Guide to Energy Masterplanning

Preface

The Scottish Government is committed to supporting a just transition to net zero. Energy decarbonisation will be key to delivering this ambition and will require whole system changes in the way energy services are delivered to our homes, businesses and industry. The required pace and scale of change demands that we move beyond stand-alone low carbon projects to a wider energy systems approach that creates more efficient and integrated solutions. Energy masterplanning can assist developers and local authorities to plan for this approach, provide for 'future proofing' and make use of energy more efficiently; ensuring that the most affordable and resilient solution is identified.

This guide provides an update to a previous version focused on decentralised energy masterplanning, produced by Scottish Enterprise in 2015 and supported by members of the Heat Network Partnership for Scotland. As our understanding of the energy transition has evolved, so have the requirements for energy masterplanning.

This Guide presents the key concepts of energy masterplanning, bringing together considerations across heat, power and transport sectors.

Acknowledgement

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About this “Guide to Energy Masterplanning”

The move to a net zero Scotland by 2045 will require rapid and large-scale changes in our energy system with the introduction of a range of low carbon energy technologies. From transformational change in the use of electric vehicles for transport, the use of heat pumps and low carbon heat networks to heat our buildings, and continuing the significant progress made over the past 10 years in decarbonising our power supply, our national and local energy systems will need to be carefully planned to make sure we have secure and affordable energy services.

An energy masterplan sets out an energy decarbonisation solution for a geographical area, which can be defined at varying scales, typically regional or sub-regional, but the process can also be usefully deployed at smaller strategic development sites. The masterplan includes spatial maps that allow energy infrastructure managers and project developers to identify low carbon energy opportunities at the earliest possible stage. It also helps to raise wider awareness and political support, and provides an evidence base to inform decisions. The energy masterplan would typically be created by a local or regional government for the defined area, and would involve engagement with local stakeholders, including incumbent energy suppliers, public and private organisations, landowners and residential owner/occupiers. To be successful, energy masterplanning requires that the lead organisation (e.g. the local authority) provides the essential role of bringing together stakeholders to promote, develop and subsequently deliver the energy masterplan.

This Guide has been produced by Scottish Enterprise and Ramboll Energy to introduce the key concepts of energy masterplanning. Whilst the focus is Scotland, the general approach is applicable to all locations. It is aimed principally at organisations that may be coordinating area-wide decarbonisation efforts, although stand-alone low carbon energy projects can also benefit through consideration of the wider energy system approach provided. The overarching objective of the Guide is to support the development of creative low carbon energy solutions that make efficient use of local energy resources and support a holistic energy system design.

The Guide is structured into five sections:

SECTION 1	Section 1 sets out the national and local policy context driving the need for low carbon energy masterplanning, including the policy levers that can be used to support the creation and delivery of plans.
SECTION 2	Section 2 considers organisations that might create energy masterplans and their drivers for doing so.
SECTION 3	Section 3 explores the reasons for energy masterplanning and the benefits that it can provide.
SECTION 4	Section 4 sets out the key steps for creating an energy masterplan, including what information is publicly available, additional data that needs to be collected, useful tools, and a description of how these elements can be incorporated into a coherent energy masterplan.
SECTION 5	Section 5 draws on best practice examples and explains how energy masterplanning assists in the development and delivery of economically viable, sustainable projects.

SECTION 1

Scottish policy position and its context within the UK

After declaring a climate emergency in 2019, the Scottish Government committed to a target of reaching net zero emissions by 2045[1]. This will require UK and Scottish Government action across all sectors, in conjunction with local authorities, communities, businesses and industry. The Scottish Government has devolved policy powers to support this action in a number of key areas within transport, heat and energy efficiency. However, nuclear energy, oil, coal, gas and electricity policy is reserved to the UK Government. Reaching this enormously challenging net zero target is therefore dependent on a coordinated approach with the UK Government.

The updated Climate Change Plan 2018-2032[2] sets out the Scottish Government's pathway for carbon emission reductions up to 2032, aiming to deliver a reduction in total emissions of 56% over its lifetime. The Climate Change Plan is supported by a developing landscape of policies and regulations to support decarbonisation across transport, power, heat in buildings and industry. These include policies that will support the deployment of low carbon technologies, such as the proposed New Build Heat Standard[3], which will require new build homes to use heating systems that produce zero direct emissions at the point of use from 2024; and the Heat Network (Scotland) Act[4] which aims to ensure the delivery of 6 terawatt hours of annual output from heat networks by 2030, connecting at least 650,000 domestic properties.

Key targets set out under Scotland's Climate Change policies include:

- Net-zero greenhouse gas emissions by 2045;
- 75% reduction in greenhouse gas emissions by 2030, and 90% by 2040;
- 50% of energy in Scotland's heat, transport and electricity consumption to be supplied from renewable sources by 2030;
- Phasing out the sale of new petrol and diesel cars by 2030;
- Phasing out the need for new petrol and diesel light commercial vehicles in the public sector by 2030;
- Reduce car kilometres by 20% by 2030;
- Decarbonise rail services by 2035;
- Ambition to remove the majority of diesel buses from public transport by the end of 2023;
- New buildings must have zero emissions heating by 2024;
- 50% of all heating systems being installed will be zero emissions systems by 2025;
- 50% of domestic buildings, and 75% of non-domestic buildings, will be heated using zero emissions systems by 2030;
- 5GW of renewable and low carbon hydrogen production in Scotland by 2030[5].

1. Climate Change (Emissions Reduction Targets) (Scotland) Act 2019
2. Securing a green recovery on a path to net zero: climate change plan 2018–2032 – update, Scottish Government, 2020
3. New Build Heat Standard: scoping consultation, Scottish Government, 2020
4. Heat Networks (Scotland) Act, 2021
5. Scottish Government Hydrogen Policy Statement, Scottish Government, 2020

1.1 Local policy levers

Delivery of these national targets will require changes in the energy system at the UK-level, such as ensuring that the national power grid has capacity to meet the increased demand of electrified heat and transport, as well as at the local level in both energy demand reduction and in decentralised energy infrastructure. Heat in buildings currently represents 20% of Scotland's emissions[6], and energy masterplanning is critical to ensuring efficient and optimal use of locally sourced renewable energy to support decarbonisation of buildings. The Heat in Buildings Strategy[7] sets out how Local Heat and Energy Efficiency Strategies (LHEES), developed by local authorities, will provide a long-term framework for taking an area-based approach to planning and delivery of the heat transition. LHEES will provide an important strategic vision to inform energy masterplanning of areas, which could be integrated with wider energy system considerations as required. Longer term, this local strategic framework will need to integrate with a whole-energy system perspective, integrating energy masterplanning for heat, power and transport.

Scottish Planning Policy[8] (SPP) (2014) outlines that Local Development Plans should seek to ensure an area's full potential for electricity and heat from renewable sources is achieved, in line with national climate change targets, giving due regard to relevant environmental, community and cumulative impact considerations. Local Development Plans should support national priorities for the construction or improvement of strategic energy infrastructure, including generation, storage, transmission and distribution networks. They should support new build developments, infrastructure or retrofit projects which deliver energy efficiency and the recovery of energy that would otherwise be wasted both within the specific development and surrounding area. SPP also advocates the use of heat mapping to help identify the potential for co-locating developments with a high heat demand with sources of heat supply. The Scotland Heat Map[9] can assist in carrying out high level heat mapping activities to assess the demand and supply opportunities in an area.

6. Securing a green recovery on a path to net zero: climate change plan 2018–2032 – update, Scottish Government, 2020
7. Heat in Buildings Strategy - achieving net zero emissions in Scotland's Buildings, Scottish Government, 2021
8. Scottish Planning Policy (SPP), Scottish Government (2014)
9. Scotland Heat Map

1.2 Current Energy System in the UK

Until recently, the model for energy supply in the UK was built on economies of scale that relied on the historical domestic abundance of coal and natural gas. Electricity generation relied on large centralised power plants, which was transported via national transmission networks to most areas in the UK, where it is subsequently delivered to end users by local distribution networks. However, the UK has made significant progress in decarbonising the electricity sector over the past 10 years. In Great Britain, the grid intensity of electricity reduced an average of 66% over 7 years to reach 181 gCO2/kWh in 2020[10], with Scotland's grid intensity reaching 44 gCO2/kWh[11].

Heat supply in the UK

The advent of industrial scale coal mining brought about a shift in the main heating fuel used in the UK as people moved away from traditional home heating fuels such as wood and peat. While coal was originally used as a solid fuel it was also used in another form, as coal or town gas. The first gas networks in the UK transported town gas to homes via networks of pipes, which was used for lighting, heating and cooking.

In 1966 the UK government switched from town gas to natural gas with the discovery of huge reserves in the North Sea.

Gas boilers are the most prevalent heating system in use across the UK serving homes and businesses. Oil, LPG, solid fossil fuel and electric heating also continue to be used, often in more remote areas where gas networks have not penetrated. As of 2021, 81% of Scotland's homes used mains gas as their primary heating fuel, and heating homes and workplaces account for around 21% of Scotland's total greenhouse gas emissions (Heat in Buildings Strategy, 2021).

The drive to net zero to limit the further damaging effects of climate change, necessarily requires a change in how heat and power is provided to homes and businesses. Around 11.1% of households in Scotland have a renewable or very low emissions heat system, such as direct electric, heat pump or biomass, with another 1.4% connected to heat networks (Heat in Buildings Strategy, 2021). This must drastically increase by 2030, with emissions from buildings required to fall by 68% to meet Scotland's interim decarbonisation targets on the pathway to 2045 net zero.

10. National Grid ESO (2021), Electricity Report (August 2021)
11. Scottish Government (2021), Climate Change Monitoring Reports (May 2021)

Electricity generation in the UK

Electricity has traditionally been generated at central locations through the burning of fossil fuels and from nuclear fission reactors to produce steam to drive a turbine to generate electricity. These large power plants emit water vapour, CO2 and other harmful gases to the atmosphere. The traditional fuels used to produce this electricity have been (in order of adoption) coal, natural gas and nuclear energy, accounting for 54% of the UKs electricity supply in 2020. Nuclear energy is the outlier of these traditional fuels in that it doesn't emit CO2 directly, but the process of mining and refining uranium ore can be carbon intensive, and the waste from nuclear plants is hazardous. This primary mix of power sources has changed recently to include a substantial proportion of generation from solar, biomass, hydroelectric and wind energy, which accounted for 38% of the UKs power supply in 2020, with the remaining 8% being imported (Drax Insights).

As electric vehicles (EVs) become more prevalent in the UK in the coming years as combustion engine cars are phased out, our demand for electricity will rise. Furthermore, as the heating of buildings is increasingly electrified, making use of technologies such as air source, water source and ground source heat pumps this demand will rise even more. As such, the demand on the National Electricity Grid will increase and local network constraints and overall capacity must be considered very carefully when planning projects.

Energy distribution

Electrical energy is transmitted from the generators via power transmission lines to local substations, which reduce the voltage supply to in the levels required for use in homes and businesses across the country. The UK and Scotland also benefit from the ability to import and export electricity through interconnectors with our European neighbours. These are actively used at a national level to balance energy demand and are managed by the National Grid.

Traditionally heat for space heating and hot water in the UK has been generated on a building-by-building basis. A significant shift in how we heat our homes occurred in the 1970s and 1980s when central heating became the norm. At present there is further shift occurring in the heating market towards community and district heating. Whilst this is not the first time the concept of providing heat to multiple consumers from a single location has been done in the UK (Nottingham has operated a large district heating system since 1972, Sheffield since 1988) there is now a real impetus behind the expansion of this approach to heating, drawing largely from the Scandinavian model in which whole cities receive their heating for space and hot water via large, interconnected heat networks. This was originally being driven by the efficiency of heat networks (one boiler instead of many to generate heat) and of the ability to utilise waste heat from power stations. Modern heat networks often use large heat pumps to heat the network, or sometimes involve many smaller decentralised heat pumps ('ambient loops') which can deliver high efficiencies by sharing heating and cooling between buildings. The efficient design of local low carbon energy systems reduces reliance on the National Electricity Grid to decarbonise heat in buildings.

1.3 Future Low Carbon Energy Systems

Future low carbon energy systems will involve a mix of technologies deployed at a wide range of sizes and will include decentralised energy, where energy is generated locally instead of at large centralised power plants (see Figure 1). Decentralised energy generation technology can include micro-renewables, hydroelectric power, wind turbines, marine energy, energy from waste plants, combined heat and power, heat only boilers (including biomass), heat pumps, geothermal, anaerobic digestion and solar. Heat is commonly distributed in district heating systems in continental Europe, and increasingly in Scotland (see the Clyde Gateway case study in Section 5), with the heat generated being pumped into homes and non-residential properties usually as hot water, through networks of highly insulated pipes. Combining these solutions with smart network infrastructure as well as heat and electricity storage solutions allows the potential to balance energy demands between heat and power networks.

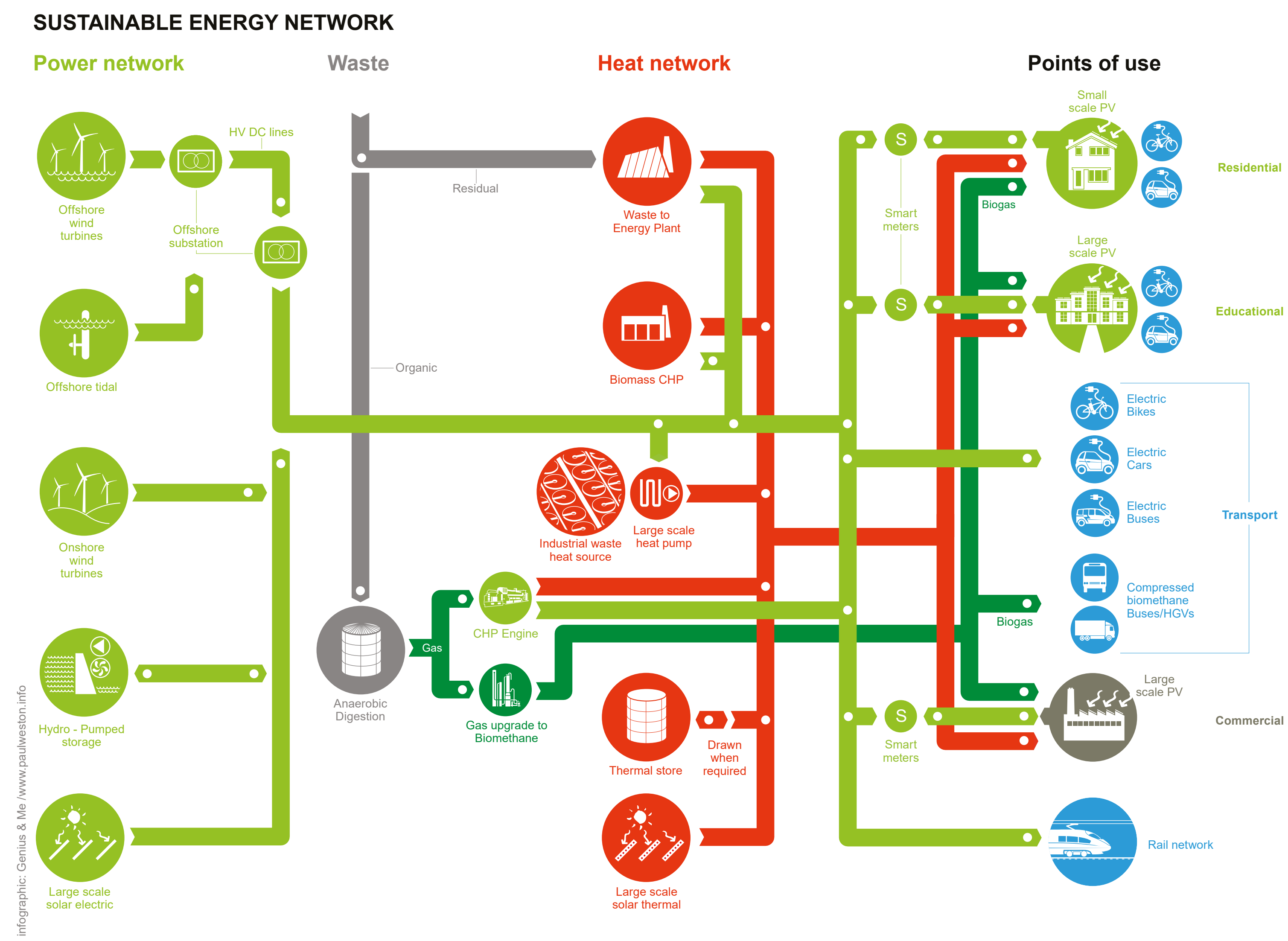
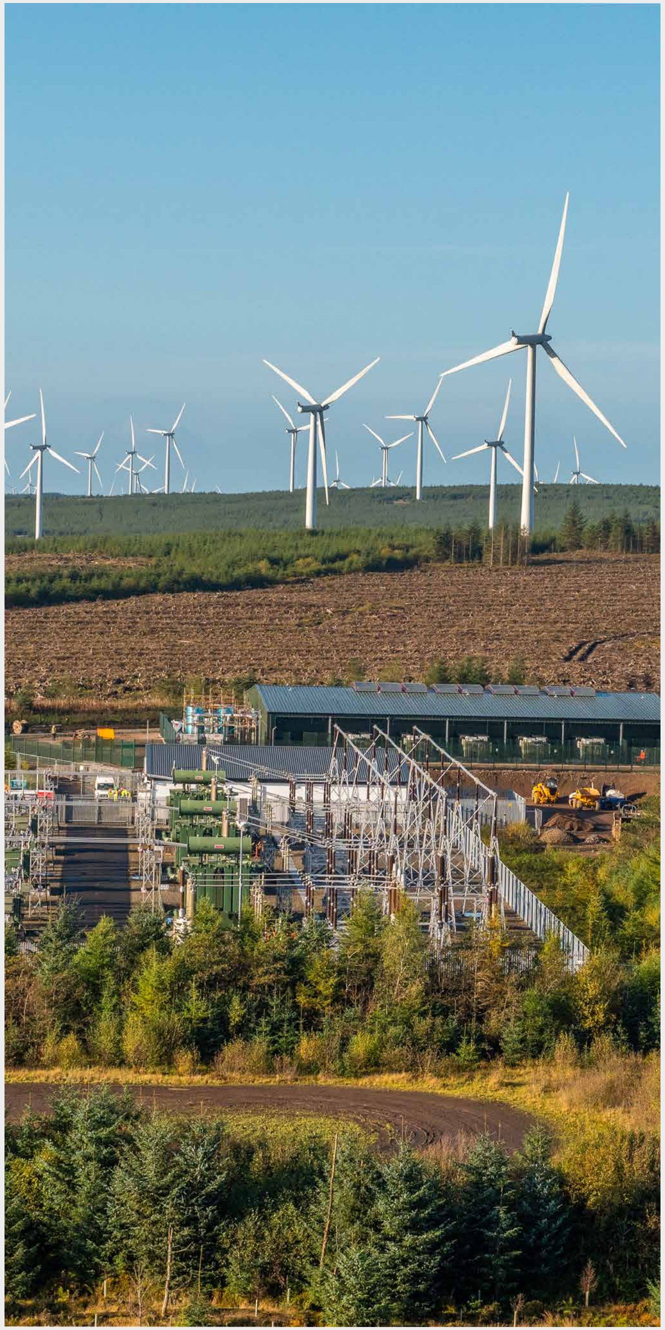


Figure 1: Example of a future low carbon energy system, integrating a mix of renewable sources, energy storage and district heating to provide a balanced and resilient system



A further step in balancing the network is the adoption of a smart energy system that integrates hardware and system controls across a network. 'Smart grid' technology can aid the:

- Transfer of energy between gas, electricity, heating and cooling grids;
- Storage of energy over long and short timescales;
- Control of demand by managing the energy supply to non-critical appliances; and
- Switching between a wide range of fuel sources, including intermittent renewables, low carbon waste to energy plants and low-grade industrial waste heat.

The technical and economic benefits of investment in decentralised energy, heat networks and smart energy systems are as follows:

- Application of technology to provide the most efficient use of the fuel content from primary fuels;
- Decentralised energy solutions are suited to urban areas particularly those with high heat demand density and/or large cooling demands;
- Provides the flexibility to manage and integrate power and heat generation sources within a network and to replace with more sustainable energy generation sources over time; and
- Network balancing allows for the potential reduction in the overall capacity required for distribution network infrastructure by utilising energy at off peak times to heat the network and thermal stores, therefore lowering the peak heat demands.

SECTION 2

Energy Masterplanning – Who is it for?

Energy masterplanning is a tool for those looking to plan and coordinate the transition to a low carbon energy system. Masterplans can also be used by those looking see how an area's energy system might change over time, such as local residents and businesses as well as people looking to deliver energy projects.

This Guide is aimed at those people looking to create an energy masterplan, for example:

Local authorities

Such as energy officers, planners, and low carbon development teams, who might coordinate the process of data collection, analysis and stakeholder engagement. Local authorities can also play a crucial role in supporting the delivery of the resulting energy masterplan.

Property developers, landowners and building operators

Particularly with the appetite to take on responsibility for some or all the development and energy services for a scheme.

Energy companies/decentralised energy providers

Prospective energy providers putting forward proposals to deploy technology as energy suppliers across an area.

A lead organisation is required to coordinate the energy masterplan that has the appetite and commitment to bring stakeholders together, and to promote, develop and subsequently deliver the energy masterplan. The energy masterplanning process should have a focus on stakeholder engagement activity in order to involve potential partners, customers and regulatory authorities to jointly develop the best solutions.

SECTION 3

Energy Masterplanning – Why do it?

A transition to a net zero Scotland will require decarbonisation of transport, buildings and industry, integrating a mix of building-level and decentralised technologies into a balanced energy system supported by capacity in the national electricity grid, demand-side management and storage. Delivery of this scale of change requires strategic planning, supported by a delivery plan to coordinate and implement new solutions, often using a phased approach for larger projects. Energy masterplanning can help to understand and prioritise energy decarbonisation opportunities spatially across a geographic area to ensure that strategic planning and projects support the delivery of an efficient and cost-effective low carbon energy system.

Figure 2 identifies the key stages, involved in delivering energy system decarbonisation, from baseline mapping through to the installation of initial projects which can then grow and interconnect into an integrated town or city-scale low carbon energy system. The term energy masterplanning can be used to describe all of the activities undertaken within Stages 1-6. However, this Guide more specifically relates to Stage 4 - the process of converting a strategic vision into specific project opportunities or targeted delivery programmes. It is important to note, however, that this is a somewhat idealised sequence and in reality, the identification and development of projects from opportunity to delivery may commence at any point within the sequence and is often an iterative process.

Stage 4 covers the assessment of the supply and demand of energy on a regional or sub-regional level, the overall aim of which is to ensure that energy projects are developed in a planned and structured fashion that ensures energy resources are used to their full potential and possible key opportunities are not lost. Energy masterplans are focussed on specific spatial geographic areas that may have been identified as a result of an assessment of multiple opportunities or because a coordinated approach is identified as providing a strong benefit to a location. Figure 2 indicates that one region may support multiple projects that could eventually expand and merge into clusters or a fully integrated city-scale energy system.

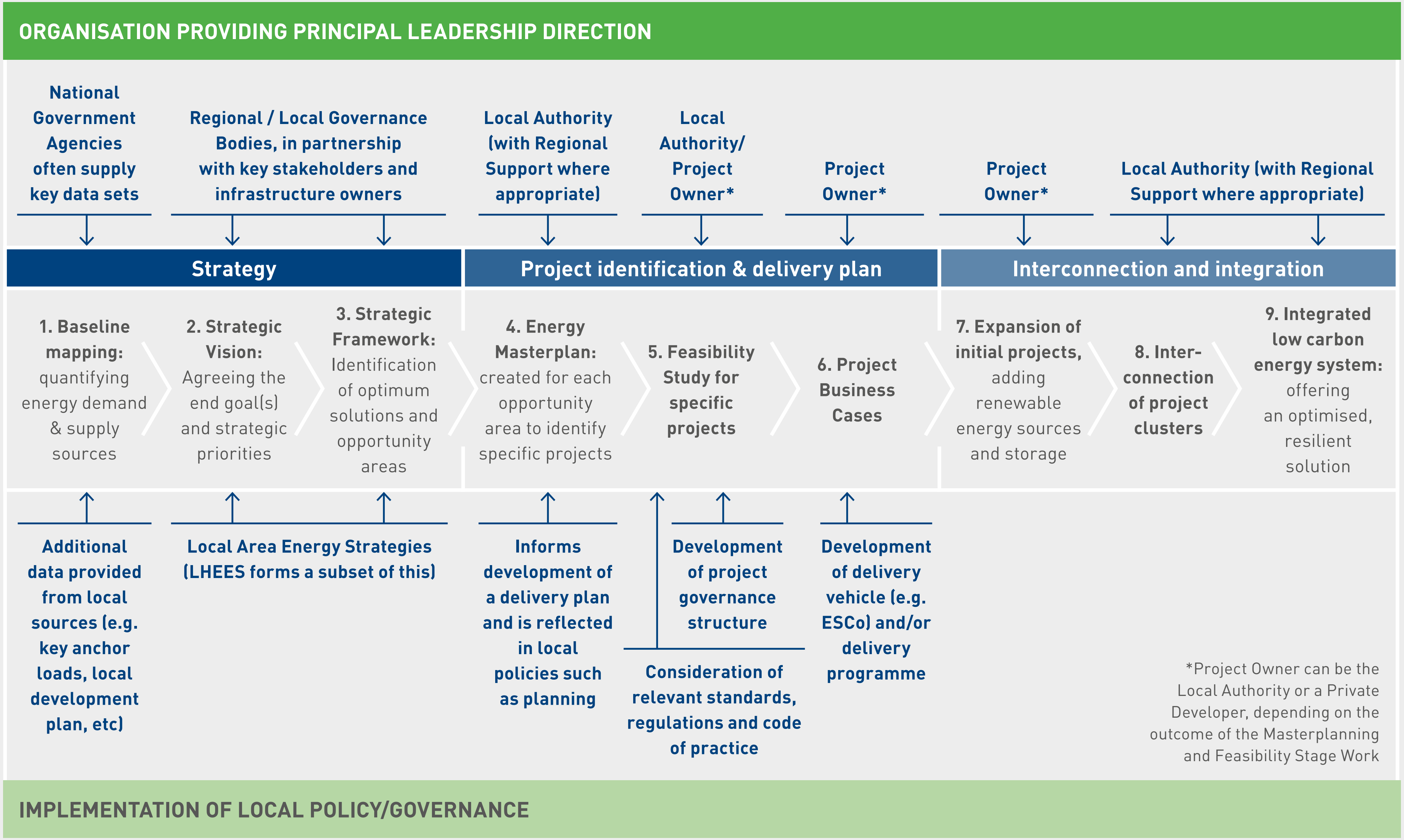


Figure 2: Development stages of strategic energy planning and project delivery

3.1 Benefits of Energy Masterplanning

3.1.1 Stakeholder Engagement

Energy masterplanning is, at its core, an exercise in joined-up thinking and provides an opportunity to engage key stakeholders and the public at the inception stage to ensure that their needs and concerns are sufficiently addressed at an early point in any infrastructure project.

3.1.2 Efficient Use of Energy Resources

Using our energy resources in a more efficient way can bring economic and environmental benefits by reducing the cost of energy to customers and reducing the emissions of harmful gases, such as carbon dioxide, to the atmosphere.

Energy masterplanning considers energy demand and supply as a complete system rather than in isolation. This allows for an integrated approach to the development of energy projects to provide a balanced energy demand and supply solution by ensuring that different technologies and solutions can be developed to work most efficiently together.

The co-generation of heat, cooling and power is one of the most efficient ways to utilise available energy resources. However, it needs to be approached in a coordinated manner, or opportunities may be missed. For example where power generation is developed with no reference to heat supply, significant amounts of heat energy can be lost through cooling towers and other forms of 'waste' heat rejection.

By using energy technologies in a smarter way; renewable and sustainable solutions can be more readily integrated into the energy supply system to work with, and to create additional capacity, within established infrastructure.

3.1.3 Economic

Energy masterplanning provides an initial assessment of the economic viability of opportunities at an early stage. This allows consideration of appropriate delivery vehicles that could be used and the value of pursuing the project in its proposed form. It also provides visibility of available opportunities to prospective investors.

A relatively small investment at the beginning of a project can save substantially in the long term by avoiding common pitfalls associated with poor planning. For example, a new heat network may be required because another heat network in the area was not designed for future expansion, which causes a reduction in overall efficiency and an increase in overall costs compared to one larger scale network.

3.1.4 Planning and Policy

The low-carbon energy solutions identified through masterplanning can help new developments and existing organisations meet climate change goals.

Energy projects often require significant investment in the wider network infrastructure. Engaging with local authority planning departments and the incumbent energy network operators at an early stage, and looking at the project in a broader context, may identify opportunities for linking in with other planned developments that would not otherwise have been considered.

Local authorities can benefit from energy masterplanning to both inform and introduce local policies and interventions, thereby ensuring that the correct tools are in place to encourage the development of the strategic vision that includes energy as a priority for an area. When rolled up to a national level, Government can also use energy masterplans to develop national strategic priorities and policies, with potentially targeted support where a specific outcome in a particular location is desired.

3.1.5 Data Collection

The data collation and assessment undertaken as part of the energy masterplanning process serves to define the scope of the energy solution for the area being looked at.

In particular it brings together disparate information into a readily understandable and usable format, allowing for the development of powerful visual aids which can be used to support stakeholder engagement.

Visualising energy flows (such as through GIS mapping tools) within an area helps in the understanding of the project and the development of innovative solutions, as well as stakeholder and public engagement.

3.1.6 Identify Opportunities and Constraints

Identification of barriers and constraints to delivery of energy projects at the early stages of project design can help considerably with the development of a successful project. Once a barrier is identified the project can be designed in a way to address this issue, preventing it from arising further down the line.

By considering the interaction of supply and demand across a wide area, opportunities can be identified to integrate projects into a holistic energy system, which may otherwise have been missed. This may be through the use of storage and smart systems and controls to maximise the efficiency of the system, or the prioritisation of different renewable energy sources through energy hierarchies to ensure resources are utilised where they are most needed.

Early and meaningful stakeholder engagement and collaboration contributes to the successful delivery of commercial projects which can provide low carbon energy to homes, businesses and public bodies.

SECTION 4

Energy Masterplanning – How to go about it?

Energy masterplanning is intended as a strategic methodology for the assessment of the supply and demand of energy on a regional or sub-regional level, and the subsequent planning for the physical implementation of solutions. This section sets out the key stages of energy masterplanning. The actual approach taken for individual projects will need to be specific to the needs of the project. In reality, it may not be possible or beneficial to insist that all of these stages must happen or take place in the order outlined here. The purpose of this document is to raise awareness of the need for project opportunities to be considered in the context of the wider energy picture.

Stages 2-6 described in Figure 2 are broken down in Figure 3 below with further details of the expected deliverables. These are the stages that may concern regional/local governance bodies. In the context of this document energy masterplanning refers to Stage 4. It is at this stage that a single regional strategic vision of a balanced energy system is converted into multiple project opportunities that require investment over a period of time to collectively achieve the intended vision.

1. Regional or Local Strategic Vision Policy Context and Targets Benefits of decentralised energy Vision for low carbon energy in the area	Development of a Regional Strategic Vision involves a high level assessment of the region and the intended benefits of adopting decentralised energy infrastructure.
2. Strategic Framework Opportunity Mapping Appraisal, weighting and hierarchy Pipeline of opportunity areas	The Strategic Framework involves a characterisation of the area to set out a clear plan with the identification of Opportunity Areas and an assessment of their relative performance based on appropriate KPIs which can then be taken forward to Stage 4.
3. Energy Masterplanning Assessment of individual opportunity areas Testing of Project Scenarios Refinement of Project Definition	The purpose of Energy Masterplanning is to define the scope of individual projects within the opportunity area outlined in Stage 3. This involves the development of hourly energy models and a technology options appraisal and high level whole life costing assessment.
4. Feasibility Study Confirmation of Assumptions under 4 Targeted Stakeholder Engagement Commercial Assessment of Project Opportunity	Feasibility Stage takes the project opportunity as defined in Stage C and tests the high level technical and commercial assumptions. The definition of the project under Stage 3 allows for an in-depth interrogation and definition of all aspects of the proposed scheme under Stage 5.
5. Business Case Delivery model and structure Financial model Finance Options	Building on the work undertaken in Stage 5 the key financial and commercial aspects of the project can be fully determined in the Business case development phase. Project Governance Structures and Financing Options can be investigated and the market approached.

Figure 3: Concept and detailed development of energy masterplanning and business case development

In practice, there are few energy masterplans in the UK that have been progressed through the full sequence outlined in Figure 3. Many schemes go directly to masterplanning without conducting a regional strategic assessment, and small developer led projects typically progress directly to feasibility. The decision as to which stage is the most appropriate will largely be dependent on the scale of the proposed project and any previous work that has been undertaken.

4.1 Methodology for Energy Masterplanning

The methodology for energy masterplanning can be divided into six stages which should ideally be addressed in order. Each stage is described below.

Data collection	• Energy Demand, tenure, ownership, location, current heat and electricity supply. • Develop energy demand map and database of the opportunity area. • Develop supply map, categorise each supply asset.
Strategy	• Decide the areas to be connected and the renewable supply asset(s) to be used. • Determine the modelling scenarios to be tested. • Determine potential local heating ,cooling and power network opportunities.
Technology Options Appraisal	• Develop hourly energy model for the system, annual and peak loads. • Assess the low and zero carbon technology supply options for the project. • Size key technical assets such as the energy generation, storage and distribution networks.
Economic Assessment	• Detemine capital and investment costs for key assets. • Determine fuel costs and other operational and maintenance costs. • Carry out whole life costing of the project opportunity (including economic costs, IRR and NPV).
Comparative Assessment of the Scenarios	• Assessment of each of the modelled scenarios based on the Project Owners' key drivers. • Ranking of the modelled scenarios and recommendations for feasibility assessment.
Project Reporting	• Report key recommendations. • Produce high level maps of the proposed opportunity. • Set out key risks that need to be addressed at feasibility stage.

12. Scotland Heat Map

4.1.1 Data Collection

The initial stage will involve the collection of key data sets:

- Data should be gathered on heat, electricity and transport demand and supply opportunities.
- In relation to heat, characterisation of the properties within the study area in terms of their building type, tenure and heat demand which can be initially estimated from the Scotland Heat Map[12] and then enhanced with supplementary national and local datasets. The map can also be used to Identify possible sources of waste heat recovery, and is expected to be regularly updated, with the last update in 2020.
- Identification of initial groups of properties by ownership or property type that can be aggregated together under one company or community group to facilitate future stakeholder consultation activity.
- The location, capacity and ownership of existing or potential heat generation sources including a review of potential energy resources.
- Understanding of grid infrastructure and network capacity constraints, challenges with grid balancing and potential solutions. For example, considering the potential to make use of smart electric vehicle charging or vehicle to grid technology to enable grid balancing .
- Information on proposed new developments in the area, through consultation with local planners and developers, including information on proposed floor areas/number of dwellings and planned energy supply plant.
- Collection of the above data into summary tables and production of a locally detailed Geographical Information System (GIS) showing heat demand and heat supply layers for the area of interest.
- Additional GIS information that should be sought in order to assist with the development of the database can include: information on proposed infrastructural works, information on utilities where available, areas of proposed development etc.

4.1.2 Strategy

Working in consultation with the key stakeholders – identify the scope of the study, i.e. the geographical extent, potential infrastructure routes, proposed connections and the supply options. This may result in a number of modelling scenarios to be tested, in order to comparatively assess these scenarios key economic performance indicators such as hurdle rates, carbon emission reduction and fuel poverty alleviation. These should be agreed with the key stakeholders. The approach to a wider stakeholder engagement should also be developed at this stage.

Stakeholders may have varying interests in the energy masterplan including:

- Potential impacts and benefits to the communities within the area of interest;
- Interest in proposed projects as a customer, supplier or investor;
- Strategic interest in the development potential of the area;
- Other key stakeholders who will be critical in influencing change.

Presentation of the overall strategy to stakeholders at an early stage helps to ensure buy-in to the project by considering the views and concerns of those concerned, beyond the technical merits of the proposals.

4.1.3 Technology Options Appraisal

An energy masterplan design should assess the capacity constraints of existing energy infrastructure and the essential network upgrades and new infrastructure that may be required.

An energy model should be developed that simulates the energy generation, distribution network operation and heat and power demands at a suitable time frequency (hourly modelling is generally appropriate) to determine energy demands and peak loads. The energy model should include appropriate predictions of future energy demands and technology replacement over an appropriate lifetime.

For heat networks, a long-term vision for the likely route of a network should be developed based upon a high-level options appraisal, taking into account potential phases of development. This can support safeguarding for future capacity needs and potential expansion of heat networks as appropriate. Constraints to development such as recent infrastructural works and areas unsuitable for network routing should be considered as part of this assessment. The technical design stage for heat networks should also identify potential locations for energy centres considering existing and planned generation capacity. The design should also identify the role of storage, including for local balancing of electricity and heat grids. This stage should provide concept layouts, pipe lengths, diameters and sizes for the heat network options and identify network routes taking into account potential risks, physical barriers and opportunities for additional connection relating to these routes.

A summary of potential low carbon technology options is included in Appendix A.

4.1.4 Economic Assessment

The economic assessment will include the development of an economic model for the technological solutions proposed in order to provide an indication of the comparative economic performance for a number of scenarios.

The economic model should identify key assumptions for the development of the analysis. The model should identify costs and revenues for the options and assess economic viability of the proposed solution using a whole life costing approach, including but not limited to, consideration of:

- Capital cost of generation plant, energy centre(s), thermal storage, electricity and heat network assets, customer interface units, EV charging infrastructure and smart metering;
- Operation and maintenance costs and planned asset replacement costs during the life of the project;
- Fuel costs;
- Wholesale price of energy that can be achieved from low carbon sources (e.g. heat from an energy from waste plant, or heat that is upgraded from low grade heat sources).
- Energy sales income based on market competitive energy supply tariffs for each consumer type (options for electricity sales should include consideration of options for selling power wholesale, netting off and private wire);
- Financial subsidies, grants or low interest loans that could support the business case for the project;
- The business-as-usual costs for each identified customer or groups of customers;
- Calculate pay-back-period, internal rate of return (IRR) and net present value (NPV) over an appropriate lifetime (for example 25- or 40-year duration), based on public and private sector hurdle rates to be agreed with the project stakeholders.

Public sector economic assessments would likely also include social costs (or benefits), for example savings in carbon emissions and avoided air quality damage (e.g. NOx, SOx, particulate matter)[13].

The economic model should be capable of testing a number of technology options. The model should take account inflation and forecast energy price rises over the life of the scheme. The model

13. UK Government guidance for the appraisal of policies, programmes and projects is provided in The Green Book.

should also present a sensitivity analysis for the key input variables.

The commercial assessment of the project should include a discussion of appropriate delivery models for the solution taking into account the results of the techno-economic analysis. Detailed business case modelling and delivery model assessment is generally carried out at the feasibility stage and beyond.

4.1.5 Comparative Assessment of Scenarios

The analysis should assess the suitability of each of the modelled scenarios based on the Project Owners' key drivers. It may be appropriate to use a method to rank the modelled scenarios.

Depending upon the scope of the masterplan it may be necessary to develop further narrative around the most favourable scenarios identified. This may extend to evaluating the options available for delivery, ownership and management of any project opportunity.

4.1.6 Project Reporting

The report should present the key recommendations from the masterplan. A high-level map of the proposed opportunity/ opportunities should be developed to provide a visual aid and demonstrate how projects can be linked together. The main risks of the project should be outlined so they can be addressed at an early stage, if possible.

4.2 Further Information

Further information on websites and useful tools for masterplanning is available at appendix B.

SECTION 5
Case studies

Low carbon energy masterplanning activities have been growing and developing in the UK for the past decade, historically focused on heat and heat networks. In England and Wales the lead organisations have been BEIS, the Heat Network Delivery Unit and the London-focused Decentralised Energy Project Delivery Unit (DEPDU). In Scotland, activities were coordinated through the Heat Network Partnership[14] (HNP). However, in more recent years the scope of energy masterplanning has been broadened to begin to consider decarbonisation of heat, power and transport together in a holistic way. The Energy Systems Catapult developed an approach and tools to support whole energy system modelling and planning[15]. Local Area Energy Plans are recommended by Ofgem for electricity distribution network operators to include in their business plans as part of their RIIO-2 Business Planning Guidance.

In this section, three examples of masterplanning are provided to showcase how masterplanning is carried out and how it leads to successful execution and delivery of projects. Each case study is based on a key theme, (1) 'city-scale, whole system energy masterplanning',(2) 'low carbon masterplanning to utilise waste heat and interconnect networks', and (3) 'low carbon masterplanning to integrate new developments into the wider energy system.' Appendix B provides links to some recent examples of noteworthy UK energy masterplans for further reading.

14. District heating Scotland
15. Energy System Modelling Environment

5.1 City-scale, whole system energy masterplanning

Case Study: The City of Cambridge, Massachusetts, USA

Cambridge, a city north of Boston, USA, with a population of 120,000, is committed to achieve carbon neutrality by 2050, with an emphasis on decarbonising buildings which account for 80% of the city's total emissions. The city developed a 25-year Net Zero Action Plan, which provides the strategic framework for achieving this goal and is reviewed every 5 years to ensure it stays relevant. The energy masterplan, identifies the optimum interventions for decarbonising buildings, considers the implications for energy security, assesses the electricity and gas infrastructure in the area, and potential energy costs to consumers.

Assessing scenarios to inform energy masterplanning

With the support of Ramboll, the City of Cambridge conducted a low carbon energy supply study, identifying how the City could transition its energy supply from fossil-fuels to low carbon sources. Options included: waste heat from subways, industry, ice rinks; sewers to provide heating and cooling; and heat pumps with sea water as the heat source. In addition to assessing heat sources, the local grid capacity and constraints were assessed. In some areas, the upgrade costs to grid infrastructure made electrification of heat economically unviable and alternative solutions were explored.

In total, ten scenarios were developed, and the City's energy supply was analysed to understand the optimum use of resources and existing infrastructure, focusing on the three most promising scenarios in detail – electrification of individual buildings, electrification of individual buildings but with district heating and cooling where viable, and district heating and cooling sourced from renewable energy. Based upon this analysis, the energy masterplan indicates zones for individual building electrification (primarily in less-dense suburbs), coupled with district energy systems in dense areas.

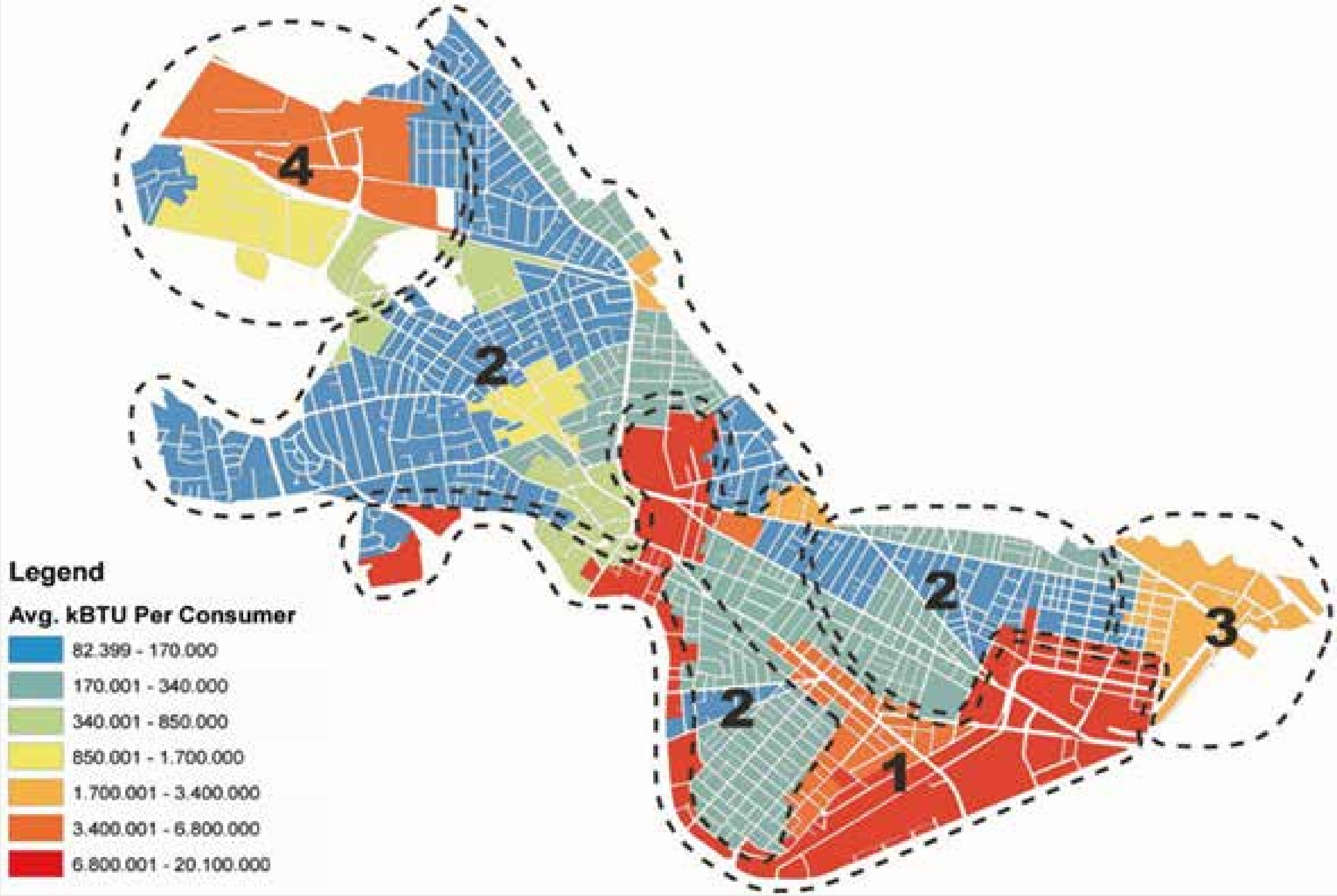


Figure 4: Zoning Example for City of Cambridge

Translating an energy masterplan into delivery

The City has made progress in delivering the measures identified in the energy masterplan using its Net Zero Action Plan for buildings, but also faced challenges introducing more unfamiliar technologies such as district energy.

Since developing their action plan in 2016, the greatest progress has been made with individual building electrification, which has been aided by updating local policy levers to drive uptake. Previously all large building owners were required to report their emissions, and starting in 2021 they must demonstrate a reduction in their emissions. There is also a voluntary programme for smaller buildings in the early stages of development.

While progress has been made with building-level electrification, one significant issue has been the ability of the local grid infrastructure to handle the increased electricity demand. Some electrification projects have been cancelled due to the requirement to upgrade local grid equipment such as substations. A strong partnership with the utility companies is thus a critical factor for success in delivering the Action Plan.

Advice for energy planners

A key lesson from the City's experiences to date has been the importance of building an environment of supportive stakeholders, and an understanding of key technologies for the projects proposed within the energy masterplan. Seth Federspiel, Climate Program Manager for the City of Cambridge, said the best advice he can give the local authority planners in Scotland is to "**bring key stakeholders to the table as soon as possible, and before technical analysis. This creates buy-in and helps to develop a plan that can be implemented successfully.**"[16 17]

16. Net zero task force
17. Low-carbon energy supply strategy for the City of Cambridge

5.2 Low Carbon Masterplanning to Utilise Waste Heat and Interconnect Networks

Case Study: Clyde Gateway, Glasgow, Scotland

Glasgow is at the forefront of low carbon decentralised energy systems. The city's Clyde Gateway project is one of five ground-breaking pilots of '5th generation district heating and cooling' (5GDHC) across Europe as part of the D2Grids project[18]. 5GDHC systems are defined as decentralised pipe networks that operate at low temperatures (5-25OC) and can support both heating and cooling of connected buildings through the use of heat pumps in individual buildings.

Clyde Gateway is one of Scotland's largest regeneration programmes, spanning over 840 hectares. It is a partnership between Glasgow City Council, South Lanarkshire Council and Scottish Enterprise, backed by funding and direct support from the Scottish Government. Since it was formed in 2008 there has been highly visible change in the area, and it was realised early in the programme that Clyde Gateway had a significant opportunity to be an exemplar community renewable energy project that considers a whole system approach.

The Need for Energy Masterplanning

In 2010/11 Scottish Power Energy Networks (SPEN) were set the task of measuring and profiling the proposed energy use and infrastructure requirements for the area, for which they produced a "Clyde Gateway: Energy Resource and Technology Assessment - Energy Masterplan". This energy masterplan and dynamic model identified technically feasible projects in the area.

The focus of the project was to use resources efficiently and interconnect with intelligent demands that, combined with energy storage, could share energy across the whole energy system. It was vital that masterplanning was used in the early stages to ensure it was possible to interconnect future heating and cooling networks and maximise the use of waste heat sources. The project has focused on a defined area but is designed to support expansion and to interlink with other energy clusters in the future.

Clyde Gateway is an example of where masterplanning identified promising projects that offer energy system benefits and improved efficiency through their co-development and interconnection that would not have been possible without this broad coordination.

18. D2Grids, rolling out 5th generation district heating and cooling

Delivering Heating Networks

Following on from SPEN's masterplan, Clyde Gateway Developments partnered with Scottish Water Horizons to deliver the heat network opportunities that were identified. The design of these projects offers the potential to share excess heat between networks and for long-term expansion and interconnection, maximising the efficiency of the local energy system.

A district heating network was developed to provide heat to both domestic and non-domestic new-builds in the area using a gas CHP unit located at Dalmarnock Wastewater Treatment Works (WWTW), which simultaneously generates electricity. The network is due to begin operation in November 2021.

Through the D2Grids pilot project an 'ambient loop' network is also being developed in the area, which is currently in the conceptual design stage. The innovative design consists of a low temperature decentralised heat network where each connected building has its own heat pump. The heat pump unit will be capable of heating and cooling, allowing any waste heat from cooling to be returned into the network. A heat exchanger will also be installed to incorporate waste heat recovered from the final effluent at Dalmarnock WWTW.

Due to the quantity of electricity required at certain times, the CHP unit will occasionally generate more heat than is required by the district heating network. The ambient loop will incorporate this excess heat into the network via a large heat exchanger enabling maximum efficiency at all times.

The 5GDHC network is designed so it can be easily expanded in the future, which allows low carbon heating to be available to future stages of the regeneration programme. Future networks can also be connected to the existing ambient loop, which ensures the network will be a valuable decarbonisation asset for years to come[19 20].

19. Clyde Gateway regeneration
20. Community energy project

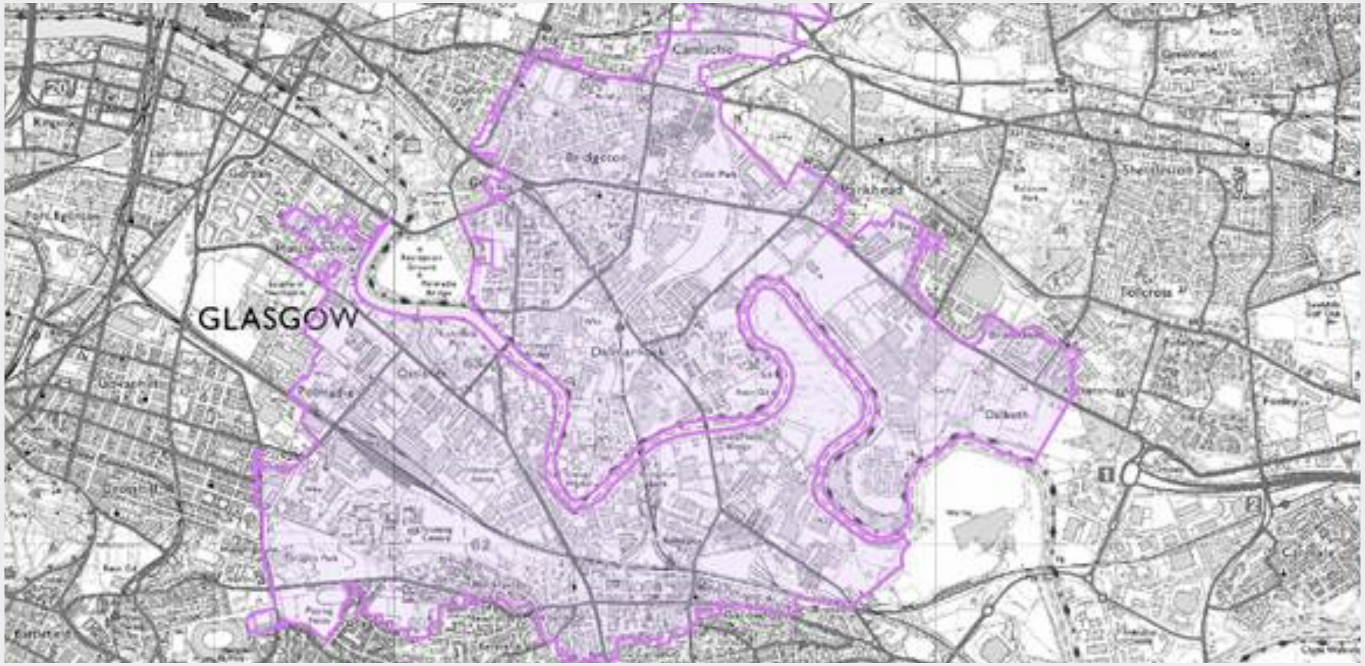


Figure 5: Clyde Gateway Regeneration Area

5.3 Low Carbon Masterplanning to Integrate New Developments into the Wider Energy System

Case Study: Riverside Heat Network, London Borough of Bexley, England

In 2015, the London Borough of Bexley commissioned the development of an energy masterplan to explore opportunities for decentralised energy in the area, with an emphasis on district heating. The council wanted to identify areas of high demand and determine whether 'waste' heat could be utilised to provide low carbon heating to the community. By assessing the whole area before selecting specific projects, they can best match energy supply and demand opportunities. The assessment started by mapping the heating and cooling loads in the Bexley Borough to identify areas of high demand. Clusters of buildings and development areas that offered the best potential for locating future district heating and cooling networks were identified, as well as extensions to any existing networks.

Integrating Low Carbon Heat Supply

The Riverside Resource Recovery (RRR) Energy from Waste (EfW) facility was identified as the primary heat supply opportunity within the study region, and the Thamesmead housing estate was identified as the area with the greatest potential for demand. A number of heat network scenarios were identified for technical and economic analysis. The results showed that there was a viable opportunity for district heating whereby the RRR facility would supply low-cost heat to the Thamesmead housing estate and the Belvedere Growth Area. Utilising this waste heat is economically beneficial for Cory Riverside Energy, the owners of the RRR facility, and so in 2020 they partnered with Vattenfall to develop heat networks to distribute the heat. The supply of waste heat allows the housing developer to receive low carbon energy for their properties, ensuring compliance with the London Plan and building regulations.

After securing funding from the BEIS Heat Network Delivery Unit, Bexley Council conducted a detailed feasibility study into the Thamesmead and Belvedere district heating network. This study considered both the technical and commercial benefits of the proposed scheme and the environmental advantages of recovering heat from the RRR facility to distribute it via a district heat network (DHN) to the boroughs of Bexley and Greenwich.

A Vision for Future Expansion and Decarbonisation

In 2019 Ramboll partnered with Vattenfall to develop a zero-carbon transition plan for a heat network developing the proposed RRR-driven DHN to a wider scheme for the East London area including the Boroughs of Bexley, Greenwich, Newham, Barking and Dagenham. A high-level masterplan was prepared on a much larger area, to be known as the East London Heat Network. The project has the potential to provide heating and cooling to residential, commercial, retail and industrial buildings, equivalent to 75,000 homes. It was proposed that the network would eventually extend 30km across four boroughs, with the RRR facility at the heart of it in the initial stages. Over time, the EfW source would be supplemented by other low carbon heat sources. This would include large heat pumps connected to an ambient temperature network and seasonal thermal storage – enabling zero-carbon heating to be achieved.

Vattenfall is working in partnership with Cory Riverside Energy to recover heat from their RRR EfW facility to heat 10,500 new homes via their Riverside Heat Network. Another EfW facility situated adjacent to the existing plant in Bexley, which was granted planning permission in April 2020, will serve another 10,500 new homes on the network. Vattenfall estimates the network will reduce carbon emission by 80-90% compared to gas boilers. The network will allow for future expansion, connecting more heat customers and other low carbon sources of heat. After the first 21,000 homes are connected other sources of heat, such as sewage heat recovery from Thames Water's treatment works at Crossness and Barking or industrial waste heat, will be required to fulfil the overall vision for the Riverside Heat

Network to supply the equivalent of 75,000 homes, making this one of the largest district heating networks in the UK and a key component in London's zero carbon transition.

For further information on this case study, please visit "Vattenfall partners with Cory Riverside Energy to offer low-carbon heating for East London homes[21]" and "Riverside Heat Network[22]".

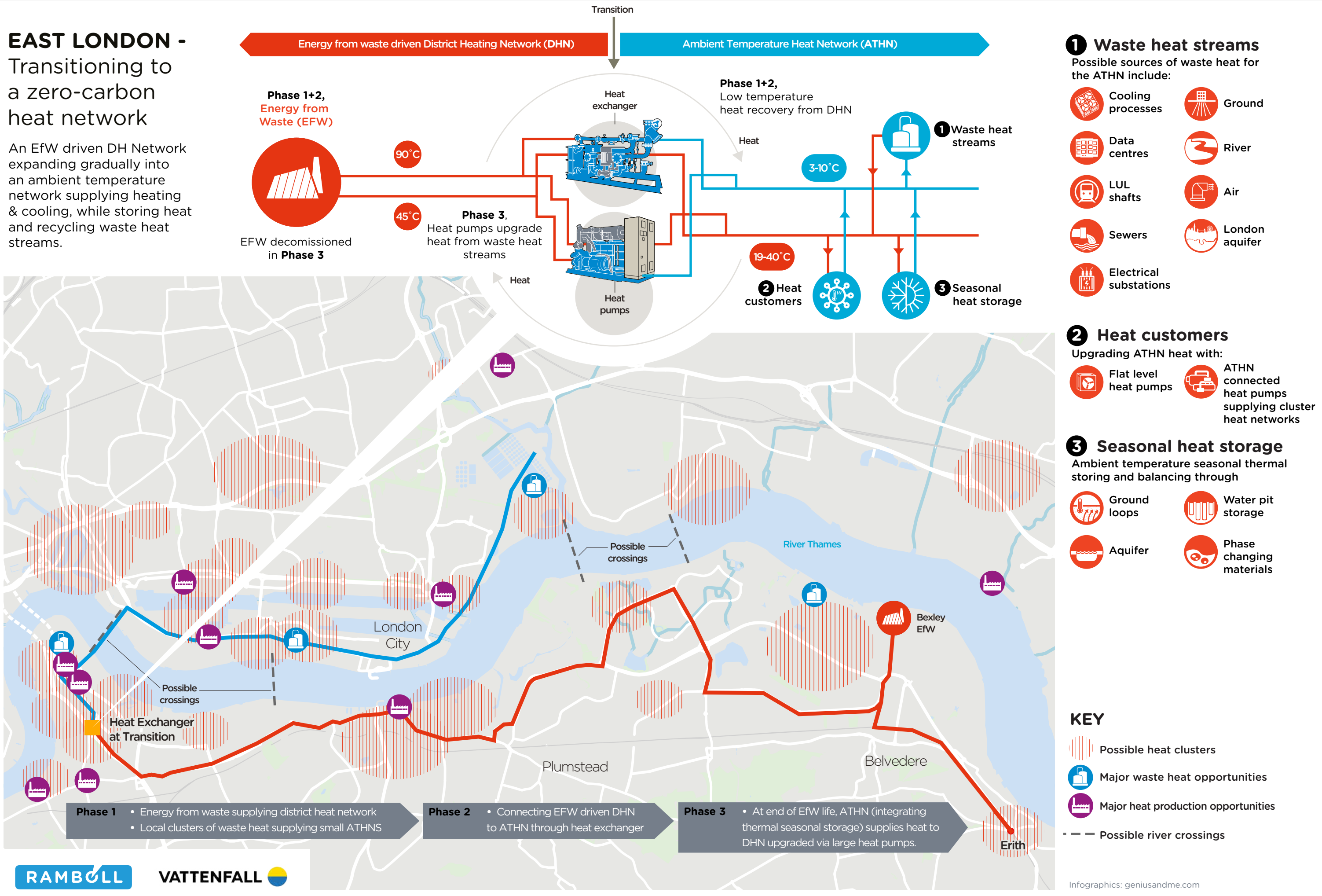


Figure 6: Ramboll and Vattenfall's future vision for the Riverside/East London Heat Network

21. https://group.vattenfall.com/uk/newsroom/pressreleases/2020/vattenfall-partners-with-cory-riverside-energy-to-offer-low-carbon-heating-for-east-london-homes
22. https://www.corygroup.co.uk/future-growth/riverside-heat-network/

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Appendices

APPENDIX A: Low and Zero Carbon technology options

The detailed and rigorous assessment of the available technology options for energy generation, distribution, storage and management sits at the core of the whole-energy system energy masterplanning approach. There are inherent challenges associated with delivering a shift from the current methods of generation and distribution of power and heat to meet demand energy for transport, heating and powering buildings and industry. These will apply, to a greater or lesser extent, to all of the technologies discussed below and will need to be considered on a case by case basis. They include:

- The public acceptance of technology solutions
- The potential impacts on fuel bills/fuel poverty
- The capital investment and operation and maintenance costs need to be justified through a robust business case;
- Environmental impacts associated with the deployment of technology which will be mitigated through planning and environmental permitting regulations (noise, air quality, visual impact, ecology, etc);
- Availability and maturity of technology;
- The establishment and development of supply chains and skills for the supply and installation of technology, which may impact on the cost and quality of solutions;
- Resilience of the technology to deliver reliable power and heat to customers; and
- The local geographical and policy challenges associated to the selected location.

Low and Zero Carbon Electricity Generation

The trend in the market is towards low and zero carbon generation in a combination of large scale plants and decentralised generation.

Solar PV

Photovoltaic cells (PV cells) convert solar radiation directly into DC electricity. Individual PV cells only provide a small amount of electricity, so they are generally grouped together into a module for convenience. Due to its modular nature Solar PV can be installed in almost any location at any size, i.e. decentralised on individual houses or as large scale centralised installations in fields, similar to wind farms. Solar PV are considered to be one of the most environmentally friendly forms of electricity generation as carbon emissions attributed to them are only due to the manufacturing process to produce them.

Wind Turbines

Wind turbines harness the power of the wind to produce electricity by powering a generator on the axis of the rotor. They can produce electricity without carbon dioxide emissions, and range in output from watts to megawatts. Similar to PV, the only carbon emissions attributed to wind turbines are due to the manufacturing process to produce them.

Wind turbines can be installed as both onshore and offshore technologies; offshore wind turbines are much larger than onshore variants and as such produce a lot more electricity. They can be installed in large scale wind farms, or in a decentralised manner on as small a scale, such as on farmland.

Hydroelectric Energy

Hydroelectric plants vary in scale from micro (supplying individual properties) to multi-megawatt scale.

Electricity from hydro-electric technology makes up approximately 12% of Scotland's electricity. Whilst the general consensus seems to be that the potential for significant numbers of additional large-scale plants is limited, there is substantial capacity for small scale and community hydroelectric schemes, although few are now being constructed as subsidies are no longer available.

Low and Zero Carbon Heat Supply Opportunities

New fuels and technologies are required to meet the challenges we face. In some cases this is through the utilisation of new technologies or improvements to old ones such as gas CHP units making more efficient use of existing fuel supplies or solar heating for homes, which has been used in warmer climates for years but which is now being used in a meaningful way in the UK due to improvements in the technology.

In some instances, this is being achieved by thinking of heat in a different way, for example using low grade heat to produce higher temperature heat through a heat pump, which is now a popular solution to zero carbon heating. Some of the key low and zero carbon technologies available are outlined below.

Solar Heating

Solar thermal collectors convert the sun's radiation into heat, which is transferred to a medium such as a water/glycol mix (to prevent freezing). This is then used to provide hot water to a building through a heat exchanger. Solar water heating is usually used for hot water generation, as this is a year-round demand. If it is used for space heating it must be combined with seasonal storage to make a meaningful impact.

Biomass Boilers

Biomass, such as straw and wood, have always been important energy sources due to their relative abundance, accessibility and cost effectiveness. However, their traditional use in open solid fuel fires is highly inefficient, harmful to health and is becoming more expensive and less accessible to the wider public.

However, by increasing the scale of the system from a single installation in a family house to a larger boiler plant supplying a district or community heating scheme, the efficiency is increased and the emissions can be treated to higher levels while maintaining sustainable economics. Biomass schemes must comply with air quality restrictions, however, the regulator and pollution control regime vary depending on the plant size and type of biomass[23].

Heat Pumps

The heat pump is essentially a refrigeration machine used in reverse by cooling a body of water or air down and heating air or water on the demand side to above ambient temperature. Thermal energy is drawn from a low temperature source and passed through the heat pump extracting heat energy and supplying this to buildings at a higher temperature. The low temperature source can either be natural; meaning the surrounding environment e.g. the air, ground or water body, or it can be man-made in the form of process or waste heat from industrial and domestic utilities. Example sources of renewable heat include minewater, sewage pipes, rivers, or boreholes. While the heat source may be renewable, a heat pump does require electricity input to operate and as such is a low carbon technology not a renewable one. As the grid continues to decarbonise, the carbon emissions associated with heat pumps is rapidly reducing. The three primary types of heat pump are as follows:

- Air Source Heat Pump (ASHP)
- Water Source Heat Pump (WSHP)
- Ground Source Heat Pump (GSHP)

Generally, WSHPs and GSHPs have higher coefficients of performance (COP) than ASHPs, and hence are more desirable to use. However, ASHPs are easier to install as there is no need for a ground loop, borehole or water source, so each has its benefits.

Hydrogen

Hydrogen can be used in a variety of applications including heating, transport and as an energy store. The use of hydrogen is a fast developing technology and its future role in energy systems is uncertain. However, to be low carbon, hydrogen has to be created by electrolysis from renewable

23. Biomass and Air Quality Information for Developers 2017

energy or the CO2 that is a by-product of steam methane reformation has to be captured and stored. Hydrogen can be a useful storage technology for local energy systems in that it can utilise renewable electricity that would otherwise be curtailed – business models for this are not clear at present, but in future the strategic placement of electrolysers on the network could have significant system benefits (see section below on energy storage technologies).

Geothermal

Geothermal energy is energy that is extracted from beneath the Earth's surface. Water and steam can be used to carry the heat to the surface, where it can be delivered to nearby buildings. In countries such as Iceland geothermal energy is regularly used for a wide range of heating applications, as well as generating electricity. The Earth's crust is thicker in the UK and hence it is more expensive to install these schemes, however, a small number of geothermal heat projects have begun operation in recent years.

Wastewater heat recovery

A wastewater recovery system utilises specialist heat exchangers to recover heat from wastewater, such as that in a sewer. These systems will typically include a heat pump to increase the temperature of the recovered heat to a useable level. This option is mainly used for municipal applications where wastewater flow is continuous. It can also be applied at a smaller scale within buildings to increase the efficiency of the heating and hot water process by extracting heat from used shower/bath water and repurposes it to warm the incoming mains water.

Combined Heat and Power (CHP) Solutions

These are plants which can generate both electricity and heat. Typically, electricity is the primary driver of the business case for the plant, with heat as a secondary factor. These can range from retrofitting existing fossil fuel power plants for heat extraction to modern CHP-ready Energy from Waste Facilities. In traditional electricity generating stations up to 70% of the primary energy can be wasted through cooling, in modern CHP plants this can be reduced to as little as 15-20%.

CHP plants can be connected to absorption chillers to provide cooling which increases utilisation of waste heat. This is referred to as combined cooling heating and power (CCHP).

A summary of CHP solutions are discussed below and are distinguished by their respective fuel source.

Energy from Waste

Energy from Waste facilities have experienced growth in popularity in the UK for the past 10 years. These plants combust residual (non-recyclable) waste from homes and businesses to raise steam which generates electricity through a turbine from which heat can be recovered. Recently gasification and pyrolysis plants are being developed which thermally treat waste producing a "syngas" that can be combusted to generate steam or diverted to a gas CHP engine. These technologies are also commonly referred to as "Energy Recovery Facilities" or "Advanced Thermal Treatment" Plants.

The technology facilitates the disposal of unwanted waste which previously would have been landfilled and generates usable energy. The burning of this waste produces CO2, however, much of this CO2 would be released during decomposition, but this would be spanned over a much longer time period . These are typically mid-size plants in the scale of tens of megawatts.

Natural Gas/Hydrogen CHP

These plants combust natural gas or hydrogen to produce both heat and electricity. The scale of these plants ranges from micro-scale CHP of a few kW to large scale power plants which use combined cycle gas turbines (CCGT) or open cycle gas turbine (OCGT). Although emissions are reduced by the efficient use of waste heat from producing electricity, most existing CHP plants burn natural gas and less carbon intensive technologies should be used instead where possible.

Anaerobic Digestion and Biogas CHP

Anaerobic Digestion plants break down organic waste (principally from agriculture, food and other organic process industry and sewage effluent). The biogas that is produced by these plants is deemed to be zero carbon because the amount of methane released by burning the biogas is equal to that released through the natural decomposition of the organic waste. The biogas created can be combusted in a gas engine CHP plant to produce both heat and electricity. The scale of these plants are normally small to mid-size plants of around 0.5 – 10 MW.

Biomass CHP

Biomass CHP plants combust wood chips, pellets, straw or other biomass material to raise the temperature of a fluid (commonly steam) which generates electricity through a steam turbine and heat can be recovered. An alternative technology is an organic Rankine cycle engine. Biomass CHP plants are deemed to be very low carbon due to their fuel source and offsetting electricity from the grid. The scale of these plants ranges from mid-scale of around 10-50 MW.

Energy Storage

Energy storage is a key challenge to managing the inconsistent demand and supply of heat and electricity. The demand profiles for heat and power vary on a daily and seasonal basis and renewable energy generation, notably wind and wave, can be unpredictable or as in the case with tidal and solar energy only available at specific times of the day. Efficient methods of large scale storage of energy to balance the heat and power system are currently being researched and proven.

Pumped Hydro

Pumped hydroelectric schemes are the primary large scale electricity storage solutions that currently exist. Scotland currently has two pumped hydro schemes and has recently granted permission for a 450 MW scheme situated above Loch Ness.

Lithium-ion Batteries

Large lithium-ion battery storages have been successfully deployed to provide back-up electrical capacity in the UK. A very wide range of storage capacities and outputs are available from lithium-ion batteries due to the capability of being modularly expanded, allowing them to be used on a building scale to optimise energy from solar panels on the roof, or on a grid level to provide some flexibility with variable renewable energies.

Hydrogen Storage

Another potential solution is to use excess electricity to generate hydrogen through the electrolysis of water. This process is approximately 80% efficient and generates waste heat, which has the potential to be utilised within a heat network if the electrolyser is sited in a suitable area of buildings with heating and/or cooling demand. Hydrogen offers a method to store energy during times of peak generation and low demand and can produce electricity and heat through combustion and fuel cells, but the technology is still in the infancy stage.

Thermal Stores

Large scale heat or thermal storage in steel tanks for daily balancing of heat networks or underground reservoirs for inter-seasonal storage has been demonstrated in Denmark. In Sweden and Netherlands there are examples of underground thermal energy stores, such as aquifer thermal energy storage (ATES) and borehole thermal energy storage (BTES), that store low grade heating and cooling and provide inter-seasonal storage. These thermal stores provide capacity to store heat and can be used alongside other technologies including heat pumps and may help to optimise the utilisation of renewable electricity in the system. A recent development in thermal storage is phase change material, which allows a higher density storage of heat with minimal temperature loss. The UK Parliamentary Office of Science and Technology issued a helpful briefing note about energy storage[24] in April 2015.

24. Research briefing, Energy Storage, 2015

Energy Distribution and Management

Generating electricity in a more decentralised manner will reduce the costs of the major infrastructure associated with transmission whilst ensuring greater local resilience and reducing energy lost through transmission.

The energy system has to be capable of delivering energy to consumers when and where it is needed. Demand varies significantly over fairly predictable daily and seasonal cycles, but supply from renewables is intermittent and not always predictable. A conversion to smart network technology and innovation in energy pricing may allow the capacity of the network to be utilised better through demand side management of the system. National Grid already balances the network by turning on and off energy generation but if they could do the same with appliances on the demand side then this could release capacity in the system. However, renewable technologies are generally intermittent, meaning it's unlikely that the UK can generate the exact amount of electricity that is required, and the grid cannot turn them on whenever they want. This means in the future there will be a requirement for a lot more electrical storage to match supply and demand on a local level, as well as some continued use of back-up electricity plants that can be switched on whenever they are required. Additionally, electrification of heat and transport will cause increased demand on the power grid, meaning the capacity of the grid must be considered during energy masterplanning. An example to consider is the type of EV charger that is installed, as fast chargers put more pressure on the grid than standard ones but are generally preferred by consumers.

APPENDIX B: Websites and tools

Useful Websites:

- Scottish Enterprise
- Heat Network Partnership for Scotland
- Scotland Heat Map
- Association for Decentralised Energy
- Carbonbuzz
- London Heat Map
- District heating installation map of the UK

Reports:

- Scottish House Conditions Survey 2019
- Local Area Energy Planning – the Method, Energy Systems Catapult, 2020
- Heat and Energy Efficiency Zoning: A framework for net zero for new and existing buildings, Association of Decentralised Energy, 2020
- TCPA Practical Guides - Guide 4: Masterplanning for net-zero energy, Town and Country Planning Association, 2020
- Example energy masterplans for London Boroughs
- US National Renewables Energy Lab Guide to Energy Masterplanning of Higher Performance Districts and Communities

Policy:

- Climate Change (Emissions Reduction Targets) (Scotland) Act 2019
- Securing a green recovery on a path to net zero: climate change plan 2018–2032 – update, Scottish Government, 2020
- Draft Heat in Buildings Strategy - achieving net zero emissions: consultation, Scottish Government, 2020
- New Build Heat Standard: scoping consultation, Scottish Government, 2020
- Heat Networks (Scotland) Bill, 2021

APPENDIX C: Glossary of commonly used terms

Advanced thermal treatment plant
Disposal of waste and generation of electricity using thermal treatment technologies.

Anchor Loads
Large buildings with relatively consistent heat demand such as leisure centres, hospitals or hotels that can act as a signficant heat offtaker and 'anchor' heat networks.

ASHP - Air Source Heat Pump

ATES - Aquifer Thermal Energy Storage

Biofuel
Organic material in either solid, liquid or gas state that is used in a combustion or thermal process to generate energy or synthesis fuels

BTES - Borehole Thermal Energy Storage

Building Regulations
Regulations that ensure building work is carried out in line with defined minimum standards

CCGT - Combined Cycle Gas Turbine

CCHP - Combined Cooling Heating and Power

CHP - Combined Heat and Power

CoP - Coefficient of Performance

Decentralised Energy Systems
Decentralised Energy (DE) is defined by the GLA as "energy which is produced close to where it's used." This means local generation of electricity and where appropriate, the recovery of surplus heat from this generation or other industrial uses for purposes such as building space heating and domestic hot water production. Heat is commonly distributed in District Heating systems, with the heat generated being pumped into homes, usually as hot water, through networks of reinforced pipes. Combining these solutions with heat storage allows the potential for balancing of the heat and power networks.

DEPDU
Decentralised energy programme delivery unit

District Cooling
A system of distributing cooling to residential and commercial properties through a network of pipes by pumping the energy in a carrier fluid (normally a water/glycol mix)

District Heating
A system of distributing heat to residential and commercial properties through a network of pipes by pumping the energy in a carrier fluid (normally a water or a water/glycol mix)

EfW - Energy from Waste

Energy centre
Building that houses heating plant for a district energy scheme

Energy storage
Storage systems that may be capable of retaining energy for short or long periods of time. These systems include fuel storage, multiple forms of thermal and electricity storage some of which are proven but more are being developed

ESCo - Energy Service Company

EV - Electric Vehicle

GIS - Geographic Information System

GSHP - Ground Source Heat Pump

GW - Gigawatt (electrical)

Heat Pump
A low temperature heat source can be converted to a higher temperature source by essestially using the refrigeration cycle in reverse.

HNP - Heat Network Partnership

IRR - Internal Rate of Return

kW - Kilowatts

KPI - Key Performance Indicator

MW - Megawatts (electrical)

MWh - Megawatt hour

Netting Off
Commercial agreement between the generator and their electricity supplier where the generator is both buying and selling electricity - the cost of any electricity bought from the supplier is considered to be the net of the value of electricity imported and exported by the generator. (A higher value for electricity sold, may be acheived in this way)

NOx - Nitrous Oxides

NPV - Net Present Value

OCGT - Open Cycle Gas Turbine

Private Wire
Electricity from a CHP is not exported to the grid but provided to customers directly from the network operator

PV
Photovoltaic – panels that convert solar radiation into electricity

RRR - Riverside Resource Recovery

Smart energy systems
A smart energy system integrates hardware and system controls across the network. They require the investment in upgraded network infrastructure, domestic and non-domestic appliances as well as the control systems to allow smart management of the grid. Smart management includes the ability to optimise the use of storage and to implement demand management.

SOx - Sulphur Oxides

Syngas
Fuel gas mixture consisting primarily of hydrogen, methane, carbon monoxide, and very often some carbon dioxide produced from the thermochemical conversion of biomass.

WSHP - Water Source Heat Pump

WWTW - Wastewater Treatment Works

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