Leeds CITY COUNCIL

Agenda:

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Report of the Director of City Development

Scrutiny Board: City Development

Date: 9th March 2010

Subject: Climate change – LZC technology delivery and in our estate

Electoral Wards Affected:	Specific Implications For:
All	Equality and Diversity ☐
	Community Cohesion ☐
☐ Ward Members consulted (referred to in report)	Narrowing the Gap ☐

1.0 Background

1.1 On the 1st September 2009, City Development Scrutiny Board received and discussed a background report outlining the importance of renewable energy in tackling climate change. Scrutiny Board agreed to concentrate on three key issues, namely:

a. Evaluating options for installing LZC (Low and Zero Carbon) energy as part of the corporate estate, with a focus on small, medium and large scale projects;

b. Development control processes to ensure that developments of over 10 dwellings or 1000 m^2 have at least 10% on-site LZC technologies;

c. The appropriate delivery structure to ensure that LZC energy, particularly large grid connected or on-site in major regeneration areas, was delivered.

1.2 The Board also agreed to discuss progress in planning policy to strategically plan for large-scale grid-connected renewable.

1.3 To allow for meaningful discussion, this has been split into two sessions. The first session (8th December 2009) covered planning issues (1.1.b. and 1.2) and this final session will focus on corporate issues (1.1.a. and 1.1.c.).

1.4 This report provides brief background and is structured so that sections 2, 3 and 4 focus on 1.1.a and section 5 focuses on 1.1c. Although there are opportunities to provide LZC energy for transport (for example through the current trial of biomethane refuse vehicles and diesel electric hybrids within our fleet) the issues are different so they are outside the scope of this report.

2.0 The need for LZC within the corporate estate

2.1 Leeds City Council is currently heavily dependent on fossil fuel based energy supplies for its buildings and schools. This dependency creates a business risk because of increasing costs of energy relating to scarcity and security of supply. Current annual costs to the authority are in the order of £20m and projected to increase in the future with energy costs projected to rise by 25-60% per year and carbon trading possibly adding penalties between £1-8m per year, depending on a number of market factors.

2.2 In order to prepare for this, a draft Carbon Reduction Framework has recently been discussed with the Environment Programme Board. This aims to set the strategic direction to make corporate buildings as close to carbon neutral as technically and financially viable by 2026. Carbon neutrality would remove all penalties for carbon emissions, and would to a great extent protect us from the worst of the cost implications of future energy scarcity.

2.3 The purpose of a Carbon Reduction Framework is to reduce Leeds City Council's current exposure to risk, because of its dependency on fossil fuels, by setting out a rationale for reducing corporate energy demand and transferring from current fossil-fuel based energy sources to LZC energy sources.

2.4 In the short-term, this will be achieved by improved energy efficiency and reducing corporate office-space, which still present significant cost-effective opportunities. In the longer term, significant amounts of on-site and off-site LZC energy will be required.

2.5 Elected Members have signalled a willingness to pursue a range of measures to reduce the Council's carbon footprint. It is recommended that Leeds pursue a 'mixed economy' approach to carbon reduction for the Council's estate and buildings based on a combination of:

- Reducing overall energy demand;
- Developing large scale opportunities for low and zero carbon technologies to provide heat and power to Council buildings;
- Developing small and medium scale opportunities for low and zero carbon technologies to provide heat and power to Council buildings.

2.6 Initial analysis suggests that to become carbon neutral the council will need to

- Reduce energy demand by the equivalent of 39,800 tCO_2. The majority of this (circa 31,000 tCO_2) can be saved by pursuing the Zero Carbon Schools Programme which seeks to make new schools zero carbon by 2016 and existing schools by 2021. The remainder would come from a mix of measures, including improved controls, more efficient boiler plant, heat recovery and pool covers at swimming pools, improved insulation and improved lighting equipment.
- Generate renewable energy equivalent to 65,400 tCO_2. This will be explored in sections 3 and 4.

3.0 Opportunities for large scale renewables

3.1 Large scale renewable generation is often deployed away from centres of population in order to minimise impacts, with the exception of Combined Heat and Power (CHP) which, due to the expense of transporting heat over distances, needs to be located close to demand. The remote nature of large scale renewables means that the national grid is often used to transport electricity to demand. Therefore specific arrangements need to be put in place to ensure that electricity generated can be credited correctly.

3.2 The main technologies that are technically suitable and commercially viable at the large scale include:

- Large wind turbines;
- Hydro-electric plant;
- Energy from waste;
- Combined Heat and Power with District Heating.

3.3 Further technical information regarding each of these technologies is given in appendix 1.

3.4 Initial analysis in mid-2009 suggested that the most appropriate technologies for the council, given consideration to technical and financial viability, were:

- Large wind turbines installed on land owned by the council could feasibly generate electricity equivalent to circa 48,000 tCO_2;
- Archimedean screws and water-wheels installed in existing infrastructure in the Aire and Wharfe could generate electricity equivalent to circa 2,700 tCO_2;
- Utilisation of electricity generated from residual waste could provide power equivalent to circa 4,000 tCO_2; Future schemes to digest food waste to produce natural gas could provide power up to 24,000 tCO_2;
- Installation of CHP and District Heating networks in the city centre could generate energy equivalent to 1,200 tCO_2.

3.5 Whilst there are no examples of large scale renewables within our existing estate, the options are relatively limited and good progress is being made to explore the more promising ones, including:

- The council is working in partnership with the University of Leeds, Leeds Teaching Hospitals NHS Trust, Leeds Met and Leeds Colleges to investigate the feasibility of extending the output from the existing Generating Station Complex to serve other city centre buildings. The initial options appraisal demonstrated that it is both technically feasible and financially viable. The next step is to secure formal agreement from all parties to proceed and to conduct a more detailed feasibility study.
- The council is working with the Partnership for Renewables (a Carbon Trust Enterprises company) to plan, finance and project manage the installation of

large renewables, including wind, on our estate. Feasibility studies show that we own land on which up to 18 turbines could operate, which would meet half of the council's electrical load. This is a contentious area in planning terms, due to the proximity to the airport and public attitudes, but the recently approved 125m turbine at Knostrop, together with new technologies which masks turbines from radar, show that they are not impossible.

- Plans are currently being developed to propose archimedian screws at St Anne's Mill, Thwaites Mill and Armley Mill.

3.6 These opportunities are all in early stages of feasibility testing. Although from initial studies they all appear technically feasible and using outline Net Present Value modelling appear to be financially viable, we would still need to find capital (from reserves, through borrowing or as a joint venture) to make them happen. There are also many other issues such as precise locations, exact technologies, public acceptance, planning restrictions, etc that need to be addressed before capital finance is sought.

4.0 Opportunities for small to medium scale renewables

4.1 Small and medium scale renewable energy projects typically relate to single sites and generally replace only a part of the on-site fossil energy consumption with renewables. Technologies include:

- Solar thermal panels;
- Small to medium wind turbines;
- Photovoltaic cells;
- Biomass boilers;
- Heat pump technology.

4.2 Further technical information regarding each of these technologies is given in appendix 1.

4.3 Initial analysis in mid-2009 suggested that the most appropriate technologies for the council, given consideration to technical and financial viability, were:

- Use of biomass boilers in schools and other large sites could generate heat equivalent to circa 700 tCO_2;
- Use of solar thermal in sports centres, particularly those with swimming pools could generate heat equivalent to circa 1,300 tCO_2;
- Use of solar thermal technologies in other buildings for provision of hot water could generate heat equivalent to circa 7,500 tCO_2;

4.4 The principle reason that small scale renewables have not been adopted more widely in the UK is that they are typically capital intensive and while energy costs remain low, their simple-payback periods are long.

4.5 Other countries have stimulated their small-scale renewables market by introducing 'feed-in tariffs' which provide a guaranteed additional payment for each unit of electricity generated using specific renewable energy technologies. The UK government confirmed in early February that it would introduce a feed-in tariff (the Clean Energy Cashback) and announced the additional guaranteed payments. A selection of these are shown in the table below:

Technology	**Scale**	**Tariff level for new installations in period (p/kWh)**			**Tariff lifetime (years)**
		Year 1	**Year 2**	**Year 3**	
Anaerobic digestion	>500kW	9	9	9	20
Hydro	>100kW - 2MW	11	11	11	20
MicroCHP	≤2 kW*	10	10	10	10
PV	≤4 kW (new build)	36.1	36.1	33	25
PV	≤4 kW (retrofit)	41.3	41.3	37.8	25
PV	>4-10kW	36.1	36.1	33	25
PV	>10 - 100kW	31.4	31.4	28.7	25
Wind	>1.5 - 15kW	26.7	26.7	25.5	20
Wind	>15 - 100kW	24.1	24.1	23	20
Wind	>100 - 500kW	18.8	18.8	18.8	20
Wind	>500kW - 1.5MW	9.4	9.4	9.4	20

4.6 This transforms the economics of small-scale renewable energy, particularly for retrofitted photovoltaics. Since this announcement was made, there has been insufficient time to assess the potential across the council buildings, but we intend to do this over the spring and early summer.

4.7 Within our existing estate, there are already a number of examples of small-scale renewables, including:

- Kippax North Junior and Infants School has both a wind turbine and photovoltaics;
- The new Garforth Library and One Stop Centre uses solar thermal;
- The John Charles Centre for Sports has a 15kW wind turbine and uses CHP.

4.8 There are plans to include small-scale renewables in a number of other schemes:

- The Leeds Arena will use a mix of renewable technologies, including solar thermal;
- Bankside school will include a range of technologies, including a large photovoltaic array.
- A number of schools in their early design stages in Building Schools for the Future program are including a range of technologies designed to reduce energy

consumption (e.g. by Passivhaus construction), and to produce on-site renewable energy.

4.9 Unlike large scale renewables, these technologies have few major restrictions and are therefore easier and quicker to install. The principle drawback is that the return on investment is often very long, although the Clean Energy Cashback is helping to make investments more attractive. Additionally, by integrating renewables into the design of new buildings or major retrofits (for example using photovoltaics as shades for windows or replacing gas boilers with biomass ones) the additional costs can be minimised.

5.0 Developing the delivery structure – Energy Leeds

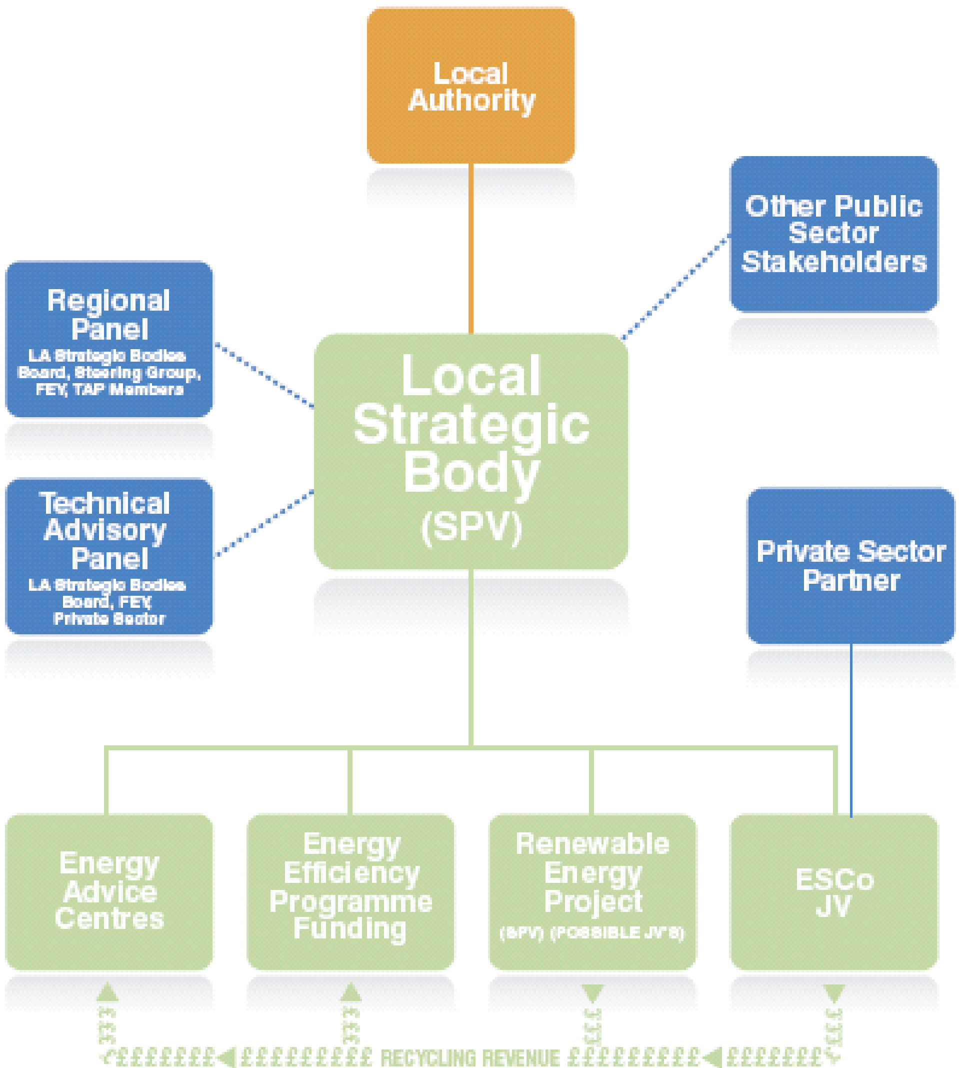
5.1 At earlier meetings, Scrutiny have been updated regarding Leeds' developing land-use planning policies (as set out in the emerging Core Strategy and Natural Resources and Waste Development Plan Documents) for renewable energy. These policies will help to guide proposed renewable energy development to the most appropriate locations in response to market demand.

5.2 In addition to this approach, early work has commenced on developing a proactive approach to energy infrastructure whereby the Council can act to facilitate large-scale low and zero carbon energy infrastructure in a more strategic manner. This work has developed out of Leeds City Council's participation in a regional project with Future Energy Yorkshire (FEY - now CO2Sense) to develop a framework for low carbon energy initiatives.

Main issues

5.3 The city of Leeds has no local energy policy and no entity or agency with responsibility for developing a policy and taking a strategic overview of energy requirements and future energy management in the city. The FEY project recommended that local authorities consider establishing such a body "to provide local authorities with a focused vehicle for interpreting, prioritising and overseeing the delivery of local authority low carbon energy policies".

5.4 The diagram below illustrates how a strategic body would be responsible for the delivery of energy related activities and would provide a mechanism by which funds can be invested in economically attractive low-carbon energy projects, with revenues recycled to support less attractive projects and to assist in funding the development of future projects.



SPV - Special Purpose Vehicle. JV - Joint Venture

Practical projects in Leeds

5.5 There is no shortage of potential low carbon energy initiatives already running in the city or being developed, for which a strategic body for energy services could provide the strategic oversight:-

- Urban eco settlements in the Aire Valley;

- Retrofitting existing housing stock (public and private) to reduce carbon emissions and address fuel poverty;

- The Council's role as a corporate landlord in owning and managing energy issues in a large number of municipal buildings;

- Generating electricity on Council-owned land such as currently being explored with the Partnership for Renewables, a Carbon Trust backed enterprise, working with the public sector to develop and manage onsite renewable energy projects;

- The potential presented by the forthcoming Residual Waste Treatment Facility and other sources of heat, together with existing and new sources of energy demand (e.g. the Arena) in the city to participate in a district heating scheme. A feasibility study has been carried out to investigate a district heating network for the civic quarter;

- The potential to generate and utilise low carbon transport fuels as part of the NGT;
- The Eastgate project, when it recommences, will include an ESCo, details to be confirmed and the Council is already seeking to support this;
- The potential of introducing an ESCo in Holbeck as a trailblazer for other regeneration areas in the city;
- The provision of energy efficiency advice and addressing fuel poverty as currently carried out by the Fuelsavers team within Neighbourhoods and Environment;
- There is potential to develop a neighbourhood heat network project based on existing electrically heated flats / multi storey buildings;
- Householder investment in new technologies (eg Ground Source heat pumps) funded by recycling money;
- Accelerated development of low carbon homes;
- Advising developers on suitable approaches to meeting planning policy requirements for renewables/CHP and facilitating delivery of on-site, near-site and off-site energy;
- Attracting finance and facilitating energy efficiency improvements to commercial and industrial sites, focussing on regeneration areas and leasehold properties.

5.6 Many of these projects are either already in place or at an advanced stage of development, yet there is no mechanism in place to seek synergies or efficiencies between these projects.

Policy drivers

5.7 The principal council policies (Leeds Strategic Plan and Council Business Plan 2008-11) now prioritise climate change, linked to the new National Indicators. The Leeds Strategic Plan includes commitments to:

- Reduce ecological footprint through responding to environmental and climate change (NI186);
- Reduce emissions from public sector buildings, operations and service delivery, and encourage others to do so (NI185);
- Undertake actions to improve our resilience to current and future climate change (NI188).

5.8 The recently adopted Climate Change Strategy; Vision for Action includes a target to reduce emissions from Leeds by 80% between 2005 and 2050 and outlines a number of areas of activity to achieve this. These include activities that may come under the remit of a Strategic Body such as home energy efficiency and low carbon energy infrastructure projects.

5.9 The national consultation on the Government's Heat and Energy Saving Strategy outlines several key policy proposals:-

- All homes to have received a 'whole house' energy makeover by 2030 with all lofts and cavity walls insulated by 2015;
- Comprehensive energy saving information and advice to be made available to everyone;
- Development of new financial measures to allow costs to be more than offset by energy savings;
- Consideration of a new delivery model to ensure greater co-ordination;
- Changes to Building Regulations to extend energy saving requirements;
- A new focus on district heating in sustainable communities;
- Encouragement of combined heat and power and better use of surplus heat.

5.10 Some of these measures were included in £1.4bn package of measures to reduce UK carbon emissions announced in the Government's recent budget. In addition, the Government will be consulting on a Renewable Heat Initiative (RHI) to encourage heat generated from renewable sources (e.g. air- and ground-source heat pumps, biomass fuelled stoves and boilers, solar-thermal water heaters and combined heat and power (CHP) plants which are fuelled from renewable sources) later this year.

5.11 Building regulations are gradually being tightened and once homes and buildings are required to reach the higher levels of performance in the Code for Sustainable Homes and zero carbon requirements in 2016 (homes) and 2020 (other buildings), it is generally recognised that these higher standards are very difficult to achieve without some form of off or near site renewable energy production or combined heat and power together with associated behaviour change by the occupants to make the most of living in a low-energy development. A scenario can be envisaged therefore where future developers are seeking to commission renewable or low-carbon technologies together with energy saving advice for occupants as part of their developments. If the city is prepared by having a strategic body in place which can take responsibility for advising developers on this, it will make Leeds a more attractive proposition for developers.

5.12 In the longer term the existence of a Strategic Body would provide a channel for any potential government or regional funding for low carbon energy measures and could also assist in the aim to develop a low carbon infrastructure for the city to attract commercial interest and ensure Leeds' competitiveness in a future which is likely to favour resource efficient economies. There are also potential advantages in Leeds having greater energy resilience and having greater control over energy supply and management.

Energy Leeds Project Board

5.13 A Project Board has recently been established to investigate and make recommendations on whether and how Leeds could establish a Strategic Body for energy services (working title 'Energy Leeds'). The outcome of the project will be a clear way forward on the steps that need to be taken to establish a strategic body if the project finds that there are advantages in having such a body.

5.14 To date the Project Board have scoped the likely functions of a Strategic Body as

- assessment of present and future city-wide energy needs,
- providing a strategic overview of sustainable energy production opportunities for the city of Leeds and it's hinterland (e.g. working with CO2Sense to provide heat maps, grid connection maps, renewable resource maps, transport maps etc),
- making the most efficiency use of existing (eg civic quarter CHP) and future energy assets,
- city-wide coordination of renewable energy and carbon reduction opportunities made available by more stringent planning laws (i.e. facilitating shared use of low carbon technologies between neighbouring developments),
- the provision of technical help and advice to public and private sector organisations in developing renewables and carbon reduction schemes,
- help and advice regarding funding and financing options including organising revenue recycling between projects and providing an interface (possibly through a separate ESCo) to buy/sell energy from new projects.

5.15 The Project Board have identified the scope of the project as seeking to deliver:

- An audit of existing and imminent energy related projects and initiatives in Leeds;
- A heat network audit making use of the energy mapping tool developed by Future Energy Yorkshire;
- Following the framework developed for the Future Energy Yorkshire regional project, recommendations on whether and how to establish a Strategic Body for energy services in Leeds covering:
    - The need for a strategic body
    - Objectives of a strategic body
    - Legal form of the strategic body
    - Financial operation of the strategic body
    - The next steps required to establish a strategic body

5.16 Clearly the possibility of creating a new city-wide agency with responsibility for energy services is a significant undertaking. Potential benefits of a strategic body include:

- the provision of a strategic overview of energy which does not exist at present and which is likely to be an important consideration in the future;

- an agency with the ability to identify and map existing and potential 'heat networks' across the city, communicating with and sharing information on practical projects;

- an agency with a clear single focus who could take responsibility for the tendering and procurement of specific local projects delivered by separate Special Purpose Vehicles or Joint Venture ESCos;

- sends a strong signal to partners and investors.

5.17 Potential risks include:

- costs of establishing a body with some restructuring within the Council likely to be necessary;

- political and legal issues;

- financial complexity of how the strategic body would operate and ensure appropriate financial arrangements are in place between separate energy projects.

6.0 Recommendations

6.1 Scrutiny Board is invited to note and comment on the contents of this report.

Appendix 1 - RENEWABLE ENERGY TECHNOLOGIES

Wind turbines

A wind turbine harnesses energy from the wind to produce electricity. The most common design is of three blades mounted on a horizontal axis, which is free to rotate into the wind on a tall tower or mast. The blades drive a generator either directly or via a gearbox (generally for larger machines) to produce electricity for consumption on site or sale to the grid. Modern designs can be very quiet in operation.

Wind turbines can be mounted on masts that are free-standing or tethered with wire guys. The greatest amount of power will be generated if turbines have a constant supply of steady wind, which is dependent on the site having a good wind profile (average wind speed of 5-6 m/s or higher) and being free of obstructions such as trees or buildings.

Wind turbines are amongst the most cost-effective renewables, on the right site. The main drawbacks are that not every site is suitable and negative perceptions amongst some local residents, based around outdated expectations of noise and subjective visual objections. For any wind-turbine application, it is essential to involve local residents early on in the design and make sure that photomontages are made available to allay fears.

In Leeds, there are only a few sites that are suitable for the largest (125m tall) turbines due to the large resident population, the number of high-quality environments, generally low wind-speeds and conflicts with radar. Smaller turbines have some potential even in these areas but give poorer returns on investment.

Biomass

Biomass, a renewable energy source, is biological material derived from living, or recently living organisms, such as wood, waste, vegetable oils and alcohol fuels. Forest residues, wood chips, waste organic material from fibre or food production and specifically grown energy crops (such as miscanthus, switchgrass, hemp, corn, poplar, willow, sorghum, sugarcane and a range of tree species) are all classified as biomass.

There are a number of technological options available to make use of the wide variety of biomass types as a renewable energy source. Conversion technologies may release the energy directly, in the form of heat or electricity, or may convert it to another form, such as liquid biofuel or combustible biogas. Examples include:

Thermal conversion - these are processes in which heat is the dominant mechanism to convert the biomass into another chemical form. The most common technology is combustion based (biomass boilers or CHP) but pyrolysis and gasification are growing in popularity.

Chemical conversion - a range of chemical processes may be used to convert biomass into other forms, such as to produce a fuel that is more conveniently used, transported or stored, or to exploit some property of the process itself.

Biochemical conversion - makes use of the enzymes of bacteria and other micro-organisms to break down biomass. In most cases micro-organisms are used to perform the conversion process: anaerobic digestion, fermentation and composting.

In Leeds there are many woods, both council and non-council, that are currently under-managed. Bringing these woodlands into a management regime would enable biomass to be extracted in a controlled manner, without a significant impact on biodiversity, amenity, or leisure usage.

Energy from Waste

Energy from waste (EfW) is the process of creating energy in the form of electricity or heat from waste. EfW is therefore a form of energy recovery to recoup some value from waste materials. Most EfW processes use a form of thermal combustion (typically incineration) to produce electricity directly with some heat recovery, or produce a combustible fuel commodity, such as methane, methanol, ethanol or synthetic fuels.

There are a number of other new and emerging technologies that are able to produce energy from waste and other fuels without direct combustion. Many of these technologies have the potential to produce more electric power from the same amount of fuel than would be possible by direct combustion.

Common thermal technologies include gasification and pyrolysis and common non-thermal technologies are anaerobic digestion and fermentation.

Hydropower

Hydropower, or water power, is power derived from the force of moving water, which may be harnessed for useful purposes. Most types of modern hydropower are used to generate electricity.

Small scale hydro or micro-hydro power has been increasingly used as an alternative energy source, especially in remote areas where other power sources are not viable. Small scale hydro power systems can be installed in small rivers or streams with little or no discernible environmental effect on things such as fish migration.

The main considerations in a micro-hydro system installation are: a sufficient and consistent flow of water, the height difference between the intake and the exit and compliance with legal and regulatory issues.

In Leeds, there is potential to install modern small scale hydro on both the river Aire and Wharfe, using some of the old civil engineering works associated with old mills. Modern Archimedian screws (slow moving encased corkscrews) can generate around 250kW of electricity on a good site and are considered to be ‘fish-safe’ and relatively quiet and unobtrusive. It is considered that the two rivers could contribute the equivalent of two large scale wind turbines, however, Leeds City Council owns only three of the many extraction points available

Combined heat and power (CHP)

CHP uses a heat engine or a power station to simultaneously generate both electricity and useful heat. CHP uses heat that would be wasted in a conventional power plant, potentially reaching an efficiency of up to 89%, compared with 55% for the best conventional plants. This means that less fuel needs to be consumed to produce the same amount of useful energy.

CHP is most efficient when the heat can be used on site or very close to it. However, an exact match between the heat and electricity needs rarely exists. A CHP plant can either meet the need for heat needs on site or use district heating to transfer excess heat to neighbouring developments.

Overall efficiency is reduced when the heat must be transported over longer distances. This requires heavily insulated pipes, which are expensive and inefficient; whereas electricity can be transmitted along a comparatively simple wire, and over much longer distances for the same energy loss.

In Leeds there already exist a number of CHP units (notably at St James's hospital, at the Carslberg-Tetley brewery and on the University of Leeds/LGI campus). There are major opportunities to develop new CHP schemes across Leeds with advanced plans to integrate CHP with the Eastgate/Harewood development, to expand the University/LGI scheme and in Holbeck Urban Village.

The biggest challenges for CHP in Leeds are raising sufficient capital finance and ensuring that new developments commit to using the heat to give investors certainty over financial returns.

Air or ground-sourced heat pumps

A heat pump is a machine that moves heat from one location (the 'source') to another location (the 'sink' or 'heat sink') using mechanical work. The most commonly understood heat pumps are fridges and freezers, which exploit the physical properties of evaporating and condensing fluids, known as refrigerants.

Recently, reversible-cycle heat pumps have started to be commonly used to for provide thermal comfort in homes and offices. These heat pumps use a vapour-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of heat flow may be reversed. Most commonly, heat pumps draw heat from the air or from the ground, but liquid source heat pumps are not unknown at riverside and lakeside sites.

Ground-sourced heat pumps require heat capturing coils filled with a heat transfer fluid to be laid in trenches or in deep bore holes, depending on the ground available. As the ground temperature stays relatively constant these provide good consistent heat sources. Air source heat pumps resemble air-conditioning units and upgrade heat from external air to a useful temperature for internal heating. Typically, below about -5^{o}C air source heat pumps struggle.

Ground and air source heat pumps have good potential in Leeds. School sites are seen as being particularly useful where large playing fields would provide suitable ground resources.

Photovoltaics (solar cells)

Solar photovoltaic (PV) systems use energy from the sun to convert solar radiation into electricity, which can be used directly to run appliances and lighting or sold to the national grid.

PV systems perform best in direct sunlight, but continue to perform well in reduced light conditions. Systems come in various forms including solar tiles, roof-integrated panels and on-roof panels. PV systems are also available for cladding buildings, forming brises-soleil, and covering walkways.

PV systems main benefits are their flexibility, suitability to many situations, ease of installation, low maintenance and production of electricity in the day when it is most needed. Their main drawback is that they are expensive with long-payback periods, although, in the right circumstances, the feed-in tariffs mentioned above significantly reduce these drawbacks.

Solar thermal (solar panels)
Solar panels can be fitted onto or integrated into a building's roof and use the sun's energy to heat a heat-transfer fluid which passes through the panel.

The fluid is fed to a heat store (e.g. a hot water tank) to provide part of the domestic hot water demand for the building. Usually another heat source will be needed to supplement collectors in winter months. Solar panels can also be used to heat swimming pools, where heat is needed all year round for pool heating and for showering.

Solar thermal installations' main benefits are their relatively low capital costs and ease of maintenance. The drawback is that they are not suitable for integration to all existing heating systems, heat production doesn't always match demand profiles (unless excess heat can be 'dumped' to a swimming pool) and the value of energy generated is currently relatively low.