible, the generation of this energy should come from renewable and low carbon sources. The next section looking into the generation of energy in Scotland in more detail and includes profiles of a range of renewable and low carbon energy generating technologies.

# Energy generation

Once opportunities to reduce energy demand through behavioural change and improving energy efficiency have been exhausted attention should focus on generating energy from more sustainable sources.

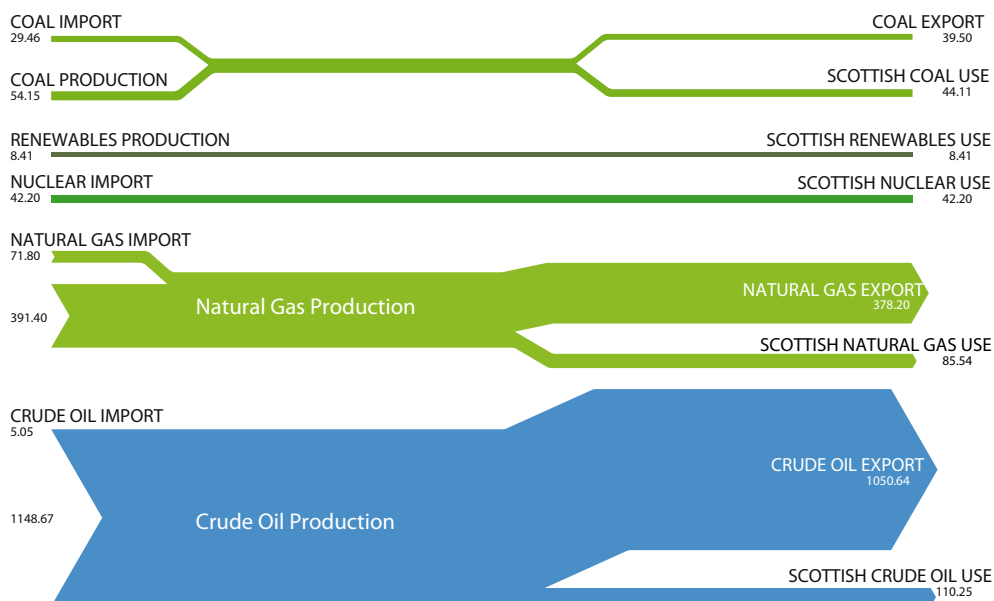
Sustainable energy generation utilises renewable energy sources and LZCT to reduce the amount of CO<sub>2</sub> generated in sourcing and generating energy. This section provides an overview of the current energy generation market in Scotland before looking in more detail at the different technologies available in moving towards more sustainable energy generation.

## An overview of energy generation in Scotland

Much of this section is based on data from the Scottish Energy Study (November 2008). A great way to understand how energy is supplied across Scotland is by using Sankey diagrams. The diagrams show readings from left to right representing the supply of fuels and their transformation such as generating electricity as well as their final use in demand sectors. It is important to note the width of the lines is proportional to the energy consumed.

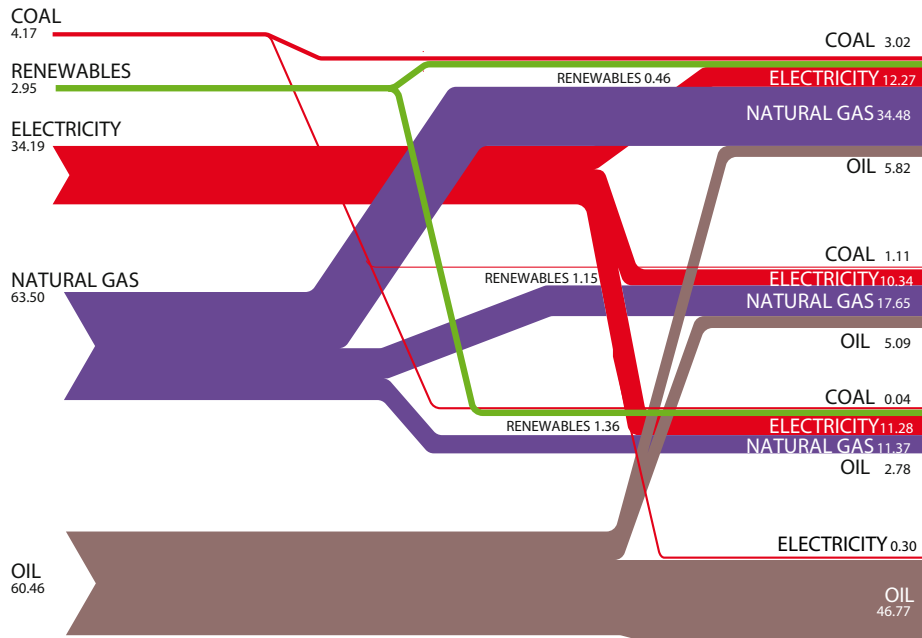
The first Sankey diagram below shows energy flows in and out of Scotland. It highlights that Scotland dominated by oil and gas; much of it going for export. The second Sankey diagram shows how energy is used by the various end use sectors in Scotland and where that comes from. Domestic energy use is the largest end use category followed by transport. The electricity in this Sankey diagram is currently generated by the mix of fuel supplies highlighted in the third diagram. As can be seen from these Sankey diagrams, the energy supply mix in Scotland is currently highly dependant on fossil fuels and as a result gives rise to high carbon dioxide emissions. The following pie charts highlight where carbon emissions are currently generated by end use.

Energy flows in and out of Scotland



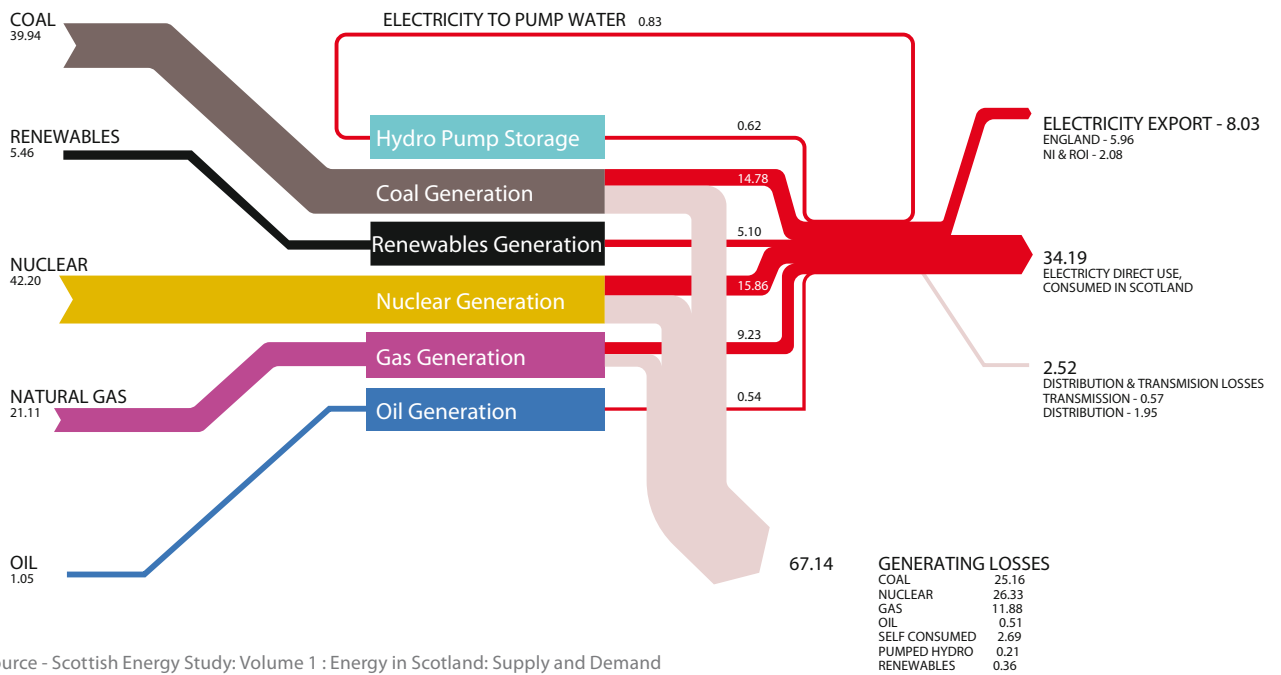
Source - Scottish Energy Study: Volume 1 : Energy in Scotland: Supply and Demand

Energy use



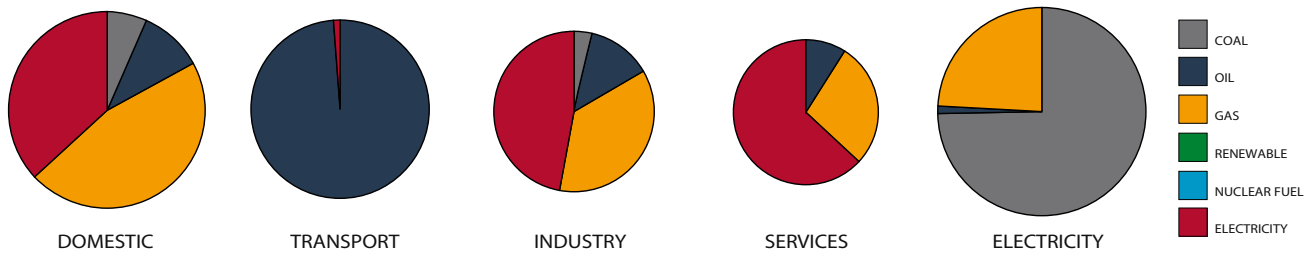
Source - Scottish Energy Study: Volume 1 : Energy in Scotland: Supply and Demand

Mix of fuel supplies



Source - Scottish Energy Study: Volume 1 : Energy in Scotland: Supply and Demand

### CO<sub>2</sub> generation by demand sector and electricity generation



Source - Scottish Energy Study: Volume 1 : Energy in Scotland: Supply and Demand

In order to reduce the amount of carbon dioxide emissions released into the atmosphere as a result of energy generation, there needs to be a significant shift towards the use of renewable energy sources that are rapidly renewed by growth (such as biomass) or nature (e.g. wind, solar). These technologies, now commonly referred to as Low and Zero Carbon Technologies (LZCTs) produce significantly lower or no CO<sub>2</sub> emissions when generating energy. This definition includes technologies such as combined heat and power. Scotland's natural resources mean that it has considerable potential to generate significant amounts of renewable energy. However, with a market dominated heavily by oil and gas available for revenue generating export, building a competitive renewable market remains a challenge. Planning policies that support renewable energy generation will help to develop this market, stimulating innovative approaches to meeting targets.

### Scale of energy generation

Traditionally energy supply has been provided by large decentralised power plants that can maintain a relatively constant output fed into the national grid. Renewable energy and LZCT, however, now provide the opportunity to generate energy (heat and/or electricity) for an individual building or collections of buildings. This 'microgeneration' creates a more flexible approach to energy generation and is strongly supported by the Scottish planning system.

The Scottish Government is also considering including some forms of microgeneration technologies as permitted development that does not require planning permission. Wind, photovoltaics and solar water heating are particularly suitable for individual buildings and biomass generators could be incorporated into large scale developments. These technologies can be particularly useful for remote development as they can be more cost effective. Large scale, centralised renewable energy generation such as wind farms, hydro, energy from waste and combined heat and power can, however, benefit from the economies of scale associated with major development and can often deliver more significant CO<sub>2</sub> savings. There are however drawbacks, for example in that planning applications are more likely to need a supporting Environmental Impact Assessment. Realistically, a combination of both micro and centralised energy generation is required. As explained in section 'Understanding Energy Requirements' the capacity of some renewable technologies cannot provide continuous energy supply and can struggle to deal with fluctuations in demand. As such, a residual back up supply is generally required.

### Micro and onsite generation

Benefits	Contraints
Cost savings over time	High capital costs per unit
Supported by the planning system	Potentially fluctuating power output
Cost effective for remote locations	
Suitable for most buildings	

### Centralised renewable energy regeneration

Benefits	Contraints
Economies of scale	High capital investment
Potentially more significant CO2 savings	Will require EIA and detailed planning studies
Can provide more constant power output	Potentially location specific (i.e. hydro)
	Heat networks can be difficult to link to existing buildings

## Renewable and Low/Zero Carbon Energy Technology Decoder

There are a wide number of available renewable energy and LZCTs suitable for a range of applications, each with associated benefits and constraints that planners will need to take into consideration when looking to reduce the energy impact of development. The next section examines each of the most viable methods of generating low or zero carbon energy in the form of a ‘technology decoder’.

The decoder aims to provide a simple overview of the various technologies, covering:

- How the technology works;
- The energy and carbon savings possible from the technology;
- The building types or load profiles best suited to the technology;
- The key issues which should be considered;
- The differing scales the technology is currently available at;
- A typical footprint of the technology to assist with an understanding off it size;
- Some typical costs of the technologies;
- Some best practice case studies of successful implementation;
- Lessons learnt from early adopters of the technology;
- The size of system required to serve one home and 500 homes to further assist with an understanding of scales.



## Micro - Wind Turbines

### Key facts

#### How it works

The most common design of a wind turbine is three blades mounted on a on a tall shaft, which is free to rotate into the wind driving a generator to produce electricity (or in some instances pump water or heat water). Alternatively, vertical axis wind turbines are not sensitive to wind direction, but have generally lower output. The turbine can be connected to the grid, or to charge a battery. In periods of high wind, turbines may produce more power than is needed which allows excess electricity to be exported back to the grid and sold to an electricity supply company. The main factor affecting output of a particular turbine is the wind speed. A small reduction in wind speed has a large impact on the power output (a site with an average wind speed of 5m/s will produce double the output as one at 4m/s and a site with an average wind speed of 8m/s will produce eight times the output!).

#### Energy/carbon savings

Wind is a completely renewable energy source with no carbon emissions associated with its operation. A domestic microwind turbine could save an average household (with a good wind regime) approximately a third of its typical energy requirement. The larger micro-wind systems can provide nearly all the electricity required in a home.

#### Building/load profile suitability

Modern turbines without gearboxes are very quiet which makes them viable also in urban areas. There are currently a few successful practical installations of roof mounted wind turbines in the UK but it is anticipated that this will be a growing market with new products being developed to overcome many of the key issues. In remote areas a microwind turbine can be used as a stand alone system where it charges a battery or in a hybrid system with diesel generator back-up.

#### Other key issues

- Average wind speed at the location of the turbine should be above 4 m/s, preferably above 7m/s. This may require a taller tower to avoid turbulence from surrounding buildings, trees, etc.
- Potential impact of noise from turbine blades and components, particularly on housing and schools, should be considered, taking into account background noise.
- Uneven and turbulent wind patterns occur near buildings and other obstacles affecting output and component lifetime.

- Potential visual impact and impact on local ecology, natural heritage, conservation areas etc. should be assessed.
- Turning blades cause a flickering shadow in sunny conditions and may need to be considered,
- Permission from local electricity supplier for connection to grid.

## Available scales

Small 1 kW building mounted turbines for a house, small 15kW for a school, 250kW for a small community or 5MW offshore wind turbine to serve a town (see large scale wind sheet).

### To serve 1 home

A small wind turbine (2 to 5kW) could meet the annual equivalent of a typical household's annual electricity requirements. If the home is not grid connected, battery storage may not meet the home's electricity requirements during calm periods and alternative back-up energy source would be required.

### To serve 500 homes

A single large wind turbine (~1MW) or numerous small wind turbines (~100 15kW turbines) could meet the annual equivalent electricity requirements of 500 homes. During calm periods an alternative back-up energy source would be required such as a grid connection (which also enable electricity export).

## Typical footprint

Smaller turbines can be roof mounted. Ground mounted turbines are usually limited by available suitable space for a turbine, as they usually must be placed a minimum distance from residential and school buildings due to noise and shadow flicker as well as a minimum distance from roads and footpaths.

## Costs

Wind is one of the most cost effective renewable energy technologies (in windy sites!). Capital cost: £2,500 to £5,000 per kW installed. A typical financial payback period on microwind in a fairly windy site is 7-12 years with a life span of 20-25 years. Low maintenance costs: a service check every two years is usually required.

## Good practice examples

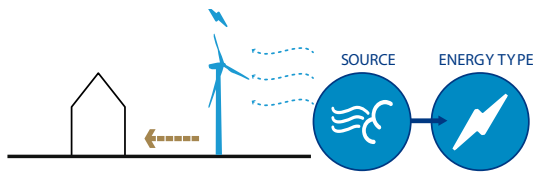
### Fife Schools Pilot Project

As part of pilot project launched by the then Deputy Enterprise Minister, rooftop micro-wind turbines have been installed on five Fife primary schools, including Collydean Primary School, Glenrothes. The initiative was jointly funded by the Scottish Executive through the Scottish Community and Household Renewables Initiative, Renewable Devices, Scottish Power and Fife Council. Each turbine can generate up to 4000 kW hours of green electricity each year, saving up to 1720kg carbon dioxide, and cutting the schools' energy bill. The turbines have also served an

education role in raising awareness of renewables amongst the pupils. (Pan 45 Annex)

### Lessons learnt from early adopters:

- It goes without saying that if the turbine location is not windy, the output will be low. However, ideal locations are often contentious such as atop hills or in open areas.
- Building mounted wind turbines in urban areas have to date not usually generated high outputs due to low wind speeds and local turbulence. New vertical axis wind turbines claim to give improved output and are being installed at a number of locations.
- Be aware of electrical losses which can be minimised by correct cable and inverter sizing.



# Large Scale Wind Turbines

## Key facts

### How it works

The most common design of a wind turbine is three blades mounted on a on a tall shaft, which is free to rotate into the wind driving a generator to produce electricity. The blades and shaft are connected to the nacelle, which contains the gearbox and other power/mechanical components. The wind turbine may have a tail or motor to align the blades with the direction of the wind to maximise energy generation. The main factor affecting output of a particular turbine is the wind speed. A small reduction in wind speed has a large impact on the power output. The UK has 40% of Europe's wind resource.

### Energy/carbon savings

Wind is a completely renewable energy source with no carbon emissions associated with its operation. Wind power (on and off shore) is considered most likely to make the most substantial contribution towards meeting renewable energy targets.

### Building/load profile suitability

Wind power has a very fluctuating and unpredictable output. This needs to be balanced by a different energy source.

### Other key issues

- Development plans should set out a spatial framework, for the consideration of wind farm proposals over 20MW.
- Impacts on landscapes and the historic environment, ecology (including birds), biodiversity and nature conservation; the water environment, communities, aviation, telecommunications, noise, shadow flicker.
- Phasing into grid: variable electricity production from wind farms need to be buffered by other energy sources.
- Offshore wind farms less likely to interfere with communities and ecology, but energy transfer to land pose a challenge.

### Available scales

Schemes range from small clusters to large wind farms. Turbines are available with outputs ranging from 500W up to 6MW.

## To serve 1 home

A small wind turbine (2 to 5kW) could meet the annual equivalent of a typical household's annual electricity requirements. If the home is not grid connected, battery storage may not meet the home's electricity requirements during calm periods and alternative back-up energy source would be required.

## To serve 500 homes

A single large wind turbine (~1MW) could meet the annual equivalent electricity requirements of 500 homes. During calm periods an alternative back-up energy source would be required such as a grid connection (which also enable electricity export).

## Typical footprint

The largest wind farm in Europe (Whitelee, Scottish Power Renewables) of 92 wind turbines, producing 450GWh/annum, covers 55km<sup>2</sup>.

## Costs

Capital costs are around £1million per MW peak output. Large scale wind turbines in good locations produce a very good income and can usually pay back within 5-10 years and then generate a good profit.

## Good practice examples

### Hadyard Hill Wind Farm

Owned and operated by Scottish and Southern Energy (SSE), has become the first wind farm in the UK able to generate over 100 megawatts (MW) of power. The 120MW, 52-turbine wind farm in South Ayrshire cost £85 million and in a year will generate enough electricity to power 80,000 homes, sufficient to supply every household in a city the size of York. The production of zero carbon electricity at the wind farm is expected to reduce emissions of carbon dioxide by almost 300,000 tonnes a year, equivalent to taking 70,000 cars off the road.

### Black Law Wind Farm

Black Law Wind Farm near Forth in South Lanarkshire was opened in 2006 and cost £90 million. With its 42 turbines and 97MW output it can power 70,000 homes with a massive carbon dioxide reduction of 200,000 tonnes a year. The project is located on the site of an abandoned opencast mine which was completely restored to shallow wetlands by Scottish Power during the wind farm construction programme. This was recognized by the Royal Society for the Protection of Birds who said that the scheme was not only improving the landscape in a derelict opencast mining site, but also benefiting a range of wildlife in the area, with an extensive habitat management projects covering over 14km<sup>2</sup>.

## Lessons learnt from early adopters

- Many wind farms meet resistance from the public during the planning phase.
- Although a renewable energy source, it demands large areas, often conflicting with wildlife and recreational use.
- There is currently a long lead in time for wind turbines due to demand outstripping supply.



# Photovoltaic Panels (PV)

## Key facts

### How it works

Photovoltaic panels consist of semi-conducting cells that convert sunlight into electricity. The panel produces electricity even in cloudy conditions, but the power output increases with the intensity of the sun. PV systems can be connected to buildings via batteries or via an inverter to the mains supply.

This way excess electricity production can be sold to the national grid. There are other large scale technologies for producing electricity from solar energy (concentrated solar power plants), but these are mainly located very in sunny climates.

### Energy/carbon savings

Once installed, PV panels generate no carbon emissions and have no moving parts. A modern gas heated 2 bed/4 person flat uses approximately 1,500kWh/year in electricity (for lights and appliances), so a typical 1kWp system would provide approximately 45% of the dwelling's electricity needs.

### Building/load profile suitability

Particularly suited to sites that use electricity during the day - offices, retail and schools.

### Other key issues

- Systems should ideally face between south-east and south-west to maximise the amount of light on the PV's.
- Generally, a roof angle of between 20-50 degrees from the horizontal is good. If this is not possible, mount the PV's on a frame at 40 degrees.
- Systems should be unshaded at all times of day if possible.
- Consider loading (especially wind loading) capacity of the roof.
- Ensure the building's metering system allows export of energy if needed.
- Birds may need to be discouraged from perching near the systems
- Protection against vandals/theft as the systems are quite valuable!
- Arrays should not be horizontal as the rain will be unable to wash them clean.
- There are no licensing requirements relating to PV systems, but consent must be obtained from the Distribution Network Operator.

- PV's efficiency decreases as their temperature rises and so need access to natural ventilation (behind the modules).

## Available scales

PV panels can come in wide variety of sizes (and colours), these can be connected to provide any module size. Roofing and glazing systems are available with PV arrays built in.

## To serve 1 home

~30m<sup>2</sup> PV panels are required to meet the annual equivalent of a typical household's annual electricity requirements. If the home is not grid connected, battery storage will not meet the home's electricity requirements in winter and a larger array or alternative energy source would be required.

## To serve 500 homes

For multiple homes, individual systems are likely to be most cost effective.

## Typical footprint

Approximately 38m<sup>2</sup> of PV panels is needed to cover the demand of a 140m<sup>2</sup> 4-bed mid terrace house with a typical electricity consumption of 3850kWh/year.

## Costs

Relatively high on costs. Cost: £5,000 to £8,000/kWp peak output for a roof mounted system, £10,000 to 5,000/kWp for façade/atrium systems. Payback is long unless they are replacing a major building element such as solar shading (see DEFRA Alnwick example).

## Good practice examples

### Crichton Castle

A scheduled monument in Midlothian is the first property in the care of Historic Scotland to be powered by renewable energy. The solar panels used to provide electricity to a small shop and ticket office, were positioned on top of one of the 14th century towers not visible to visitors (PAN 45 Annex).

## Lessons learnt from early adopters

- Theft of PV panels is on the increase, so securing and surveillance of PV is recommended.
- Vandalism has occurred on a number of sites with low natural surveillance, use of clear plastic to protect the panels has led to obvious reductions of output.
- PV systems work well with green roofing systems as the green roofs help to keep the PV panels cool in summer which increases panel efficiencies.



# Solar Thermal Hot Water

## Key facts

### How it works

Solar water heating systems comprise solar collectors (tubes or flat plates), a heat transfer system (a fluid in pipes) and a hot water store e.g. domestic hot water cylinder. The solar collector heat exchanger preheats water from the mains and a conventional boiler (gas or electricity) is used to reheat the water to a temperature high enough to prevent legionella growth in the storage tank. The systems work very successfully in all parts of the UK, as they can work in diffuse light conditions. (Passive solar heating though good building design is not considered here but is another excellent way of profiting from solar heat in buildings).

### Energy/carbon savings

The average domestic solar hot water system can reduce CO<sub>2</sub> emissions by 0.25-0.5 tonnes/year, depending on the fuel replaced, and provide almost all of a home's hot water during the summer months. Even in winter months there is a significant contribution to preheating water. System's savings average at around 454kWh/year saving per m<sup>2</sup> of flat plate collector, or 582kWh/year per m<sup>2</sup> for an evacuated tube system.

### Building/load profile suitability

Particularly suited to sites which require hot water, particularly during the day - housing, apartments, hospitals, leisure centres or offices with canteens, washrooms and showers.

### Other key issues

- Systems should ideally face between south-east and south-west to maximise the amount of light on the solar collector panels.
- Systems should be unshaded at all times of day if possible.
- Minimise the distance from panels to hot water tank.
- Space is required for a hot water tank if combi boilers currently provide instantaneous heat and hot water.
- Consider loading capacity of the roof.
- Birds may need to be discouraged from perching near the systems.
- Protection against vandals.
- Arrays should not be horizontal as the rain will be unable to wash them clean.

## Available scales

From small domestic systems (3-4m<sup>2</sup>) to larger systems which meet up to 50% of a large building's hot water demand.

### To serve 1 home

A ~4m<sup>2</sup> solar hot water system should meet 40-60% of a typical household's annual domestic hot water requirements.

### To serve 500 homes

For multiple homes, individual systems are likely to be most cost effective unless the homes are linked into a district heating system.

## Typical footprint

A 4m<sup>2</sup> collection area will provide between 50% and 60% of a typical home's hot water demand.

## Costs

Household system (4m<sup>2</sup>) costs from £2,500 -£4,000. Discounts will be available for bulk purchases. There can be a large variation in the costs of installation labour, pipework, fittings etc for commercial systems that depend on site-specific issues.

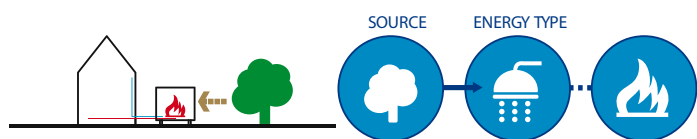
## Good practice examples

### Aberdeen City Council

Aberdeen City Council has constructed one of the largest solar panel installations in the UK to heat the community swimming pool at Bridge of Don Academy. The 180m<sup>2</sup> installation covers the entire roof of the pool with 60 state-of the-art, low maintenance solar hot water panels, using evacuated tube technology. The panels are not visible from ground level. For educational purposes, the project will have a public display facility, which will show throughout the year the level of solar energy input to the pool.

## Lessons learnt from early adopters

- Don't touch evacuated tubes after a sunny day - they get very hot!
- Controls must be set up correctly so that water is only transferred to the hot water tank when it is providing a benefit.
- Controls should be in place to prevent overheating of the hot water cylinder and fluid in the tubes (such as drainback systems).

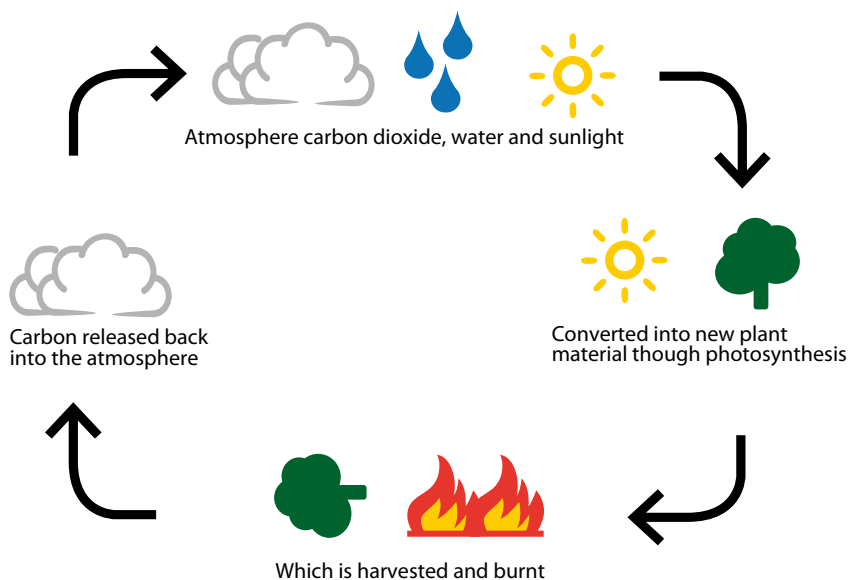


# Biomass

## Key facts

### How it works

Bio-fuelled boilers burn biomass (such as woodchip, wood pellets or straw), bio-diesels (such as rapeseed oil, vegetable oil) or biogases (such as bio-methane) to provide heat in a similar way as coal, oil or gas fired boilers or alternatively in a stand alone, more traditional stove.



## Energy/carbon savings

There are no primary energy savings as bio-fuel boilers are typically as efficient as or less efficient than gas-fired boilers. However, bio-fuelled heating is considered low carbon or near carbon neutral as the bio-fuel usually absorbs similar levels of carbon dioxide emissions in its growth as it gives off in its combustion. Energy and emissions in the transport and processing of the bio-fuels does result in some emissions (Scottish Building Standards emissions calculations assume a carbon factor of 0.025kgCO<sub>2</sub>/kWh for biomass heating compared to 0.194kgCO<sub>2</sub>/kWh for natural gas and 0.422kgCO<sub>2</sub>/kWh for grid electricity).

## Building/load profile suitability

Bio-gas and bio-diesel boilers have very similar properties to gas and oil fired boilers and so are suitable for most heating load profiles. However, biomass boilers are slower to respond to fluctuations in demand and so suit a more steady heat load. Biomass boilers are usually not

suitable for city centre locations due to fuel delivery issues, but also due to nitrous oxide emissions.

## Other key issues

- Sufficient fuel storage is needed to avoid frequent transport deliveries.
- Access for fuel delivery vehicles.
- Local fuel source should be used to reduce transport and associated emissions (typically less than 30 miles).
- Exhaust gases require a flue that rises above the roofline of nearby buildings.
- Domestic biomass boilers are larger than standard boilers and are unlikely to fit into small properties.
- Arrangements for maintenance: ash disposal and de-coking.

## Available scales

Small scale biomass heating systems range from single room heaters hand fed with logs, through to industrial units with fully automated fuel handling systems using wood chips for large scale steam or combined heat and power (CHP) operation.

### To serve 1 home

A small wood burning stove or pellet boiler (~5 to 10kW) could meet all of a typical home's annual heating and hot water requirements.

### To serve 500 homes

A large biomass boiler energy centre linked to housing via a district heating arrangement could meet home's annual heating and hot water requirements. Higher density housing systems are more viable to reduce district heating infrastructure costs.

## Typical footprint

The plant room space required is typically 0.127m<sup>2</sup>/kW installed capacity (for example a 500kW boiler to serve most of a secondary school's heating requirements would require around 60m<sup>2</sup> plant room space plus fuel storage). The necessary fuel storage area depends on the frequency of delivery and depth of fuel store but this area can be as large as the plant room.

## Costs

Biomass boilers are usually more expensive than conventional boilers and may require construction of a bespoke boiler house and fuel store. Costs vary from £100/kW to £320/kW for biomass boilers from 50 - 1250kW. They are unlikely to achieve any major fuel cost savings using biomass/biogas unless the biomass is obtained as a free waste product. The Renewable Heat Obligation may provide improved financial performance.

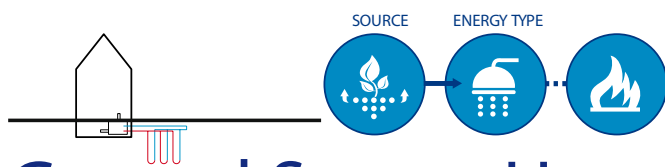
## Good practice examples

### **Barnsley's Communal Biomass Heating System**

Barnsley's Communal Biomass Heating System is the UK's largest working example of a process using wood arising from local woodland management to heat community housing (166 flats in three buildings). The Sheffield Road Flats project received the 2006 UK 1st Prize in the Ashden Award for Sustainable Energy. The project contributed towards Barnsley Metropolitan Borough Council achieving a 40% reduction in carbon emissions in 2005, with similar energy cost savings passed on to residents. The fuel store measures 9.5m x 4m x 3m giving approx. 100m<sup>3</sup> of useable storage, which will provide approximately one week's supply in winter and three to four weeks in summer.

### Lessons learnt from early adopters

- High quality, reliable fuel sourcing with alternative suppliers in the area is vital.
- Fuels must be compatible with the boiler and augers and should be testing to ensure quality.
- Buildings with “peaky” heat demands such as lightweight, highly insulated buildings with high internal gains (e.g. modern offices, schools, etc) may not suit biomass boilers unless there are high levels of thermal storage.



# Ground Source Heat Pumps

## Key facts

### How it works

A heat pump works like a refrigerator removing heat from a cold place to a warmer place. Heat sources may be external air, water or the ground. Ground source heat pumps are used to extract heat from the ground to provide space and water heating to both individual houses and any type of non-domestic building. A heat exchange fluid circulates in ground collectors (coils) buried in the ground and transfers the heat to a heat pump via a heat exchanger. The ground has a near constant temperature at about the annual average external temperature making it more efficient and robust than a heat pump using the external air or water as a heat source. For every kWh of electricity put into it, the heat pump returns 3 - 4kWh heat. The heat can be used for space heating, preheating of ventilation air as well as the heating of domestic hot water (although efficiencies are lower). In summer, the system can be used for cooling either by reversing the heat pump, or by circulating the fluid in the cool ground.

### Energy/carbon savings

A ground source heat pump uses only a third of energy compared to conventional heating systems. Compared to electrical heating, only using a third of the electricity means carbon emissions are reduced to a third. However, as other means of heating may have lower carbon emissions per unit of energy, carbon savings are smaller. Energy savings for cooling can be as high as 90%.

### Building/load profile suitability

Ground source heat pump (GSHP) systems can be used in individual houses, blocks of flats with communal heating and almost any size of non-domestic building (limited by available area of ground for boreholes). A particular use is where natural gas is not available making the ground source heat pump more economical. GSHPs are mostly suitable for low temperature heating, such as under floor heating or oversized radiators, but heat pumps can produce temperatures high enough to provide domestic hot water.

### Other key issues

- Technical feasibility depends on ground conditions.
- Ground conditions will affect ease of construction and system performance.
- A large area is required for horizontal pipe systems or access to drill for vertical pipes.
- Permission is likely to be required for ground drilling or borehole use (depth of 15 to 150m).

- Access for drilling rig at construction stage.
- With horizontal systems, the ground above may become colder and delay plant growth in spring, or if a car parking lot, frost in winter.
- Consider in advance whether archaeological remains exist on the development site.

## Available scales

Cheapest and smallest are air source heat pump (air to air/air to water) systems suitable for small houses (efficiency decreases in cold weather). Large systems are usually limited by available area for boreholes.

## To serve 1 home

A small domestic Ground Source Heat Pump (~5 to 10kW) could meet all of a typical home's annual heating and hot water requirements.

## To serve 500 homes

Large Ground Source Heat Pump systems (typically in systems of up to 100kW) may be viable for high density housing via a district heating arrangement to meet their annual heating and hot water requirements.

## Typical footprint

For a single house, a horizontal system would require garden area of at least 100m<sup>2</sup>.

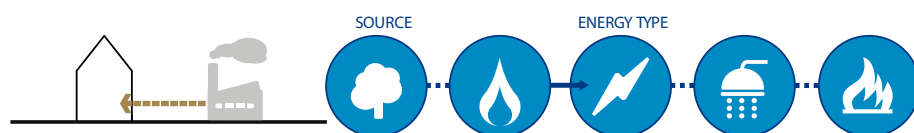
## Costs

The main additional cost in a ground sourced heat pump system is the installation of the pipes in the ground, which depends on the ground conditions and length or depth needed to be installed. Horizontal trenches are cheaper than vertical boreholes. Additional capital costs for a house is around £2,500 whereas up to £50,000 to supply 50% of the heating demand of a 3,000m<sup>2</sup> office building.

## Good practice examples

### IKEA Distribution Centre

One of the largest ground source heating and cooling systems in the UK was implemented in 2003 in the IKEA Distribution Centre located in Peterborough. The system is used to service the 3000m<sup>2</sup> of office area that is part of the 130 000m<sup>2</sup> distribution centre. The ground loop system consists of 8km of underground pipework installed in 45 vertical boreholes drilled to 70m depth. (London Renewables Toolkit).



## Combined Heat and Power (CHP)

### Key facts

#### How it works

In conventional electricity generation stations heat is usually a waste product that dissipates into the atmosphere (losing over 45% of the energy generated). Further losses then occur in the transmission of electricity. Combined heat and power (CHP) systems work by generating electricity near or onsite and has the advantage of allowing the capture of the waste heat for space and water heating. This can either be done by district heating, or small scale by central heating of buildings (micro CHP). The CHP can be powered by fuels such as gas/biogas, diesel/bio-diesel, biomass as well as waste producing around 30% electricity, 50% heat with 20% losses. When linked to an absorption chiller (a device which uses waste heat as its power to provide cooling), unwanted summer heat can be used to provide cooling in summer.

#### Energy/carbon savings

With biomass or biogas fuels, carbon emission savings can get towards 100%. However, as the fuel type may be non-renewable (gas, oil), the energy/carbon savings are due to the heat normally rejected to the atmosphere at central power stations as well as the energy loss in the transportation of electricity over the grid. Typically, fossil fuel powered CHP achieves a 35% reduction in primary energy usage compared with conventional power stations and heat only boilers. It should be noted that if the electricity used in a building/site came from a low/zero carbon source, then natural gas fired CHP could actually increase carbon emissions.

#### Building/load profile suitability

Commercial CHP is fairly common in premises which have a simultaneous demand for heating and electricity for long periods such as hospitals, recreational centres and hotels. Gas or diesel is the most convenient fuel for micro CHP but is not renewable. At present, only larger communal systems are available for biomass fuelled CHP. CHP by incineration or gasification of waste is currently only suitable on a large scale and usually requires a district heating infrastructure.

#### Other key issues

- Combustion gases will require an external flue usually terminating above the ridge line of the building.
- Ideally larger CHP plants should be housed in stand-alone building to avoid noise and vibration issues.

- Consultation with local interest groups and residents likely to be required to obtain planning permission approval.
- District heating infrastructure for large scale CHP can be very costly.
- Import-export meters need to be installed in buildings with micro CHP.

## Available scales

- Stirling engines: Gas fired ~1kW electrical/3 - 6kW heat are suitable for larger new houses or older houses with a high heating demand.
- Internal combustion engines: from 5kW electricity/10kW heat upwards are suitable for groups of flats, grouped residential buildings such as nursing homes and small commercial premises.
- Large scale CHP can provide heating and power for whole cities.

## To serve 1 home

A small Stirling engine CHP unit (~1kWe, 6kW heat) could meet all of a typical home's annual heating and hot water requirements and make a significant contribution to annual electrical requirements.

## To serve 500 homes

A large Combined Heat and Power energy centre linked to housing via a district heating arrangement could meet the home's annual heating, hot water and most if not all of their electrical requirements. Higher density housing systems are more viable to reduce district heating infrastructure costs.

## Typical footprint

For a typical CHP plant to serve 500 homes: footprint is 15 x 25m, 4m high main section, 7-9m high thermal store area and flue. For domestic micro CHP the area required is approximately the same as for a conventional boiler.

## Costs

With a good base heat load, CHP is very economical due to the lower energy running costs. The payback on installing a CHP system can be 3-5 years with maintenance costs being met by ongoing savings. Energy Services Companies will fully fund, design, install, manage and operate large scale CHP and get their financial return from energy sales.

## Good practice examples

### Large Scale CHP - Woking Borough Council

The project comprises 1.46MWe of CHP, 1.4MW of heat-fired absorption cooling and 163m<sup>3</sup> of thermal storage distributed over six building complexes in Woking Town Centre. Buildings are interconnected with heat and chilled mains and high voltage/low voltage private wire networks. Due to the mixed technology approach, the scheme satisfies its own electrical demands and

exports surplus power over the public wires to sheltered housing residents and other local authority buildings.

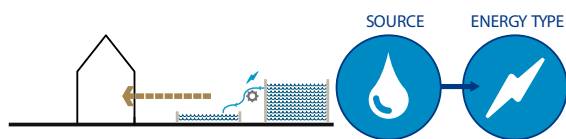
Woking Borough achieved the following energy and emissions savings over the 15 years from 1991 to 2006 within its own buildings:

- Energy consumption savings (2006) = 52%
- CO<sub>2</sub> emission reductions (2006) = 82%
- Sustainable energy self generation (2005) = 82%
- Renewable energy self generation = 11%

Savings of nearly £4.9 million have been achieved by the council, with further savings for householders and businesses in the borough.

### Lessons learnt from early adopters

- Work with commercial and non-commercial partners to meet environmental goals.
- Community engagement and consultation is vital. Consult the public and listen to their views.
- Promote continuous monitoring of progress. Progress monitoring is important to ensure that actions can be delivered as outlined.
- Maximise use of technology and technological expertise. The pooling together of expertise both in-house and from external advisors maximises the efficiency and deliverability of projects.
- Recognise that local sustainable energy can be small or large scale.
- Don't miss opportunities to secure external funding.



# Hydro Power

## Key facts

### How it works

Electricity is generated from the energy of water flowing down rivers or streams. The water causes the turbines to rotate, driving a generator that produces electricity. The water can be stored in reservoirs to be used when needed, making this energy source both reliable and stable. Micro hydroelectric plants often have no reservoir (run-off-river) in which case only part of the stream is diverted and later returned to the river. If there is no reservoir the power output depends entirely of the water flow, which varies with precipitation and snow melting. It should then be connected to the grid, so that excess electricity production can be sold and shortfall met by the grid.

The scope for new hydro-electric schemes in Scotland is likely to be limited. However, there may be an increasing number of proposals for small scale run-off river projects and, together with the continuing refurbishment of existing large schemes, this should ensure that hydro continues to play an important part in Scotland's renewable energy mix.

### Energy/carbon savings

This is an entirely renewable energy source with no carbon emissions associated once installed. Building/load profile suitability: micro hydro is suitable for buildings in close proximity to a watercourse (typically less than a mile). They can be used as a stand alone system in remote areas or farms. The flow rate in most streams is largest in winter, unless precipitation is predominantly snow (in which case the flow rate is largest in spring), which corresponds well to the highest energy need. In this way micro hydro balances out well with a PV system.

### Other key issues

- All watercourses of any size are controlled by SEPA. To remove water from them (even though it may go back in) will almost certainly require their permission in the form of a licence.
- Impacts on the natural and cultural heritage, water regimes, fisheries, aquatic habitats and species and cumulative impacts must be adequately addressed by applicants.
- Connection to grid, installation cost.

### Available scales

Height difference of water (head) can vary from a metre in the smallest hydroelectric schemes,

to several hundred metres height from the reservoir to the turbines. Micro hydro typically has an output of up to 100kW while the largest in the world, the Three Gorges Dam in China has an output of 22,500MW.

### To serve 1 home

A small hydro system (1 to 3kW) could meet the annual equivalent of a typical household's annual electricity requirements. If the home is not grid connected, battery storage may be required to meet the home's electricity requirements at times in the year.

### To serve 500 homes

A single medium (300kW to 800kW) scale hydro scheme could meet the annual equivalent electricity requirements of 500 homes. To allow for maintenance, an alternative back-up energy source would be required such as a grid connection (which also enable electricity export).

### Typical footprint

If the hydroelectric plant has a dam, the major area requirement is the reservoir. Some hydro electric plants are underground.

### Costs

Can be cost intensive to build and maintain. Otherwise a source of free electricity.

### Good practice examples

#### **Npower renewables**

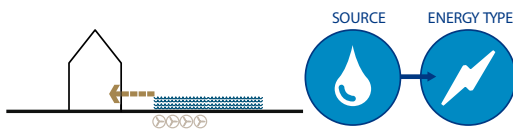
Npower renewables began producing electricity at Blantyre from the river Clyde in 1995. It is now capable of producing 575kW of clean power from its single Kaplan turbine. In order to assist salmon in the river, a fish ladder was installed to enable them to make their way up stream to spawn.

#### **Micro hydro turbine**

In Castle Douglas, Scotland a home owner has had a micro hydro turbine installed. The 3kW Francis Turbine produces 8000kWh a year. This is assumed to save 3.6 tonnes of CO<sub>2</sub> emissions each year. The Ironmacannie Mill, which from 1640 until 1950 ground the grain from the surrounding farms, was transformed with the help of Good Energy to produce electricity. Good Energy pays them 10 pence for every unit they produce, even the ones they use on site.

### Lessons learnt from early adopters

Many large scale hydro electric dams have had massive impacts on ecology as well as displacement of people. Also, covering land with water, causes massive decay of the plants and animals which leads to production of biogas (methane) which is a strong greenhouse gas.



# Marine Renewable Technology - Waves and Tidal

## Key facts

### How it works

There are numerous ways of extracting energy from the sea, but only a few are well tested and commercial. Tidal energy uses the tidal height difference to produce energy. The high tide fills a reservoir with sea water which is later released through turbines when the tide is low.

Alternatively turbines can be placed in straits where a strong current is created when the tide goes in and out. The turbines drive generators to produce electricity almost like an underwater wind turbine.

Wave energy captures the movement in the waves and transforms it to electricity through variants of Oscillating Water Column or Point Absorber technology. Systems can be floating, fixed to the seabed or ashore. The power output increases with the size of the waves.

Osmotic power is a relatively new technology based on the principles of osmosis. In an osmotic power plant, sea water and fresh water are separated by a membrane. The sea water draws the fresh water through the membrane, thereby increasing the pressure on the sea water side. The increased pressure is used to produce electricity by driving a turbine. Prototypes have been built, but are not expected to be commercial until 2015.

### Energy/carbon savings

This is considered an entirely renewable energy source with no carbon emissions in operation.

### Building/load profile suitability

So far most wave or tidal energy systems are only profitable in remote coastal areas where alternative power production is limited or expensive. Projects so far range from providing electricity to a few houses, to a whole community.

### Other key issues

- Tidal energy systems will have a lower output during low and high tide, and a maximum output between these stages. As the tides occur at different times each day, the maximum output might not coincide with the maximum need.
- The power output from wave energy will vary with the wind, but even in quiet weather there will still be rolling waves.

- Location - proximity to users.
- Shipping lanes.
- Robustness and access for maintenance.
- Underwater tidal turbines have little visual impact. Marine life has not been reported to be obstructed by the pilot projects, but the impact of a large cluster of turbines is unknown.

## Available scales

Can provide electricity to a group of houses or a whole community.

### To serve 1 home

Individual systems are not currently available.

### To serve 500 homes

A single large system (~1MW) could meet the annual equivalent electricity requirements of 500 homes. During calm periods an alternative back-up energy source may be required such as a grid connection (which also enable electricity export).

## Costs

Marine energy technology is still developing such that any cost estimates are very difficult. Most projects currently depend on financial support and grants.

## Good practice examples

### Marine Current Turbines Ltd

British company have installed a 1.2MW tidal energy converter in Strangford Lough, Northern Ireland. This is a commercial project.

### European Management Energy Centre (EMEC)

EMEC based in Orkney is at the forefront of the development of marine-based renewable energy technologies that generate electricity by harnessing the power of waves and tidal streams. As the first centre of its kind to be created anywhere in the world EMEC offer developers the opportunity to test full scale grid connected prototype devices in unrivalled wave and tidal conditions.

### Pelamis

The worlds first commercial wave energy project Pelamis, is situated in Agucadoura, Portugal currently consists of three 750kW energy converting machines in operation. Once completed its installed capacity of 21 MW should meet the average annual electricity demand of more than 15,000 Portuguese households whilst displacing more than 60,000 tonnes per year. The technology is provided by Pelamis wave power, a company based in Edinburgh.

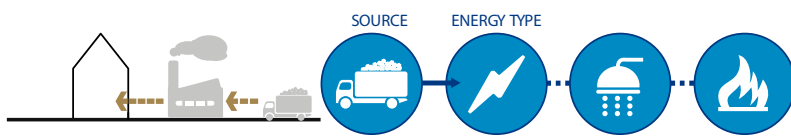
### Osmosis power plant

A prototype osmosis power plant is built by Statkraft just outside Oslo. With the improvement in

membrane technology, Stakraft hopes to have a full scale power plant in operation by 2015.

### Lessons learnt by early adopters

The world's first tidal power station was built at the estuary of the river Rance in France in 1966. Although commercially viable, the ecological impacts were severe.



# Energy from Waste - Anaerobic Digestion

## Key facts

### How it works

Biological treatments of waste include Anaerobic Digestion (AD) and aerobic digestion also known as composting. Only biodegradable waste such as green (e.g. garden), food waste, animal slurry etc can be treated with these processes. Other biodegradable material such paper and cardboard can be treated, however they take longer time to degrade so input levels are limited. Both AD and composting are treating the waste by mimicking the natural process of degradation. The main difference between the two is that composting is taking place in presence of oxygen, whereas AD takes place in absence of oxygen.

During composting biodegradable material is decomposed into carbon dioxide, water and heat through microbial respiration, resulting to a stabilised residual solid material, “compost”. During AD biodegradable material is converted into methane and carbon dioxide (the mixture is known as “biogas”) and water, leaving a partially stabilised wet organic mixture known as “digestate”. The biogas generated during the AD process can be burned to generate heat and electricity through a CHP system, or can be used as transport fuel. The compost and the digestate after suitable treatment and subject to the relevant quality protocol and other environmental legislation can be applied on to land as a soil conditioner.

### Energy/carbon savings

Diverting particularly the biodegradable fraction of waste and recovering energy has significant carbon saving benefits. AD and composting are more sustainable options than landfill and thus they are higher in the waste hierarchy. By diverting waste from landfill, substantial quantities of greenhouse gases such as methane and carbon dioxide that would have otherwise been produced are controlled and utilised to generate valuable energy (in the case of AD). If biogas is utilised to produce transport fuel, it could replace diesel and this option would bring significant carbon savings.

By introducing the compost and digestate back into the soil, natural nutrients are not lost and the quality of land is improved.

### Building/load profile suitability

It is more efficient if AD plants operate constantly without any turndown (apart for maintenance

reasons), thus a steady demand for energy would be required. Most suitable end users of the excess recovered heat are applications such as hospitals, recreational centres, hotels and industrial processes.

The electricity generated could be fed into the Grid or otherwise supplied to an energy user with relatively invariable demand such a district heating system, or industrial processes.

## Other key issues

- Waste should only be considered for an AD scheme once prevention, reuse, and recycling and composting options have been exhausted.
- Quality/purity of biogas, compost and digestate.
- Plant/facility siting and associated issues of traffic.
- Air emissions / health effects including odours, bio-aerosols and dust.
- Flies, vermin and birds.
- Noise, visual intrusion and public perception.

## Available scales

Composting can be applied in a very small scale such as that of an individual household, with a composter to treat leftover food and garden waste, up to larger scales of 50,000 tonnes of organic waste per annum and more.

At present the minimum commercially viable AD plant scale for the treatment of food and/or green waste is in the region of 5,000 tonnes of organic waste per annum. Consequently, an AD scheme treating food and green waste from households would roughly need an excess of 10,000 houses.

Smaller applications can be viable if attached to existing farming facilities, treating farming organic waste and producing small amounts of electricity. Due to their modular concept, AD systems can be applied to larger scales as well.

## To serve 1 home

Composting of waste. AD is not currently available at this scale.

## To serve 500 homes

A large AD plant supplying electricity straight to the Grid could generate the equivalent annual electrical requirements of these homes. Currently the idea of linking up AD plants to district heating systems, such as is the case with some large EfW plants, is not very common. However, if AD plants are located closer to potential industrial users of new housing developments that could have district heating systems, the option of utilising the recovered excess heat becomes more attractive.

## Typical footprint

The area required for biological treatment facilities depends on a number of factors such as the total material throughput, residence time, type of configuration, pre and post treatment processes. In general, AD processes have shorter retention times, thus have smaller facilities than composting. However, often AD facilities require post treatment processes such as composting in order to improve the quality of the digestate, which increases their landtake. Although, landtake is highly variable a rule of thumb is that between 0.5 and 1m<sup>2</sup> per tonne of input material would be required. Thus for example a 5,000 tonnes AD facility would require a total area of roughly between 2,500 and 5,000m<sup>2</sup>.

## Costs

Capital and operational costs associated with composting facilities are lower than those of AD plants. Indicative cost of an “in-vessel composting” (in-vessel composting covers enclosed technologies, either in buildings and/or on specifically designed vessels such as tunnels, drums or towers) facility would be in between £30 and £60 per tonne of waste per annum.

AD costs depend on size and vary between the different providers, however the indicative capital cost of a large 1MWe plant would be £3 to £4 million, with an operational and maintenance cost of 3% of the capital cost per annum.

## Good practice examples

### Home composting

Home composting schemes are good practice examples of resource efficiency, because they involve relatively low-cost technology, treating household organic waste close to the source and reducing vehicles movements of waste collection trucks that would otherwise collect this waste fraction and transport it to a central waste treatment facility. Social benefits include public involvement and engagement in sustainable resource and waste management.

### Biocycle project

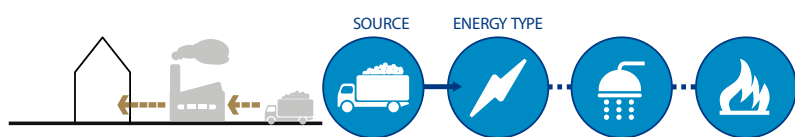
Based in Ludlow, Shropshire, the Biocycle project uses AD to treat source separated organic waste. The demonstrator plant is designed to process 5,000 tonnes of waste annually. The process produces liquid and solid digestate for use on local farms. The biogas is combusted in a CHP unit and supplies electricity to the grid. Some of the power generated is used to run the plant and also to charge the electric collection vehicle. The gross annual electricity production is designed to give up to 1,440,000kWh dependent upon waste feedstock, with process plant consumption of 125,000kWh, thus a net output of 1,315,000kWh. The electricity qualifies for Renewable Obligation Certificates (ROCs). The gross annual heat production is estimated to be up to 2,400,000kWh with process plant consumption of 800,000kWh which is circulated through two heat exchangers to provide heating for the tanks.

The process has a potential net output of 1,600,000kWh that could be used as part of a local district heating system. The options for exporting this heat to a neighbouring ecopark are currently investigated.

## Lessons learnt from early adopters

AD and less so composting systems are sensitive to the composition of the incoming wastes. Thus consistency in quality of the feedstock and sufficient pre-treatment (i.e. segregation) to ensure a “clean” organic stream are crucial for the optimum performance of the process. Consequently, AD and composting schemes are best suited in cases where separate organic waste collections (green and food waste) are already in place and/or they form part of a Mechanical Biological Treatment (MBT) facility where mechanical segregation takes place before the biological treatment.

Securing suitable markets and outlets for the compost and digestate are vital aspects of an AD or composting scheme, as is the quality of the biogas, compost and digestate.



# Energy from Waste (EfW) - Thermal treatment

## Key facts

### How it works

Extracting energy from waste can be done by a number of thermal treatment technologies including the more established process of incineration and the Advanced Thermal Treatment (ATT) processes such as gasification and pyrolysis. Both incineration and ATT offer the option of thermally treating residual waste and recovering energy. The main difference between these processes is the amount of air (oxygen) present. Pyrolysis takes place in absence of air, gasification in partial air (not enough to allow full combustion of waste) and incineration in excess air (sufficient to allow “complete” combustion of waste). EfW technologies can be applied for the treatment of domestic household waste to produce heat to be distributed as district heating, potentially combined with power production (CHP). The gas generated can be used for burning and with some cleaning it can be used in internal combustion engines as part of combined heat and power systems.

Thermal treatment technologies of waste can be combined with mechanical processes where the recyclable fraction of the Municipal Solid Waste (MSW) such as glass and metals for example is separated beforehand and processed in recycling facilities. Another option is for the waste to be separated at source.

### Energy/carbon savings

Thermal treatment of household waste is not carbon neutral; however compared to the alternative of landfill energy recovery is a preferred option as supported by the waste hierarchy. If the household waste is sent to the landfill, it is imperative that the landfill gas (methane and carbon dioxide) is harvested especially as methane is a much more powerful greenhouse gas than carbon dioxide. Profiting from the heat through CHP/district heating becomes a good use of resources and increases the overall efficiency of the plant.

### Building/load profile suitability

It is more efficient if AD plants operate constantly without any turndown (apart for maintenance reasons), thus a steady demand for energy would be required. Most suitable end users of the excess recovered heat are applications such as hospitals, recreational centres, hotels and industrial processes.

The electricity generated could be fed into the Grid or otherwise supplied to an energy user with relatively invariable demand such a district heating system, or industrial processes.

## Other key issues

- In most cases EfW plants require a district heating infrastructure to make use of heat, there is currently a lack of this in UK.
- Waste should only be considered for energy recovery once prevention, reuse, and recycling and composting options have been realised.
- Treatment of flue gases from EfW plant.
- Quality/purity of biogas, compost and digestate.
- Plant/facility siting and associated issues of traffic.
- Air emissions / health effects including odours, bioaerosols and dust.
- Flies, vermin and birds.
- Noise, visual intrusion and public perception.
- Most suitable waste streams to be treated are those with high calorific value and high gate fee. The high calorific value will ensure higher energy recovery and high gate fees will enhance the commercial/ financial viability of an EfW scheme.
- If a CHP option is considered through a district heating system, suitable heat users must be available in close proximity.

## Available scales

Minimum commercially viable scale at present would be in the region of 10,000 tonnes of suitable waste per annum (this would be the equivalent of 15,000 homes) for pyrolysis/ gasification with energy recovery. The same figures for incineration with energy recovery are minimum scale of 50,000 tonnes of suitable waste per annum originating from approximately 80,000 homes.

There is no real maximum capacity of EfW plants because they can be constructed in modular manner; however the biggest EfW plants around the world at the moment have capacities around 1,000,000 tonnes of waste per annum.

## To serve 1 home

Not currently available.

## To serve 500 homes

A large Energy from Waste energy centre linked to housing via a district heating arrangement could meet the homes' annual heating, hot water and most if not all of their electrical requirements (example of Veolia's Sheffield Energy Recovery Facility linked to the local district heating system). Higher density housing systems are more viable to reduce district heating infrastructure costs.

## Typical footprint

Typical example of a 90,000 tonnes per annum facility would have an indicative buildings' area of 5,000 - 6,000m<sup>2</sup>, a total indicative landtake of 2Ha and an indicative stack height of 60-70m. Typical example of general ATT plant with a 50,000 tonnes per annum capacity would have an indicative buildings' area of 3,000m<sup>2</sup>, a total indicative landtake of 2Ha and an indicative stack height of 30-70m.

## Costs

Indicative capital costs for incineration for a typical 50,000 tonnes per annum facility are in the region of £25m. Indicative capital costs for ATT technologies for a typical 25,000 tonnes per annum facility are in the region of £10m. Maintenance and operation costs are typically 3% per annum of the total capital cost.

## Good practice examples

### Veolia Environmental Service

Veolia Environmental Services is working in partnership with Sheffield City Council and has built an Energy Recovery facility (ERF), as part of an integrated waste strategy for the city. The ERF is capable of handling 225,000 tonnes per annum. This produces:

- Up to 61MW of thermal energy for the District Energy network (designed to provide green energy for local consumption); and/or
- Up to 19MW of electricity to the National Grid.

### The Chineham Energy Recovery Facility

The Chineham Energy Recovery Facility processes approximately 90,000 tonnes of non-recyclable waste each year - saving significant amounts of rapidly diminishing landfill space and generating around 7MW of electricity for the National Grid, enough to power more than 8,000 local homes.

### ENERGOS

ENERGOS Isle of Wight EfW plant has the potential to export 1.8MW of electricity for 7,500 hours per year from 30,000 tonnes of residual waste. The process includes an initial gasification stage followed by high temperature oxidation.

### Compact Power

Compact Power and Bristol Council are collaborating on the development of the ATT Avonmouth facility. The facility has the capacity to treat approximately 20,000 tonnes of biodegradable municipal waste and produce electricity and heat.

## Lessons learnt from early adopters

Public perception is still a key factor to consider, although if communities can see the benefits of an EfW plant (e.g. cheap renewable heat and electricity) and the absence of health

implications to the local population can be clearly demonstrated, the perceptions change in favour of such schemes.

Government incentives in the form of external funding are available to promote such technologies.

Appropriate siting of facilities is a crucial factor in terms of the local and/or regional requirement for such a scheme. Proposals for new facilities need to be in line with national, regional and local waste and spatial strategies.

## Exercise

**Develop design concepts for a zero carbon canal-side apartment block in Edinburgh.**

A large 20 storey, canal-side apartment block is proposed on a Brownfield site in Edinburgh. The developer would like to create a new building which is a striking example of sustainable design and would like the building to be zero carbon in operation. Using the information you have learnt from this self learning pack, consider possible design concepts to reduce the building's energy demand and well as potential energy supplies to try and reduce operational carbon emissions to achieve net zero carbon emissions.

The key features for the site/proposed building are:

- Rectangular plot with canal to southern boundary
- Fully glazed building with four 2-bed apartments on each floor and a large penthouse suite on the top floor.

What do you think are the most appropriate **Energy Efficiency Measures** that could be used to reduce energy demands?

---

---

---

---

---

---

---

---

What do you think are the most appropriate **Energy Sources** that could be implemented to help meet the client's zero carbon goals?

---

---

---

---

---

---

---

---

What are the constraints (if any) of the above solutions that need to be considered and what information should be provided to support the planning application?

---

---

---

---

---

---

---

---

## Model answer

**What do you think are the most appropriate Energy Efficiency Measures that could be used to reduce energy demands?**

Design should firstly take advantage of passive design opportunities followed by structural initiatives.

- The southern exposure is ideal for passive design. Ideally the building should have its long axis along the east-west axis.
- The glazing should be concentrated on the south-facing side to allow for optimal solar gain conditions and natural lighting. This will also allow the greatest views towards the canal. Architectural shading devices can be added to prevent over-heating in summer.
- Light wells could be used to allow natural light into the apartments on the north-facing side.
- A green roof could be considered.
- Good insulation along with efficient lighting and appliances should be used to reduce energy load. Natural ventilation systems should be included.
- A communal heating system for the building will ensure energy is efficiently used in the building.

**What do you think are the most appropriate Energy Sources that could be implemented to help meet the client's zero carbon goals?**

Once the energy demand has been minimised, a number of energy generation options could be considered.

- Electricity could be generated using photovoltaics on the roof and façade.
- Micro-wind installations are likely to be successful because of the buildings height and therefore wind exposure; however these will only contribute a relatively small amount of electricity.
- Solar and wind technologies will create a visual statement of sustainability for the building.
- A small combined heat and power or district heating system could be installed in the basement or lower level of the building to serve the whole building. Options to also link in to surrounding development should be investigated. Biomass could be utilised as a renewable fuel.
- A communal hot water system would efficiently supply hot water. Solar hot water systems on the roof could assist in heating of an elevated tank.
- Heat pumps could use the latent heat from either the ground or the canal to reduce electricity supply to heating (though heating is likely to be best met using other fuels).
- The canal is unlikely to offer any opportunity for hydro-electricity due to slow flow and lack of change in height.

**What are the constraints (if any) of the above solutions that need to be considered and what information should be provided to support the planning application?**

The planning application should outline the strategy to meet zero carbon, with corresponding carbon calculations, which firstly reduces expected energy use and then provides energy generation on-site. Implications on the building's structure should be outlined as well as ongoing management proposals. It is likely that a building management body will be needed to manage and maintain the systems within the building. If biomass is utilised, the source of supply and demonstration of design to accommodate fuel storage and delivery should be outlined.

Westerton House, Westerton Road  
East Mains industrial Estate  
Broxburn  
EH52 5AU  
Tel: 01506 775558  
Fax: 01506 775566  
Email: [info@improvementservice.org.uk](mailto:info@improvementservice.org.uk)  
[www.improvementservice.org.uk](http://www.improvementservice.org.uk)

Feb 2011



The Improvement Service is devoted to improving the efficiency, quality and accountability of public services in Scotland through learning and sharing information and experiences.

