Garden City Standards for the 21st Century

Practical Guides for Creating Successful New Communities

guide 4

masterplanning for net-zero energy

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Guide 4: Masterplanning for Net-Zero Energy

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The Lady Margaret Paterson Osborn Trust

CATAPULT Energy Systems

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The TCPA Practical Guides

Across the UK there is a shortage of housing, and it is increasingly understood that we need to plan and build new large-scale developments, in addition to renewing existing towns and villages. At the same time, many people worry that any new places built will be no more than soulless, unattractive dormitory suburbs. How can we prevent such outcomes? How can we ensure that new large-scale developments become socially and economically successful places – places that will improve over time, and in which people will want to live for generations to come? The answer lies in the Garden City development model – a proven way of funding, creating and maintaining successful high-quality places. A true Garden City is a place created following the Garden City Principles, set out in the box below.

National planning policy guidance on a range of issues has been greatly reduced, so practical advice about how to create successful new places is more important than ever. The Guides – on location and consent; finance and delivery; design and masterplanning; masterplanning for net-zero energy; homes for all; planning for arts and culture; planning for green and prosperous places; creating health-promoting environments; long-term stewardship; 'edible' Garden Cities; people, planning and power; modern methods of construction; and sustainable transport – are not detailed handbooks but instead set out the scope of opportunities for ambitious councils who want to create high-quality, large-scale new developments, whether or not they are able to follow all the Garden City Principles. The Guides highlight key points for consideration and offer signposts to sources of further detailed information. They are 'living' documents that will be periodically updated to reflect key policy changes. Although they are focused on policy in England, the principles and key recommendations can be applied across the UK. The Practical Guides will help anyone attempting to create great places, for everyone, whether or not they describe what they are trying to achieve as a 'Garden City'.

The Garden City Principles

A Garden City is a holistically planned new settlement that enhances the natural environment and offers high-quality affordable housing and locally accessible work in beautiful, healthy and sociable communities. The Garden City Principles are an indivisible and interlocking framework for delivery, and include:

- Land value capture for the benefit of the community.
- Strong vision, leadership and community engagement.
- Community ownership of land and long-term stewardship of assets.
- Mixed-tenure homes and housing types that are genuinely affordable.
- A wide range of local jobs in the Garden City within easy commuting distance of homes.
- Beautifully and imaginatively designed homes with gardens, combining the best of town and country to create healthy communities, and including opportunities to grow food.
- Development that enhances the natural environment, providing a comprehensive green infrastructure network and net biodiversity gains, and that uses zero-carbon and energy-positive technology to ensure climate resilience.
- Strong cultural, recreational and shopping facilities in walkable, vibrant, sociable neighbourhoods.
- Integrated and accessible transport systems, with walking, cycling and public transport designed to be the most attractive forms of local transport.

The TCPA has produced an extensive set of policy and practical resources on Garden Cities, which can be found at http://www.tcpa.org.uk/pages/garden-cities.html

Summary

Garden Cities are exemplars of sustainable living, and as such they must deal with the overwhelming challenge of climate change. It is hard to overemphasise the degree to which climate change affects every aspect of planning for new and renewed places. Garden Cities offer a unique opportunity to deliver net-zero (i.e. net-zero greenhouse gas emissions) or energy-positive development, and they must cope with the impacts of changes to the global climate that have already been set in motion, including increased risk of flooding and overheating.

Responses to the multiple impacts of climate change need to be embedded in design and delivery approaches right from the very conception of a new community. Reducing carbon dioxide emissions remains the key priority for our collective future, and decentralised and community-owned energy generation, based on a model familiar in other parts of Europe, as well as helping to meet this aim, can also offer long-term income streams to help fund the wider enterprise of place-making.

Garden cities and suburbs should be designed to make a sufficient contribution to keeping global warming to below 1.5°C – they should be net zero from the outset. Garden Cities should also be designed to withstand, as far as possible, global warming of at least 3°C – it would be exceptionally risky to do otherwise.

This Practical Guide focuses on mitigating climate change, and outlines how large-scale new development being brought forward can be in line with the UK's carbon dioxide emissions targets. It considers headline issues in planning for renewable energy, provides an overview of energy planning principles, and signposts policy resources produced by other organisations. Its three main messages are:

- New Garden Cities can be and must be exemplars of how to plan energy-efficient, smarter, net-zero communities.
- Some of the key building blocks in meeting this aim will be better building fabric and advanced control, alongside the right infrastructure and heat system generation and storage technologies.
- If Garden Cites are to serve as exemplars, a whole-system, integrated approach must be taken to energy planning and spatial planning, and a net-zero strategy should developed.

In producing this Practical Guide the TCPA has partnered with Energy Systems Catapult, which has been pioneering work in energy masterplanning through its development, demonstration, policy and regulatory support in relation to 'local area energy planning' (LAEP). This Practical Guide – part of a series on creating successful new communities (available from the TCPA website, at **https://www.tcpa.org.uk/guidance-for-delivering-new-garden-cities**) – is intended not just for developers and planners, but also for those who will manage new settlements and work with new communities.

Stop press...

During the production of this Practical Guide the government announced, through its *Planning for the Future White Paper*, major plans to rewrite the English planning system. However, any changes resulting from these plans will take time to implement, and in the meantime the current system will continue to be used to deliver high-quality places. In any event, the principles of energy planning set out in this Practical Guide apply equally to the creation of masterplans under the current system or under a more codified and zonal approach.

1 Introduction

1.1 The climate challenge

The impacts of the climate crisis are intensifying. Severe weather events such as intense rainfall, flash-flooding, droughts and heatwaves are fast becoming the new norm, and their frequency and severity will only increase in future. In 2020, Storm Ciara, dubbed 'the biggest storm this century' by the Met Office, battered most of the UK, bringing 97 mph winds and widespread flooding as 177 millimetres of rainfall fell in as little as 24 hours[1] and 675,000 homes were left without power.[2]

The UK will experience the impacts of sea level rise, with devastating consequences for some coastal communities, while extreme rainfall will lead to flash-flooding and fluvial flooding inland. Higher temperatures during the summer months will lead to more frequent droughts, posing significant risks to people's health and wellbeing.[3]

Global average temperatures are already 1°C higher than they were in pre-industrial levels, and this increase is likely to reach 1.5°C between 2030 and 2052.[4] In 2018, the Intergovernmental Panel on Climate Change (IPCC) announced that there were only 12 years remaining to stabilise the global temperature at less than 1.5°C above pre-industrial levels[5] – beyond which there are growing risks of catastrophic and irreversible global impacts. Even if this target is reached, there will still be significant impacts through severe weather incidents and sea level rise.

The urgency of the threat facing humanity, and the now almost unequivocal acceptance of the risks across business, society, governments and academia, are key reasons why the United Nations Conference on Climate Change in Paris in December 2015 resulted in an unprecedented agreement among the 195 nations represented that action on climate change must accelerate. The Paris Agreement was clear on both the goal and the urgency required to meet it. Key commitments included:

- Holding the increase in global temperature to well below 2°C above pre-industrial levels, and pursuing efforts to limit the increase to 1.5°C.
- Requiring Parties to the Agreement to reach a peak point in greenhouse gas emissions as soon as possible, and to undertake rapid reductions thereafter.

The Paris Agreement represents an enormous challenge in delivering a rapid transition away from fossil fuel use, but it is already encouraging much greater investment in renewable energy.

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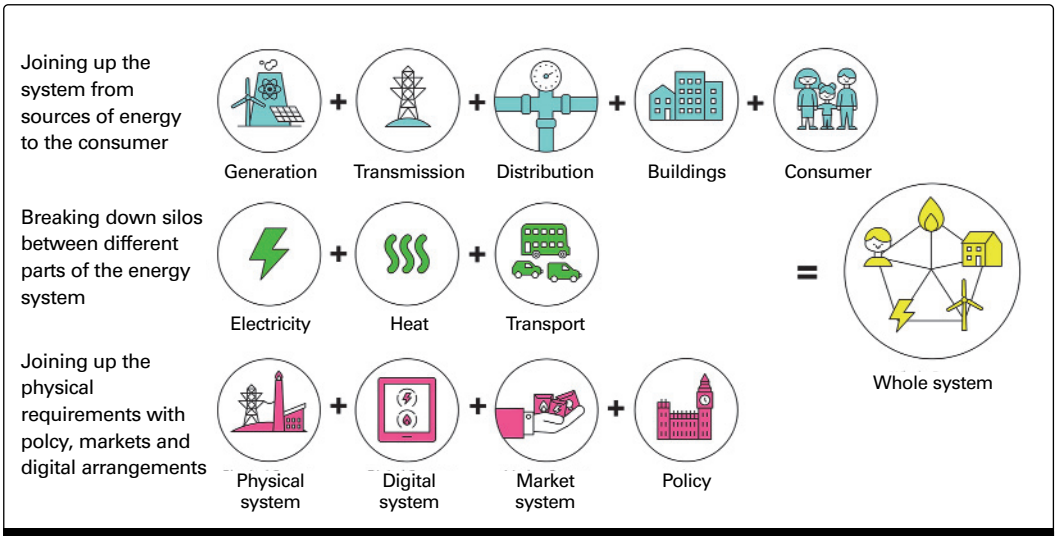
1 'Storm Ciara'. Webpage. Met Office. **https://www.metoffice.gov.uk/weather/warnings-and-advice/uk-storm-centre/storm-ciara**

2 'Storm Ciara: Floods and travel disruption as UK hit by severe gales'. *BBC News*, 9 Feb. 2020. **https://www.bbc.co.uk/news/uk-51425482**

3 *UK Climate Change Risk Assessment 2017. Synthesis Report: Priorities for the Next Five Years*. Committee on Climate Change, Jul. 2016. **https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Synthesis-Report-Committee-on-Climate-Change.pdf**

4 V Masson-Delmotte, *et al.*: *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Summary for Policymakers*. Intergovernmental Panel on Climate Change, Oct. 2018. **https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf**

5 *Ibid*.



Elements of a whole-system approach
Source: Energy Systems Catapult

If we are to limit global warming to 1.5°C, energy, land, infrastructure (including transport and buildings) and industrial systems will need to be rapidly and radically transformed, with fundamental emissions reductions in all sectors. This will require a wide portfolio of mitigation options and a significant upscaling of investments in those options.[6] It is still possible to limit global warming to 1.5°C if countries across the world act fast enough. However, at the time of writing, the pledges by individual nations are sufficient only to limit global warming to 3°C[7] – well beyond what the latest scientific consensus believes is safe. In this context, planners and designers of Garden Cities and new settlements should work to the strong assumption that global temperature increases are likely to be well in excess of 3°C (possibly as much as 5°C[8]), and should aim to ensure that places will be sufficiently resilient to the predicted climate impacts.

Guidance on how best to plan for climate change at the local level is set out in the joint TCPA and RTPI document *Rising to the Climate Crisis: A Guide for Local Authorities on Planning for Climate Change*.[9]

1.2 The Garden City opportunity

Planning for new and renewed communities has a vital role to play in dealing with climate change – by delivering renewable energy systems; ensuring that there are high levels of

6 V Masson-Delmotte, *et al.*: *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Summary for Policymakers*. Intergovernmental Panel on Climate Change, Oct. 2018. **https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf**

7 *Ibid*.

8 T Miles: 'Global temperatures on track for 3-5 degree rise by 2100: U.N.'. News Article. Reuters, 29 Nov. 2018. **https://www.reuters.com/article/us-climate-change-un/global-temperatures-on-track-for-3-5-degree-rise-by-2100-u-n-idUSKCN1NY186**

9 *Rising to the Climate Crisis: A Guide for Local Authorities on Planning for Climate Change*. Town and Country Planning Association/Royal Town Planning Institute, Dec. 2018. **https://www.tcpa.org.uk/Handlers/Download.ashx?IDMF=fd66dbe5-2b88-4acf-b927-256a82db9abe**

Integrating solar photovoltaic installations with the building fabric in Letchworth Garden City

energy efficiency in buildings; implementing sustainable transport systems; and implementing a whole range of resilience measures, from strategic flood defences to green infrastructure for urban cooling. Above all, planning can take the long view, not just addressing the needs of today but also preparing for a changing climate, looking 50 and 100 years ahead.

New Garden Cities must be beacons of best practice in delivering smart, energy-positive systems as part of the wider energy system – creating communities that are environmentally, socially and economically sound. Garden Cities provide a unique opportunity to deliver energy-positive communities, thus helping to mitigate the carbon footprint of nearby existing housing stock. They should draw on the latest advances in technologies in the UK and around the globe, using digital technology, data and better building fabric to achieve, at the very least, net-zero energy use (i.e. produce net-zero greenhouse gas emissions). To attain this, carbon awareness – a consideration of the relationship between development decisions, energy use, and carbon dioxide emissions – should be high throughout the entire planning and design process.

A major advantage of the Garden City approach is that net-zero solutions can be laid down across a whole town in an integrated, whole-system approach, so that individual buildings can be incorporated within combined solutions, rather than being developed in isolation, with individual feasibility studies. As new, linked settlements with a good range of associated facilities (including schools, community and commercial buildings, and public and green spaces), new Garden Cities provide the scope and scale to allow developers to convert innovation into cost-effective products and become leaders in the net-zero housing market. The Ministry of Housing, Communities and Local Government's *Garden Communities* prospectus outlines how Garden Cities must be future-proofed, and requires that their masterplanning 'should include anticipation of the opportunities presented by technological change such as … renewable energy measures'.[10] The Homes England Garden Communities toolkit contains further guidance on designing for the future and preparing a masterplan.[11]

10 *Garden Communities*. Ministry of Housing, Communities and Local Government, Aug. 2018. **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/805688/Garden_Communities_Prospectus.pdf**

11 *Garden Communities Toolkit*. Homes England, Sept. 2019. **https://www.gov.uk/guidance/garden-communities**

2 Policy context

There are international and national polices for carbon dioxide emissions reduction and energy planning, but the current energy and planning policy framework in England is fluid, with many policies changing and little short-term certainty. There remains uncertainty over the UK's alignment with EU policy on carbon dioxide emissions reduction and energy production post-Brexit – this applies both to spatial planning policy and to the regulations and market mechanisms in wider energy policy.

Local authorities have a responsibility to help to secure the progress on meeting the UK's emissions reduction targets, both through direct influence on energy use and emissions (by, for instance, encouraging renewable energy and promoting low-carbon modes of travel) and by bringing others together and encouraging co-ordinated local action. At the time of writing this Practical Guide, over 80%[12] of local authorities in the UK had officially declared a 'climate emergency', pledging their commitment to tackling climate change at a local level.

2.1 Carbon dioxide emissions reduction targets

The United Nations Framework Convention on Climate Change unequivocally states that limiting global temperature increases to 1.5°C would significantly reduce the risks and impacts of climate change.[13] This statement is stronger than the UK's recent amendment of the Climate Change Act 2008, which commits the country to reducing carbon dioxide emissions to net zero by 2050 – some campaigners warn that such a target is still too low to prevent catastrophic climate change.[14] To meet the net-zero target by 2050, the government has set five-yearly carbon budgets (see Table 1), which currently run until 2032.

In December 2020, the Committee on Climate Change (CCC) is due to advise the UK government on the level of the sixth carbon budget (2033-2037), which will be the first

Table 1 The five carbon budgets required under the Climate Change Act 2008

Budget	Carbon budget, Metric tons of carbon dioxide equivalent	Reduction below 1990 levels, %
First carbon budget (2008-2012)	3,018	25
Second carbon budget (2013-2017)	2,782	31
Third carbon budget (2018-2022)	2,544	37 by 2020
Fourth carbon budget (2023-2027)	1,950	51 by 2025
Fifth carbon budget (2028-2032)	1,725	57 by 2030

12 *List of Councils Who Have Declared a Climate Emergency*. Climate Emergency UK, 2020. https://www.climateemergency.uk/blog/list-of-councils/

13 The Paris Agreement. United Nations Framework Convention on Climate Change, Jan. 2016. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

14 P Weston: 'Zero carbon 2050 pledge is too slow to address catastrophic climate change, campaigners warn'. *The Independent*, 12 Jun. 20019. https://www.independent.co.uk/environment/climate-change-uk-2050-net-zero-carbon-climate-change-act-a8955796.html

carbon budget set in line with the new net-zero target.[15] By the end of June 2021, the government will legislate a sixth carbon budget.[16]

The CCC says that 'meeting the 2050 target will require that emissions from energy use – power, heat and transport – are almost eliminated'.[17] Short-term policy on climate change currently suffers from uncertainty; but the long-term direction should be very clear. Reaching net-zero emissions requires an annual rate of emissions reduction that is 50% higher than under the UK's previous 2050 target and 30% higher than has been achieved on average since 1990,[18] underlining the level of change needed. Given that the average lifespan of a development is taken to be 100 years, new Garden Cities will last for many decades and must be planned to be net zero in all aspects from the outset – or risk extremely expensive retrofitting costs in decades to come.

In May 2019, the CCC recommended to the government that a net-zero greenhouse gas target for 2050 should deliver on the commitment that the UK made by signing the Paris Agreement. In June 2019, this target was legislated by the UK government, with the Climate Change Act 2008 amended to reflect this. In the report *UK Housing: Fit for the Future?*[19] the CCC stated that all new homes must be built to be 'low-carbon, energy and water efficient and climate resilient', and claimed that 'the costs of building [to achieve this aim] are not prohibitive, and getting design right from the outset is vastly cheaper than forcing retrofit later', arguing that 'from 2025 at the latest, no new homes should be connected to the gas grid'.

The CCC's most recent carbon emissions reductions progress report, published in June 2020,[20] warned that current government policy on carbon reduction does not 'measure up to meet the size of the Net Zero challenge'. The report highlights key potential roles for local authorities and network operators in driving early planning and progress, if backed with necessary resources. It also recognises a key role for local authorities in relation to enforcing regulation, delivering low-carbon public housing, and ensuring that new developments are assessed from the perspective of wider local services (for example public transport). The report also recommends that local authorities play a key role in local area energy planning.

2.2 National law on climate change mitigation

The energy and planning policy environment has been a confusing and contradictory area over the last ten years. In particular, a number of decisions have set back the UK's progress to net zero significantly:

- the removal of support for the development of new onshore wind turbines;
- the abandonment of the zero-carbon commitment for domestic buildings;
- the abandonment of the Code for Sustainable Homes; and
- reductions in the subsidies for renewable technologies.

15 'CCC to publish Sixth Carbon Budget in September 2020'. News Story. Committee on Climate Change, Oct. 2019. **https://www.theccc.org.uk/2019/10/17/ccc-to-publish-sixth-carbon-budget-in-september-2020/**

16 '2020 Progress Report to Parliament – your questions answered'. Webpage. Committee on Climate Change, Jul. 2020. **https://www.theccc.org.uk/2020/07/17/2020-progress-report-to-parliament-your-questions-answered/**

17 *Sectoral Scenarios for the Fifth Carbon Budget. Technical Report.* Committee on Climate Change, Nov. 2015. **https://www.theccc.org.uk/publication/sectoral-scenarios-for-the-fifth-carbon-budget-technical-report/**

18 *Reducing UK Emissions: 2019 Progress Report to Parliament.* Committee on Climate Change, Jul. 2019. **https://www.theccc.org.uk/publication/reducing-uk-emissions-2019-progress-report-to-parliament/**

19 *UK Housing: Fit for the Future?* Committee on Climate Change, Feb. 2019. **https://www.theccc.org.uk/publication/uk-housing-fit-for-the-future/**

20 *Reducing UK Emissions: Progress Report to Parliament.* Committee on Climate Change, Jun. 2020, p.13. **https://www.theccc.org.uk/publication/reducing-uk-emissions-2020-progress-report-to-parliament/**

In consequence, a significant issue now facing planners and communities in England is how to respond to today's challenging policy environment for energy planning. The TCPA and partners have been examining the remaining legal duties on spatial planning regarding climate change mitigation, and in particular Section 19 of Planning and Compulsory Purchase Act 2004 (as amended), which sets out the following powerful requirement:

> *'(1A) Development plan documents must (taken as a whole) 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.'*

This obligation – introduced through the Planning Act 2008 alongside the Climate Change Act 2008 – makes climate mitigation and adaptation central principles of plan-making.

Plan policies must be 'designed to secure' the outcomes in question, which requires a number of things in practice. In respect of emissions ('mitigation'), these requirements include:

- a robust assessment of the potential for local policy to achieve local emissions reductions over the plan period, taking into account the UK's net-zero commitment under the Climate Change Act 2008;
- a local target set in accordance with that potential;
- an assessment of proposed policies' consistency with that target; and
- a monitoring framework that uses relevant indicators to track the performance of adopted policies (i.e. reporting at least annually as part of the Annual Monitoring Report process).

2.3 National planning policy on climate change mitigation

The National Planning Policy Framework (NPPF) sets out the key national planning priorities for England.[21] It is non-statutory guidance and is a material consideration in plan-making and development management decisions. The NPPF, revised in July 2018 (with minor updates in February 2019), is accompanied by online Planning Practice Guidance.

Paragraph 148 of the NPPF underlines that tackling climate change is central to the economic, social and environment dimensions of sustainable development. Paragraph 149 and accompanying footnote 48 set out an expectation that local planning authorities will adopt proactive strategies to mitigate and adapt to climate change, in line with the Climate Change Act 2008 and Section 19 of the 2004 Planning and Compulsory Purchase Act. This has the effect of making the objective of at least a 100% reduction in carbon dioxide emissions (net zero) by 2050 clearly relevant to the discharge of the duty on planning authorities to shape policy which reduces carbon dioxide emissions.

As a result, local planning authorities will need a clear grasp of their carbon profile, and their policy should support ***radical*** reductions in carbon dioxide emissions.

Paragraph 8 of the NPPF makes clear that 'mitigating and adapting to climate change' is a core planning principle. To be in conformity with the NPPF, Local Plans should reflect this principle, ensuring that planning policy clearly and comprehensively deals with climate change mitigation and adaptation. The NPPF also highlights climate change as a key part of strategic planning policy which local authorities are legally obliged to set out in their Local Plans (see paragraph 20 and footnote 12 of the NPPF).

21 *National Planning Policy Framework*. CP48. Ministry of Housing, Communities and Local Government, Feb. 2019. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6077/2116950.pdf

2.4 Working within the legal and policy environment in England

How then should decision-makers approach the issue of carbon dioxide emissions reduction? Parliament has made it clear that climate change is a pre-eminent policy consideration in the preparation of Local Plans. The requirement of the Section 19 duty is to contribute to mitigation and adaptation. The NPPF reflects this duty by asking for radical reductions in greenhouse gas emissions and by linking the provisions of carbon reduction strategies to the targets of the Climate Change Act. This must mean that each Local Plan should have a carbon reduction strategy which is 'in line with' the Climate Change Act. Given the weight and clarity of these provisions, they cannot be overturned simply by arguments about viability, which are represented only in policy. Even if individual policies on carbon dioxide emissions reduction may be found unsound on viability grounds, the Planning Inspectorate should not approve a Local Plan unless its policies, taken together, clearly meet the Section 19 duty and NPPF policy.

Despite the uncertain policy environment, the development and declining installation costs of technologies such as photovoltaic systems make renewable energy options viable without subsidy. The development of Garden Cities offers the vital scale factor that can reduce installation costs for comprehensive rooftop deployment and for large, stand-alone renewable energy equipment.

The CCC's latest progress report[22] recommends that local authorities play a key role in local area energy plans. Local area energy planning was pioneered by Energy Systems Catapult to help inform and support local authorities, distribution network operators, businesses and communities in planning for a cost-effective low-carbon transition to achieve net-zero energy use.[23] ESC has been working with Ofgem and the Centre for Sustainable Energy to develop guidance[24] to support the development of consistent, robust and transparent local area energy plans and encourage the development and application of transparent and consistent methodological approaches across industry. local area energy planning can support investment decisions by identifying a set of feasible decarbonisation pathways for an area, leaving space for their delivery through appropriate market or funding arrangements. It can act as an accelerator for the transition by increasing confidence in the 'direction of travel' for network infrastructure and downstream technology options, allowing businesses to develop investable solutions and consumers to gain greater understanding of what a net-zero future can mean for them. Innovative concepts currently under development, such as 'smart' local energy systems,[25] can also play a role in unlocking opportunities through a better understanding of local systems and decarbonisation options.

A Garden City net-zero energy masterplan should fit within the wider local area energy plan and network investment plans, which, in turn, should be developed in the context of the wider national energy strategy and other related policies.

Recommendation	**Garden Cities should exploit the commercial opportunities for the design and delivery of net-zero, smart local energy systems.**

22 *Reducing UK Emissions: Progress Report to Parliament*. Committee on Climate Change, Jun. 2020. **https://www.theccc.org.uk/publication/reducing-uk-emissions-2020-progress-report-to-parliament/**

23 'Local Area Energy Planning: Supporting clean growth and low carbon transition'. Webpage. Energy Systems Catapult, Dec. 2018. **https://es.catapult.org.uk/reports/local-area-energy-planning/**

24 *Local Area Energy Planning: The Method*. Final Review Draft. Centre for Sustainable Energy and Energy Systems Catapult, for Ofgem, Jul. 2020. **https://es.catapult.org.uk/wp-content/uploads/2020/08/LAEP-method-final-review-30-July-2020.pdf**

25 See Energy Systems Catapult's 'Overview of PFER consortia projects' webpage, at **https://erishub.com/projects/**

Box 1
Forthcoming policy announcements relating to energy

UK energy and environmental policy is undergoing significant change. *The Government Response to the Committee on Climate Change's 2020 Progress Report to Parliament*[i] suggests that major strategy documents will be published in late 2020/early 2021, including:

- an Energy White Paper, focusing on energy system transformation, skills, and resilient economic growth;
- a National Infrastructure Strategy, detailing the government's long-term ambitions, including on decarbonisation and adaptation;
- a Transport Decarbonisation Plan, setting the government's ambition to cut greenhouse gas emissions across the entire transport system;
- a Heat and Building Strategy, setting out the immediate actions that government plans to take to reduce emissions from the current building stock, as well as indicating the strategic direction for wide policy framework development; and
- an interim report from the Treasury's Net Zero Review, considering how the transition to net zero will be funded, and reviewing the distribution of costs between households, businesses, and taxpayers.

The publication of a Net Zero Strategy is also expected ahead of COP26 (the 26th UN Climate Change Conference, scheduled for November 2021), to provide an overview of the government's vision for transitioning to a net-zero economy while unlocking economic growth and employment opportunities.

At the time of writing there is limited detail on these strategies, but wide range of policy change is likely to have direct or indirect implications for energy masterplanning.

i *Government Response to the Committee on Climate Change's 2020 Progress Report to Parliament.* HM Government, Oct. 2020. **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/928005/government-response-to-ccc-progress-report-2020.pdf**

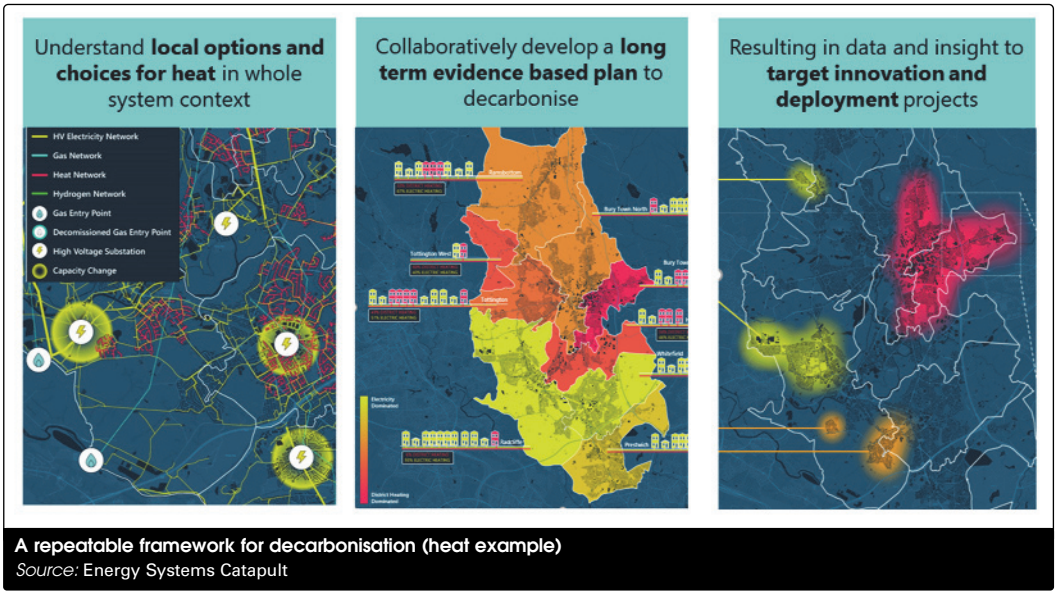
2.5 The viability challenge

The costs and revenues associated with renewable energy solutions are changing rapidly – for example, the cost per watt of energy generated by photovoltaics has decreased by 90% in the last decade, and the cheapest form of new electricity generation is now renewables, coupled with effective storage. In the past, such schemes have been seen as an additional cost to development, but in fact they can actually enhance the viability of a scheme over the long term.

Energy assets require upfront investment, but they can also provide long-term revenues. For example, a heat network requires capital investment to build energy centres, pipes, home connections, etc. and there are ongoing operation and maintenance costs, but it produces revenues from the sale of heat to homes over long term. There are ongoing assumptions that low- and zero-carbon technologies are not as cost-competitive as alternatives, but over the lifetime of a development this is unlikely to be the case. However, a shift in mindset is required to view energy infrastructure as an investment opportunity, rather than a cost.

The energy assets in homes should also be considered, and the case for this can be made by focusing on future-proofing and the delivery of low-carbon options with high consumer appeal and value (in terms of how it can benefit the occupant).

3 Masterplanning for energy



A repeatable framework for decarbonisation (heat example)
Source: Energy Systems Catapult

The energy masterplanning process in Garden Cities is distinctive in its commitment to net-zero and energy-positive outcomes, and in terms of community and municipal ownership. The development of a Garden City offers a unique opportunity to build energy-positive places which can offset carbon dioxide emissions from nearby existing communities.

Recommendation	**A net-zero energy masterplan must be developed as a core part of the overall corporate strategy for a new Garden City. It should be drawn up in the context of the wider local area energy plan, and should reflect the guidance on energy strategies set out in Section 4 of this Practical Guide.**

3.1 The importance of energy masterplanning

Masterplanning at the large scale offers a unique opportunity to consider and plan for a robust net-zero energy infrastructure that will support the aspirations of a sustainable community. In transforming the UK's energy systems towards net zero, all development should consider electricity, heat and transport holistically, and not, as in the past, in silos.

As part of the planning for a Garden City all authorities should undertake local area energy planning for the wider area in order to understand how the whole of the new community's energy system can be decarbonised.

All these issues must be considered from the earliest stage, and will have a major influence on the Garden City masterplan. Particular attention should be given to the locality's wider

local area energy plan[26] and the related infrastructure plans of electricity, gas and heat network operators, and to opportunities to utilise existing, decentralised, low-carbon and net-zero energy supply systems and to foster the development of new opportunities to develop infrastructure to supply both proposed development and existing homes and buildings. Such opportunities could include co-locating potential heat customers and heat suppliers. The masterplanning process should be used to consider a holistic, net-zero energy system design in the context of the wider local area and to identify potential for solutions at all scales, including community-scale schemes.

There is a need for an evidence-based understanding of the technical potential of different energy system designs – including the suitability of different low-carbon and net-zero energy generation and storage technologies, distribution infrastructure, and conversion technologies. Decisions on the optimal and most desirable energy system design will be influenced by the Garden City development's design strategy and its location and scale, alongside the decarbonisation of the wider area – which should be informed by whole-energy-system, cost-optimal energy planning activity. This is important to prevent the Garden City from being regarded as an energy island; its resilience, cost and other impacts/benefits to residents will be dependent on the energy system choices being made to decarbonise the wider region.

A whole-energy-system approach considers:

- the integration and trade-off between gas, heat and power and their associated networks;
- the energy supply chain, including energy production, storage, and use, with options to build, upgrade, or decommission assets;
- energy networks, as well as building fabric and generation, storage and heating systems, and the decarbonisation of transport systems;
- the spatial relationships between buildings and energy networks; and
- long-term resilience when making near-term decisions, mitigating the risks of stranded assets and overall costs to society.

3.2 Building community and political support for a new approach

Delivering a net-zero Garden City will require strong political leadership, embedded in the corporate strategy of the chosen delivery vehicle. The TCPA's Garden City Practical Guide on *Finance and Delivery*[27] sets out how these wider principles might work in relation to different methods of delivery.

The delivery team leading the development of the Garden City will need to be prepared to set out the moral and the scientific case for why zero-carbon, energy-positive and climate-proof development is needed. A strong communication strategy is vital in building public understanding and enthusiasm for new technologies, and it will need to consider the needs of future residents, alongside the products and services that will be needed to deliver 'new' solutions. The *People, Planning and Power* Practical Guide[28] provides guidance on strategies for putting communities at the heart of planning for Garden Cities.

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26 *Local Area Energy Planning: Supporting Clean Growth and Low Carbon Transition*. Energy Systems Catapult, Oct. 2018. **https://es.catapult.org.uk/wp-content/uploads/2018/12/Local-Area-Energy-Planning-Supporting-clean-growth-and-low-carbon-transition.pdf**

27 *Guide 2: Finance and Delivery*. Garden City Standards for the 21st Century: Practical Guide for Creating Successful New Communities. TCPA, Nov. 2017. **https://www.tcpa.org.uk/Handlers/Download.ashx?IDMF=d4eb68bb-95c3-4b8d-b9b9-a6cb080d76bb**

28 *Guide 11: People, Planning and Power*. Garden City Standards for the 21st Century: Practical Guide for Creating Successful New Communities. TCPA, Mar. 2019. **https://www.tcpa.org.uk/Handlers/Download.ashx?IDMF=72df778a-6aec-4315-a93e-8e56859af93a**

3.3 Net-zero energy strategies for Garden Cities

A robust net-zero energy strategy will be central to successful energy masterplanning for a Garden City. The energy strategy should be seen as a core part of the overall corporate strategy and infrastructure delivery plan for the new development, and as the key tool for developing an integrated energy system masterplan and delivering infrastructure and in-home technologies. There is no defined standard for such a strategy, but the golden thread will be a focus on all aspects of energy consumption, generation, distribution, management, and ownership (alongside the decarbonisation of the wider local and national energy systems). Issues such as energy efficiency in the building fabric and in transport thus fall within the strategy's remit, even when their implications – such as residents' commuting patterns – are complex. This breadth of approach is vital if the principles of producing net-zero places are to be followed.

3.4 The purpose of a Garden City net-zero energy strategy

A net-zero energy strategy should consider the energy demands, generation, storage, supply and management opportunities for each stage in the development process, as well as interaction with the wider energy system. This would allow for strategic decision-making on the energy system design options and on the infrastructure and technologies that might need to be installed at an early stage in the development of the site, such as district heating. Preparation – and subsequent refinement – of the energy strategy should be fully integrated into the development process, from the earliest planning stage and throughout the masterplanning and design stages. Everyone in the development team will need to be 'energy and carbon aware' as the masterplan evolves and as buildings are designed – particularly when changes are made. In addition, there are many options and trade-offs regarding the optimal energy infrastructure and system choices for sites. A whole-system approach should be used in which implications for the site are considered alongside the impact that any decision may have on the wider energy system, so that development will positively impact on other areas and so that wider society may benefit from low-carbon energy opportunities.

The route to net zero for each Garden City must be based on a context-specific assessment of opportunities, constraints, risks, costs, and benefits. This assessment will need to consider the wider local energy system within which each Garden City will function, and the maturity of local area energy plans[29] and wider network investment across electricity, gas and heat within the locality.

There is no standard template approach that can be applied to every development, but each Garden City energy strategy should be underpinned by common principles.

Development and refinement of the net-zero energy strategy should take account of and where necessary identify and resolve conflicts between:

- the application of a whole-system approach, including defining net-zero energy system design options and a preferred strategy for achieving net zero;
- upfront capital costs and the whole-life cost effectiveness of carbon-saving options; and
- the opportunities and constraints of alternative methods of financing the achievement of the net-zero and energy-positive objective.

29 *Local Area Energy Planning: Supporting Clean Growth and Low Carbon Transition*. Energy Systems Catapult, Oct. 2018. **https://es.catapult.org.uk/wp-content/uploads/2018/12/Local-Area-Energy-Planning-Supporting-clean-growth-and-low-carbon-transition.pdf**

3.5 Long-term management of assets

Garden Cities are likely to need one or more organisations to take ongoing responsibility for developing, installing, operating and maintaining central generating equipment and distribution networks on-site, and also for maintaining on-site energy generation, storage and management systems installed in individual homes and non-domestic buildings. A holistic strategy would extend the role of such organisations to support for low-carbon lifestyles and behaviour and low-carbon business operation in the emerging Garden City – and, as far as possible, over time. To encourage the uptake of renewable energy technologies, organisations can adopt an energy service business model which eliminates the upfront cost for the consumer by providing the finance to purchase and install such technologies, which is then paid for through the cost savings on energy expenditure. The TCPA's *Long-Term Stewardship* Garden City Practical Guide[30] outlines successful models for managing assets generated by the development process – including energy systems – in perpetuity.

3.6 Opportunities for community stewardship and innovative business models

The Garden City energy strategy should encourage and support community- and/or municipally-owned business models. It could also recognise local energy generation and supply as a tangible benefit and encourage activity that promotes local generation, with a view to linking it to local supply – such as co-location of generation with demand, and the promotion of smarter energy infrastructure.

New Garden Cities can, and should, use community-owned energy systems and other innovative consumer-centric business models to deliver better net-zero energy outcomes for their citizens, more comfortable homes, better control, lower costs, and greater utility. This would also create opportunities for local job creation, as well as safeguarding vulnerable consumers and ensuring that businesses are competitive. The main benefits of community energy projects include:

- income generation and support for local service provision;
- cost savings;
- local employment;
- shares for local organisations and people;
- community empowerment;
- education, skills, and training;
- improved community cohesion;
- health improvements;
- energy security;
- carbon savings;
- awareness raising; and
- air quality improvements.

The government's Community Energy Strategy (updated in 2015)[31] recognises that community energy has the potential to be transformative but is in the early stages of

30 *Guide 9: Long-Term Stewardship.* Garden City Standards for the 21st Century: Practical Guide for Creating Successful New Communities. TCPA, Dec. 2017.
https://www.tcpa.org.uk/Handlers/Download.ashx?IDMF=6326f215-8260-47d6-998d-f0e76aef09fd

31 *Community Energy Strategy Update.* Department of Energy and Climate Change, Mar. 2015.
https://www.gov.uk/government/publications/community-energy-strategy-update

development and needs support to flourish. The stated ambition in the strategy is that every community that wants to form an energy group or take forward an energy project should be able to do so, regardless of background or location.

Since May 2015 there have been many changes to the policy landscape for community energy, including the removal of the government's Feed-in Tariff scheme, the end of pre-registration for community renewable schemes, changes to the tax relief available for community energy investors, and proposals to introduce 20% VAT on some small-scale renewable energy installations. In place of the Feed-in Tariff, licenced electricity suppliers are now obligated to pay small-scale low-carbon generators for electricity exported to the grid; this is known as the Smart Export Guarantee (SEG). The changes now make delivering community energy more challenging. Community rooftop solar, wind and hydroelectric systems are now very unlikely to be able to go ahead once all the changes come into effect. But community-owned renewable heat schemes may still be an area for communities to explore and for local authorities to support.[32]

New Garden Cities present an opportunity to pioneer new consumer-centric energy business models that deliver citizens the outcomes they want from using energy without the carbon dioxide emissions. People generally care more about the experience and value they get from the energy they use than the technology that delivers it. However, different people may want different outcomes, with some primarily interested in cost effectiveness, others prioritising comfort and health.

Energy service business models tailored to individual households needs and providing effective asset management of new in-home technologies through advanced control and data could enable consumers to pay for the outcomes that they want and systems to be optimised to ensure viable operation. The marketing and promotion of new low-carbon and net-zero homes and lifestyles in the new community could provide an opportunity to develop consumer-centric 'options' that would allow people to tailor their homes through various control or technology options and service packages. Detailed guidance on how planners can support the long-term stewardship of Garden Cities is available in the TCPA's *Long-Term Stewardship* Garden City Practical Guide.[33]

3.7 Case study – North West Bicester Eco-town

North West Bicester Eco-Town is part of the Bicester 'Garden Town' vision. Bicester's population is set to double to around 50,000 residents, with more than 10,000 new homes due to be built by 2031. The North West Bicester masterplan will contribute to the provision of these new homes, with supporting infrastructure, including generous green spaces, community and social facilities, commercial premises, and leisure facilities. North West Bicester offers an opportunity to enable innovative zero-carbon living.

In 2009 North West Bicester was announced as one of four government-designated 'Eco-towns'. In 2014 Bicester (including North West Bicester Eco-Town, Graven Hill, and South West Bicester) was awarded 'Garden Town' status by the government, and it became a pilot project for the NHS Healthy New Towns in 2016.

32 *Community Energy: State of the Sector 2020*. Community Energy England/Community Energy Wales, Jun. 2020. **https://communityenergyengland.org/files/document/385/1592215769_CommunityEnergy-StateoftheSector2020Report.pdf**

33 *Guide 9: Long-Term Stewardship*. Garden City Standards for the 21st Century: Practical Guide for Creating Successful New Communities. TCPA, Dec. 2017. **https://www.tcpa.org.uk/Handlers/Download.ashx?IDMF=6326f215-8260-47d6-998d-f0e76aef09fd**

A2Dominion

The North West Bicester Eco-town is being planned with sustainable energy supply to the fore

The energy objectives for North West Bicester are defined by its Eco-town status. The foundation of the sustainable energy objectives for the development is the original Eco-Towns Planning Policy Statement (PPS),[34] which was regrettably revoked in March 2015 but with an exemption for North West Bicester. The underpinning ambition, as set out in the Eco-Towns PPS (Policy ET 7.1), is for the new community to be zero-carbon:

> *'The definition of zero carbon in eco-towns is that over a year the net carbon dioxide emissions from all energy use within the buildings on the eco-town development as a whole are zero or below.'*

The site is allocated in the Cherwell Local Plan 2011-2031 (Part 1) by Policy Bicester 1, which allocates the site for a new zero-carbon mixed-use development, including 6,000 homes. The zero-carbon requirement is therefore also embedded within local planning policy.

The North West Bicester masterplan is embedded within an adopted Supplementary Planning Document (SPD),[35] dated February 2016, and sets out the detail of how these standards will be met. A comprehensive masterplan energy strategy for North West Bicester highlights the importance of consultation and collaboration: 'arriving at the final energy strategy for NW Bicester has involved an iterative process of development and testing of proposals, discussions with Local Authority officers and consultation with wider stakeholders'.[36] The SPD does, however, allow flexibility in respect to how the true zero-carbon requirement can be met, to acknowledge changes over the life of the development – in particular to account for technological advances. The site is also within multiple land ownerships, which has resulted in separate planning applications across the site, and here that flexibility can

34 *Planning Policy Statement: Eco-towns. A Supplement to Planning Policy Statement 1*. Department for Communities and Local Government, Jul. 2009. **https://www.gov.uk/government/publications/eco-towns-planning-policy-statement-1-supplement**

35 *North West Bicester Supplementary Planning Document*. Cherwell District Council, Feb. 2016. **https://www.cherwell.gov.uk/downloads/download/281/north-west-bicester-spd-main-document-february-2016**

36 *NW Bicester Masterplan: Masterplan Energy Strategy*. Hyder Consulting (UK), for A2Dominion, Mar. 2014. **https://www.cherwell.gov.uk/downloads/download/1385/north-west-bicester-masterplan-documents**

ensure that each part of the development meets the requirements individually, even if this involves some variation on how the requirement is achieved.

The first phase of the development is guided by four key energy principles:

- ***On-site electricity generation:*** Every home in the first phase of the development has rooftop solar panels, making it the UK's largest domestic solar array (equivalent in area to two-and-a-half football pitches).
- ***District heating:*** A gas-fired combined heat and power district heating system will provide heating and hot water for every home.
- ***Energy-efficient homes:*** The homes will be built sustainably, using timber frames, and will be highly insulated with triple-glazing.
- ***Sustainable transport:*** The community design will give priority to walking, cycling or taking the bus, with the aim of reducing the proportion of journeys made by car to 50% (compared with the Bicester average of 67.5%).

To ensure that the masterplan is successful, it was widely consulted upon within the local authority and the community. The North West Bicester Eco-town is an 'exemplar', with the first phase of the development demonstrating how a net-zero community can be delivered at scale. Moving forward, close attention to achieving this goal will be required, set against the policy requirements and the North West Bicester SPD, informed by the masterplan energy strategy.

4 The net-zero strategy process

The development of an energy strategy follows a familiar policy development route. It must be framed by the wider public participation strategy for the new Garden City, including engagement with the community and other key local stakeholders. The process must be based on questions such as:

- How much carbon dioxide is currently being emitted?
- By how much do we need to reduce carbon dioxide emissions?
- What actions are needed to achieve to reach this target?
- How does this fit with the local authority's other socio-economic objectives?
- How should this progress by monitored and reviewed?

Energy Systems Catapult has been working with the Centre for Sustainable Energy to develop a methodology for the delivery of local area energy planning (LAEP)[37] as part of Ofgem's RIIO-ED2 Sector Specific Methodology. The work has been informed by the input of a steering group which included members from the Department for Business, Energy and Industrial Strategy, the Committee on Climate Change, the Scottish Government, the Welsh Government, and Innovate UK.

Meeting the challenge of energy system decarbonisation needs local leadership, engagement, and initiative-taking. This is because of both (*a*) the nature and challenges of the systemic changes required (and how they vary between places) and (*b*) the sheer volume and distribution of people and organisations who will need to be involved in making them. LAEP is a process which has the potential to inform, shape and enable key aspects of the transition to a net-zero energy system.

If done well, LAEP can provide sound foundations for effective and sustained local action to cut carbon dioxide emissions taken by well informed local leaders and initiative-takers. The resulting plan can potentially underpin specific proposals to upgrade local energy networks in order to enable decarbonisation in line with local objectives. Done well and consistently across many localities, LAEP can inform sharper, more effective and better targeted national policies.

The methodology outlines four key elements for LAEP:

- the use of robust technical evidence, produced using analytical techniques which consider the whole energy system and make consistent use of available data, and whose strengths and weaknesses are well understood;
- a comprehensive assessment of wider non-technical factors which need to be understood and addressed to secure change;
- a well designed and involving social process which engages appropriate stakeholders effectively, uses the technical evidence appropriately, and manages vested interests effectively, thus ensuring that the resulting plan can be seen as an informed and legitimate representation of local intent in relation to energy system decarbonisation; and
- a credible and sustained approach to governance and delivery.

In developing a Garden City, these elements can be translated into the stages set out in the rest of this Section.

37 *Local Area Energy Planning: The Method*. Final Review Draft. Centre for Sustainable Energy and Energy Systems Catapult, for Ofgem, Jul. 2020. **https://es.catapult.org.uk/wp-content/uploads/2020/08/LAEP-method-final-review-30-July-2020.pdf**

4.1 Stage 1: Set a net-zero energy vision and objective

To create truly resilient new places, councils and their delivery partners must think long term about the impact of and opportunities presented by new development, and must set local carbon and energy targets. The creation of a new Garden City offers an opportunity to undertake world-leading development that goes beyond minimum requirements and so make a place that will stand the test of time. Garden Cities are in a unique position to deliver energy-positive developments which will play a leading role in helping the UK reach its target of net zero by 2050.

The masterplan and wider policy for the Garden City must ***be in line with the carbon reduction targets set out in the Climate Change Act 2008***, and in line with the local authority's wider carbon reduction strategy. To meet these targets in practice, ***the new development must be net zero, or more likely, energy-positive***. The principles encapsulated in the following recommendations provide a benchmark for carbon and energy resilience and should be adopted in the corporate and design strategies for new developments.

Recommendation	**New Garden Cities must be aligned with long-term scientific and international policy consensus on climate change in order to deliver net-zero and energy-positive communities.**

Recommendation	**Garden Cities must demonstrate the highest standards of innovation in net-zero technology in order to reduce the impact of climate-change-inducing emissions. They must be net zero in that, over a year, the net carbon dioxide emissions from all energy use within the buildings in the Garden City are zero or below.**

4.2 Stage 2: Understand future energy demands and opportunities (data- and evidence-gathering)

The energy strategy must be founded on strong, reliable data on the expected energy demands and carbon performance of the new community and on the interaction of site design and the energy use of buildings and the transport system. It should also be drawn up within the context of the wider energy system, for example network operator investment and decarbonisation plans. This provides the benchmark for evaluating future performance and allows for clear assessments of the community's likely energy consumption and carbon dioxide emission levels over time. It can then inform the assessment of different energy system configurations for the community, including the potential for on-site renewable energy generation and storage and the use and development of existing infrastructure and available natural resources such as waste heat. A comprehensive assessment of different energy system design options can thus be developed, enabling the best choice of infrastructure to be made in the context of the wider local area and energy generation, distribution, storage and management technologies within the community, and for individual buildings.

Based on the evidence gathered, the policy priorities within the scope of the masterplan should be determined (for example energy, building fabric, mobility, etc.). These should then be used as a starting point for exploring technological and design options.

4.3 Stage 3: Investigate technology options

Delivery of a net-zero or energy-positive Garden City will require the development of integrated energy solutions to generate, store, supply and manage energy on site and within individual homes and buildings. There is a wide range of low-carbon and renewable energy generation, storage and management technologies that could be used, and their interaction with the wider energy system should be considered.

Electricity can be generated and supplied by wind, solar photovoltaic and hydroelectric assets. The costs of community and domestic electricity storage technologies are decreasing rapidly, and the potential to future-proof buildings through the installation of energy storage options at a later date should be factored into designs. Heating and hot water can be provided by centralised energy centres that use combined heat and power (CHP), biofuel and electric heating technologies to supply district heating in a network connecting individual homes and buildings, or through individual electric and hybrid heating solutions, including ground, air source and hybrid heat pumps, solar thermal, and thermal storage technologies. The sustainability of any biomass system and the carbon dioxide emissions saved by its use will depend on the fuel used and its source. Gas-fired CHP is not zero carbon unless supplied by zero-carbon gas, but it may provide a transitional step in enabling district heating.

For small-scale district heating systems, support is available from the government in the form of the Non-domestic Renewable Heat Incentive, although this is due to close to new applicants in 2021.[38] The development of the energy strategy should include provisions for working with industry and distribution network operators to ensure that smart energy infrastructure is in place, including electric vehicle charging (see the *Sustainable Transport* Practical Guide[39] for guidance on planning for sustainable transport in Garden Cities), developed alongside network operators' plans for energy network investment to support the transition to a net-zero energy system (for example plans to convert gas networks to hydrogen, or the electrification of heating and mobility systems).

In addition, the energy strategy should consider proximity to any existing or planned smart local energy systems or other neighbouring local area energy plans, noting the intrinsic connection and interdependency of optimal solutions for the site and the wider region.

Further information on the different technology options available to create net-zero energy systems is set out in Annex 1.

Recommendation	**Garden Cities should maximise the opportunities offered by smaller-scale, community- and individually-owned energy generation facilities.**

38 See the Non-domestic Renewable Heat Incentive (NRHI) webpage, at **https://www.gov.uk/non-domestic-renewable-heat-incentive**

39 *Guide 13: Sustainable Transport.* Garden City Standards for the 21st Century: Practical Guide for Creating Successful New Communities. TCPA, Sept. 2020. **https://www.tcpa.org.uk/Handlers/Download.ashx?IDMF=6d804d4f-e66b-4b50-ad6f-26abfe610cac**

4.4 Stage 4: Develop energy system design options

Development a number of site-specific future energy system design options, informed by the location's wider local area energy plan and evidence gathered for the particular site, is a valuable way of assessing the appropriateness of different energy system designs and technology options. Development of these different scenarios allows for a wider public debate on alternatives and deeper consideration of how best to integrate the site's energy system with its wider masterplanning.

4.5 Stage 5: Economic and social assessment of alternatives

Comprehensive assessment of the alternative future energy scenarios is required to gauge, for each case, both its long-term effectiveness in terms of carbon dioxide emissions reduction in relation to the target set for the Garden City, and its financial viability. Such assessments should be set within the context of the opportunities for long-term investment and community ownership and effective management and operation of on-site and in-home energy assets; this will allow the costs and benefits of different options to be evaluated, with wider local (for example job creation) and social considerations also being taken into account.

Table 2 on the next page outlines some of the existing tools and guidance to help local authorities assess policy options.

4.6 Stage 6: Delivery plan

A detailed delivery plan can then be formulated for the preferred option. It needs to be developed through consultation with distribution network operators for gas and electricity in the locality of the Garden City, and in tandem with any heat network operator negotiations with prospective energy services providers, funders, and contractors. It must clearly express the policy priorities determined for the Garden City.

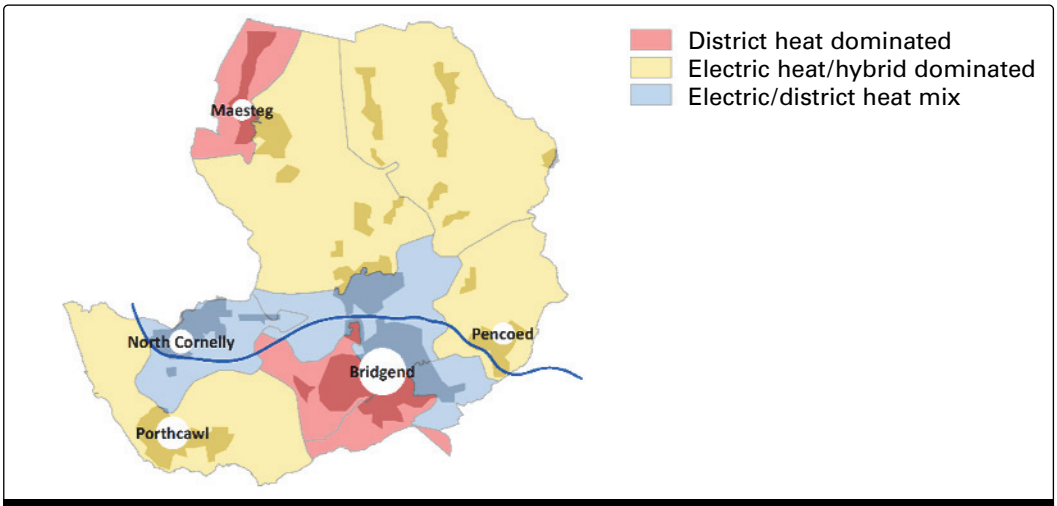
4.7 Stage 7: Monitoring and reporting

Reporting is a critical and ongoing part of the net-zero energy strategy, designed to gauge the wider long-term energy and carbon dioxide emissions performance of the new development. Reporting should include a full range of carbon performance assessments – covering buildings, transport, energy production, etc. – in order to give a complete carbon profile of the new community. For example, an annual, publicly available report should summarise the energy used and generated by the community and the associated carbon emissions, assessing these outcomes against the targets set in the net-zero energy strategy.

Table 2 Tools and guidance for assessing policy options

Tool/guidance	Notes	Link
SCATTER greenhouse gas reporting tool	Methodology to help local authorities to better assess policy choices based on their capacity to contribute to meeting a carbon reduction target. It analyses 45 potential emissions reduction interventions and can thus help local authorities in developing climate action plans and assessing which set of policy decisions will achieve the greatest carbon savings locally.	https://scattercities.com/
Google Environmental Insights Explorer (EIE) tool	Uses similar data to SCATTER to provide city authorities with a picture of current emissions levels by using Google Maps data to develop a baseline to compare future progress against other cities. The tool is intended to help cities to develop a plan to reduce and measure emissions levels by estimating city level data for: ■ building emissions; ■ transport emissions; and ■ renewable energy potential (solar).	https://insights.sustainability.google/
EnergyPath Networks®	Whole-system optimisation tool designed to help understand local energy systems and explore future local energy system designs, in order to cost effectively meet net-zero ambitions. The Local Energy Asset Representation (LEAR) part of the tool suite uses data and machine learning techniques to provide a visual representation of existing local energy assets.	https://es.catapult.org.uk/capabilities/modelling/local-energy-system-modelling/
Aspects of Integration – Supporting Systems Integration in Complex Energy Projects	Framework developed under the Prospering from the Energy Revolution Programme by the Energy Systems Catapult to encourage systems thinking on how local energy systems integrate with each other and with broader national systems.	https://es.catapult.org.uk/comment/aspects-of-integration/
Decarbonise Buildings: Towards an Enduring Policy Framework	Guidance on an enduring policy framework to reach net zero, outlining six steps to build markets for net-zero buildings.	https://es.catapult.org.uk/reports/policy-framework-to-decarbonise-buildings/?download=true
THERMOS (Thermal Energy Resource Modelling and Optimisation System)	An open-source software tool designed to make heat network planning faster, more efficient, and cost effective.	https://www.thermos-project.eu/home/
Practical Guides for Creating Successful New Communities: *Guide 2 – Finance and Delivery*	Guide on the wider funding opportunities for new Garden Cities using private investment and municipal bonds. All the routes set out in the guide could also apply to energy funding.	https://www.tcpa.org.uk/guide-2-finance-and-delivery

4.8 Case study – developing and delivering a local area energy plan for Bridgend



Dominant heating systems in 2050 by area within the BCBC boundary
Source: Energy Systems Catapult, using OS data © Crown copyright and database right 2018

Bridgend County Borough Council (BCBC) has a vision to make Bridgend in South Wales a decarbonised, digitally connected, smart county borough. In doing so it will transition to a low-carbon, decentralised energy system that works for its individuals, communities, and businesses. In one of the UK's first group of three demonstrators in the Smart Systems and Heat Programme, Energy Systems Catapult worked with BCBC, the Welsh Government, Western Power Distribution, Wales & West Utilities and a number of other local stakeholders to pilot a new whole-system approach to local area energy planning (LAEP).

The local area energy plan helped to develop a shared understanding of the local area's energy system today and the inter-relationship between energy demand and the infrastructure plans of the electricity, gas and heat network operators, as well as the opportunities for managing and reducing energy demand and using decentralised renewable and low-carbon energy generation and storage. The local area energy plan provided insight into the potential pathways, opportunities and investment needed to securely and affordably decarbonise. It can be used to help support and inform the energy strategies of new development within the area, to ensure that they align and support the creation of a smarter, integrated local energy system.

LAEP is an iterative process, and BCBC expects to continue to monitor and develop the plan to ensure that it supports local and national ambitions for achieving net zero, using increasingly open and accessible data and accounting for the development of technology and national energy policy. With a refreshed LAEP process and significant learning from developing the Smart Energy Plan[40] (in terms of how different technologies function locally, high-value propositions for consumers, and business models that support projects and encourage commercial investment), BCBC is looking to create structures and tools that enable decarbonisation to happen at scale. Combined with creating a supportive local energy market and digital end-to-end service offerings for domestic and non-domestic consumers, decarbonisation will be enabled to occur at rates that will help to achieve the UK's net-zero ambitions.

40 *Smart Energy Plan – Bridgend County Borough Council.* D37/D38. Smart Systems and Heat Programme, Phase 2. Energy Systems Catapult, 2018. **https://es.catapult.org.uk/wp-content/uploads/2019/02/ESC_SSH2_D37-D38-Smart-Energy-Plan-Bridgend.pdf**

Table 3 BCBC project timeline

2018	2019 *FIT scheme closes – UK leaves EU*	2020: *WG carbon target/budget end – Smart meters rolled-out – WG elections*	2021: *RHI planned closure – Current Arbed end date – Local elections*	2022 *UK elections – Current WG RE Support Service end date*	2023 *ERDF funding ends*	2024	2025: *WG elections (if not earlier) – WG carbon budget (2021-25)*
DP1 Bridgend Town Lower Carbon District Heat (DH) Network Phase 1: 1st step to decarbonising Bridgend town.							
	DP2 Bridgend Town Lower Carbon DH Network Phase 2: Build on DP1 business case and extend heat network.						
DP3 Energy Efficiency Projects: Tackle fuel poverty by installing energy efficiency measures in areas in need.							
	InP1 Fully Targeted Retrofit: Understand the benefits of dynamic modelling and performance monitoring and how these can help develop more compelling retrofit offerings for consumers.						
	InP2 Hybrid Heat Pumps and Full Electrification: Build on the success of the FREEDOM project and further explore the role of hybrid heat pumps in the overall decarbonisation of the Bridgend energy system.						
InP3 Caerau Mine Water Gas-to-District Heating Transition: Deliver a demonstrable example of a low-carbon DH system which transitions existing residential consumers from gas heating to DH.							
InP4 Affordable Urban Heat Networks (HNs): Establish solutions for reduced HN costs & improved efficiencies.							
	InP5 Electrification of Heat through Energy as a Service: Deliver energy as a service to heating consumers via different electrified heating technology packages and gain insights to assist further roll-out if successful.						
InP6 Intelligent Bridgend Energy System Design: Explore the benefits that arise from integration of heat, electricity & transport systems							
				Activity A Non-Domestic Building Data: Gather data on Bridgend's non-domestic buildings and update the Strategy.			
	Activity B Low & Zero Carbon DH Energy Sources: Identify and investigate potential lower- and zero-carbon heat sources for DH networks to feed in to future projects.						
Activity C Planning Policy Alignment with Decarbonisation Strategy: Ensure the new LDP accounts for the Local Area Energy Strategy.							
Activity D Establishing Bridgend as a Centre for Innovation: Effectively market Bridgend as an area to trial innovation projects and stimulate economic growth.							
Activity E Identify Power, Transport and Digitalisation Projects: Develop complementary electricity, transport and digital infrastructure projects alongside the heating projects to ensure that decarbonisation takes place in a joined-up manner.							
				Activity F Scoping Future Delivery Plans: Ensure continual learning to achieve large-scale deployment initiatives.			

5 Further resources

There is an increasing range of detailed advice on energy masterplanning, such as that provided by:

- K Henderson: *Energising Masterplanning: An Integrated Approach to Masterplanning for Sustainable Energy*. Expert Paper 1. SPECIAL project. TCPA, Jun. 2015. **http://www.special-eu.org/assets/uploads/SPECIAL_EP1.pdf**
- *Local Area Energy Planning: The Method. Final Review Draft*. Centre for Sustainable Energy and Energy Systems Catapult, for Ofgem, Jul. 2020. **https://es.catapult.org.uk/reports/local-area-energy-planning-the-method/**
- *Local Area Energy Planning Guidance for Local Authorities and Energy Providers*. Energy Technologies Institute. Energy Systems Catapult, Oct. 2018. **https://es.catapult.org.uk/wp-content/uploads/2018/12/Local-Area-Energy-Planning-Guidance-for-local-authorities-and-energy-providers.pdf**

The following organisations and websites offer key information and guidance on climate change adaptation and mitigation:

- Association for Environment Conscious Building — **https://www.aecb.net/#**
- Association for Decentralised Energy — **https://www.theade.co.uk/**
- Bioregional — **https://www.bioregional.com/**
- BRE (Building Research Establishment) — **https://www.bregroup.com/**
- CPRE, the countryside charity — **https://www.cpre.org.uk/**
- Carbon Trust — **https://www.carbontrust.com/**
- Centre for Sustainable Energy — **https://www.cse.org.uk/**
- Community Energy England — **https://communityenergyengland.org/**
- Ministry of Housing, Communities and Local Government — **https://www.gov.uk/government/organisations/ministry-of-housing-communities-and-local-government**
- Department for Environment, Food and Rural Affairs — **https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs**
- Department for Business, Energy and Industrial Strategy — **https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy**
- Energy Saving Trust — **https://energysavingtrust.org.uk/**
- Energiesprong — **https://energiesprong.org/**
- Energy Systems Catapult — **https://es.catapult.org.uk/**
- Environment Agency — **https://www.gov.uk/government/organisations/environment-agency**
- Friends of the Earth — **https://friendsoftheearth.uk/**
- Institute for European Environmental Policy — **https://ieep.eu/**
- Landscape Institute — **https://www.landscapeinstitute.org/**
- London Sustainable Development Commission — **https://www.london.gov.uk/about-us/organisations-we-work/london-sustainable-development-commission**
- Natural England — **https://www.gov.uk/government/organisations/natural-england**
- NHBC Foundation — **https://www.nhbcfoundation.org/**
- RenewableUK — **https://www.renewableuk.com/**
- Royal Society for the Protection of Birds — **https://www.rspb.org.uk/**
- Royal Town Planning Institute — **https://www.rtpi.org.uk/**
- Town and Country Planning Association — **https://www.tcpa.org.uk/**
- UKCIP (UK Climate Impacts Programme) — **https://www.ukcip.org.uk/**
- UK Green Building Council — **https://www.ukgbc.org/**

Annex 1

Technologies to be considered during Garden City energy masterplanning for the net-zero process

Technology	Type	Description	UK policy, funding, and trends	Design considerations, deployment costs, and performance
Gas networks	Infrastructure	In Britain there are eight gas distribution networks that deliver natural gas to homes and commercial premises through transmission pipes to heat space and water.	■ The installation of gas boilers in new-build properties is to be phased out from 2025 in the UK, as part of the Future Homes Standard.[A1] ■ National Grid and partners are launching a £10 million trial project[A2] to test whether in future hydrogen could offer a low-carbon alternative to heat homes and industry.	■ It currently typically costs up to £1,000 to connect a property to a gas distribution network.[A3] Industry is developing a range of hydrogen and hydrogen-ready boilers,[A4] and a number of hybrid heating systems combining a gas boiler and a heat pump are on the market.[A5] ■ The Committee on Climate Change has reported that it would cost £4,800 to install low-carbon heating in a new home, but might cost up to £26,300 in an existing home.[A6]
Heat networks	Infrastructure	Heat networks take heat energy from various sources (buildings, energy centres, etc.) and distribute it to neighbouring buildings via a network of highly insulated underground pipes.	■ The Committee on Climate Change has estimated that around 18% of UK heat will need to come from heat networks by 2050 if the UK is to meet its carbon reduction targets.[A7] ■ From February to June 2020, the UK government held a consultation to seek views on policy options for the development of a regulatory framework for heat networks.[A8]	■ Heat networks are well suited to areas of high heat density and are most common in denser urban areas. ■ Heat networks offer the option to use different sources of low-carbon heat energy over time without the need for locally disruptive major infrastructure upgrades.

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A1 https://www.gov.uk/government/consultations/the-future-homes-standard-changes-to-part-l-and-part-f-of-the-building-regulations-for-new-dwellings
A2 https://www.nationalgrid.com/5-aug-2020-national-grid-launch-ps10m-trial-project-test-if-hydrogen-can-heat-homes-and-industry
A3 https://www.myjobquote.co.uk/costs/cost-of-running-gas-to-a-property
A4 https://www.worcester-bosch.co.uk/hydrogen
A5 https://www.b-snug.com/
A6 https://www.theccc.org.uk/publication/uk-housing-fit-for-the-future/
A7 https://www.gov.uk/guidance/heat-networks-overview
A8 https://www.gov.uk/government/consultations/heat-networks-building-a-market-framework

Technology	Type	Description	UK policy, funding, and trends	Design considerations, deployment costs, and performance
Heat networks *(Continued)*			■ The Heat Networks Investment Project (HNIP) will provide £320 million of capital funding to gap-fund heat network projects in England and Wales.[A9]	
Electricity networks	Infrastructure	Electricity distribution networks carry electricity from the transmission grid to users. In Britain there are 14 distribution network operators (DNOs), with each responsible for managing the distribution of electricity for a set region.	■ In the third quarter of 2019, 40% of the UK's electricity supply came from renewables; 39% came from coal, oil and gas; and the remainder came from nuclear power.	■ The costs of connecting a property to the electricity distribution network varies greatly.
Wind	On site	Wind turbines harness the power of the wind to generate electricity. They can be deployed in large windfarms or at the household level in certain circumstances – known as micro-wind turbine systems.[A10]	■ Wind contributed 20% of the UK electricity generation in 2019, making it the nation's primary source of renewable energy.[A11] ■ There are currently no national grant schemes to assist with the cost of a wind power system.	■ The UK has significant onshore wind potential. Onshore wind is one of the cheapest forms of renewable energy at the right scale and location and the government has signalled support for onshore wind.[A12] ■ Offshore windfarms are more expensive to install, but they are able to generate more power than onshore farms owing to the increased wind intensity and consistency at sea.
Battery storage	On site	Battery storage centres can help to maintain the resilience and stability of an electricity grid powered by renewables (for example by providing electricity even when the wind is not blowing).	■ In July 2020, the UK government announced that it will relax planning legislation to make it easier to construct large batteries to store renewable energy from solar power installations and windfarms.	■ Battery energy storage capacities installed in the UK by the end of 2022 will be 50 times what they were as 2017 ended, and the associated costs are dropping fast. ■ Battery storage is uniquely flexible, and can help in varying how and when energy is used, providing flexibility for system and network operators.

A9 https://www.gov.uk/government/publications/apply-for-heat-networks-investment-project-hnip-funding

A10 https://www.hiesscheme.org.uk/renewable-energy/home-wind-turbines/

A11 https://www.carbonbrief.org/analysis-uk-renewables-generate-more-electricity-than-fossil-fuels-for-first-time?utm_content=buffer92635&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer

A12 https://beismedia.blog.gov.uk/2020/03/03/support-for-onshore-wind-to-drive-green-commitment/

Technology	Type	Description	UK policy, funding, and trends	Design considerations, deployment costs, and performance
Solar PV	On site and in home	Solar electricity panels, also known as photovoltaics (PV), capture energy from the sun and convert it to electricity. Solar panels do not need direct sunlight to work and can generate electricity on a cloudy day. However, the stronger the sunlight, the greater the amount of electricity generated. Most solar PV systems are made up of panels which are installed on a roof, but there are also systems that can be ground-mounted or installed as solar tiles. PV panels are most efficient when orientated to the south, but this is not essential for them to work effectively.	■ The UK Solar PV Strategy,[A13] published in 2013, sets out the government's vision for scaling up solar PV in the UK. Among its 'guiding principles' was the aim to support solar PV sufficiently to help deliver the UK's target of 15% renewable energy in final consumption by 2020. Government data[A14] suggests that the UK had achieved 13.2% of final energy consumption from renewable sources by 2019. By July 2020, solar accounted for 13,451 megawatts[A15] of a total renewable electricity capacity of 48.5 gigawatts.[A16] ■ In January 2020, the UK government introduced the Smart Export Guarantee (SEG), which ensures that small-scale generators of renewable electricity, such as homeowners, are paid for the excess energy they generate.[A17]	■ The cost per kilowatt of small-scale solar PV has decreased from £2,080 in 2013/14 to £1,562 in 2019/20.[A18] The average cost of a domestic solar PV system is approximately £4,800 for a 3.5 kilowatt system.
EV charging	On site and in home	Electric vehicle (EV) charging points can be installed almost anywhere where there is a connection to the national grid.	■ In 2019 it was announced that it will soon be mandatory for all new-build homes to have an EV charging point installed.[A19]	■ A full charge of a pure (100%) electric vehicle will give a typical range of over 100 miles.

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A13 https://www.gov.uk/government/publications/uk-solar-pv-strategy-part-1-roadmap-to-a-brighter-future
A14 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/894920/Press_Notice_June_2020.pdf
A15 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/920082/Solar_photovoltaics_deployment_August_2020.xlsx
A16 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/920621/Renewables_September_2020.pdf
A17 https://www.ofgem.gov.uk/environmental-programmes/smart-export-guarantee-seg/about-smart-export-guarantee-seg
A18 https://www.gov.uk/government/statistics/solar-pv-cost-data
A19 https://www.gov.uk/government/news/electric-car-chargepoints-to-be-installed-in-all-future-homes-in-world-first

Technology	Type	Description	UK policy, funding, and trends	Design considerations, deployment costs, and performance
Solar PV *(Continued)*				■ The cost of using an EV charge point varies, depending on which type of charge point is used.[A20] If charging at home, a full charge might currently cost £4-£6; if using a public charge point, £8-£10. This is much cheaper than driving a petrol-fuelled car for the same distance, which will cost approximately £13-£16.[A21]
Building fabric	In home	Buildings can be designed to both minimise energy demand and carbon dioxide emissions throughout their lifetime. This involves careful consideration of siting and design, construction, use, upkeep, renovation and eventual demolition.	■ From October 2019 to February 2020, the UK government ran the first of a two-stage consultation: *The Future Homes Standards: Changes to Part L and Part F of the Building Regulations for New Dwellings.*[A22] To be launched in 2025, the standard will require all new homes to be future-proofed with low-carbon heating and higher levels of energy efficiency.	■ Future-proofing building design to facilitate changes to technologies over time should be factored in from the outset. ■ The UKGBC's *Net Zero Carbon Buildings: A Framework Definition*[A23] and the Energy Systems Catapult's *Six Steps to Zero Carbon Buildings*[A24] outline a potential future policy framework to help decarbonise homes.
Heat pumps	In home	Heat pumps are an effective and efficient way to heat buildings. They work by absorbing heat from a source and then transferring it to a liquid, which is then compressed to heat it further. This heat is then transferred to water, which is used to heat a property.	■ The Committee on Climate Change has estimated that 19 million heat pumps need to be installed in UK homes and businesses by 2050 to help meet the net-zero target set by the government.[A25] ■ The Renewable Heat Incentive (RHI) provides financial support to the owner of a renewable heating system for seven years. Those who install heat pumps are eligible for the scheme.	■ Typical costs for ground source heat pump installation, including groundworks, are in the region of £20,000, which may increase to £27,000 if new heat distribution systems in the home are required. Typical costs for air source heat pump systems are in the region of £9,000 for a small system using the existing heat distribution system, but may reach £22,000 in a larger home where a new distribution system is also required.[A26]

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A20 https://www.spenergynetworks.co.uk/userfiles/file/Electric_Vehicle_Handbook.pdf
A21 https://energysavingtrust.org.uk/advice/electric-vehicles/
A22 https://www.gov.uk/government/consultations/the-future-homes-standard-changes-to-part-l-and-part-f-of-the-building-regulations-for-new-dwellings
A23 https://www.ukgbc.org/wp-content/uploads/2019/04/Net-Zero-Carbon-Buildings-A-framework-definition.pdf
A24 https://es.catapult.org.uk/comment/six-steps-to-zero-carbon-buildings/
A25 https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-Technical-report-CCC.pdf
A26 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/913508/cost-of-installing-heating-measures-in-domestic-properties.pdf

Technology	Type	Description	UK policy, funding, and trends	Design considerations, deployment costs, and performance
Heat pumps *(Continued)*				■ Ground source heat pumps are more expensive to install but are much more efficient than air source heat pumps and therefore will provide greater cost savings over the long term. ■ Air source heat pumps are generally easier to install than ground source pumps, as they do not require land to be dug up. Ground source heat pumps require land – the amount of land available will determine whether the ground loop is laid horizontally (requiring more land) or vertically (requiring less land, but more expensive). ■ Hybrid heat pumps combine an electrically driven heat pump with a gas boiler, along with a dedicated controller. These systems provide flexibility in use of gas and electricity in meeting home heating demands. Approximate costs are £6,000-£10,000, depending on system design.[A27]
Boilers	In home	Boilers heat water, which is then transported along pipes and into radiators to provide space heating, or for direct use as hot water. Most commonly, boilers use natural gas as fuel to heat water. However, boilers can also be powered by electricity or wood chips (biomass).	■ The UK government announced in March 2019 that gas boilers will be banned in all new homes built after 2025.[A28] ■ The Renewable Heat Incentive (RHI), described above, also applies to biomass boilers.	■ The costs of installing boilers vary, depending on the type. Approximate costs are: ● Combi: £1,600-£3,500. ● Heat only: £1,400-£2,500. ● System: £1,500-£2,800.

A27 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700572/Hybrid_heat_pumps_Final_report-.pdf
A28 https://www.theguardian.com/environment/2019/mar/13/hammond-says-gas-heating-will-be-replaced-by-low-carbon-systems

Technology	Type	Description	UK policy, funding, and trends	Design considerations, deployment costs, and performance
Battery storage	In home	Battery storage can be deployed both on the grid and at an individual consumer's home or business. It is often combined with a renewable source of energy (such as solar PV) to enable households to make and consume their own power on demand.	■ While still expensive, battery storage used to store renewable energy in the home is fast becoming an increasingly viable option, with a growing number of products of offer, such as the Moixa smart battery system and the Tesla Powerwall.[A29]	■ The costs of installing in-home battery storage are approximately: ● 4 kilowatt-hour battery: £5,000 (nine-year lifespan). ● Inverter: £800 (12-year lifespan). ● Solar PV 4 kilowatt size: £6,200 (25-year lifespan).[A30] ■ It is likely that the battery will need to be replaced before the solar PV system.
Thermal storage	In home	Thermal stores are highly insulated hot water tanks that can store heat energy for many hours. They are often used in conjunction with a renewable energy source to store energy generated as heat until it is needed.	■ Innovation in thermal storage offers potential for more compact storage of heat energy in homes and buildings. Technologies such as Sunamp Heat Batteries[A31] have the potential to help reduce the space taken by thermal storage and integrate with renewable and low-carbon heating technologies.	■ The cost of a 500 litre hot water thermal store is approximately £2,500. The costs of other forms of thermal storage are higher and more variable, depending on system design.
Smart heating controls	In home	Smart heating controls allow residents to efficiently manage the temperatures in their homes, and can result in a 35% reduction in energy usage. They are a potentially important enabler in the effective integration and operation of low-carbon heating technologies in new and existing homes.[A32]		■ Prices range from around £100 per home for a basic model, up to several hundred pounds. ■ Households can save up to £150 a year on their energy bills.

A29 https://www.forbes.com/sites/quora/2015/05/14/heres-why-teslas-battery-is-a-big-deal/?sh=4719f715c53c#2ea7102ac53c

A30 https://energysavingtrust.org.uk/home-energy-storage-right-me/

A31 https://www.sunamp.com/residential/

A32 https://es.catapult.org.uk/reports/pathways-to-low-carbon-heating-dynamic-modelling-of-five-uk-homes/