AECOM

Renewables Areas for LCC Local Plan Update

Report

Leeds City Council

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Delivering a better world

Quality information

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Revision History

Revision	Revision date	Details	Authorized	Name	Position
0	18/05/22	Partial draft issue for client comment	EJ	Ewan Jones	Associate Director
1	27/07/22	Full Issue	EJ	Ewan Jones	Associate Director
2	24/08/22	Revision to brownfield areas	EJ	Ewan Jones	Associate Director
3	08/09/22	Revision to bird habitat buffer in NW	EJ	Ewan Jones	Associate Director

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We would be grateful to be informed of all requests by third parties for information contained in this document.

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1. Introduction

Leeds City Council appointed AECOM to deliver a study to identify suitable areas and criteria for renewable and low carbon energy sources and supporting infrastructure for the Leeds District. The study will be used to inform the Local Plan Update (LPU) so that renewable energy opportunity areas can be shown on the Policies Map and thereby help secure the development of renewable energy generation facilities in Leeds. The appointment also includes some high-level analysis of the potential renewable capacity of the LCC area and how this may contribute towards LCC and national carbon targets.

LCC has set out the following elements of work to be delivered, these are addressed in the following sections:

- **Requirement 1:** Detailed mapping illustrating opportunity areas for large scale solar photovoltaic installations should be identified.
- **Requirement 2:** Detailed mapping illustrating opportunity areas for onshore wind turbine installations should be identified.
- **Requirement 3:** Consideration of the potential for other renewable energy generation (e.g. anaerobic digestion, hydro (maps to be provided by LCC), waste, biomass, hydrogen etc.) should also be considered as justification for potential criteria based policy.
- **Requirement 4:** To advise on how much energy storage may be needed in Leeds. From both a strategic capacity perspective (i.e. grid demands and potential for different connection methods and different renewable technologies arising from installed capacity) and a local demand. Opportunity mapping for significant areas i.e. where grid connection is strategically important. This may include guidance on electricity storage, current technologies and business models.
- **Requirement 5:** Identify for the strategic potential the preferred site characteristic and importance of grid connection proximity and capacity.
- **Requirement 6:** Quantitative figure for technical potential for each energy type.

2. Planning Policy Context

This section of the report sets out a summary of the key plans, policies and legislation that has relevance in terms of climate change and low carbon energy. This summary is not exhaustive but focuses on the influential factors and important drivers in a local plan-making context.

2.1 International Agreements

2.1.1 Paris Agreement 2015

The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 parties at COP 21 in Paris, on 12th December 2015 and entered in to force on 4th November 2016. Its goal is to limit global warming to below 2.0°C, and pursuing efforts to limit to 1.5°C, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate neutral world by mid-century.

As part of the 2015 Paris Agreement cities have been called upon to increase their efforts for both mitigation and adaptation actions, reducing emissions and building resilience. Local Plans should plan strongly and positively to demonstrate deliverable strategies to tackle climate change, and the need to refuse applications which do not comply with local and national policy. Local Plans should also ensure that the strategies are implemented through robust monitoring.

2.1.2 COP26

The UK hosted the 26th United Nations Climate Change Conference of the Parties (COP26) in Glasgow between 31st October and 13th November 2021. The aim of COP26 was to bring together parties to accelerate action towards the goals of the Paris Agreement and the UN Framework Convention on Climate Change. COP26 saw

200 countries agreeing to the Glasgow Climate Pact, designed to accelerate action on climate change. The Pact is designed to drive action across the globe on:

- Mitigation – reducing emissions
- Adaptation – helping those already impacted by climate change
- Finance – enabling countries to deliver on their climate goals
- Collaboration – working together to deliver even greater action

During the production and review of Local Plans, Local Planning Authorities should incorporate mitigation, adaptation, finance, and collaboration into policy making and the site selection process to ensure that the most climate effective decisions are made for the district.

2.2 Key UK Legislation

2.2.1 Environment Bill

The Environment Bill was first introduced in the House of Commons in the 2019-2020 parliamentary session. The legislation completed its passage through parliament on 13th October 2021 and received Royal Assent on 9th November 2021, forming the Environment Act 2021.

Following the UK's exit from the European Union, the Environment Act operates as the UK's new framework on environmental protection. The Act outlines new laws that relate to nature protection, water quality and clean air, as well as additional environmental protections which had previously come from Brussels. The Act outlines the requirement for a long-term target in relation to air quality, water, biodiversity and resource efficiency and waste reduction. Local Plans should, therefore, outline how the Local Planning Authority can aid the government in achieving these targets and the aims set out in Environmental Improvement Plans and Policy Statements.

2.2.2 Climate Change Act 2008

The Climate Change Act 2008 is a legally binding target, stating that "*it is the duty of the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least 100% lower than the 1990 baseline*". The target originally stood at a decrease of 80% against the 1990 baseline. However, this was then amended to change the target to a decrease of at least 100%, permittable by section 2.1 of the Act. The 1990 baseline means the cumulative amount of net UK emissions of carbon dioxide for that year, and net UK emissions of each of the other targeted greenhouse gases for the year that is the base year for that gas. This is monitored annually in a report published by the Secretary of State.

Local authorities have a responsibility to help to secure progress on meeting the UK's emissions reduction targets. Local Plans should contain policies which contribute to the mitigation of, and adaptation to, climate change, in line with the Climate Change Act. For example, by encouraging, facilitating, or requiring renewable energy and low-carbon modes of travel.

2.2.3 Planning & Compulsory Purchase Act

The Planning and Compulsory Purchase Act received Royal Assent in May 2004 and reformed the existing Town Planning and Compulsory Purchase Framework in the United Kingdom. As part of the reform, the Act imposed on those with plan-making functions an objective of contributing to the achievement of sustainable development and enacted policies originally set out in 'Sustainable Communities – Delivering through Planning, July 2002'.

Crucially, section 19(1a) states that Local Plans should include "*policies designed to secure that the development and use of land in the local planning authority's area contribute to the mitigation of, and adaptation to, climate change".*

In addition, Section 33A states that LPAs and County Councils must engage constructively and actively through the Duty to Cooperate in relation to strategic matters such as sustainable development. Finally, Section 39 states that all planning bodies must exercise their function with the objective of contributing to sustainable development.
National Planning Policy Framework (2021).

The NPPF (2021) outlines how Plans must demonstrate that they are addressing climate change. Chapter 14 addresses how planning policy can help mitigate, and adapt to, climate change, flooding, coastal change, water supply, biodiversity, landscapes, and the risk of overheating from rising temperatures. Paragraph 153 of the NPPF states that *"policies should support appropriate measures to ensure the future resilience of communities* *and infrastructure to climate change impacts, such as providing space for physical protection measures, or making provision for the possible future relocation of vulnerable development and infrastructure"*.

Further the NPPF states that new development should not be vulnerable to the impacts of climate change and can help to reduce greenhouse gas emissions through its design. New developments should provide a positive strategy for energy from renewable, low carbon and decentralised sources and identify areas for these sources, and the supporting infrastructure, within the development. In addition, LPAs should support community-led initiatives for renewable and low carbon energy, including development outside Local Plan and Neighbourhood Plan allocations and strategic policies.

In relation to flooding the NPPF states that Local Plans should direct development away from areas at highest risk of flooding. Where this is not possible, the development should be made safe during its lifetime without increasing flood risk elsewhere. Strategic policies set out in Local Plans should be informed by Strategic Flood Risk Assessments, consider cumulative impacts and advice from the Environment Agency, other relevant flood risk management authorities, and lead local flood authorities.

Plans should apply a sequential, risk-based approach to the allocation of development to avoid areas at risk of flooding from any source, the current and future impacts of climate change and areas which may be required for flood management. Plans should not allocate development if there is a reasonable alternative in an area with a lower risk of flooding. When not possible, an exception test must be applied and all sections must be satisfied for the plan to be able to allocate the development site.

Plans should seek to relocate existing development at risk of flood in the long term and new development should provide improvements in green infrastructure and other infrastructure necessary, preferably natural, to reduce the causes and impacts of flooding.

2.3 Leeds City Council Policies

2.3.1 Adopted Local Plan

The adopted Local Plan sets out the Council's vision and strategy for the area until 2033 and provides the basis for decisions on planning applications. The key documents which make up the Local Plan are:

- Core Strategy
- Natural Resources and Waste Local Plan
- Site Allocations Plan
- Aire Valley Leeds Area Action Plan

2.3.1.1 Adopted Core Strategy

The Core Strategy reflects principles of climate change mitigation and adaptation by seeking to locate development in sustainable locations. However, the focus of the Plan review is not on strategic matters relating to growth locations, housing, and employment targets. The key policies relating to climate change that can be influenced by the review are set out in the issues and options document. Those of most relevance to this renewables study are listed below[1]. There may also be scope to introduce new policies, which will be discussed in the following chapters.

- G1 – Enhancing and Extending Green Infrastructure
- EN1 – Climate change – Carbon dioxide reduction
- EN3 – Low Carbon Energy
- EN4 – District Heating
- EN6 – Strategic waste management
- EN8 – Electric vehicle charging infrastructure

[1] *Acknowledging that the Council has commissioned several other studies to deal with specific issues such as viability and carbon reduction targets.*

2.3.1.2 Adopted Natural Resources & Waste Local Plan

Adopted in January 2013, the Leeds Natural Resources and Waste Local Plan sets out the Council's policies on the future use of Natural Resources and Waste up to 2026. This document sets out policies which have an effect on minerals, waste, energy, water, or air and sets out how the planning system can help to achieve a more efficient use of natural resources. The Natural Resources and Waste Local Plan sets out the vision and strategic objectives of:

- An efficient use of natural resources
- A zero-waste high recycling society
- A low carbon economy

The key policies relating to climate change most relevant in the context of this renewables study are listed below:

- Energy 1 – Large Scale Wind Energy Generation
- Energy 2 – Micro-Generation Development
- Energy 3 – Heat and Power Energy Recovery
- Energy 4 – Heat Distribution Infrastructure

2.4 Structure of this Document

Under each form of renewable energy discussed in this report, AECOM has outlined the current policy position in the adopted Local Plan and provided recommendations for changes in light of the evidence gathered.

3. Requirement 1 & 2: Solar & Wind Maps

AECOM has produced maps of the opportunity areas that are potentially suitable for wind turbines and ground-mounted solar farms within the LCC boundary. These maps take account of multiple factors and constraints including those listed below.

1. Flood risk,
2. Proximity to housing,
3. Best and most versatile agricultural land, including impacts on farms and agricultural tenancies,
4. Registered parks and gardens,
5. Landscape character[2],
6. Highway, public rights of way & trainline impacts,
7. Archaeology, scheduled monuments, and registered battlefields,
8. Listed buildings and heritage impacts,
9. Green infrastructure, and areas of bird sensitivity particularly at Fairburn and Mickletown Ings,
10. Tree preservation orders and ancient woodland,
11. Proximity of sensitive receptors to noise and vibration,
12. Future developments – Leeds City Council's allocation plans,
13. HS2 safeguarding areas,
14. Airport and airbase operational areas.

To produce the maps, digital GIS mapping layers from the list were collated and filtered, then GIS software was used to overlay the constraints to show the areas unlikely to be suitable for either wind or solar farms (due to one or more factors). The remaining areas within the LCC boundary were deemed to be opportunity areas potentially suitable for either wind or solar farms. Full details of the mapping methodology is provided in Appendix A.

[2] We note that the Leeds Landscape character assessment is now 28 years old and so does not reflect changes to landscape that have occurred since this assessment. To mitigate this challenge, AECOM drew on inhouse landscape architecture team with local knowledge supplemented with satellite and publicly available imagery.

Government guidance identifies a preference for renewable energy development to be located on appropriate brownfield land rather than on greenfield sites and, wherever possible, as a starting point, avoid locations in the greenbelt and on Grade 1, 2 and 3a agricultural land. In light of this guidance, three maps have been produced for wind farms and three maps for ground-mounted solar farms. These maps show three scenarios:

1. **Scenario 1:** Opportunity areas on brownfield land only,
2. **Scenario 2:** Opportunity areas on all land excluding greenbelt,
3. **Scenario 3:** Opportunity areas on all land (including greenbelt).

By measuring the size of the potential opportunity areas, the potential maximum capacities for wind and solar were calculated (see Table 1 and Section 7.1). Section 5 assesses this potential output against the calculated electricity use in the LCC area and then assesses the potential role that electrical energy storage could play in balancing supply and demand.

Figure 1 to Figure 3 show the mapped opportunity areas for wind turbines in the LCC boundary. Figure 4 to Figure 6 show the mapped opportunity areas for ground-mounted solar farms. High resolution versions of these maps are provided separately along with the GIS files. The variation in the wind and solar maps is largely due to the spatial requirements of each technology. Larger buffer distances are needed for wind to allow for potential 'topple distances'. The distances used here are based on relatively small commercial wind turbines (75m tall). While larger turbines may be more constrained than these maps suggest, this approach makes the maps useful for all sizes by not excluding land that may still be an opportunity area for smaller wind turbines. The other large difference between the maps is due to the large buffer distance for wind turbines surrounding Leeds Bradford Airport[3]. A full breakdown of layers used in the mapping is provided in Appendix A, including buffer distances of exclusions in the map.

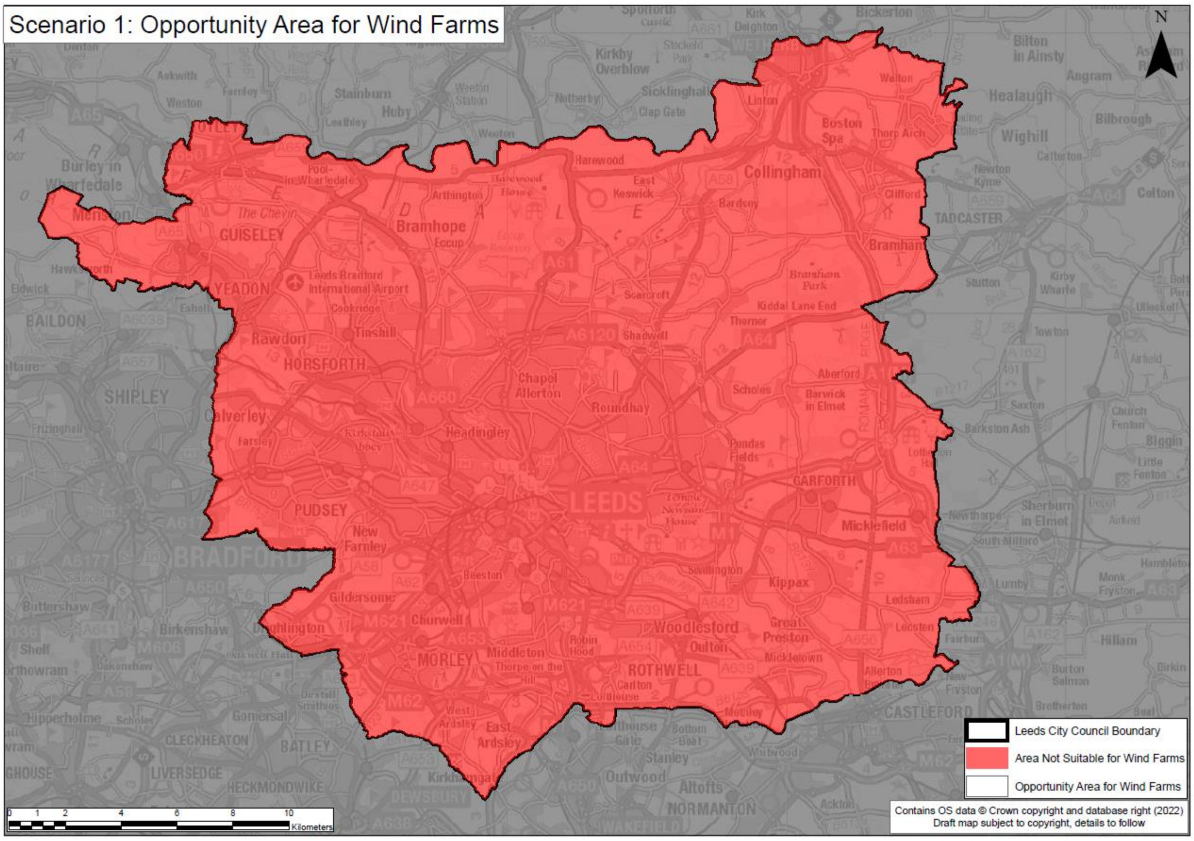

Figure 1: Opportunity Areas for Wind Turbines – Scenario 1: areas on brownfield land only

[3] Wind turbines can interfere with radar equipment such as that used at airports. The wind turbine opportunity map includes a 5km exclusion zone has been mapped around the Leeds Bradford Airport as a means of mitigating this issue (although other mitigation options are available).

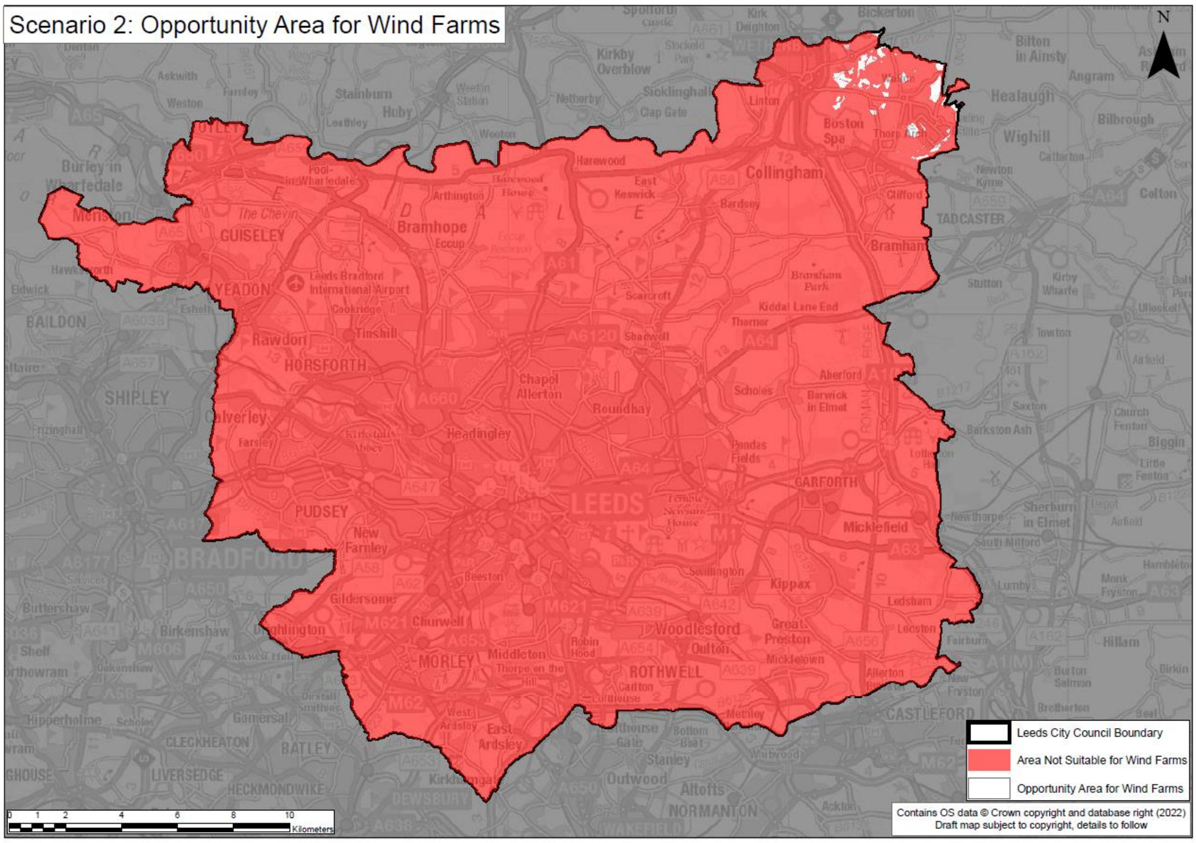

Figure 2: Opportunity Areas for Wind Turbines – Scenario 2: areas on all land excluding greenbelt

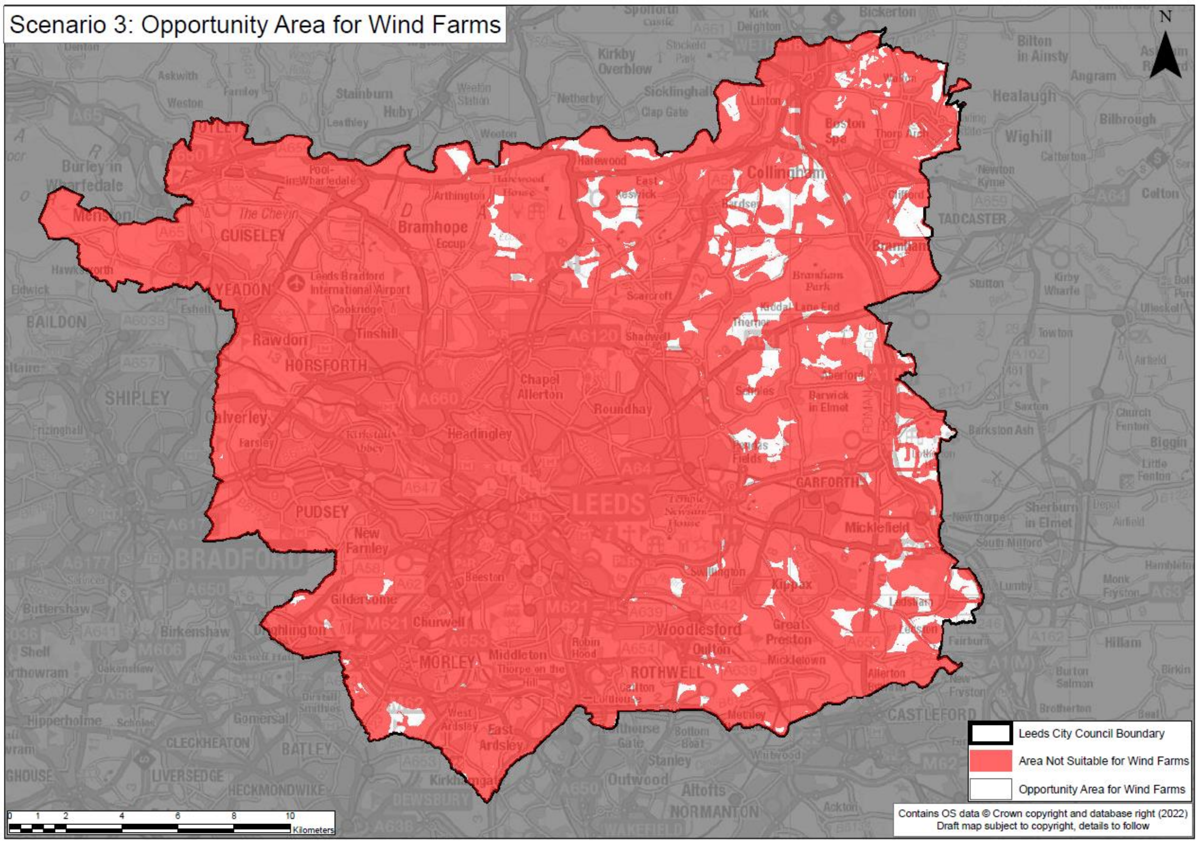

Figure 3: Opportunity Areas for Wind Turbines - Scenario 3: areas on all land (including greenbelt)

The above three maps (Figure 1 to Figure 3) show the three scenarios for wind turbine opportunity areas.

Scenario 1 (brownfield only, Figure 1) shows that there are no brownfield areas which would be suitable for wind turbines

Scenario 2 (excluding greenbelt, Figure 2) has opportunity areas totalling 168ha. these areas are mostly in the northeast of the LCC area (near Wetherby).

Scenario 3 (including greenbelt, Figure 3) shows larger areas of opportunity to the north and east of Leeds main urban area, (which is largely greenbelt land), a total of 3,030ha.

All three wind opportunity maps exclude areas in the northwest of the LCC area. Many constraints are present here, most notably Leeds Bradford Airport.

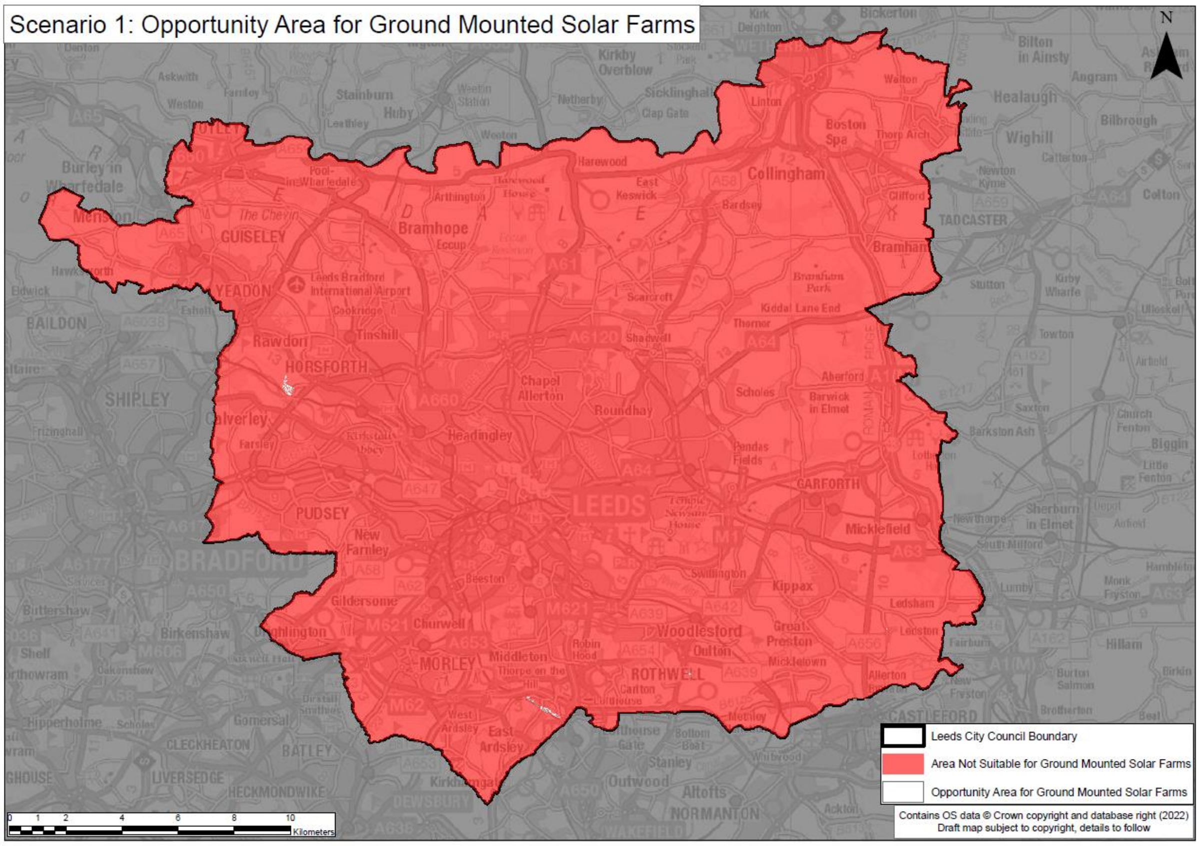

Figure 4: Opportunity Areas for Ground Mounted Solar farms - Scenario 1: areas on brownfield land only

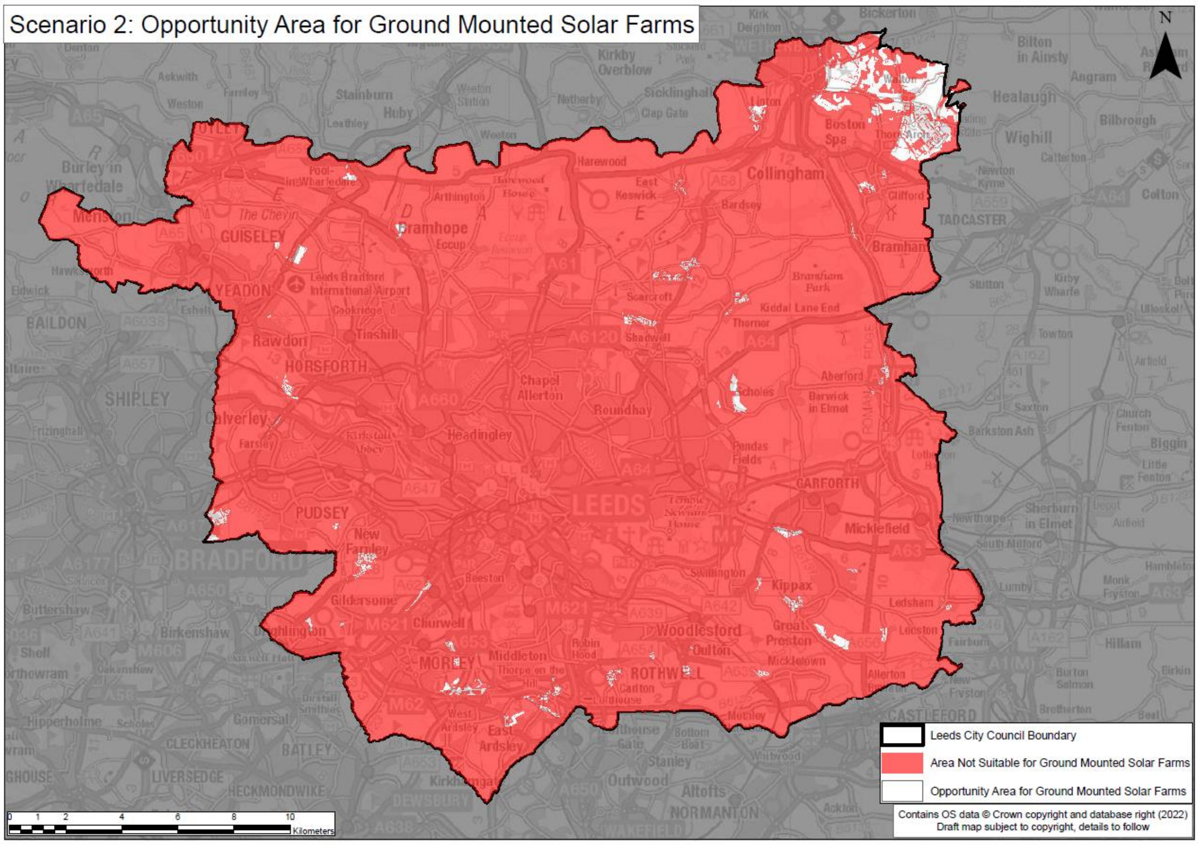

Figure 5: Opportunity Areas for Ground Mounted Solar farms - Scenario 2: areas on all land excluding greenbelt

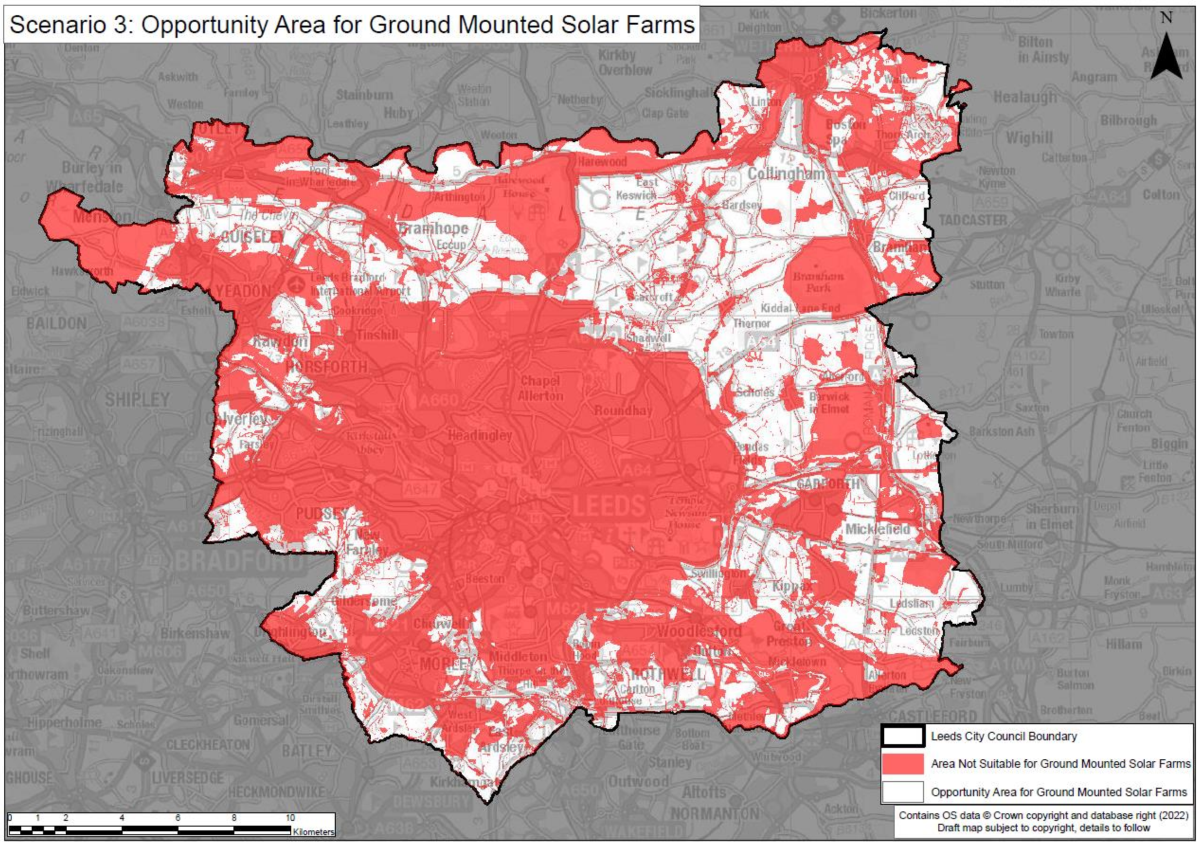

Figure 6: Opportunity Areas for Ground Mounted Solar farms - Scenario 3: areas on all land (including greenbelt)

The above three maps (Figure 4 to Figure 6) show the three scenarios for ground mounted solar farm opportunity areas.

These solar farm opportunity area maps show a greater total opportunity area than the equivalent maps for wind. This larger potential is mostly due to the buffer distances surrounding railways and roads being smaller for solar than wind.

Scenario 1 (brownfield only, Figure 4) shows that the opportunity areas are small and in the west and south of Leeds; the potential area totals 6ha.

Scenario 2 (excluding greenbelt, Figure 5) shows large areas of opportunity to the northeast (near Wetherby). There are also some areas surrounding the main urban areas area with the greatest concentration in the northeast near Wetherby. The total opportunity area shown in Figure 5 is 1,140ha.

Scenario 3 (including greenbelt, Figure 6) shows large areas of opportunity surrounding the main urban area, with a total of 19,637ha. The largest areas of opportunity are northeast of Shadwell and up to Boston Spa.

Scenario	Explanation	Wind		Solar	
		ha	% of LCC area	ha	% of LCC area
1	Potential on brownfield land	0	0.0%	6	0.01%
2	Potential on all land excluding greenbelt	168	0.3%	1140	2.1%
3	Potential on all land (including greenbelt)	3,030	5.5%	19,391	35.1%

Table 1: Wind and Solar opportunity areas in Leeds

3.1 Wind & Solar: Implications/ Input for the Local Plan Review

Current Policy Position

Policy EN3 of the Core Strategy sets out broad support for low carbon energy generation, particularly large-scale schemes (>0.5MW).

Wind: Though the core strategy includes a map of wind speeds, it does not explicitly identify wind opportunity areas in policy terms. Para 032 of the NPPG makes it clear that this is not sufficient to support a wind energy opportunity policy.

In the Natural Resources and Waste Local Plan, *Policy Energy1:Large Scale Wind Energy Generation* provides criteria for determining acceptability that remain valid.

Solar: The current development plan does not explicitly identify locations that may be suitable for large scale solar schemes. There are also limited policy details relating to scheme acceptability.

Potential Changes

The outputs of this study identify locations that could be designated as wind opportunity areas in the Plan Review. It is recommended that these locations are mapped and supported through the Plan review; thus allowing for greater take-up of commercial wind schemes. Para 154 of the NPPF and Para 005 of the NPPG encourage this action.

The study identifies preferable locations in terms of ground mounted solar farms. As a minimum, it is recommended the plan includes a policy to support appropriate development in these locations (a choice may need to be made with regards to the extent to which opportunity areas ought to include Green Belt and best and most versatile agricultural land).

Where opportunities for wind and solar schemes are most preferable / strong, it may be an option to safeguard land for such uses (further encouraging development and ensuring opportunities are not sterilised).

Introduce policy criteria to address acceptability factors for ground mounted solar schemes.

4. Requirement 3: Criteria for Other Renewables

AECOM has developed a set of criteria which influence the suitability of a location to the development of the following renewable/low-carbon energy technologies:

- Anaerobic digestion,
- Energy from waste,
- Biomass,
- Hydro-electric,
- Hydrogen production.

To develop these criteria, AECOM has drawn on input from a range of in-house AECOM expertise in the areas listed in Section 2 as well as other criteria which our research suggests should be considered.

4.1 Anaerobic Digestion & Energy from Waste

Anaerobic Digestion (AD) and Energy from Waste (EfW) plants can be considered to be similar in some ways; the principal similarity is that they are both industrial processes that process waste and produce energy. These processes have a role to play in the wider energy system, however their use should not disincentivise more sustainable alternatives (prevention of waste production, re-use of items/materials and recycling). Figure 7 shows the waste hierarchy as set out in the National planning policy for waste[4]. AD and EfW both fall under “other recovery”[5] which is preferable to “disposal”; disposal includes landfill and incineration where no useful energy is captured or used[6].

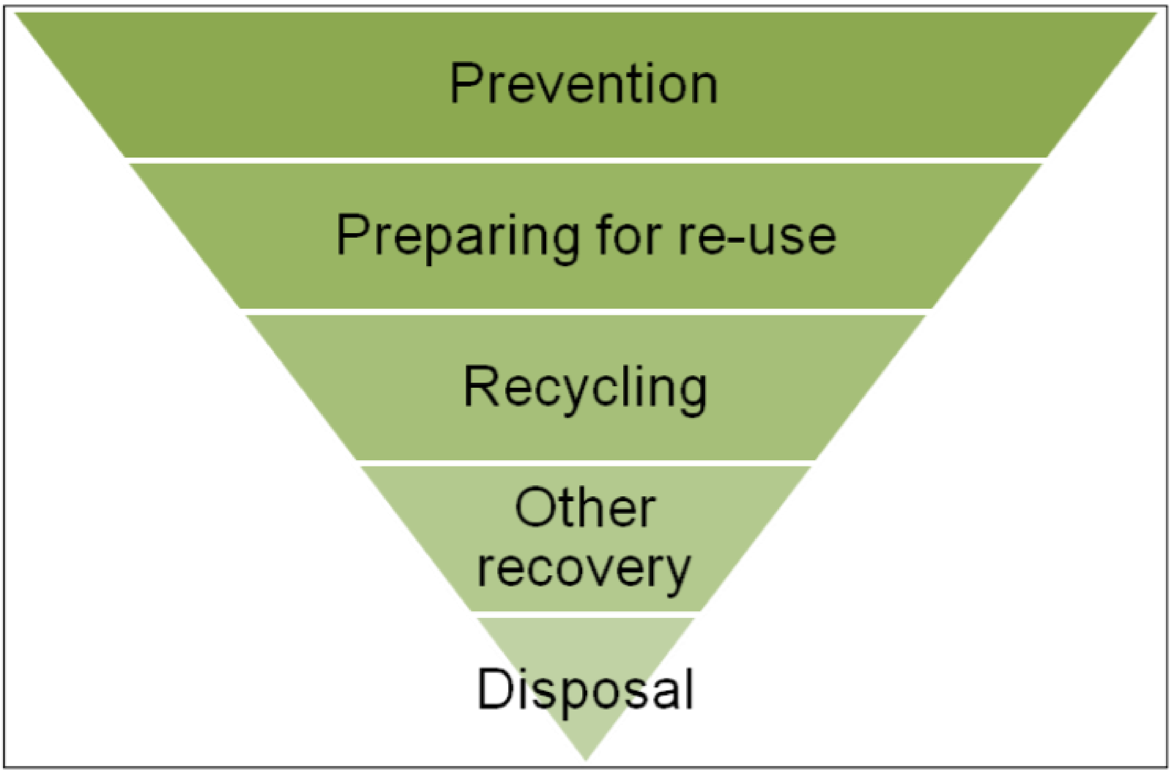

Figure 7: Waste hierarchy as set out in the National planning policy for waste.

[4] https://www.gov.uk/government/publications/national-planning-policy-for-waste/national-planning-policy-for-waste
[5] https://www.legislation.gov.uk/eudr/2008/98/annex/II
[6] https://www.legislation.gov.uk/eudr/2008/98/annex/I

4.1.1 Anaerobic Digestion

Anaerobic Digestion plants use bacteria to decay organic waste materials (food, garden, agricultural waste and sewage etc.) producing biogas (principally methane). The biogas is captured, normally processed, and then can be used as an energy source in one or more of the following ways:

- Injected into the gas grid to then be used elsewhere;
- Combusted to produce heat only (biogas boilers);
- Combusted to produce heat and generate electricity (biogas CHP or AD-CHP).

The bacteria digesting the feedstock are most active at a temperature of around 30-40°C[7]; to maintain this temperature most plants will use some of the biogas as a fuel source. This use of heat may account for approximately 30-50% of the heat available from a typical plant. The remaining heat, gas and/or electricity can be exported from the process as outlined above.

After the biogas has been collected, the residual solid/liquid produce (digestate) can generally be used as a soil improver so long as it meets the appropriate quality standards.

Air pollution from AD plants includes the products of combustion (which are broadly analogous to those associated with natural gas combustion, primarily CO_2 and NOx), and odours produced by the digestion process. Odours should be controlled to reduce impacts on the surrounding area.

4.1.2 Energy from Waste

The term “Energy from Waste” covers any process which converts waste into a form of energy. AD plants are therefore a subset of EfW. Practically speaking most other EfW plants are based on a combustion/incineration process however other EfW processes such as pyrolysis, gasification etc. are possible. The remainder of this document takes EfW to mean specifically combustion/incineration-based EfW, however some of the discussion and criteria may apply to other types of EfW plant.

Combustion-based EfW plants can accept a wider variety of feedstocks than AD plants. AD facilities can only accept organic wastes, whereas other EfW facilities can accept mixed and residual waste streams containing a wide range of materials which may include, for example, plastic, paper and other materials that have not been separated for recycling. Some of the materials which are routinely combusted in EfW plants are potentially recyclable. Following the waste hierarchy (see Figure 7) the more sustainable treatment for these materials would be recycling. However, not all potentially recyclable materials can be separated and recycled, for either technical, practical, or economic reasons, and where this is the case then energy recovery at an EfW plant is preferrable to landfill disposal.

The process of incineration of waste creates emissions which are released into the atmosphere. As such, regulation of waste incineration is controlled by legislation. In England, permitting requirements are implemented by the Environmental Permitting (England and Wales Regulations) 2016, as amended. An environmental permit will set conditions which limit the discharge to air, water and soil of specified substances. Planning permission must also be granted for construction of new EfW facilities – those of output less than 50MW require local planning approval under the Town and Country Planning Act while facilities of output greater than 50MW require a Development Consent Order granted by the Secretary of State.

UK legislation also provides for a “waste hierarchy” as set out in Figure 7; this gives priority to preventing waste. When waste is created, the hierarchy gives priority to preparing it for re-use, then recycling, then recovery (including incineration where energy is captured for use as heat and/or electricity), and lastly disposal (e.g. landfill and incineration where there is no energy recovery).

In its December 2018 Resources and Waste Strategy the then UK Government said that “*Incineration currently plays a significant role in waste management in the UK, and the Government expects this to continue.*” The strategy also indicated that the Government may consider a tax on incineration, should other policies to incentivise recycling not deliver the required results.

EfWs can be a controversial form of waste management. Proposals for new EfW facilities often face strong public opposition if plants are sited in the wrong locations. Some environmental groups oppose the principle of EfW including specific campaign groups such as UKWIN (UK Without Incineration Network). UKWIN argues that,

[7] The exact temperature depends on the specific process.

among other things, EfW is a barrier to a circular economy – preventing resources from being reused, depresses recycling, is a nuisance and gives rise to air pollution concerns[8].

Emissions from EfW plants are typically highly abated but will still contain a variety of pollutants including fine particulates, CO_2 and NOx. Odours associated with the collation and processing of waste prior to incineration should also be controlled. In 2010, the Health Protection Agency published a report on the impact on health of emissions to air from municipal waste incinerators[9]. This states that:

> *"The Health Protection Agency has reviewed research undertaken to examine the suggested links between emissions from municipal waste incinerators and effects on health. While it is not possible to rule out adverse health effects from modern, well-regulated municipal waste incinerators with complete certainty, any potential damage to the health of those living close-by is likely to be very small, if detectable. This view is based on detailed assessments of the effects of air pollutants on health and on the fact that modern and well managed municipal waste incinerators make only a very small contribution to local concentrations of air pollutants. The Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment has reviewed recent data and has concluded that there is no need to change its previous advice, namely that any potential risk of cancer due to residency near to municipal waste incinerators is exceedingly low and probably not measurable by the most modern techniques. Since any possible health effects are likely to be very small, if detectable, studies of public health around modern, well managed municipal waste incinerators are not recommended."*

4.1.3 Anaerobic Digestion & Energy from Waste Criteria

The National Planning Policy for Waste[10] sets out a number of criteria and issues that should be considered in relation to EfW and AD plants. The National Policy Statement for Renewable Energy Infrastructure (EN-3)[11] sets out criteria that apply to energy from biomass and/or waste over 50MW[12]. The criteria set out below do not seek to duplicate these but suggest areas where they may be built upon.

- AD/EfW plants should not be located in flood zone 3 unless the Sequential and Exceptions tests can be fulfilled and mitigation measures are shown to fully mitigate flood risks to the plant itself and do not increase the risk of flooding or other associated risks to other developments, infrastructure, natural habitats or farmland.

The waste stream should be demonstrable through a Needs assessment and unlikely to be disrupted or substantially reduced by factors such as increased recycling rates, competition from other AD or EfW plants and/or changes to the production of waste such as might be caused by changes to waste collection regimes. Or, where such reductions or disruptions are expected, these should be suitably mitigated, for example, by identifying alternative sources of waste that could fill any shortfalls. A suitable and reliable mix of waste streams will be required for the operational life of the AD/EfW plant although in planning terms there is an element that some of this becomes a commercial risk for the operator. Whilst it may be challenging to guarantee the supply of waste from a specific source for the whole of this period, appropriate projections should be made to avoid the risk of the AD/EfW plant becoming a stranded asset and to minimise the need for movement of waste over long distances.

It must be shown that the proposed AD/EfW plant will operate in compliance with the waste hierarchy as shown in Figure 7 and described in further detail in the National planning policy for waste[13]. Furthermore, it should be demonstrated that the proposed plant should not negatively impact nor disincentivise any of the following:

- Any actions to reduce the generation of waste;
- The re-use of waste materials;
- Recycling of waste materials.

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[8] https://commonslibrary.parliament.uk/research-briefings/cdp-2020-0014/
[9] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/335090/RCE-13_for_web_with_security.pdf
[10] https://www.gov.uk/government/publications/national-planning-policy-for-waste/national-planning-policy-for-waste
[11] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47856/1940-nps-renewable-energy-en3.pdf
[12] Many AD and EfW plants fall below the 50MW threshold.
[13] https://www.gov.uk/government/publications/national-planning-policy-for-waste/national-planning-policy-for-waste

The proposed plant should not undermine the supply of waste to other pre-existing EfW plants except in cases where this is demonstrably helpful to the wider national waste strategy. This might occur where a pre-existing plant is reaching the end of its operational life and the proposed plant is intended to replace some or all of its role in the wider waste system.

- The negative impacts of the transport of feedstock to the AD/EfW plant should be suitably mitigated. Negative impacts could include:
  - Increased congestion on local roads causing a significant increase in local journey times for others.
  - Reduced local air quality especially where fossil-fuelled vehicles are used.
  - Increased noise from vehicle movements.
  - Where rail transport is proposed this is more desirable than road transport especially where waste is to be transported over longer distances.
- Air emissions from the proposed plant should be suitably mitigated such that there is minimal impact air quality. This includes odours and dust; products of combustion are required to meet standards under the environmental permitting regime. Any EfW will be required to demonstrate human health impacts are appropriately assessed and mitigated through risk assessment, including for trace species such as dioxins and furans.
- AD/EfW plants have the potential to produce both heat and electricity for use elsewhere. Electricity can be supplied into the national grid and heat can be supplied to other buildings through district heat networks. Proposed AD/EfW plants should be designed and located to facilitate the export of both heat and electricity (this can be based upon either existing or new developments or a mixture of the two). Demonstration of meeting this requirement should take account of the efficiency of the operation of the plant when exporting heat and /or electricity and the potential need to reinforce the electricity network and/or extend existing district heat networks.
- Proposals for AD and/or EfW plants should demonstrate good design in respect of landscape and visual amenity.
- Proposed AD and/or EfW plants should not be located close to residential buildings. A minimum separation distance of 100m and 50m is expected for EfW and AD plant respectively. However greater distances may be required in some circumstances to mitigate issues such as visual impact and air quality etc.
- Proposals for AD and/or EfW plants should consider the plant’s resilience to drought, especially where river water is to be used for cooling. Where the project is likely to have effects on water quality or resources the applicant should undertake an assessment and demonstrate that appropriate measures will be put in place to avoid or minimise adverse impacts of abstraction and discharge of cooling water. Where applicable, the design of the cooling system should locate intakes and outfalls to avoid or minimise adverse impacts. There should be specific measures to minimise fish impingement and/or entrainment and the discharge of excessive heat to receiving waters.
- Proposals for AD and/or EfW plants should also be Carbon Capture Ready (CCR) and/or have Carbon Capture and Storage (CCS) technology applied.
- Proposals for AD and/or EfW plants located in greenbelt will generally be considered to be inappropriate development. Careful consideration must therefore be given to the visual impact of projects. Developers will need to demonstrate very special circumstances that clearly outweigh any harm by reason of inappropriateness and any other harm if projects are to proceed.
- Proposals for AD and/or EfW plants should include a noise assessment of the impacts on amenity. The primary mitigation for noise for AD and EfW generating stations is through good design to enclose plant and machinery in noise-reducing buildings, wherever possible, and to minimise the potential for operations to create noise. Noise from turbines should be mitigated by attenuation of exhausts to reduce any risk of low-frequency noise transmission.
- Proposals for AD and/or EfW plants should include an assessment and include mitigation of the risk of insect infestation with particular regard to the handling and storage of waste for fuel.

4.2 Biomass

Biomass is plant-based material used as fuel to produce heat and/or electricity. Biomass may be produced as a by-product of an industrial or agricultural process or grown and harvested specifically for use as a fuel. This section discusses some of the key considerations applicable to biomass for any use. Sections 4.2.1 and 7.2.3 focusses specifically on the use of biomass for electricity generation (i.e. biomass-fired power plants).

Biomass fuel can be used as a source of heat for buildings or industrial processes or as a fuel for electricity generation. Whilst biomass has been considered to be low carbon this view is often disputed in terms of life cycle emissions.

Burning biomass (wood, straw, grass etc.) releases carbon dioxide (CO_2). Biomass can be considered to be a renewable energy source on the basis that the CO_2 released during burning was relatively recently[14] absorbed by the plant whilst it was growing and may be reabsorbed if another plant is growing in its place. However, further CO_2 emissions are caused by the harvesting, processing and transportation of the biomass. In some cases, there may be emissions associated with the growth of the biomass crop if fertiliser, pesticide, or irrigation is used. These secondary emissions mean that, in many cases biomass is classed as low carbon rather than zero carbon.

However, assuming that the CO_2 absorbed by new plants negates that released through burning biomass, overlooks the critical need to reduce atmospheric CO_2 quickly. Most biomass is produced from wood which has taken several decades to grow. If a tree is cut down and burnt today and immediately replaced with a new sapling, it will take several decades before the CO_2 released will be reabsorbed. Figure 8 shows the UN IPCC carbon reduction pathways to limit global warming to 1.5°C; this shows that there is a need to rapidly reduce global CO_2 emissions by 2030 and to continue a slightly less rapid reduction to zero by mid-century. The use of woody biomass is not readily compatible with the most viable decarbonisation pathways because, whilst it may be carbon neutral in the long term it often has a short-term carbon footprint.

[14] The typical life of a tree varies depending on the species but can be between a few decades and several hundred years. This is a much shorter carbon cycle than that associated with fossil fuels which are produced from the remains of plants and animals that lived millions of years ago.

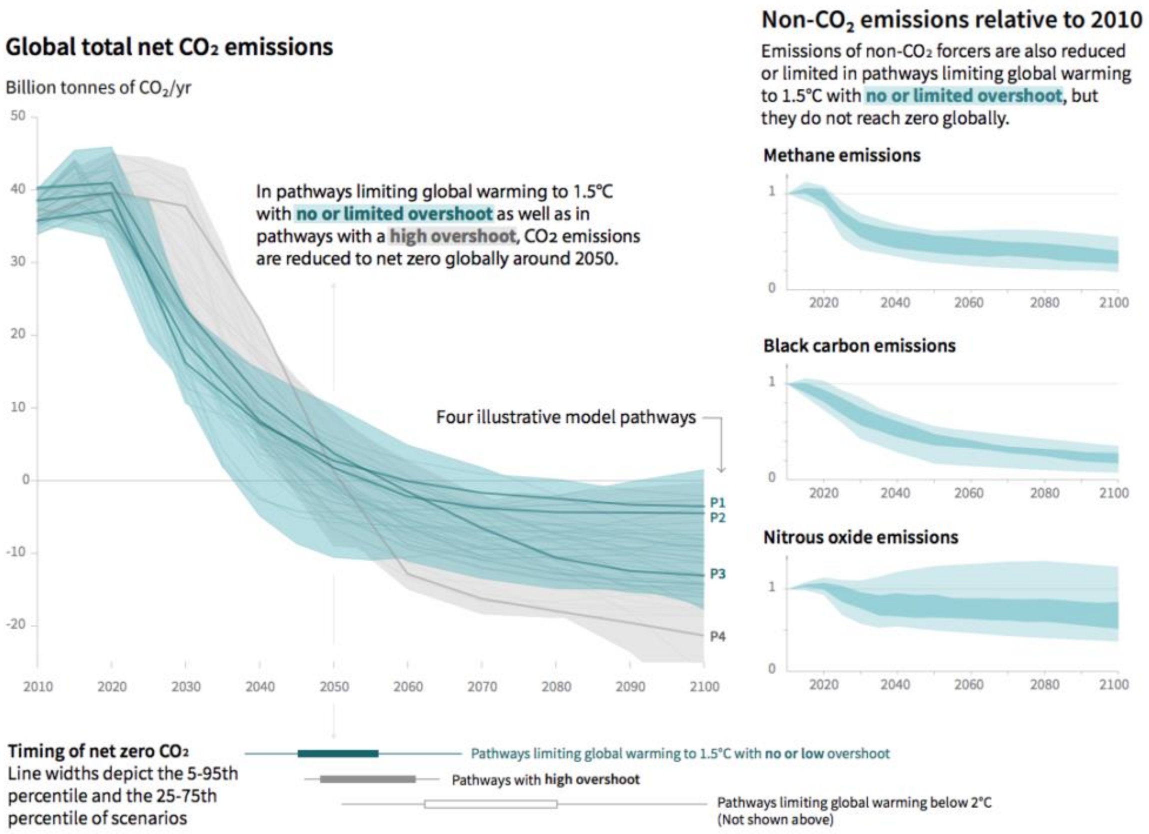

Figure 8: Illustration of the timings of net zero for CO_2 for meeting the 1.5°C limit under "no or limited overshoot" (blue) and "high overshoot" (grey) scenarios. Also shown are emissions reductions required for methane, black carbon and nitrous oxide (right). Credit: IPCC (pdf)[15]

The combustion of short rotation biomass crops (e.g. miscanthus) or biomass waste (e.g. straw) can avoid the problem of the short-term carbon footprint described above because the time taken for these plants to regrow and reabsorb the carbon emitted through their combustion is much shorter.

Biomass combustion releases other pollutants such as nitrous oxides and black carbon that negatively impact local air quality and further contribute to global warming. The smaller graphs to the right in Figure 8 show these pollutants also need to be reduced to limit climate change.

Biomass production has been criticised for displacing food production. This is applicable where biomass is grown as a crop on land which could otherwise be used to grow food crops. This approach is generally used for the shorter rotation crops such as willow or grass-based fuels.

4.2.1 Biomass Criteria

For the reasons outlined above we do not recommend that biomass production or use beyond small scale or locally sourced materials be actively encouraged by the LCC planning policies unless the feedstock is to be waste biomass. Waste biomass may be residual material from agricultural and forestry activities e.g. straw/brash. Waste wood from construction and demolition activities is classified as waste, hence a plant burning this would typically be classified as an EfW plant (see Section4.1). Where applications for biomass use are submitted, we recommend the following criteria be imposed:

- Taking account of the time it will take for CO_2 to be reabsorbed by replacement plants/trees, the proposed use of biomass should align with the need to reduce atmospheric CO_2 concentrations in the next decade in line with UN and UK targets. Where short rotation biomass crops are to be used, it should be demonstrated that the production of these will not displace food production. This analysis should account for the emissions across the complete biomass fuel supply chain, i.e. harvesting/supply – treatment/ drying/ chipping/pelletisation and energy conversion efficiency.

[15] https://www.carbonbrief.org/in-depth-qa-ipccs-special-report-on-climate-change-at-one-point-five-c

- The biomass fuel should be transported to the site using low carbon vehicles or the distance should be limited to no more than 30 miles.
- The impact of increased vehicle movements should be adequately considered and mitigated.
- The local air quality impacts of the biomass fuel combustion (and associated vehicle movements) should be mitigated.
- Proposals for biomass power plants should demonstrate good design in respect of landscape and visual amenity.
- Proposals for biomass power plants should consider the plant's resilience to drought, especially where river water is to be used for cooling. Where the project is likely to have effects on water quality or resources the applicant should undertake an assessment and demonstrate that appropriate measures will be put in place to avoid or minimise adverse impacts of abstraction and discharge of cooling water. Where applicable, the design of the cooling system should locate intakes and outfalls to avoid or minimise adverse impacts. There should be specific measures to minimise fish impingement and/or entrainment and the discharge of excessive heat to receiving waters.
- Proposals for biomass power plants should also be Carbon Capture Ready (CCR) and/or have Carbon Capture and Storage (CCS) technology applied.
- Proposals for biomass power plants located in greenbelt will generally be considered to be an inappropriate development. Careful consideration must therefore be given to the visual impact of projects. Developers will need to demonstrate very special circumstances that clearly outweigh any harm by reason of inappropriateness and any other harm if projects are to proceed.
- Proposals for biomass power plants should include a noise assessment of the impacts on amenity. The primary mitigation for noise for biomass power plants is through good design to enclose plant and machinery in noise-reducing buildings, wherever possible, and to minimise the potential for operations to create noise. Noise from turbines should be mitigated by attenuation of exhausts to reduce any risk of low-frequency noise transmission.
- Treatment of residues (primarily biomass ash) should be demonstrated to be compatible with local and national waste and environmental policies.

4.3 Hydro-electric

Hydropower remains the most established, widely used and long-lasting renewable resource for electricity generation globally. Opportunities depend on suitable topography and rainfall to provide sufficient water flow and pressure (head). Owners of small-scale sites (micro-hydro < 2,000 kW) can benefit from renewable electricity to off-set imported power from long-term capital assets. With routine maintenance, hydro installations can be long lasting (turbines 50 to 100 years, weirs and waterways up to 100 years). The long water turbine life is due to the turbine operating speed being fixed, usually being low (500rpm to 1,000rpm) and for the majority of time the load is steady. Other than the bearings, there is no thermal stress on the machine and wear due to sand and other foreign matter passing through the turbine is usually eliminated by screens, traps and de-sanding chambers.

Hydro turbines are of two types:

- Impulse turbines – where the flow in the supply pipeline (the penstock), is converted into one or more jets of water which are arranged to be guided onto the turbine runner as coherent jet(s) of water which travel through the air before impact. The runner turns the turbine shaft. Spear valves are used to convert the pressure energy in the penstock pipe into kinetic energy in the jet(s) of water.
- Reaction turbines – where the water is guided into the turbine casing by guide vanes in such a way that hydro-dynamic forces can act on the turbine runner to convert the pressure energy in the penstock into shaft power (manifested by a pressure drop across the turbine).

In either case, the shaft power developed by the water turbine is then harnessed to drive the shaft of a synchronous or asynchronous generator.

Hydropower schemes can operate very efficiently if suitably designed; up to 90% from water to wire for industrial hydro-electric schemes and more than 85% for micro-hydro and mini-hydro schemes. Initial capital costs (and therefore, investment) are considerable, but this is offset by the long lifespan and low operation and maintenance costs. Civil structures and engineering are usually considerable; at the intake and outfall (weirs, chambers and retaining walls), for pipeline supports (thrust blocks) and for the powerhouse floor slab with integrated foundation and various plinths and voids for installation of the electro-mechanical equipment.

For industrial scale hydroelectric power schemes (> 20MW), the challenge is to mitigate and eliminate environmental impact. This can usually be done by compensation for loss of environment and provisioning for things like safe (migratory), fish passage using fish ladders. Habitat for fauna and flora in depleted reaches of rivers used for hydropower can be at risk to changes in the natural stream flow unless suitable compensation flows at the intake are arranged for. Dams and weirs disrupt the connectivity of rivers and can result in sedimentation. Intakes and outfalls for micro-hydro schemes are invariably screened to the extent that juvenile fish cannot swim into the intake and arranged so that the approach velocity is (typically) no more than about 0.3m/s. Provisions for screening, sediment transit and compensation flow in the depleted reaches are usually mandated by environmental agencies concerned and become conditions of licencing.

4.3.1 Hydro-electric Criteria

Leeds City Council should consider the criteria below when assessing the potential impacts of micro-hydro schemes. These principles are aligned to recommendations from the British Hydropower Association.

- A hydro-electric system should not increase risk of flood damage from a watercourse. It must be demonstrated that the net effect of any raising of levels in the watercourse or impoundment and diverting water from existing flows does not significantly increase the potential risk of flooding surrounding land or property.
- The proposed scheme arrangement should not adversely affect other water users, such as livestock farmers, fish farms, water sports clubs, water companies. Mitigation measures should be agreed for continued use or compensation agreed.
- Land habitat of protected species should not be damaged. In areas which are likely or known to provide support for protected species, a qualified walk over survey should be conducted to determine the population and to confirm no significant impacts will be caused by construction or operation of the hydro scheme. Any identified breeding or dwelling sites should be avoided during construction.
- Hydro schemes should not create electrical risk. Their installation and servicing should meet current standards. Where grid connected a connection offer must be agreed with the relevant DNO.
- Where there are penstocks these should be buried if feasible and otherwise made safe.
- Powerhouse structures and design should attenuate the noise levels of the turbine and generator to acceptable levels 1m away from the building in populated or frequented area. Turbine houses should be fitted with appropriate levels of sound insulation and close-fitting doors as necessary.
- Turbine houses should not be unsightly if in urban areas or places of natural beauty; they should be constructed using materials appropriate to the environment. Heritage or otherwise controlled areas should not be affected, or consents should be obtained. All neighbouring property owners must be notified and not opposed to the scheme.

A hydro-electric system should not risk significant damage to the fish population in the river basin as a whole. Mitigation measures include:

- Screen the entry of water at the abstraction point and the outflow to restrict access to the turbine.
- Limit the disturbance of water and waterbed at the turbine outflow.
- Ensure an environmental flow (‘compensation flow’) and supplementary ‘residual flows’ which will provide sufficient riverbed coverage and flow, to sustain important habitat and food resource.
- Where there is significant use by fish (judged by qualified walk over survey) and any weir reconstruction or new structures exceeding the height of natural obstacles, provide suitable alternative fish passage up and down the watercourse; and protect fish spawning habitat such as weir pools against potentially adverse changes in flow.
- Mitigate adverse changes in sedimentation resulting from impoundment changes by mechanical means.

4.4 Hydrogen Production

Hydrogen offers a potentially low or zero carbon means to store and transport energy. When hydrogen is burnt the emissions given off are typically water vapour, however some nitric oxide is also produced due to the temperature of combustion. Hydrogen can also be used in a fuel cell to generate electricity and heat.

Hydrogen can be produced in three main ways; these are conventionally distinguished by a colour-based naming system:

- **Grey Hydrogen:** Is produced from natural gas[16] by splitting the hydrogen from the carbon atoms in the natural gas molecules. This process releases CO_2 which is typically released into the atmosphere and contributes to climate change. This means of production is currently the most economically viable and most widely used globally and in the UK.
- **Blue Hydrogen:** Is produced in the same way as grey hydrogen but more than 90% of the CO_2 by-product is captured and pumped into geological reservoirs (typically depleted offshore gas or oil fields) for long term storage. This technology is widely favoured by industry at this stage because it is currently believed to be the most cost-effective long-term way to achieve low-carbon hydrogen production at the scale indicated to be required by Government but is criticised by environmental groups primarily because it fails to address the leakage of natural gas (which is itself a potent greenhouse gas) and because not all the CO_2 is captured. It is also considered by some groups to be a means of continuing to use natural gas resources and infrastructure.
- **Green Hydrogen:** Is produced by using renewable electricity[17] to split water into hydrogen and oxygen. The oxygen is typically released to the atmosphere and does not contribute to climate change.

Other colours are sometimes used to refer to more specific means of production however these are generally a subset of the three categories above. For example, “yellow hydrogen” generally refers to a subset of green hydrogen where purely solar energy is used.

The use of green and/or blue hydrogen is often considered a key part of national and global decarbonisation strategies. The ability to produce hydrogen from surplus renewable electricity and then use it at a later time is likely to play a key role in the medium- and long-term storage of energy when a greater proportion of UK electricity is produced from intermittent renewable sources.

Hydrogen can be blended into the natural gas that is currently widely used for space heating and cooking in homes and businesses. However, these uses can also be decarbonised using heat pumps and electric cookers so should arguably be a secondary priority when compared to other sectors that are less easily decarbonised by non-hydrogen means; these sectors include:

- Industries which require high temperatures such as steel and glass manufacture.
- Some types of transport (particularly HGVs, shipping and potentially trains) where batteries may be too large or heavy to be viable[18].
- Hard-to-treat buildings in areas where district heat networks are unlikely to develop. These are typically older listed buildings in rural areas. Listed buildings cannot readily be retrofitted with fabric improvements to reduce their heating demands and facilitate the use of heat pumps. District heat networks (DHNs) can provide an alternative means of decarbonisation for buildings with higher heat demands, however DHNs are typically only viable in areas where the heat demand is concentrated (such as in urban centres).

The production of green hydrogen (i.e. by electrolysis of water) produces waste heat that can be used to supply heat demands in other buildings or processes. To increase the viability of using waste heat in this way, it is desirable to locate electrolyser plants close to areas with heat demands (principally urban areas). However, running counter to this is the need to reduce safety risks associated with the storage of hydrogen.

[16] It is possible to use other fossil fuels; where coal is used this is referred to as black hydrogen and where lignite is used the product is referred to a brown hydrogen.
[17] Although it is possible to produce hydrogen using non-renewable electricity this is rarely considered economically viable and is higher carbon than direct production from the fossil fuel.
[18] Battery technology is developing rapidly so may yet overcome these challenges and become the preferred energy source for these forms of transport.

4.4.1 Hydrogen Production Criteria

- The production transportation or storage of hydrogen presents the risk of explosion. Any proposed development which will either produce, storge or transport hydrogen should include adequate mitigation measures such that the explosion risks are acceptable. Hydrogen production, transport or processing facilitates are likely to trigger COMAH and Hazardous Substances Consent requirements.
- Hydrogen production facilities can produce significant noise. Proposed developments should incorporate suitable noise attenuation measures such that noise impacts to nearby sensitive receptors are suitably mitigated. Proposals for hydrogen production or processing plants should include a noise assessment of the impacts on amenity. The primary mitigation for noise is through good design to enclose plant and machinery in noise-reducing buildings, wherever possible, and to minimise the potential for operations to create noise. Noise from compressors should be mitigated by attenuation to reduce any risk of low-frequency noise transmission.
- Production of hydrogen by means of gas reformation (grey hydrogen) should include carbon capture utilisation and storage (CCUS) systems.
- Hydrogen production facilitates using electrolysis (green hydrogen) typically require a significant water supply. Water supply arrangements should appropriately consider impacts on wider water infrastructure (e.g. loss of pressure to other water users) and/or environmental impacts such as impacts to local water courses and wildlife (especially during drought conditions).
- Hydrogen production facilities vary significantly in size and visual impact. Electrolysis plants (producing green hydrogen) can be largely containerised and are relatively unobtrusive. Blue or grey hydrogen production facilitates tend to be part of large petrochemical plants. Proposed hydrogen production facilitates should seek to mitigate their visual impacts.
- Proposals for hydrogen production or processing plants located in greenbelt will generally be considered to be inappropriate development. Careful consideration must therefore be given to the visual impact of projects. Developers will need to demonstrate very special circumstances that clearly outweigh any harm by reason of inappropriateness and any other harm if projects are to proceed.
- Hydrogen production and processing facilities typically produce waste heat that may be used by other sites or processes. Proposed hydrogen plants will be considered more favourably where there is a realistic potential to make use of this waste heat in the local area.
- Proposed hydrogen plants will be considered more favourably where they are to be located close to the prospective hydrogen user(s). The use of hydrogen should typically be prioritised for high temperature industries, haulage and/or hard-to-treat buildings which cannot readily use other low carbon heat sources.

4.5 Other Renewables: Implications/ Input for the Local Plan Review

Current Policy Position	Potential Changes
Hydro-power Policy EN3: The Council supports appropriate opportunities to improve energy efficiency and increase the large scale commercial renewable energy capacity, as a basis to reduce greenhouse gas emissions. This includes hydro-power. There are no firm policy requirements with regards to hydro-power in the Core Strategy. However, Paragraph 5.5.42 of the Core Strategy outlines potential for development of hydropower facilities on the rivers Wharfe, Aire and Calder. Whilst these are only likely to have capacity for small-scale generation, some of the weirs are large enough to contribute to the overall requirement for grid-connected renewable energy. The Natural Resources and Waste Plan supports hydro power, but limits this to micro-generation. Policy Energy 2 Micro Energy Generation states that any schemes would need to be acceptable against a range of factors, but	The NPPF does not specify exactly how Local Authorities should approach hydro electricity generation, but suggests in Para 158(a) that even small scale projects provide a valuable contribution towards cutting emissions. As identified in this study, there are some key factors that need to be addressed to ensure that hydro-electricity schemes are sustainably delivered. In particular, this includes issues relating to flood risk and the quality of the environment. The Plan Review offers the potential to incorporate such criteria into a new or existing policy. This is supported by NPPG para 003 which states that local planning authorities should consider the policies needed to secure development in the right places.

there are no explicit clauses or requirements relating to hydro energy specifically.	
Energy from Waste Policy EN6 within the Core Strategy broadly identifies a waste management strategy, and in the supporting text states that energy from waste could contribute towards the strategy. Policy Energy 3 and Energy 4 within the Natural Resources And Waste Plan are supportive of combined heat and power, and state that energy from waste schemes should demonstrate potential for CHP. The National Waste Management Plan (2014) is supportive of Local Waste Plans that identify suitable sites and areas for energy from waste schemes.	It may be useful to refer to the acceptability criteria for energy from waste schemes.
Biomass The Natural Resources and Waste Plan supports Biomass, but limits this to micro-generation. Policy Energy 2 Micro Energy Generation states that any schemes would need to be acceptable against a range of factors, but there are no explicit clauses or requirements relating to biomass specifically.	The study outputs suggest that no further policy measures are necessary with regards to the strategic approach to biomass. However, it may be useful to refer to the acceptability criteria for biomass by amending or replacing Policy Energy 2 (Micro generation) within the Natural Resources and Waste Plan.
Hydrogen The current Local Development Plan for Leeds makes no specific mention of hydrogen production.	The UK Hydrogen Strategy (2021) identifies that planning (amongst other factors) could be a regulatory barrier to hydrogen schemes. Leeds Council could take a proactive approach to facilitating appropriate schemes by; broadening the scope of low carbon policies to encourage such uses, and by introducing appropriate criteria to guide such developments.

5. Requirement 4: Energy Storage

To assess the strategic need for energy storage, AECOM has modelled and analysed the electricity output of the identified potential low and zero carbon (LZC) technologies and the modelled electricity demand in the LCC area.

To quantify the potential output from LZC technologies, the following technical potential capacities were taken from the analysis described in Section 7 assuming an extensive build-out of these technologies working within the limits identified:

- Energy from waste (EfW) plants: 360,000 MWh/yr
- Anaerobic digestion CHP plants: 3,060 MWh/yr
- Biomass-fired power plants: 18,900 MWh/yr
- Hydro-electric plants: 2,260 MWh/yr
- Solar PV farms: 2,000,000 MWh/yr
- Wind farms: 380,000 MWh/yr

Figure 9 shows the relative scale of the electrical output figures listed above. This shows that solar PV has the greatest potential, followed by wind and EfW plants. The remaining LZC sources have the potential to contribute less than 1% of the total modelled output collectively.

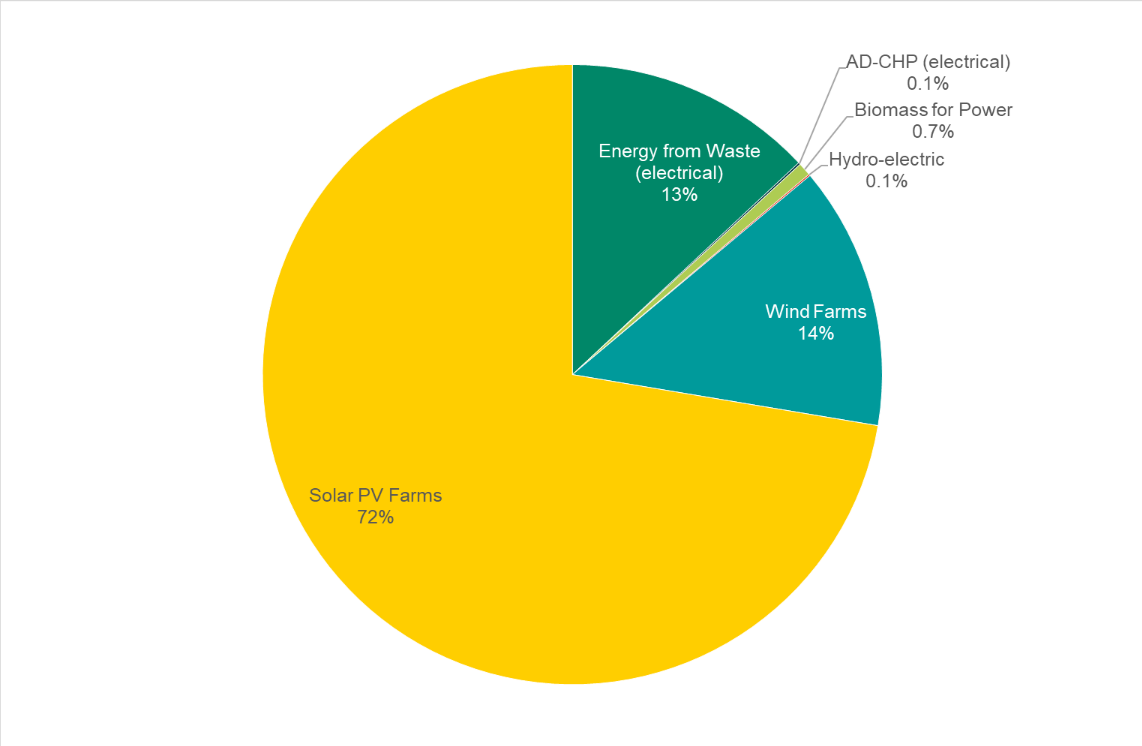

Figure 9: Indicative breakdown of potential annual outputs of LZC technologies in the LCC area

Figure 10 shows the resulting total potential LZC electricity output profile for a typical year compared to the modelled electricity demand profile for the LCC area. The potential LZC electricity output varies seasonally (being dominated by solar PV) and frequently fluctuates both above and below the modelled electricity demand. This suggests that there may be a role for large electricity storage systems to be used to store power from times when local supply exceeds demand and then to discharge when demand exceeds supply (typically only a few hours later). This use of electricity storage would help to increase the self-sufficiency of the LCC area and to balance the national supply and demand of electricity (assuming that most other parts of the country will be deploying similar measures to decarbonise).

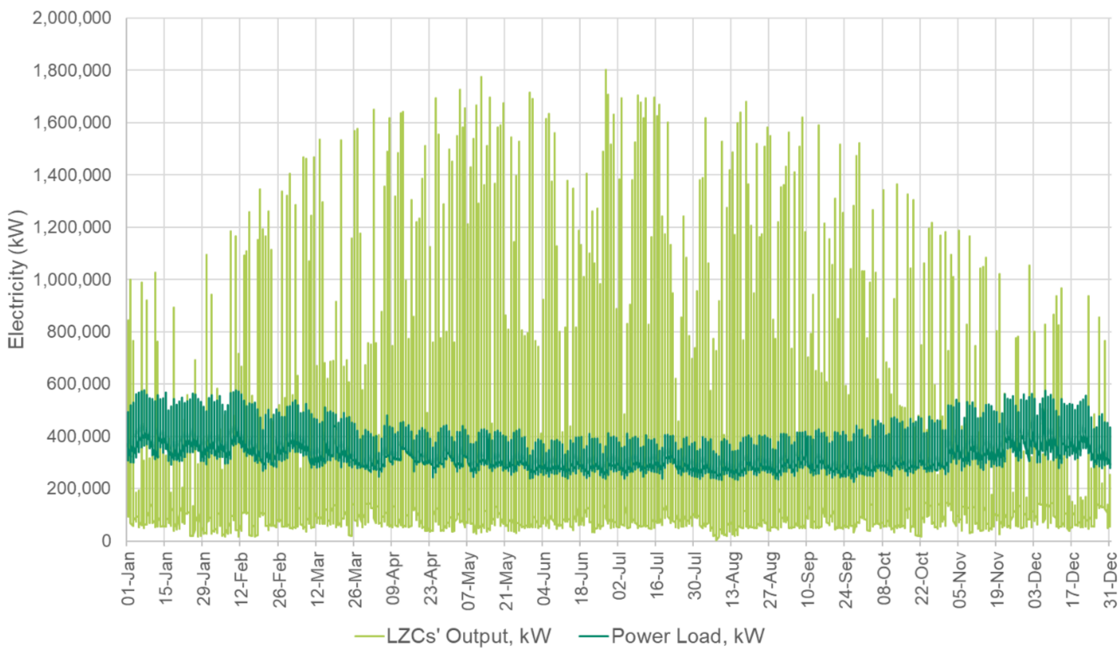

Figure 10: Modelled electricity demand and potential low and zero carbon (LZC) electricity generation profiles for the LCC area for a typical year

Using the electricity supply and demand profiles shown in Figure 10, a range of battery sizes were modelled to assess the degree to which they might be used to increase the self-sufficiency of the LCC area. The degree of self-sufficiency can be expressed as the percentage of electricity demand which is supplied from LZCs in the LCC area. The higher this percentage, the more self-sufficient the area is.

Figure 11 shows how the percentage of electricity imported into the LCC area could reduce as the collective size of battery storage is increased. Three scenarios have been considered:

- **Scenario A:** Based on the current electricity use of the LCC area and the maximum potential LZC technology capacity (as shown in Figure 10).
- **Scenario B:** Based on the current electricity use of the LCC area and half of the maximum potential LZC technology capacity.
- **Scenario C:** Based on projected future electricity use of the LCC area (factoring increased use from electric vehicles and heat pumps[19]) and the maximum potential LZC technology capacity.

This analysis suggests that, in scenario A, the degree of self-sufficiency increases from 52% to 68% in a broadly linear fashion as the battery size is increased from zero up to around 2,500MWh. As the battery size is increased further the rate of improvement in self-sufficiency decays and levels off at around 75%. This shows that the use of battery systems at a city-scale may be cost effective up to a limit of around 2,500MWh, however beyond this scale the cost effectiveness of increased battery capacity will reduce. The reason for this is that, beyond around 2,500MWh the battery storage begins to be used for longer-term storage (longer than a few hours). Batteries are generally better suited to short-term storage (up to around 6 hours is currently typical)[20]; longer term storage is more typically provided by other technologies such as pumped hydro or emerging technologies such as compressed air or hydrogen. The Scenario A curve shown in Figure 11 levels off at around 6,000MWh; this suggests that, in addition to 2,500MWh of battery storage, there is potential use for a further 3,500MWh or longer-term storage (see Section 7.1.4).

The curves for scenarios B and C show a similar curved decay to scenario A with the following characteristics:

- Scenario B:
  - Broadly linear improvement from 37% to 40% achieved by 1,000MWh of battery storage.
  - Levels off at around 43% when 3,000MWh of storage is deployed (implying use for up to around 2,000MWh of longer-term energy storage).
- Scenario C:
  - Broadly linear improvement from 43% to 55% achieved by 3,500MWh of battery storage.
  - Levels off at around 60% when 7,000MWh of storage is deployed (implying use for up to around 3,000MWh of longer-term energy storage).

[19] Projection based on Committee on Climate Change analysis https://www.theccc.org.uk/wp-content/uploads/2019/05/CCC-Accelerated-Electrification-Vivid-Economics-Imperial-1.pdf

[20] The capital cost of batteries is broadly proportional to the storage capacity (doubling the capacity of a battery system typically doubles its capital cost). However, many other energy storage technologies have an element of fixed cost for the production plant and a relatively low variable cost for the means of storage. For example, an electrolyser which produced hydrogen is relatively expensive, however the vessels required for storing the hydrogen produced are relatively cheap. This means that, once an electrolyser is purchased, the means of storing greater quantities of hydrogen (for longer periods) is relatively small.

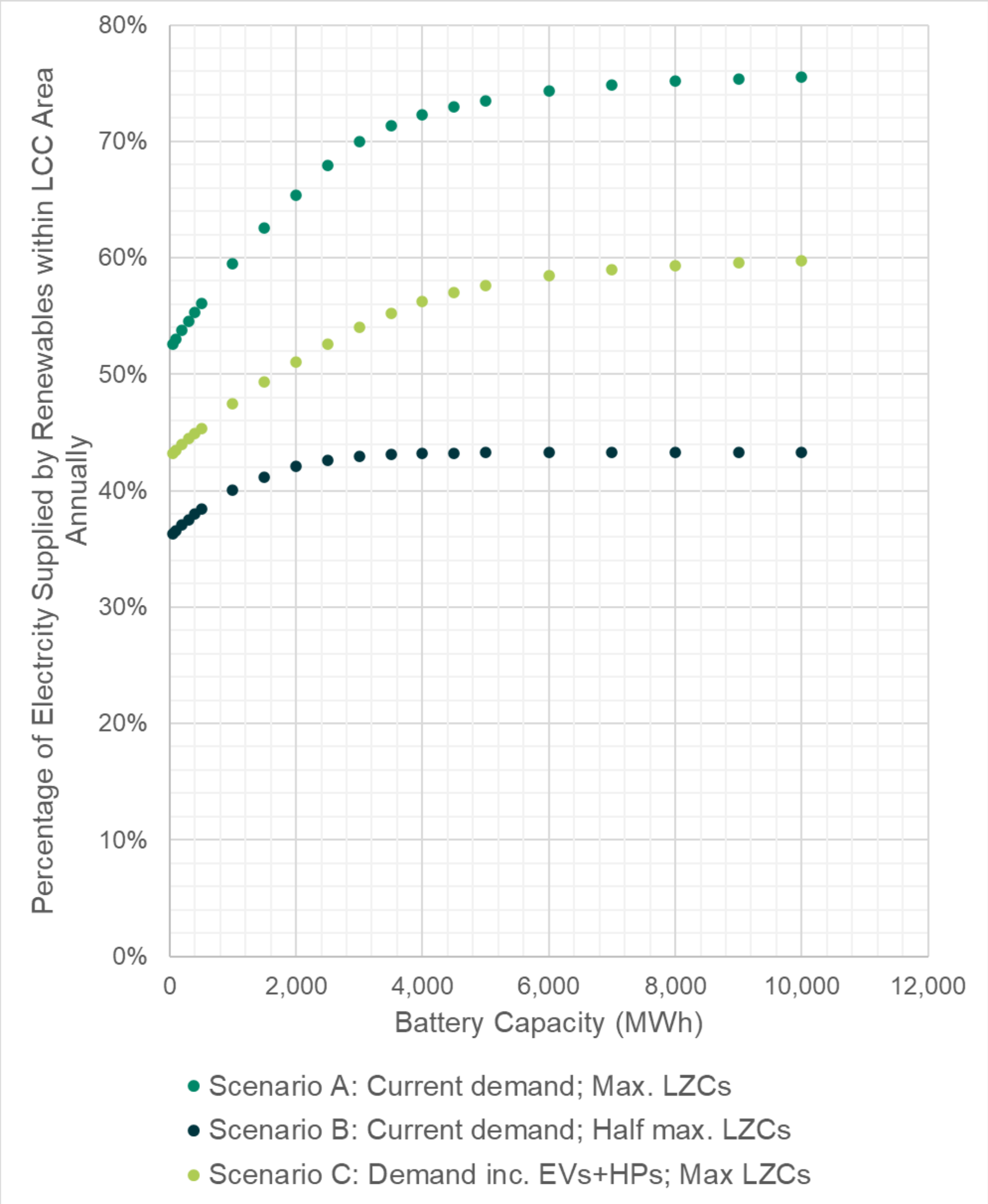

Figure 11: Analysis of modelled relationship between battery capacity and proportion of electricity being imported from outside the LCC area

Battery systems are typically located in one of the following three places:

- **Co-located with wind or solar PV farms:** This can allow developers to install PV or wind capacity which exceeds the capacity of the grid connection and to provide power at times when electricity prices are high rather than when the renewable plant is generating (which is dependent on the weather).
- **Close to electrical substations and grid supply points:** To directly provide grid support services. When connected to grid supply points (which link the national transmission network to the local distribution network) these might be considered to be providing national-level grid support.
- **Within the premisses of a large electricity user:** This is typically done where security of electricity supply is particularly important or where the electricity demand fluctuates over a large range. This type of installation may not require planning permission if it is within an existing building.

Typical capacities for battery parks in the UK currently range from around 100-500MWh (approximately 0.4ha to 2.0ha), however this is likely to increase in the coming years as battery prices fall, energy prices rise, and the use of intermittent renewables (such as wind and solar PV) increases.

5.1 Battery Storage

As battery technology has developed and costs have fallen, the use of large battery installations or battery parks to support national electricity networks and to make money through simple trading of electricity has become increasingly viable.

The wholesale price of electricity can vary widely throughout the day and night. Prices typically peak in early evening when demand is high; the lowest costs typically occur at night when demand is low. In this context battery systems can make a profit by storing and releasing power at times determined by the short-term market prices.

The increased use of distributed and intermittent electricity generation (such as wind and solar PV) has also increased the need for the types of grid support services that battery parks can provide.

- **Firm Frequency Response:** National Grid pays operators of batteries and other power plant equipment to provide sub-second responses to help smooth and correct fluctuations in grid frequency.
- **Balancing Mechanism:** National Grid pays operators of batteries and other power plant equipment to supply capacity to the grid operator at agreed times to help it balance network supply and demand.
- **Capacity Market contracts:** National Grid pays operators of batteries and other power plant equipment to respond when there is a high risk that a system stress event could occur. This happens very rarely but the payments are typically awarded simply for being available to provide the service for a period even if it is not needed/used.

Although these types of grid support services can be supplied by conventional fossil-fuelled equipment, battery parks are widely seen as preferable because they:

- do not rely on the continued use of fossil fuels (and are therefore compatible with carbon reduction targets);
- do not cause local air pollution;
- they produce less noise.

Battery parks can technically be located anywhere with an adequate grid connection (subject to other planning requirements) however it can be advantageous to collocate them with other power generation technology, especially technologies with intermittent output (such as wind and solar PV). Colocation can allow the operators to store locally generated power to release it at times when prices are higher. Doing this on the same site as the generation plant means that, when initially storing the electricity (prior to a subsequent export), the operator is not using the public grid and so avoids paying charges for its use. A co-located battery park can also allow wind and solar PV parks to be developed with peak outputs which are larger than the installed grid connection can accommodate. Any power generated above the peak capacity can be stored and exported later when output is lower. This can avoid the costs of installing higher capacity grid connections.

Whilst battery costs have fallen, their costs remain sufficiently high that they are not (currently) considered to be a viable means of storing electricity for more than a few hours in most circumstances. Typically, this limit is deemed to be around 4 hours although it may be slightly longer in some cases.

Battery parks generally contain several shipping containers (or buildings of similar scale and appearance), inside which batteries and electronic controls are housed. Electrical infrastructure such as transformers may be located externally or in a small (typically single storey) building. To facilitate access these containers/buildings will generally be spaced a few meters away from each other; the site will require occasional vehicle access. The site will be secure and typically be surrounded by a high fence. Sound levels from battery parks are generally low, consisting mainly of cooling fans running inside the battery containers/buildings. Visual and noise impacts may be mitigated to some extent through screening and attenuation measures.

Several battery technologies are currently available or in development, each of these use different chemical substances to store electricity. The most commonly used battery technology currently is lithium-ion batteries (such as are widely used in portable electronics and electric vehicles. Lithium-ion batteries have the potential to explode or burn (although this is rare), other battery technologies may present other risks such as the potential for liquids to leak etc.

5.1.1 Battery Park Criteria

- Battery parks may present risks such as explosion, fire or pollution. Any proposed development which will contain large quantities of batteries should include adequate mitigation measures such that the explosion and fire risks are acceptable. Hydrogen production, transport or processing facilitates are likely to trigger COMAH and Hazardous Substances Consent requirements.
- Proposed developments should have a noise impact assessment carried out and if there are relevant noise receptors the development should incorporate suitable noise attenuation measures such that noise impacts to nearby sensitive receptors are suitably mitigated. Proposals for battery parks should include a noise assessment of the impacts on amenity. The primary mitigation for noise is through good design to enclose plant and machinery in noise-reducing buildings, wherever possible, and to minimise the potential for operations to create noise. Noise from cooling fans should be mitigated by attenuation to reduce any risk of low-frequency noise transmission.
- Battery parks are typically largely containerised and are relatively unobtrusive. Battery parks should seek to mitigate their visual impacts.
- Battery parks should not be located in flood zone 3 unless the Sequential and Exceptions tests can be fulfilled and mitigation measures are shown to fully mitigate flood risks to the equipment itself and do not increase the risk of flooding or other associated risks to other developments, infrastructure, natural habitats or farmland.

5.2 Energy Storage: Implications/ Input for the Local Plan Review

Current Policy Position	Potential Changes
There are no policies that deal with energy storage within the current Leeds Local Development Plan.	The NPPF states that Local Planning authorities should support and plan for low carbon energy and ‘associated infrastructure’. Energy storage can be considered as supporting infrastructure, and therefore, it may be appropriate to introduce a policy that is supportive of appropriate energy storage facilities, and refers to areas of potential.

6. Requirement 5: Grid Connection Analysis

AECOM has recommended that this analysis is approached as a separate work package which is undertaken after the other works described in this document. A fee proposal for this can be provided upon request.

AECOM proposes to run a grid connection analysis for each wind and solar PV site/area identified under requirements 1 and 2, providing a suitable point of connection with the grid for the estimated size of generation. Our exact approach to this will be informed by the findings of the other scoped works however at the time of writing we anticipate that we will assess the connection potential for systems with potential sizes of 1-5MW at 11kV, 5-10MW at 33kV and 10MW+ at either 33kV or 132kV depending on grid constraints. For each potential site, a preferred point of connection (POC) and grid constraints in the area will be identified. AECOM will then outline the process for connection and liaise with the DNO to understand any other developments in the area or enabling works which could impact the renewable generation connecting to the suggested POC.

6.1 Grid Connection: Implications/ Input for the Local Plan Review

Current Policy Position	Potential Changes
The Leeds Local Plan and Natural Resources and Waste Local Plan do not make reference to grid connection within	Leeds City Council should review the target of achieving 75MW of grid connected energy by 2021 as this date has passed, and look at setting a new target for the future.

a policy, however it is mentioned in the following paragraphs:

Paragraph 5.5.39 of the Core Strategy outlines the Council's aim to achieve a grid connected renewable energy target of 75MW by 2021. This target was set in 2013 when the current figure was 11MW of renewable energy provision.

Paragraph 5.12 states that large-scale installed grid-connected onshore wind energy could significantly contribute to meeting Leeds' renewable energy targets.

Paragraph 5.26 states that although energy demand management and decentralised energy opportunities can reduce the reliance on grid supplies, conventional grid supplies of both gas and electricity will continue to be the main ways in which energy is conveyed to Leeds. Therefore, it is important that development takes due regard of energy infrastructure requirements.

Policies supporting grid connection infrastructure and the phasing of development to allow for grid capacity improvements could be useful, but are not considered essential in a Local Plan.

7. Requirement 6: Technical Potential

To assess the potential renewable energy generation capacity that the LCC region can support AECOM has undertaken a two-pronged, hierarchical approach which will analyse the following technologies in two categories:

- Non-thermal:
  - Wind,
  - Solar PV,
  - Hydro-electric,
  - Hydrogen.
- Thermal:
  - Energy from Waste,
  - Anaerobic digestion,
  - Biomass for power.

The potential scale of total renewable energy developments identified in this section are necessarily approximate. These figures should not be viewed as upper limits on what is possible but rather indicative of the potential. For example, the scale of solar PV farm developments identified in Section 7.1.2 is based on the current typical panel efficiency, as this efficiency increases, the output of a PV farm per hectare will increase and so the total potential capacity of the LCC area will also increase.

7.1 Non-thermal Renewable Technologies

Non-thermal renewable technologies are generally considered preferable to thermal with regard to the impact on local air quality and vehicle movements etc. (see Section 4.2 for example). AECOM has assessed the LCC area's capacity for the listed non-thermal technologies drawing on the analyses undertaken for Requirements 1-4 above.

7.1.1 Wind Turbines

Opportunity areas for wind turbines have been identified in Section 2 and are shown in Figure 1 to Figure 3. For the purpose of gaining an understanding of the approximate amount of energy potential wind turbines in the LCC area could produce a further analysis of these areas has been undertaken. Table 1 shows the areas of opportunity for each scenario, these values have been used to calculate the maximum wind farm capacity[21]. The

[21] Potential wind farm capacity has been calculated by multiplying the opportunity area by 0.09 MW/ha. This figure has been taken from *Renewable and Low-carbon Energy Capacity Methodology. Methodology for the English Regions*, DECC 2010. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/226175/renewable_and_low_carbon_energy_capacity_methodology_jan2010.pdf

resulting value was then multiplied by 2,882 MWh/MW, (taken from BEIS Regional Renewable Statistics [22] for Leeds City Council). Table 2 below shows the capacities and outputs for each of the three scenarios.

Scenario	Description	Opportunity Area (ha)	Potential Wind Turbine Capacity (MW)	Potential Wind Turbine Output (MWh/yr)
Scenario 1 maximum opportunity area	Brownfield only	0	0	0
Scenario 2 maximum opportunity area	Excl. greenfield	168	15	43,500
Scenario 3 maximum opportunity area	Incl. greenfield	3,030	273	786,000
Scenario 3 reduced opportunity area to mitigate cumulative landscape and visual impact	Incl. greenfield	NA	90	380,000

Table 2: Potential wind turbine capacity for the LCC area

The wind turbine opportunity areas identified in Figure 1 (Scenario 1) and Figure 2 (Scenario 2) are typically very small and widely distributed pockets of land. As such, if wind turbines were constructed on several of these sites, each site would likely only be able to accommodate one large turbine. The cumulative interaction of installing turbines on most or all of these sites would be minimal, because the sites are so widely distributed.

The wind turbine opportunity areas identified in Figure 3 (Scenario 3) are large and often only separated from the next adjacent site by a few tens or hundreds of meters. If wind turbines were to be installed across most of these areas, then the cumulative effect would become significant as wind turbines would become dominant in the landscape. The mitigation of this cumulative impact is a complex design and analysis task which is routinely undertaken as part of the Landscape and Visual Impact Analysis chapter of the Environmental Impact Assessment (EIA). For the purposes of this analysis, it is not possible to precisely assess how many wind turbines could be accommodated before the cumulative effect becomes significant. However, DECC *Renewable and Low-carbon Energy Capacity Methodology* document suggests that, for the purpose of a high-level analysis, wind farms should typically be no closer than 10km from each other. Using this rule of thumb and assuming a typical (onshore) wind farm capacity of 30MW, it is estimated that the identified Scenario 3 wind turbine opportunity areas might reasonably accommodate up to approximately 135MW of large wind turbines.

7.1.2 Solar PV

Opportunity areas for ground mounted solar PV farms have been identified in Section 2 and are shown in Figure 4 to Figure 6. For the purpose of gaining an understanding of the approximate amount of energy ground-mounted solar PV farms could contribute in the LCC area a further analysis of these areas has been undertaken. Table 1 shows the areas of opportunity for each scenario, these values have been used to calculate the maximum solar farm capacity[23]. The resulting value was then multiplied by 1,005 MWh/MW, (taken from BEIS RRS[24] for Leeds City Council). Table 3 below shows the capacities and outputs for each of the three scenarios.

Scenario	Description	Opportunity Area (ha)	Potential Solar Farm Capacity (MW)	Potential Solar Farm Output (MWh/yr)
Scenario 1 maximum opportunity area	Brownfield only	6	5	4,689
Scenario 2 maximum opportunity area	Excl. greenfield	1,140	912	916,000
Scenario 3 maximum opportunity area	Incl. greenfield	19,391	15,513	15,597,000
Scenario 3 reduced opportunity area to mitigate cumulative landscape and visual impact	Incl. greenfield	NA	2,200	2,000,000

Table 3: Ground mounted solar PV potential in the LCC area

The solar PV farm opportunity areas identified in Figure 4 (Scenario 1) and Figure 5 (Scenario 2) are typically very small and widely distributed pockets of land. As such, if PV farms were constructed on these sites, each site

[22] Available at: https://www.gov.uk/government/statistics/regional-renewable-statistics

[23] Potential wind farm capacity has been calculated by multiplying the opportunity area by 0.8 MW/ha. This figure has been taken from *Renewable and Low-carbon Energy Capacity Methodology. Methodology for the English Regions*, DECC 2010. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/226175/renewable_and_low_carbon_energy_capacity_methodology_jan2010.pdf

[24] Available at: https://www.gov.uk/government/statistics/regional-renewable-statistics

would only be able to accommodate a small PV farm, this may reduce the economic viability of the development. Furthermore, the cumulative interaction of installing PV farms on most or all of these sites would be minimal.

The solar PV farm opportunity areas identified in Figure 6 (Scenario 3) are large and often only separated from the next adjacent site by a few tens or hundreds of meters. When viewed from a distance, PV farms are typically less visible than wind farms because they are only a few meters high. Nevertheless, if PV farms were to be installed across most of the Scenario 3 opportunity areas, then the cumulative effect would become significant. The mitigation of this cumulative impact is a complex design and analysis task which is routinely undertaken as part of the Landscape and Visual Impact Analysis chapter of the EIA. For the purposes of this analysis, it is not possible to precisely assess the PV farm capacity which could be accommodated before the cumulative effect becomes significant. The DECC *Renewable and Low-carbon Energy Capacity Methodology* document which provides a proxy for this issue with regard to wind farms was written in 2010 before PV farms were commonly developed in the UK, and therefore does not provide any guidance on PV farms. Therefore, a rule of thumb has been derived by reviewing recent planning applications for PV farms. This suggests that, for the purpose of this high-level analysis, it is reasonable to assume that a minimum distance between large PV farms might typically be around 2km. On this basis, and assuming a typical large PV farm has a capacity of 50MW, it is estimated that the identified Scenario 3 PV farm opportunity areas might reasonably accommodate up to 1850MW of solar PV.

7.1.3 Hydro-electric

Locations considered for hydropower are the weir points marked in Figure 12. This is for the purpose of gaining an understanding of the approximate levels of energy the technology could contribute in the LCC area. In practise it may be beneficial to create a larger 'run of river' scheme with a greater output (for example, where a series of weirs are close together). Individual opportunities will become clearer when the sites can be visited during the detailed feasibility study stage.

The potential for hydroelectric generation in the LCC area was estimated following the method described below.

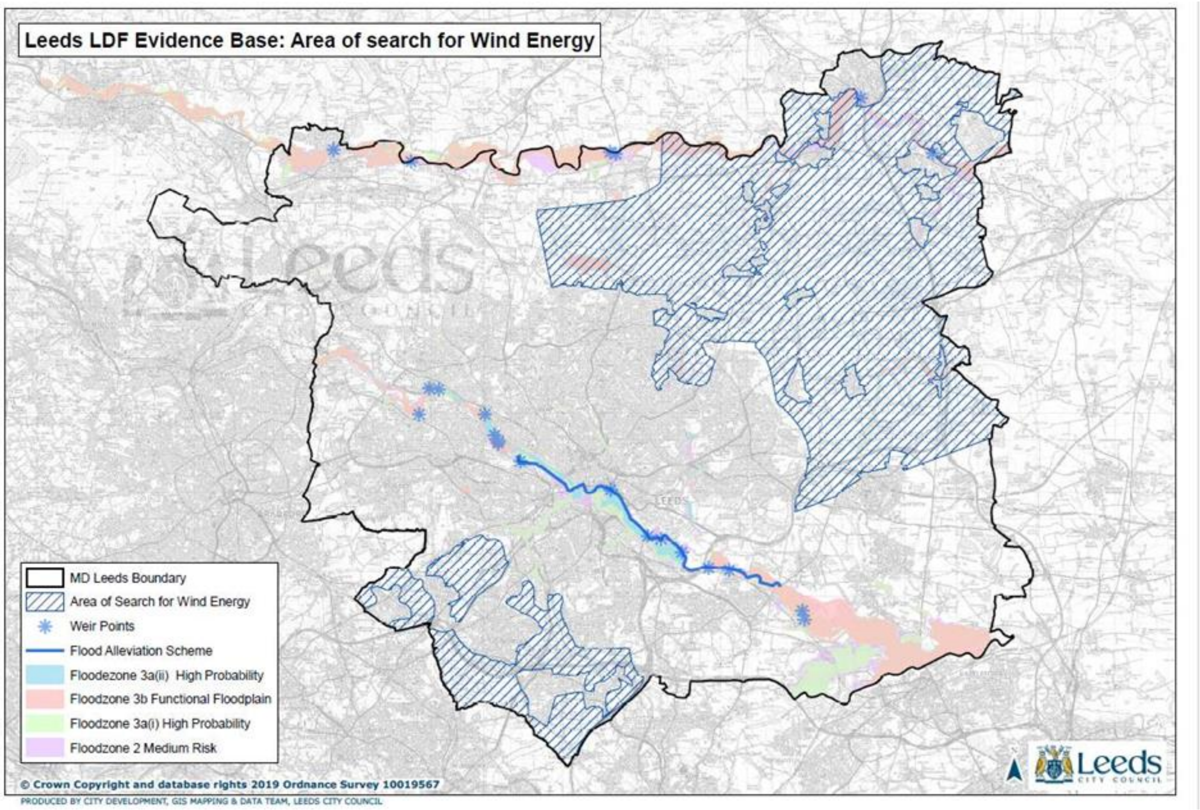

Figure 12: Map showing weir points considered for hydroelectric generation

7.1.3.1 Hydro-electric method

Weir locations marked on supplied map were investigated using publicly available satellite imagery (i.e., by desk-based survey, not site-based survey). Two weirs marked in Figure 12 could not be located and one was found to be breeched; these sites were excluded from resource assessment analysis.

The differences in height between water levels above and below the weirs (head heights), were approximated following a desktop approach using digital mapping for the 19 identified weirs on the rivers Aire and Wharfe.

Flow data required to estimate hydropower potential for both rivers were taken from the National River Flow Archive (NRFA). These flow statistics are based on historic, gauged flow measurements.

Calculations for hydro opportunities on the Aire were based on the averages of NRFA mean flow data collected upstream and downstream of the marked weir locations for example Equation 1 shows the calculation of flow rate at a location on the River Aire downstream of the confluence with Bradford Beck.

$$\frac{\left((Aire\ at\ Bingley\ Mean\ Flow + Bradford\ Beck\ at\ Shipley\ Mean\ flow) + Aire\ at\ Armley\ Mean\ Flow\right)}{2}$$

Equation 1: Example calculation of flow rate at weir location.

A similar approach was carried out to estimate flow available from the Wharfe, utilising NRFA measured data from the upstream locations 'Wharfe at Ilkley' and 'Washburn at Lindley', averaged against 'Wetherby Flint Mill'. In reality water turbines located further downstream would benefit from higher levels of flow (due to the larger catchment areas) and turbines further upstream would see less flow (due to smaller catchment area), but for the purposes of this exercise an approximate average flow is deemed sufficient. Periods of NRFA data collection span several decades in each case.

Assumptions:

- 5% of head loss has been assumed for each location due to energy losses at the civil works intake structures (such as screened sumps).
- Leakage through weirs has been estimated at 2% of available flow given the historic nature of the weirs.
- Turbine efficiency of 88% has been assumed for all opportunities (this is representative of commercial water turbines designed for low head applications such as propeller and semi-Kaplan turbines).
- No assessment of the practical 'buildability' of any of the schemes has been undertaken. Low head sites can be complex as factors such as risks to powerhouse flooding, intake and outlet fish screening requirements and restrictions in available space all need consideration.
- Water flow available for turbine generation has been based on allowing for a Q95 environmental flow ('hands off' flow) with an additional allowance for residual flow of 25% of river flow in excess of the environmental flow. Environmental and residual flows are usual Environmental Agency requirements; both figures are determined during the application process for an abstraction licence. In subsequent stages of feasibility assessment, river flow duration curves based on the catchment area at the specific sites will need be obtained using standard methods. This data allows an accurate energy study to be conducted taking account of seasonal variations in river flow, turbine operation under part-flow condition and actual river levels.
- Since the aim is to calculate the potential for hydropower, loss of flow through any potential fish passes has not been considered. Some form of screening will be required by the Environmental Agency.
- Suitability of desktop-based approximating of head heights is only suitable for high-level study. For feasibility studies measurements should be taken at the weir locations.

7.1.3.2 Hydro-electric results

A total of 19 weir locations on the rivers Aire and Wharfe were considered. The river Wharfe has the theoretical potential for approximately 81 kW of hydropower and the river Aire approximately 277 kW. The total yield estimate is 2.3 GWh per year.

River	Number of hydro opportunities	Total estimated hydro capacity potential across all identified locations (kW)	Total estimated hydro generation potential across all identified locations (MWh/yr)
Wharfe	4	81	277
Aire	15	277	1980
Total	**19**	**358**	**2258**

Table 4: Hydro-electric potential in the LCC area

7.1.4 Hydrogen Production

The potential role of hydrogen in the UK and global energy system is widely debated. A recent publication by the London Energy Transformation Initiative[25] (a network of built environment professionals) points out that the use of hydrogen in a boiler (be it green or blue) has a substantially lower overall efficiency than using a heat pump even when the electricity is generated in a gas-fired power station. On the other hand, Northern Gas Networks and others have teamed up to form the H21[26] programme of projects seeking to demonstrate the technical viability of converting the existing gas network to operate with hydrogen. The H21 proposal is to produce blue hydrogen in Teesside which would then be supplied to the Leeds region.

As described in Section 4.4, the priority uses of hydrogen should arguably be those which cannot viably decarbonise by other means (e.g. high temperature industries). Given the low efficiency of hydrogen production, the most economically viable means of production may be to make use of surplus electricity at times when generation exceeds demand. In this context hydrogen effectively becomes a means of medium or long-term energy storage.

The analysis of energy storage opportunities described in Section 5 focusses on the use of batteries to provide energy storage for a period of a few hours. The analysis suggests that there may be a role for hydrogen (or other longer-term energy storage technologies) to provide up to around 3,500MWh of energy storage. This quantity might be provided by producing green hydrogen (using surplus electricity to electrolyse water) this could then be stored before being sent to uses such as:

- Electricity production (typically in fuel cells);
- High temperature industries (e.g. glass or steel manufacture);
- Haulage;
- Heat for hard-to-treat buildings in areas where district heat networks are unlikely to develop.

7.2 Thermal Renewable Technologies

The regional capacity for the listed thermal renewable technologies is influenced by a range of interacting complex factors; of primary interest is the available waste/feedstock streams that are suitable for each technology and how these might evolve in response to changing economic and policy landscapes.

The following sections summarise the potential electrical capacity of EfW, AD and biomass given their respective feedstock volumes available.

7.2.1 Energy from Waste

Developments in government recycling targets and in recycling technologies are expected to decrease the amount and types of materials sent for residual waste disposal, reducing overall residual waste tonnage.

[25] https://www.leti.london/_files/ugd/252d09_54035c0c27684afca52c7634709b86ec.pdf
[26] https://h21.green/

Figure 13 below illustrates the surplus EfW capacity in Leeds once the new EfW is commissioned in Skelton Grange (2025) and if government recycling targets are achieved by 2030. These figures are based on the DEFRA Waste Interrogator 2020 database[27].

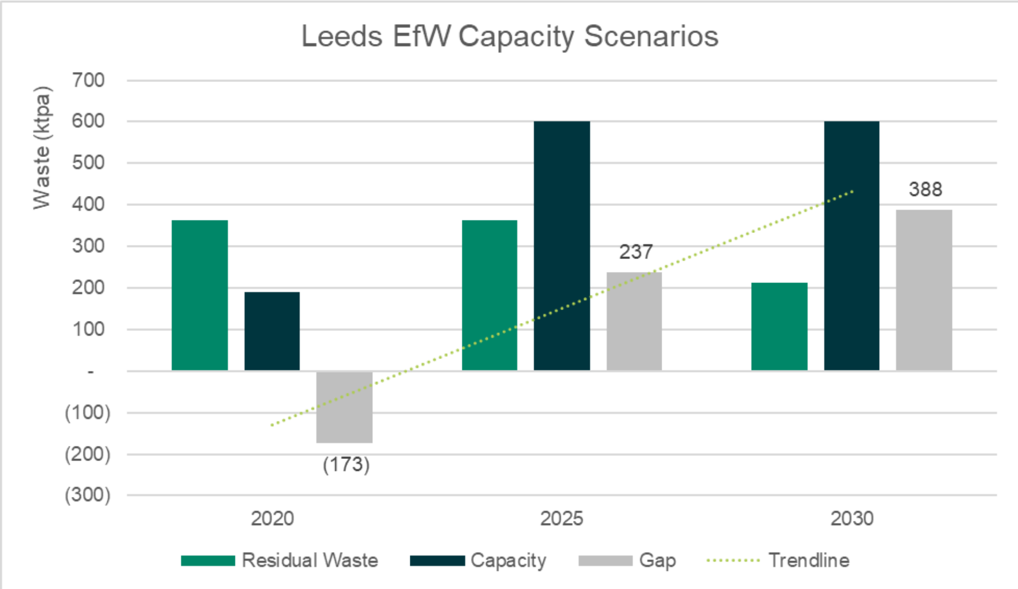

Figure 13: Scenarios for estimating capacity requirements for EfW treatment of household-like waste originating in Leeds. Waste Interrogator 2020

Assuming that the recycling target for municipal waste of 65% will be achieved against the existing recycling rate of 41% for LCC waste, municipal residual waste from the Leeds City Council area is estimated to decrease by 40-42%, from 189ktpa[28] to 111ktpa.

The capacity of the existing Leeds RERF is estimated at 200ktpa with a permit for 190ktpa of household-like waste using 2020 tonnage figures (insert ref). LCC waste made up 97% of this tonnage in 2020. This plant processes the domestic “black bin” waste from the LCC area.

155kt of non-hazardous waste originating in Leeds was sent for incineration at Ferrybridge in Wakefield in 2020.

A new 410ktpa capacity EfW has been granted planning permission in Skelton Grange. Given the scale of this plant’s capacity it is expected that some waste will be imported from outside the Leeds City Council Area as well as absorbing most/all remaining (non-domestic) waste streams in the LCC area.

Evolving energy policy means that over the coming years there is likely to be a greater amount of waste diverted to recycling and anaerobic digestion. The total quantity of waste may also be reduced by trends towards a more circular economy. All of this means that the quantity of waste available for EfW plants may reduce and the calorific value of the waste is likely to reduce.

Scenario		Municipal Solid Waste Stream (tonnes/yr)	(MWh/yr) [based on calorific value of 9MJ/kg]	(MWh/yr) [based on calorific value of 8MJ/kg]
Leeds RERF	2020 waste delivered	190,000	128,000	114,000
	2030 Incineration tonnes	111,000	75,000	66,000
Proposed Skelton Grange EfW permitted capacity		410,000	277,000	246,000
Total future capacity assuming both plants import waste to operate close to permitted capacity		**600,000**	**405,000**	**360,000**

Table 5: Summary of existing and potential EfW capacity in Leeds City Council area

[27] https://data.gov.uk/dataset/bb40d091-a346-4b75-aa54-df7d347bed93/2020-waste-data-interrogator
[28] DEFRA data shows that 189kt of waste was sent to the Leeds RERF in 2020.

The finding of this review feeds into the energy storage analysis described in Section 5. For the purposes of the energy storage analysis a figure of 360GWh/yr of electricity has been selected. This figure is selected on the basis that the one existing and one proposed EfW plants in the LCC area are projected to process more waste that the LCC area is likely to provide, and that waste will likely be imported to keep the two plants operating at capacity. In this context it is deemed undesirable to develop further EfW plants to further increase the need to transport waste from beyond the LCC boundary.

7.2.2 Anaerobic Digestion

Government policy aims to reduce the amount of food waste and to make separate collections mandatory for all English councils. This will increase the feedstock available for anaerobic digestion in Leeds as food waste is not collected separately from a majority of households.

The range of feedstock available in the LCC area for additional anaerobic digestion treatment is estimated to range from 13ktpa to 26ktpa.

Circa 52ktpa of food waste is estimated to have been incinerated at the Leeds RERF in 2020. Were this material to be separately collected at a capture rate of 50% this would equate to circa 26ktpa. A capture rate of 50% would be typical for food collection in a well-performing developed country.

UK government supports and is committed to meeting the UN Sustainable Development Goal (SDG) to reduce food waste by 50% by 2030[29]. Applying this 50% reduction in food waste generation at source, to the 26ktpa of food waste estimated above results in a projected future food waste stream equating to circa 13ktpa.

Three scenarios shown in Figure 14 illustrate the potential range of AD outputs of heat and electricity in the LCC area. The low scenario assumes a 50% reduction in food waste and a 50% capture rate. The high scenario assumes a 50% capture rate and no reduction in overall food waste volume. The medium is the average of the high and low scenarios. The conversion from tonnes of waste to thermal and electrical output are based on the following conversion factors:[30].

- Net electricity output 157kWh/t;
- Net heat output 261kWh/t.

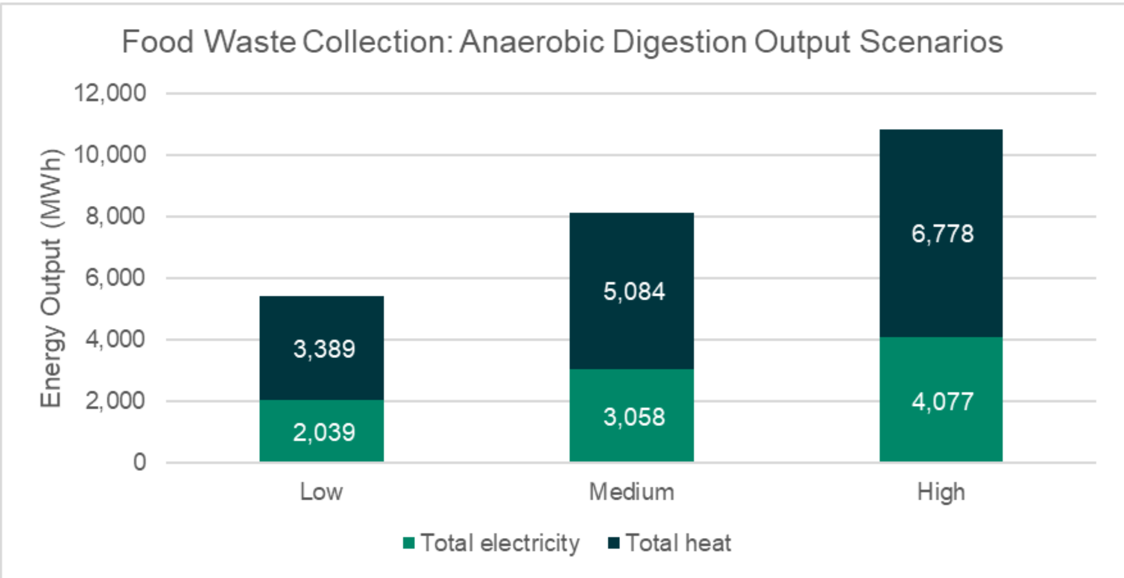

Figure 14: Estimated outputs of heat and electricity from separate collections of food waste in Leeds

[29] https://lordslibrary.parliament.uk/food-waste-in-the-uk/
[30] Banks, C.J., Heaven, S., Zhang, Y., Baier, U. (2018). Food waste digestion: Anaerobic Digestion of Food Waste for a Circular Economy. Murphy, J.D. (Ed.) IEA Bioenergy Task 37, 2018: 12

The finding of this review feed into the energy storage analysis described in Section 5. For the purposes of the energy storage analysis a figure of 3,058MWh/yr (equating to an average power output of 350kW) has been selected. This figure is selected as the energy storage analysis considers electrical energy storage only.

7.2.3 Biomass for Power

The potential capacity of electricity production from Biomass in the Leeds City Council area have been previously undertaken in the following previous studies:

1. AECOM, March 2011, *Low Carbon and Renewable Energy Capacity in Yorkshire and Humber*.
2. Weaver, C. Thomas, D. Yao, W. 2016, *What is the Biomass Resource Available to Leeds City Council, and how can its use be maximised?* University of Leeds.

Although both of these studies would benefit from being revised with up-to-date information they provide an estimate of the biomass resource within the region. Note that the work by Weaver *et al* is a summary of the work by Thomas[31] which describes the methodology adopted and which could be used as the basis of future work.

The results of the March 2011 AECOM study are summarised in Table 6, Table 7 and Table 8. Table 6 identifies the capacity in 2010/2011 with Table 7 and Table 8 providing a forecast of the electricity and heat potential.

	Biomass Energy Crop	Biomass Woodfuel	Biomass Agricultural Arisings (Straw)	Biomass Waste Wood	Total
Leeds City Council	-	0	0	-	0
Leeds City Region	-	8	7	-	15
Yorkshire & Humber	-	12	78	-	90

Table 6: Current (March 2011) Capacity (MW)

	Biomass Energy Crop	Biomass Woodfuel	Biomass Agricultural Arisings (Straw)	Biomass Waste Wood	Total
Leeds City Council	5.7	-	1.3	3.2	10.2
Leeds City Region	62	-	16	10	88
Yorkshire & Humber	185	-	93	17	295

Table 7: Potential Resource – Electricity (MW)

	Biomass Energy Crop	Biomass Woodfuel	Biomass Agricultural Arisings (Straw)	Biomass Waste Wood	Total
Leeds City Council	10.4	33.3	2.6	6.5	52.8
Leeds City Region	112	190	32	21	355
Yorkshire & Humber	335	364	185	33	917

Table 8: Potential Resource – Heat (MW)

The AECOM 2011 study did not account for arboricultural arisings from the pruning of trees etc. due to the difficulty in quantifying the resource and the logistical issues in sourcing. At the time of the study the largest

[31] Thomas D. Biomass Assessments for Local Planning Authorities – A Case Study with Leeds City Council.

biomass facility in operation was the 4.7MW_e system at John Smith's Brewery Tadcaster, Selby. This was supplied by spent grain and local wood chip.

The study went on to summarise the resource potential in the region as:

- 0.56 million tonnes of straw/annum which could support 93MW_e of installed capacity.
- 64,000 ha of energy crops (8,339 ha short rotation coppice and 55,832 ha miscanthus) producing approx. 1.1 million oven dried tonnes (odt) per annum. This could support 185 MW_e installed capacity. At the time of writing 1800 ha of energy crops planted in the region.
- 100,000 odt per annum of waste wood from the construction sector was assumed to be available by 2020 (assuming 50% of the available wood could be used for energy generation) supporting an estimated 17MW_e of generation capacity. This could also be supplemented by wood waste from the commercial and industrial sector mixed waste stream (estimated as 318,000 tonnes per annum in 2009[32]).
- The Forestry Commission estimated that 22,000 odt of wood fuel would be available from woodland management of both Commission and private sector holdings in the region by 2020. This was assumed from woodland of more than 2 ha but did not take account of the feasibility of extracting the wood. At the time the Forestry Commission had a contract to supply 100,000 tonnes of forestry residue to the 30MW_e biomass plant at Sembcorp, Wilton.

The study concluded that biomass had a significant potential in the region with few physical, environmental or planning factors that would impact its deployment. It also concluded that the resource is most likely to be located in the rural areas of the region i.e. around York and North Yorkshire where potential for energy crop on non-food producing land was possible.

The work by Weaver *et al* was focussed on the biomass wastes available to Leeds City Council. This was estimated to have a current (2016) biomass potential of 55,000 tonnes per annum (±8,000 tpa) equivalent to 2 MW_e (±0.7 MW_e). The future biomass potential was calculated to be 90 $\times 10^5$ tpa (± 9 $\times 10^5$ tpa) equivalent to 210 ±50 MW_e. These headline figures account for both woody and wet biomass and the study concluded that there was sufficient biomass resource available to Leeds City Council for both large- and small-scale energy production. The specific biomass potential from woody biomass is reproduced in Table 9.

Type of Waste	Source of Waste	Total Mass Available (tpa)	Mass Available for Bioenergy (tpa)	Energy on Burning (MJ/year)	Future Potential Mass (tpa)	Future Potential Energy on Burning (MJ/year)
Wood	Woodland Arisings	1900	1900±600	$(8\pm3)\times10^6$	$(6\pm2)\times10^3$	$(26\pm9)\times10^6$
	Arboricultural Arisings	3×10^3	$(3\pm1)\times10^3$	$(3\pm1)\times10^7$	$(3\pm1)\times10^3$	$(3\pm1)\times10^7$
	Construction Waste	7802	1400±300	$(10\pm1)\times10^7$	$(16\pm4)\times10^3$	$(24\pm7)\times10^8$
	Household Timber Waste	1×10^4	$(3\pm1)\times10^3$	$(4\pm2)\times10^7$	$(3\pm1)\times10^3$	$(4\pm2)\times10^7$
Totals		**23×10^3**	**$(9\pm3)\times10^3$**	**$(9\pm4)\times10^7$**	**$(28\pm8)\times10^3$**	**$(3\pm1)\times10^8$**

Note: Energy values are higher heating values

Table 9: Estimated Woody Biomass Waste Arisings & Energy Potential

Adopting these waste streams, the current (2016) power capacity was 1.0 ±0.3 MW_e with a future potential of 3.0 ±1.0 MW_e.

The authors estimated that in the foreseeable timeframe (2016 – 2020+) the available wood wastes would be limited to small-scale decentralised combustion systems as they considered the Veolia Energy Recovery facility

[32] Resource Efficiency Yorkshire

(13 MW_e EfW plant) sufficient for handling any surplus wood wastes without the need to construct additional large scale combustion plant.

Caveats within the report identified that future studies should account for the following aspects when reviewing available biomass resource:

- Quantification of omitted biomass resources including, food waste from council commercial outlets and council contracts.
- Identification of wastes produced by other organisations within the Leeds area.

In addition, the report did not take into account the potential for energy crops.

The Defra, December 2020 study[33], provides a recent assessment of land area under miscanthus and short rotation coppice cultivation. This is reproduced for Yorkshire & The Humber in Table 10 and Table 11.

	2010	2013	2016	2017	2018	2019
Total Area (ha)	2,100	2,039	1,779	1,598	1,614	1,910

Table 10: Total Area of Miscanthus, Yorkshire & The Humber

Miscanthus yields are quoted as ranging from 10 – 15 oven dried tonnes/ha. This assumes that the region will produce 19,100 – 28,650 odt. At an energy content of 17 MJ/kg (dry basis)[34] giving 324,700 – 487,050 GJ/y.

	2010	2013	2016	2017	2018	2019
Total Area (ha)	911	743	601	540	506	433

Table 11: Total Area of Short Rotation Coppice, Yorkshire & The Humber

Short Rotation Coppice yields are estimated to vary between 8 – 17.5 odt/ha/y but no official figure is available due to the variability in yield caused by planting timescales, site conditions, planting method, crop type and regional variations. Using these values, the region could be expected to produce 3,464 – 7,577.5 odt/y. At 16 GJ/odt[35] this is equivalent to 55,424 – 121,240 GJ/y.

The UK Government's Biomass Policy Statement states that the forthcoming Biomass Strategy (due for issue late 2022) will review the availability of biomass resource for the UK market.

The finding of this review feed into the energy storage analysis described in Section 5. For the purposes of the energy storage analysis a figure of 3.0MW_e has been selected. This figure is taken from the Weaver, Thomas, Yao, 2016 report and reflects the projected future electrical capacity from waste biomass energy streams in the Leeds City Council area. This value has been selected on the basis that the use of waste biomass rather than purpose grown biomass is preferable and that the large-scale transportation of fuel from outside of the council area is undesirable.

[33] Defra, Crops Grown for Bioenergy in the UK: 2019, Published 10th December 2020
[34] Defra, Miscanthus: Planting and Growing. Available at http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000IL3890W.18LWUY6C9703FC
[35] NNFCC, 2010, Crop Fact Sheet – Short Rotation Coppice Willow (SRC). Available at https://www.nnfcc.co.uk/files/mydocs/SRC%20-%20Nov%202010.pdf

Appendix A Wind & Solar Farm Opportunity Areas Mapping Method

The table below sets out the factors and constraints accounted for in creating the wind and solar farm opportunity area maps, under scenario 3. Scenario 2 uses all the same exclusions as scenario 3, but also excludes greenbelt land from the opportunity areas. Scenario 1 uses the same exclusions as scenario 3, but then further restricts the opportunity areas to brownfield land only.

	Category	Feature Class Name	Source	Wind	Solar
Physical	Highways, Rail and PROW	Railway	https://osdatahub.os.uk/downloads/open/OpenMapLocal?_ga=2.172374433.363488328.1652791137-467544382.1646229763	Exclude 75m buffer	Exclude 10m buffer
		RoadLink_Clip	https://osdatahub.os.uk/downloads/open/OpenRoads		
		Def_Paths	https://data.gov.uk/dataset/f3233ce2-1fe6-4b86-88f4-40b31710a874/leeds-public-rights-of-way	Exclude 3m buffer	Exclude 3m buffer
	Archaeology, Battlefields, Listed Buildings	Listed_Buildings	https://historicengland.org.uk/listing/the-list/data-downloads/	Exclude 75m buffer	Exclude 10m buffer
		Battlefields_Clip			Exclude no buffer
		WorldHeritageSites_Clip			
		ScheduledMonuments_Clip			
		Parks and Gardens			
		Leeds_Conservation_Areas_28_10_20	https://data.gov.uk/dataset/ad428d72-2635-41e0-8e42-873f682e1fd6/leeds-conservation-areas		
	Future developments	ELA_base_sites	Leeds City Council	Exclude no buffer	
		HSG_base_combined			
	HS2	INFRA_HS2_SAFEGUARDED_AREA	Leeds City Council		
	Airports	Leeds_Bradford_Airport	Leeds City Council	Exclude 6km buffer	
	Helipads	Helipad	Helicopter Landing Sites (U.K.) – Google My Maps: https://www.google.com/maps/d/viewer?msa=0&ll=53.85722339961094%2C-1.4622694764644284&spn=8.678373%2C25.466309&mid=1-wqhMTo7feJ-GpeRU3tDlAmdgeq&z=10 Maps - UK Airfields: http://www.ukairfields.org.uk/maps.html	Exclude 1km buffer	NA to map (No exclusion)
	Proximity to users and receptors	Residential	Leeds City Council	Exclude 400m	Exclude 10m
		PopDLess2000_PV	https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/lowersuperoutputareapopulationdensity	exclude > 2000people/km2	Exclude > 2000people/km2
Environmental	Agricultural	Agricultural_Land_Clasification_Post1988	https://naturalengland-defra.opendata.arcgis.com/datasets/Defra::agricultural-land-classification-alc-grades-post-1988-england/about	Exclude 1-3a with no buffer	Exclude 1-3a with no buffer

Category	Feature Class Name	Source	Wind	Solar
Trees and Ancient Woodland	Ancient_Woodland_Clip	https://naturalengland-defra.opendata.arcgis.com/datasets/Defra::ancient-woodland-england/about	Exclude 75m buffer	Exclude with no buffer
	LeedsCityCouncil_TPOs	https://data.gov.uk/dataset/f367f7c9-52b3-4845-a22e-9410317b8442/tree-preservation-orders	Exclude 15m buffer	Exclude 15m buffer
	ECO_TPO_LIVEVIEW	Leeds City Council		
Impacts on Biodiversity & Habitat Loss	SAPAVL_Greenspace_Clip	Leeds City Council	Exclude with no buffer	Exclude with no buffer
	Special_Protected_Areas_Clip	https://data.gov.uk/dataset/174f4e23-acb6-4305-9365-1e33c8d0e455/special-protection-areas-england	Exclude with no buffer	Exclude with no buffer
	Special_Areas_of_Conservation	https://data.gov.uk/dataset/a85e64d9-d0f1-4500-9080-b0e29b81fbc8/special-areas-of-conservation-england		
	SSSI_England	https://naturalengland-defra.opendata.arcgis.com/datasets/Defra::sites-of-special-scientific-interest-units-england/about		
	National_Parks_Clip	https://naturalengland-defra.opendata.arcgis.com/datasets/d333c7529754444894e2d7f5044d1bbf/explore?location=52.933359%2C-1.078352%2C6.76		
	National_Nature_Reserves	https://naturalengland-defra.opendata.arcgis.com/datasets/Defra::national-nature-reserves-england/about		
	Local_Nature_Reserves_Clip	https://naturalengland-defra.opendata.arcgis.com/datasets/Defra::local-nature-reserves-england/about		
Floods	Floodzone_3a_i_HighProbabality_Clip	Leeds City Council	Exclude no buffer	Exclude no buffer
	Floodzone_3a_ii_HighProbabality_Clip			
	Floodzone_3b_Functional_Floodplaine_Clip			
Landscape Character	Landscape_Types - exact same as PDF landscape character areas	Leeds City Council	Details are given below	Details are given below
RSPB	RSPBAvianRecords_LCC	RSPB via Leeds City Council	Exclude no buffer	NA to map (No exclusion)
NW Leeds, east of Hawksforth Moor	NW_LCC	Advised by the council to exclude this area for wind	Exclude no buffer	NA to map (No exclusion)
Windspeed	Windspeed	Leeds City Council	Exclude <5m/s @45m - Leeds is all above this threshold	NA to map (No exclusion)
Settlement Hierarchy	LDF_SETTLEMENT_HEIRARCHY	Leeds City Council	Exclude no buffer	Exclude no buffer

Table 12: Overview of layers added to the wind and solar maps shown in Section 3

The Leeds City Council Landscape Character Assessment map[36] was used to exclude particular areas of land for the wind and solar maps. The wind maps excluded the following landscape types:

- River gorge
- River valley
- Urban fringe parkland
- Wooded escarpment
- Wooded parkland
- Wooded plateau edge valleys.

The solar maps all excluded:

- Encapsulated countryside
- Gritstone moorland
- Pastoral escarpment
- River gorge
- Urban fringe parkland
- Wooded escarpment
- Wooded parkland
- Wooded plateau edge valleys.

The mapping method outlined above accounts for many of the constraining factors which limit the development of wind and solar PV farms. However, there are several other constraints which are too complex to include in this type of strategic-level analysis, which nevertheless should be considered when developing proposals for these development types. For example, electromagnetic interference from wind turbines can affect radar and communication equipment such as that found at airfields. The constraints to wind farm development caused by the need to mitigate electromagnetic interference has not been included in this mapping exercise because the degree of interference is dependent on several wind farm-specific factors such as:

[36] Landscape Character Assessment page 21: https://www.leeds.gov.uk/docs/1%20Parts%201-3%20reduced.pdf

- Turbine height;
- Turbine design (different models will produce varying levels of interference potential);
- Exact location of wind turbine relative to the topology;
- Sensitivity of the specific radar equipment in use in the area and it's exact location.

Similarly, the capacity of the local electricity grid is a key influencing factor in determining a site's suitability for wind and solar farms. This factor has not been included in this analysis because:

- Grid capacity changes over time as the DNO and National Grid develop and modify the infrastructure and as the demands of other electricity users and generators changes.
- It is always technical possible to provide a suitable grid connection, however the cost of providing this can vary greatly. Where the existing infrastructure is close to the site and has sufficient spare capacity, the cost of connection can be small, however where the required connection requires extensive network upgrades extending over large distances the cost of connection can easily be several million pounds. This constraint is not principally a matter for the planning officers but rather for the developer and the DNO/National Grid to resolve. If the cost of connection is too high, the site may not be developed economically.