Centre for
Sustainable Energy

Developing a **sustainable energy masterplan strategy** for the Temple Quarter Enterprise Zone

Commissioned by Bristol City Council
Final report (Revised 6 Oct 2014)

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Executive Summary

Bristol City Council (BCC) has commissioned the Centre for Sustainable Energy (CSE) to develop the basis for a sustainable energy masterplan for the Temple Quarter Enterprise Zone (TQEZ). The TQEZ covers approximately 70 hectares of land in central Bristol, and its development forms one of the largest urban regeneration projects currently underway in the UK consisting of a mixture of commercial and public sector buildings with a small proportion of residential.

A Zero Carbon TQEZ

The key aims of the study have been to review the available options for installing low and zero carbon energy supply technologies within the TQEZ at both the micro and district scale, and to provide recommendations for their effective delivery in order to meet the aspirations of BCC and partners that the TQEZ becomes a zero carbon development. This report presents the findings of the study and includes a review of:

- Baseline energy demands and related carbon emissions arising from existing and proposed buildings within the TQEZ over the three phases of the development.
- Available renewable energy resources and constraints.
- Low and zero carbon energy supply opportunities, including modelling of various potential scenarios.
- Planning policy considerations and delivery options.
- Stakeholder engagement activities undertaken within the study.

For the purposes of this study, zero carbon can be defined as ‘zero net operational emissions’, where total emissions from heat and electricity use in buildings during occupation are offset by displaced emissions from low or zero carbon on-site heat and electricity generation within the TQEZ. This assumes that such generation can be used to offset the Zone’s emissions whether the energy is used within the Zone or exported to external users. Other ‘off-site’ options, such as Allowable Solutions also remain, but will depend on the agreed definition of zero carbon (hereafter referred to as ‘Zero Carbon’). The definition in this study is applied to two cases: in relation to new development only and to combined existing and new development across TQEZ. The study does not consider the impacts and decarbonisation opportunities of waste, water or transportation.

Energy demands of TQEZ

As would be expected, the demand for energy within the TQEZ is likely to increase in line with more buildings being built and occupied within TQEZ. Figure 1 below provides an overview of the way in which total demand is predicted to grow during the three phases of development set out within the TQEZ Spatial Framework[1]. These figures represent a ‘business as usual’ scenario, and assume that developers will meet, but not exceed, the minimum energy efficiency standards set through Building Regulations. The impact of future changes to these regulations has been estimated based on a series of assumptions, which are set out within the main body of the report.

It should be noted that although energy demand increases throughout the three phases of development, corresponding overall CO_2 emissions begin to decrease as a result of the expected decarbonisation of the UK’s electricity supply mix over this period.

[1] Bristol City Council City Design Group: Temple Quarter Enterprise Zone Spatial Framework, Second Edition, April 2013.

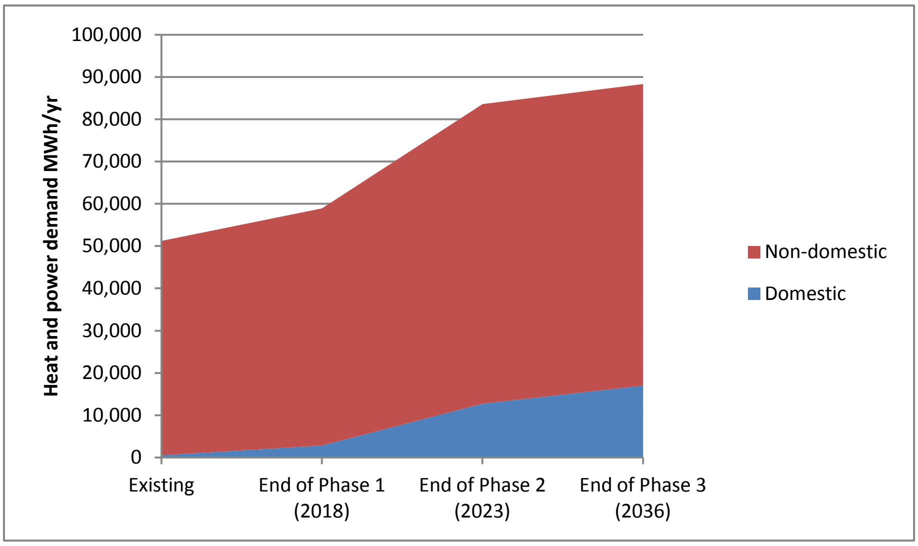

Figure 1: TQEZ cumulative energy demands

Renewable energy resources

Few 'large scale' renewable energy resources, such as large onshore wind, were identified within the boundary of TQEZ. The lack of open space, low urban wind speeds and the planning constraints associated with residential properties effectively exclude the erection of standalone wind turbines. Previous studies have indicated that the watercourses are unsuitable for hydroelectric generation; however, BCC has identified and is exploring potential hydroelectric generation at Netham Weir, which is just outside the TQEZ. Decarbonisation of mains gas supplies through the injection of biogas into the gas grid is another potential option for Bristol, although outside the scope of this study. This requires production of biogas through processes such as anaerobic digestion and will for example help to increase the CO_2 savings associated with gas CHP.

An assessment was also undertaken of sustainable woodfuel sources within a 20km radius of the TQEZ boundary. This found that existing woodland, if managed correctly, could provide almost 20,000 tonnes of wood fuel each year. This is potentially enough to satisfy the annual heat and power needs of the entire TQEZ through the installation of biomass technologies. Within this radius, there may also be potential for the growth of nearly 10,000 tonnes per year of woody energy crops.

Low and zero carbon energy supply scenarios

A number of carbon reduction scenarios have been modelled on TQEZ using combinations of building-integrated renewables and combined heat and power (CHP) district energy systems to explore on-site Zero Carbon concepts. In this context, the term 'building-integrated' is used to describe micro or small-scale systems that serve individual buildings in contrast to district energy, where an energy centre supplies a network of buildings. District energy supply networks were identified on the basis of selecting zones with the highest spatial heat demand density (i.e. dense building clusters with relatively high heat loads) over the three TQEZ development phases.

Figure 2 below shows a heat map of the area overlaid with routes of illustrative district heating networks, and Table 1 describes the scenarios considered and their key impacts on emissions using a 'business as usual' Phase 3 CO_2 emissions baseline of approximately 18,000 tonnes per year.

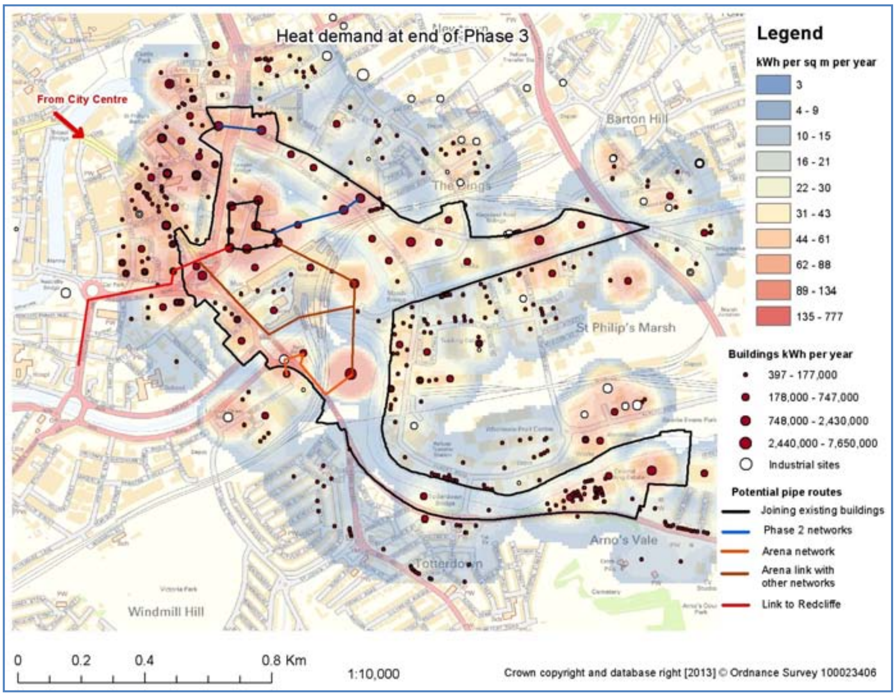

Figure 2: District heating opportunities within TQEZ at end of phase 3 (also showing potential external links to schemes under consideration in Redcliffe and the City Centre)

Scenario	Phase 3 CO_2 reduction on new development	Phase 3 CO_2 reduction on all existing and new development	Approx additional capital cost	Description
Scenario 1: BIR only	57%	34%	£15m	Solar PV, biomass boilers for larger buildings and a combination of heat pumps and solar thermal systems for smaller buildings. The heat technologies have been modelled as meeting optimum base heat loads as a minimum whilst remaining within the realms of technical and financial viability. Renewable electricity BIR comprises solar PV only and is based on estimates of roof area and orientation.
Scenario 2a: BIR + small biomass CHP	57%	43%	£20m	As per Scenario 1, but with a relatively small district heating network of existing buildings served by a 1.4MWth biomass CHP plant. This is assumed to displace some of the BIR heating renewables throughout the buildings served by the CHP.
Scenario 2b: BIR + small gas CHP	57%	27%	£15m	As per Scenario 2, but with a 1.4MWth gas CHP plant instead of biomass.
Scenario 3: BIR + large scale biomass CHP	(Not modelled)	52%	£27m	A theoretical 5MWth biomass CHP plant supplying a non-defined heat network, but where use of its heat and electricity output is prioritised within the TQEZ. This is assumed to displace all of the BIR heating within the TQEZ as modelled in Scenario 1, leaving just solar PV as the BIR element of this scenario.

Table 1: Scenario descriptions and headline findings

Figure 3 illustrates the Phase 3 CO_2 reductions for all TQEZ existing and future buildings.

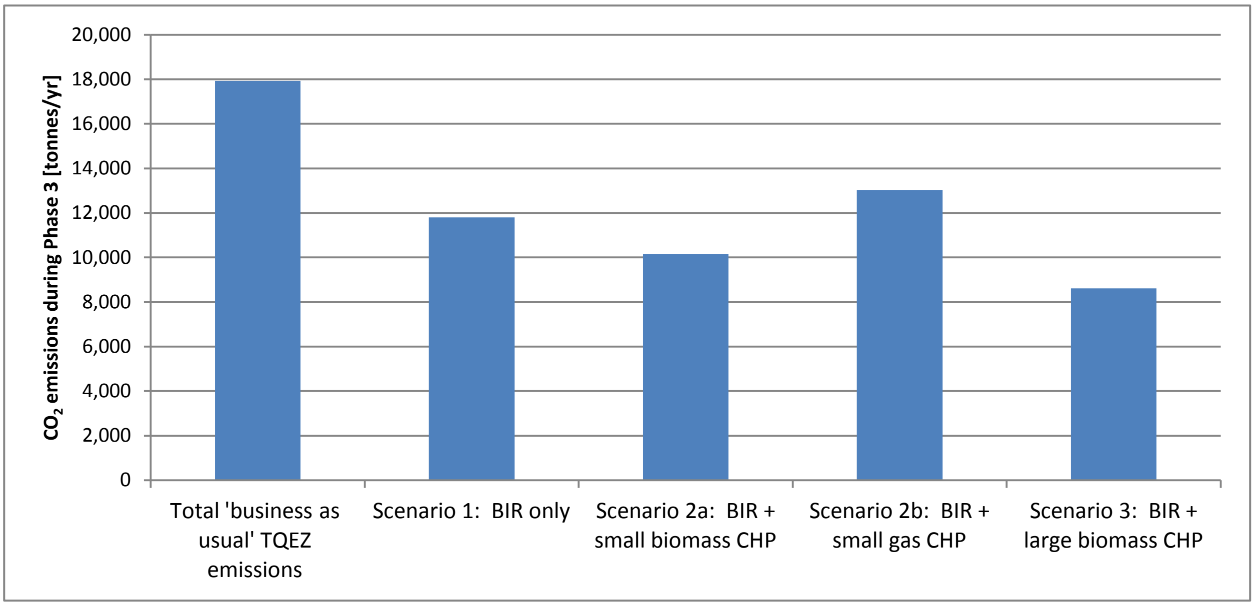

Figure 3: Summary of total CO_2 reduction potential (all existing and future TQEZ development) from modelled scenarios involving building-integrated renewables (BIR) and combined heat and power (CHP) district energy systems

Summary conclusions

- Examples of district energy networks across the zone have been modelled, with large scale biomass CHP being the most promising energy supply option in terms of singularly contributing to a Zero Carbon scenario. The assessment of building-integrated renewables has also shown potential for significant emission savings across the TQEZ using technically and financially viable technologies and would be needed alongside a district energy solution to maximize savings. This high level analysis suggests that, like for like, biomass CHP would provide greater returns than mains gas CHP and lower emissions. Viability, however, will need deeper analysis and careful monitoring to account for issues such as future changes in technology, subsidies, fuel costs and obligations on developers.

- Although it is thought Scenario 3 may approach on-site Zero Carbon for new development, it is still some way off from achieving on-site Zero Carbon for the TQEZ as a whole. If all emissions from existing and future TQEZ buildings are to be fully mitigated on-site, renewable heating would in some cases need to be sized to meet peak heating requirements, and significantly more renewable electricity generation would be needed within the TQEZ. Solar PV deployment in new development sites could further contribute through innovative building design and/or the use of ground-mounted solar PV arrays in dead-space (strips or parcels of land without another use). Whilst increasing the size of biomass CHP may close the gap, the corresponding heat generated would most likely exceed the demand of TQEZ and so would need to be exported in order to maintain value and plant financial viability. Other ‘off-site’ options, such as Allowable Solutions also remain, but will depend on the agreed definition of Zero Carbon.

- There may be opportunities in the future to expand a first-phase district heating network to additional existing or future development sites within TQEZ, as well as potentially linking up to networks being developed elsewhere in Bristol. This will require a strategic view of Bristol’s future energy infrastructure and is very much dependent on the appetite of developers and others to invest in these solutions.

- Acting independently, most developers within the TQEZ are currently unlikely to exceed sustainable energy requirements beyond existing or forecast planning policy or building regulations, including linking up to district energy solutions. If TQEZ is to become Zero Carbon the opportunities for the supply of sustainable energy need to be seen as attractive to developers, their investors and customers (building occupants) and other stakeholders in TQEZ. If designed correctly using a collaborative approach, appropriate sustainable energy solutions are more likely to be taken up by developers and other TQEZ stakeholders. The timing of this study is important; the development of the TQEZ has already begun, and in order to make the most of the opportunities it presents, engagement and leadership from BCC is required.

- Financially viability is clearly an essential criterion for most developers in weighing up sustainable energy options. The Allowable Solutions mechanism (carbon offsetting) in particular presents an opportunity to help finance these options. Allowable Solutions put developers in control of how to achieve zero-carbon standards through the use of both additional onsite renewable energy measures and offsite carbon saving initiatives. Other potential funding routes for delivering sustainable energy within TQEZ include the Community Infrastructure Levy (CIL), and using Feed in Tariff (FiT) and Renewable Heat Incentive (RHI) renewable energy generation subsidies.

- In researching this study, a number of uncertainties were identified which will need to be considered during further development of the TQEZ energy masterplan. These are largely a result of the long period over which TQEZ will develop which creates challenges in predicting energy demand figures, costs and revenues and the impact of future Building Regulations.

Key recommendations

In further developing and refining the TQEZ energy masterplan, BCC need to prioritise continuing stakeholder engagement, and to set an Allowable Solutions framework and Energy Services Company (ESCo) that developers find attractive enough for investment and delivery of the decarbonisation requirements. In order to achieve this, CSE recommends that BCC:

1. **Facilitate a more detailed energy masterplanning process** - coordinate further energy masterplanning activities with the STEEP project[2] (Systems Thinking for comprehensive city Efficiency Energy Planning) to engage stakeholders in the masterplanning process, and thereby develop a process model which reflects a shared vision and strategy of a sustainable TQEZ. This should include achieving a consensus on an overarching aim or target regarding energy use and/or emissions such as one of the scenarios considered in this report, but one which also has stakeholder buy-in, is clear in its scope and can be monitored.
2. **Define and further investigate the most suitable district heating network option** - using the preliminary heat mapping work and network options presented in this report, investigate further the potential for a district energy scheme which initially connects TQEZ existing buildings. This investigation should:
    - Obtain actual heating demand data for the existing buildings that would potentially connect to the network (shown in Table 14), whilst checking the appetite of stakeholders and testing viability to connect to the district heating network.
    - Examine in more detail the potential network routes and the position of the energy centre, taking regard of the infrastructure constraints in the TQEZ and possibilities for a cooling network.

[2] http://www.smartsteep.eu/

- Take into account strategic opportunities to link up with district heating options being considered for areas adjacent to the TQEZ such as the proposed scheme in the Redcliffe area and/or an energy centre in St Phillips.
- With potential customers of the network, decide upon a suitable delivery model.

3. **Provide 'Zero Carbon' support to developers by**:
    - Providing developers with more clarity on which policies they will need to comply with, especially policies BCS13-15 within the Bristol Core Strategy and how 'Zero Carbon' should be interpreted.
    - Providing developers with details of how the Council will work with them to achieve Zero Carbon developments through the creation of a shared ESCo and Allowable Solutions framework.
    - Developing a design guide on how buildings can meet Zero Carbon standards through measures such as passive solar design, natural ventilation, super-insulation, on-site generation and, where available, ways to fully benefit from local district heating/cooling networks e.g. provision for future connection, incorporation of low temperature heat distribution systems and building-wide cooling circulation loops.
    - Ensuring that any emerging ESCo delivery vehicle can benefit developers by maximising potential subsidies for zero carbon development such as the Community Infrastructure Levy, Allowable Solutions or other sources of finance. It should also encompass a structure which allows different levels of ownership and risk management between the council, customers (TQEZ developers, building occupants and residents) and investors. BCC will need to consider whether TQEZ needs a specific ESCo, or whether a Bristol-wide ESCo will be sufficient.
4. **Embed Zero Carbon infrastructure across all TQEZ developments** - embed sustainable energy considerations within other development work for the TQEZ such as:
    - Consideration of proposed energy network routes when specifying infrastructure for utility service corridors e.g. use of multipurpose ducting which could accommodate district heating pipes.
    - When conducting ground surveying, include investigation of ground conditions for proposed district heating routes and the potential for boreholes as a heat/cooling source for ground source heat pumps.
5. **Maximise use of local sustainable energy resources -** investigate further the opportunities to utilise the area's sustainable energy resources to help achieve a Zero Carbon TQEZ. This might include:
    - District or single building cooling/heating using technology such as water source heat pumps in conjunction with the area's waterways.
    - District or single building cooling/heating using waste water systems.

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1 Introduction

This report presents the outputs of a sustainable energy master-planning study conducted in 2013-14 by the Centre for Sustainable Energy (CSE) on behalf of Bristol City Council (BCC), focusing on Bristol's Temple Quarter Enterprise Zone (TQEZ). Sustainable energy master-planning is a relatively recent concept lacking a unilaterally accepted definition.

The TQEZ is a large area in central Bristol, comprising of existing buildings including Bristol Temple Meads station and the existing Paintworks site, and high profile new development sites such as BCC's proposed arena at the Diesel Depot site. In total, there are approximately 28 hectares of previously developed 'brownfield' sites that could provide an estimated 500,000m^2 floor space for employment and residential usage.

The development of these brownfield sites splits across three phases. Whilst more details are known about development starting in the first phase, plans for the second and third stages are less defined. As a minimum, each site has generally been assigned an estimated floor area breakdown, split between 'residential', 'employment' and 'other'. The timescales of development phases are:

- Short Term Phase 1 (2013 – 2018)
- Medium Term Phase 2 (2018 – 2023)
- Long Term Phase 3 (2023+)

A 'Zero Carbon' TQEZ

The purpose of this energy master-planning process is to inform BCC on the levels of increased energy demand and carbon emissions expected from the development of TQEZ, the opportunities to mitigate these increases via sustainable energy supply solutions and recommendations on how BCC can help realise these opportunities.

There is an aspiration by BCC and partners that the TQEZ becomes a zero carbon development. For the purposes of this study, zero carbon can be defined as 'zero net operational emissions', where total emissions (i.e. both those regulated and unregulated by Building Regulations[3]) from heat and electricity use in buildings during occupation are offset by displaced emissions from low or zero carbon on-site heat and electricity generation within the TQEZ. This assumes that such generation can be used to offset the Zone's emissions whether the energy is used within the Zone or exported to external users. Other 'off-site' options, such as Allowable Solutions also remain, but will depend on the agreed definition of Zero Carbon. The definition in this study (hereafter referred to as 'Zero Carbon') is applied to two cases: in relation to new development only and to combined existing and new development across TQEZ. The study does not consider the impacts and decarbonisation opportunities of waste, water or transportation.

Realising TQEZ's sustainable energy supply potential will not only help developers and building occupants to better prepare for a sustainable future, it will also:

- Contribute towards Bristol's 40% carbon reduction target and 30% energy reduction target[4].
- Assist developers in meeting BCC's energy-related policies included within their Core Strategy policies BCS13-15[5], including a 20% onsite renewable energy requirement. For example, there may be better

[3] Regulated emissions are those limited by Building Regulations and relate to energy used by space and water heating, fixed lighting and pumps/fans. They do not include emissions from cooking or appliances and for dwellings typically represent around two-thirds of total emissions.
[4] Both targets are set against a 2005 baseline, within BCC's Climate Change & Energy Security Framework: www.bristol.gov.uk/page/environment/council-action-climate-change
[5] Adopted November 2011: www.bristol.gov.uk/page/planning-and-building-regulations/planning-core-strategy

opportunities identified by considering strategic district-scale solutions rather than adopting a building-by-building approach.

- Set a positive approach to sustainable energy within new development in Bristol for years to come; thereby helping continue the work within the BCC's Energy Services[6], and galvanize the council's position as European Green Capital[7].

The timing of this study is important. The development of the TQEZ has already begun, and in order to make the most of the carbon-saving opportunities it presents, engagement and leadership from BCC is required. This study forms the first step, identifying options BCC and others can take within the TQEZ, and starting the engagement process with TQEZ stakeholders.

The study considers:

- The available sustainable energy supply resources and constraints facing larger-scale, non-building-integrated low-carbon energy generation.
- The estimation of the energy demands and carbon emissions of TQEZ's existing buildings and future developments. These form the basis of heat demand maps.
- The modelling of energy supply options, including the potential for district heating or combined heat and power (CHP) and opportunities for integrating low and zero carbon energy generation into existing and future buildings within TQEZ. Deployment scenarios consider the minimum and maximum technically and financially viable opportunities.
- Planning policy (including Building Regulations) implications, alongside opportunities for funding and the potential for an Energy Services Company (ESCO) as a delivery mechanism.
- The engagement of TQEZ stakeholders, to provide data and collect their views on decarbonisation approaches.

This study aims to inform BCC's actions in the near-term, using the best available data and an understanding of the sustainable energy sector. Whilst it is important to consider options for encouraging the deployment of low and zero carbon technologies at this stage, there are still large uncertainties surrounding the progression towards zero carbon buildings, the application of planning policy within TQEZ, the characteristics and phasing of new development, and the costs and subsidies available for sustainable energy solutions. As further data becomes available, this study's findings will need to be updated and fed into the evolving TQEZ sustainable energy masterplan. BCC will need to lead and collaborate on the development of this masterplan in order to set out a realistic strategy and action plan.

CSE believes the Systems Thinking for comprehensive city Efficiency Energy Planning (STEEP) project[8] provides an effective platform to help develop the shared energy masterplan. STEEP is a European initiative that BCC is working on alongside University of Bristol, CSE, Arup and European partners in Florence and San Sebastian. It will compliment the work necessary to define this strategy, and to consider the energy consumption and carbon emissions arising from a wider range of sources, including both transport and other infrastructure.

[6] BCC Strategic Energy Unit: http://www.bristol.gov.uk/page/environment/strategic-energy-unit
[7] Bristol was awarded the European Green Capital Award for 2015: http://bristolgreencapital.org/european-green-capital-award/
[8] The STEEP website provides more information on the objectives, timescales and partners of this EU FP7 funded project: http://www.smartsteep.eu/

2 Methodology

This section sets out the methodologies used in conducting:

- Resource & constraints assessments
- Estimating energy demand and heat demand mapping
- Energy supply modelling
- Stakeholder engagement

2.1 Resource and constraints mapping

Low and zero carbon energy generation opportunities within TQEZ are limited by factors such as raw resources and building characteristics, as well as other external constraints. The Bristol Citywide Sustainable Energy Study was undertaken in 2009 by CSE for Bristol City Council as part of the Local Development Framework evidence base[9], and identifies the city's main sustainable energy resources.

The resource potential for wind, solar and hydroelectric power has been reassessed under this project and updated where possible using more recent studies. The available biomass resource was previously assessed based on the City of Bristol boundary, and needed reassessment for this study using the TQEZ boundary.

2.1.1 Biomass resource

The potential biomass resource available for use within TQEZ is focused on woodfuel and was assessed under the assumption that only resources within a 20km radius would be suitable, with anything beyond that distance being considered unsustainable to transport. Two sources of biomass were analysed: woodland residues and woody energy crops.

The latest Forestry Commission National Forest Inventory (2011) was combined with typical yields of the different types of woodland to calculate the potential existing woodland resource within 20km of TQEZ.

In addition to the existing woodland resource, there is also potential for energy crops to be grown. Short rotation coppice (SRC) and miscanthus are the most common form of energy crops in the UK, and can be grown on agricultural land of grades 1-3 (arable land). The total technical potential resource for energy crops was assessed by looking at the total amount of suitable agricultural land within a 20km radius of the TQEZ, using land classifications from the Department for Environment, Food and Rural Affairs (DEFRA)[10].

A series of constraints were then applied to the gross potential land area to establish a more practical resource estimation:

- Areas where the wind speed is over 7m/s at 10m above ground level is unsuitable to growing miscanthus.
- Urban areas, grassland and common land have been added as a constraint to the use of energy crops.
- Protected land and woodland are excluded.

Various scenarios regarding the proportion of this net land area that could be used for energy crops were then assessed and yield factors applied to assess the potential energy crops energy resource.

[9] http://www.bristol.gov.uk/page/planning-and-building-regulations/bristol-citywide-sustainable-energy-study
[10] Available from www.magic.gov.uk

2.1.2 Additional constraints to low and zero technologies

Other constraints to sustainable energy technologies investigated in this study include:

- Existing infrastructure such as highways, train tracks, waterways and utilities. These may constrain the routes of district energy networks, but also offer opportunities to integrate energy infrastructure with other utilities or alongside existing infrastructure.
- Existing listed buildings have comparatively lower carbon-saving opportunities, as retrofitting works are limited through their potential to cause damage to the building fabric or cause harm to the historic appearance.
- The phasing and mix of future development sites will guide renewable and low-carbon integration into new development and the opportunity to connect development sites and existing buildings with district energy schemes.
- Flood risk areas that district energy schemes or energy centres may need to avoid, or at least mitigate against and therefore incur additional cost.
- Air quality and smoke-control zones, which will limit the types of combustion plant (such as biomass boilers) allowed and at the very least require assessment of predicted emissions.

The 'Utilities Strategy for Spatial Framework' study[11] was used to identify constraints arising from existing infrastructure.

2.2 Estimating energy demand

2.2.1 Existing energy demand

In order to explore and identify the most appropriate combination of low and zero carbon energy supply measures for implementation within the Enterprise Zone, the energy demand of its existing buildings was first calculated. Heat demand was mapped across the zone using CSE's National Heat Map tool[12], which is based on a bottom-up address level model of heat demand, estimated from a range of sources including published sub-national energy statistics and industry standard benchmarks.

A buffer zone of 50 metres was applied to the perimeter of the Enterprise Zone to allow for the identification of locations where heat demand was sufficient for district heating networks to be possible, without excluding those where the useful heat demand was not entirely focused inside the zone boundary.

The demand for electricity is not included within the heat map data, therefore this was calculated separately for non-domestic premises using heated floor areas and the associated CIBSE benchmarks for electricity consumption based on property type. For residential properties, Lower Layer Super Output Area (LSOA) electricity consumption data was apportioned to account for the area covered by TQEZ, and then assigned to individual properties in line with floor area estimates.

2.2.2 Future energy demand

As the Enterprise Zone is a major redevelopment project there are a large number of new developments planned for construction during the coming decade, which will have a significant impact on the distribution of energy demand. The development type (i.e. 'residential', 'employment' or 'other') and the likely floor areas for these developments have been previously estimated per land parcel and are stated within the Temple Quarter

[11] Mott MacDonald (2013-14) study for BCC
[12] National Heat Map website: http://tools.decc.gov.uk/en/content/cms/heatmap/about_map/about_map.aspx

Enterprise Zone Spatial Framework documentation. At this point in time, these proposals are at varying stages of development, in most cases with relatively few additional details available regarding their form or function.

Due to both a lack of suitable benchmarks and future regulatory uncertainty, these figures should be considered to be ballpark figures. Key areas of uncertainty within the future energy demand calculations include:

- The accuracy of the floor area estimates within the spatial framework, and the proportion of each of the floor areas that is likely to be classed as heated space.
- Detailed use and function of buildings.
- Future local and national building/construction standards and their impact on levels of energy efficiency and on-site generation.
- Building fabric characteristics to estimate peak heat demands.

Also, it should be noted that this analysis focused purely on the demand for energy arising from the say-to-day running of buildings, and that energy consumption of site infrastructure (street lighting, transport and so on) has not been considered here.

Emission factors

The developments listed in the spatial framework are split into three time phases; 2013 to 2018, 2018 to 2023, and 2023 onwards. Baseline energy demand and associated carbon emissions for the Enterprise Zone have been calculated for each of these phases, taking into account the expected tightening of Building Regulations Part L and predicted grid carbon intensity for both gas and electricity over time. When calculating emissions from existing and projected energy demands, CO_2 conversion factors were used from the publication '2012 Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting'. These are reproduced in the table below:

Year	Electricity [$kgCO_2/kWh$]	Gas [$kgCO_2/kWh$]
2013	0.44548	0.2055
2014	0.45	
2015	0.43	
2016	0.4	
2017	0.37	
2018	0.35	
2019	0.34	
2020	0.32	
2021	0.28	
2022	0.25	
2023	0.22	
2024	0.2	

Table 2: CO_2 conversion factors for electricity and gas

2.3 Energy supply modelling

The approach taken to modelling sustainable energy supply to the TQEZ put into context the Zero Carbon scenarios mentioned above in conjunction with an assessment of district heating opportunities with corresponding Combined Heat and Power (CHP) energy centres, and a separate assessment of opportunities for building-integrated renewable energy systems. In this context, we use the term 'building-integrated' to describe micro or small-scale systems that serve individual buildings. Although there will also be some cooling demand within TQEZ, viability of district cooling is more difficult to establish without detailed data and so has not been considered within the scope of this study. Cooling technologies, however, are discussed in Section 5.1.

2.3.1 District heating opportunities

CSE's initial approach to assessing areas for district heating potential is to apply an overlay analysis whereby different criteria corresponding to favourable conditions for district heating, such as the presence of anchor loads or high density residential loads, are identified from the heat map and other sources. Favourable conditions are then transformed into separate GIS layers, and overlaid to find areas where some or all of the criteria are true or meet defined thresholds. CSE then investigated these areas further to assess the applicability of district energy.

However, as TQEZ is a relatively small area, it was more appropriate to manually assess mapped heat loads by first examining potential clusters and comparatively high heat loads, and then to investigate potential link routes. The network routes assume fairly direct links between sites to get an initial idea of linear heat density – an approximate indicator used to help establish relative viability. If BCC wishes to proceed with developing a TQEZ district heating solution, more functional routes will need to be defined, taking into account existing and proposed transport infrastructure and strategic link-up opportunities. Energy centre locations have not been considered at this stage, as this too should be incorporated into a more in-depth study once there is greater clarity on the composition of development sites.

An initial high-level measure of heat network viability is to calculate linear heat density (MWh/m/yr) for mapped networks, which is a measure of the annual amount of heat the network will deliver per metre of its length. Financial viability will be greater at higher linear heat densities, where shorter cheaper pipe runs transfer more heat. There is currently little information in the UK as to the minimum level of linear heat density threshold above which schemes may warrant further detailed study. Overall viability clearly depends on many factors such as heat demand profile, plant technology, flow temperatures and economic conditions, and so use of this parameter is limited to making relative comparisons between the networks identified. CSE has conducted a high-level financial appraisal on those networks that have the highest linear heat densities.

2.3.2 District cooling opportunities

Sites with large and continuous cooling demands could potentially be serviced via low carbon district cooling networks instead of conventional vapour compression modular units driven by electricity. Viability is however difficult to establish unless accurate data on cooling loads is available; high level studies using broad estimates will not produce useful results and so district cooling is considered outside the scope of this study. However, options for cooling networks which warrant further study at TQEZ include the following: [13]

- Seeing as district heating with CHP is already a likely measure at TQEZ, Combined Cooling, Heating and Power (CCHP) or tri-generation could be employed, where an absorption chiller is powered by heat from a CHP unit, although if gas CHP is used then benefits will significantly reduce in the future.

[13] More information on absorption cooling technology and tri-generation is available via DECC's CHP Focus: http://chp.decc.gov.uk/cms/cooling-technology/

- Due to the area's waterways, 'free' cooling using water source heat pumps could potentially work in conjunction with CHP plant or where the water is used as an alternative to air-condenser cooling.
- Large scale electrical chillers using low carbon electricity and employing storage of cooling energy e.g. using free cooling from night-time air or operating during nights when electricity is cheaper and the CO_2 emissions factor is lower.

2.3.3 Building-integrated renewable heating opportunities

If designed appropriately, each development site within the TQEZ may be technically suitable for building-integrated renewable heating. There is also the opportunity to retrofit existing buildings with renewable heating where conditions allow. The options considered for building-integrated renewable heating include: biomass boilers, heat pumps and solar thermal systems.

Heating systems can only be sized and have their viability confirmed during either the detailed design of individual buildings, or via a site appraisal for existing buildings. The following analysis provides indicative renewable heating opportunities, based on typical load factors.

Using the latest government-backed research into the performance of renewable heating[14], each TQEZ existing building and development site's peak heat load was calculated; and then adjusted using the ratio between the heating benchmarks used within the baseline model and the heat-energy benchmark used within the report, to reflect the more robust energy-demand modelling applied in this study. The benchmarks used are given below.

Building type	Annual total heating demand (kWh/m^2)	Peak load (W/m^2)
School, pre 1990	127	123
School, modern	62	70
Hotel, pre 1990	196	100
Hotel, modern	136	60
Office, pre 1990	144	90
Office, modern	78	70
Industrial, pre 1990	73	100
Industrial, modern	82	80
Average	112	87
Average modern	90	70

Table 3: Heating requirement benchmarks for modelling renewable heating options

Peak heating capacity figures were then multiplied by the peak load factor appropriate to each renewable technology in order to estimate the capacity of renewable heating system for each building/development site. The renewable heat generation was then calculated by applying the proportion of annual load to the building's predicted heat consumption.

[14] Research on the costs and performance of heating and cooling technologies (SWEETT report for DECC, Feb 2013): www.gov.uk/government/uploads/system/uploads/attachment_data/file/204275/Research_on_the_costs_and_performance_of_heating_and_cooling_technologies__Sweett_Group_.pdf

Building type	Biomass		Heat pumps		Solar thermal	
	% peak load	% annual load	% peak load	% annual load	% peak load	% annual load
School, pre 1990	50%	80%	35%	55%	11%	6%
School, modern	57%	77%	39%	47%	19%	10%
Hotel, pre 1990	100%	100%	9%	20%	31%	16%
Hotel, modern	64%	66%	50%	80%	30%	15%
Office, pre 1990	70%	80%	29%	64%	4%	2%
Office, modern	70%	83%	83%	93%	4%	2%
Industrial, pre 1990	75%	85%	43%	55%	9%	4%
Industrial, modern	78%	83%	67%	80%	9%	4%
Average	69%	81%	48%	65%	13%	6%
Average, modern	67%	77%	60%	75%	16%	8%

Table 4: Renewable heating load factors

Economy of scale means that biomass boilers are generally cheaper at larger scales in terms of capital cost per MW of heat output and more efficient to run (requiring less maintenance). For this reason, a minimum non-domestic biomass boiler capacity threshold of 100 kW has been applied for assessing renewable heating opportunities. Effectively this means this study assumes only buildings or development sites with biomass heat capacities of >100kW are suitable for biomass boilers. If a building has a biomass heating demand capacity of less than 100 kW, a combination of heat pumps and solar thermal systems has been assumed as the most appropriate renewable heating technology.

2.3.4 Modelling solar PV potential

In 2011, Bristol City Council commissioned a solar map[15] to assess the solar power generation potential of every rooftop (and other suitable structure) in Bristol. This used data about the shape and location of every building in the city, along with detailed height data using Light Detection and Ranging (LiDaR). This mapping data was used to assess the solar PV potential on existing buildings. A 60% net:gross factor was applied to the map data, to account for mapping overestimates as found in the solar map evaluation report[16].

The solar potential for new development sites needed however to be based on their area. The assumptions used for development site solar potential were as follows:

- The total roof area in each development site will cover 60% of the site area
- 50% of roof area in each site will have a suitable orientation for solar panels
- Where a roof area is suitable for solar panels, 75% of the suitable roof area will be covered in panels
- 1 square meter of solar panels has a capacity of 0.125 kWp
- Solar PV systems have an average 8% load factor

Capital cost data for solar PV was sourced from DECC's 2012 PV cost update[17].

[15] Bristol City Council solar map: www.bristol.gov.uk/page/environment/solar-energy
[16] Bristol Sunshine: An Analysis of Rooftop Solar Mapping (2011, BCC): www.bristol.gov.uk/sites/default/files/documents/environment/climate_change/5%20Bristol%20Sunshine%20-%20An%20Analysis%20of%20Rooftop%20Solar%20Mapping.pdf
[17] The costs of solar Photovoltaic (PV) used in DECC's model for the UK Feed-In Tariff, Parsons Brinckerhoff: www.gov.uk/government/uploads/system/uploads/attachment_data/file/43083/5381-solar-pv-cost-update.pdf

2.4 Stakeholder engagement

The original scope of work for this study set out a detailed plan for engagement with a broad range of stakeholders, including those from organisations with a regulatory function as well as existing landowners and building occupants. It was later discovered that the Council's STEEP project (Systems Thinking for comprehensive city Efficient Energy Planning) would also involve engagement with the same group of stakeholders on very similar topics, and it was decided that this section of the study should be scaled back to focus on interviewing a smaller number of key stakeholders in greater depth.

CSE identified a shortlist of potential stakeholders using a list of planning submission applicants and a list of TQEZ landowners supplied by BCC. These stakeholders were prioritised based on the size of their development planning applications or of the land parcel that they owned. Contact details for individuals within each of the organisations listed were obtained and a letter of introduction was drafted for distribution by BCC. CSE followed up the letter by email and followed up the request by telephone. During this process it was found that a number of the targeted companies had ceased to operate.

Despite CSE's best efforts to contact and engage stakeholders, only three individuals agreed to participate in this study. CSE had offered either to meet stakeholders in person or to conduct the interview over the phone, and it is unclear why developers did not respond to these requests, however the most likely reason is they saw the study as a low priority.

CSE originally designed the engagement process to run using structured interviews, the template for which is included within Appendix 1. During the interviews, CSE found that few were able to provide greater detail than already included in their application. Section 7 presents the broad findings. Where stakeholders were able to provide greater detail of their proposed development, these details were used to inform the energy demand modelling of future developments.

3 Resources and constraints analysis

3.1 Assessment of sustainable energy resources

3.1.1 Wind power

The Bristol Citywide Sustainable Energy Study included a constraints analysis for three scales (2MW, 300kW, 15kW) of wind power, identifying places that could be suitable for the installation of wind turbines. Within the TQEZ, there were no places that were found to be suitable for these scales of wind power. This was due to low wind speed and high building (dwelling) density. Wind turbines must be positioned far enough from dwellings for noise and other impacts to be acceptable under planning legislation. These conditions have not changed and there remains little potential for wind energy within the TQEZ, unless there are significant changes to planning policy and the conditions applied to safeguard building occupants from excessive impacts from wind turbine developments. Micro-scale 'rooftop' turbines are also not considered further as their input would be minimal in the low urban windspeeds encountered in the TQEZ and their viability below that of other low carbon generation options.

3.1.2 Hydropower

Bristol City Council recently commissioned a feasibility study for hydropower generation at Netham Weir, around 800m from the edge of the Enterprise Zone. This found that tidal variations reduced the potential output of the scheme, but that taking these into account the generating capacity of a 100kW hydropower installation at Netham Weir would be around 385,000 kWh per annum. This would translate into a Feed-In Tariff income of £92,530 per annum, providing an IRR of around 10%. Whilst this renewable energy resource is outside of the TQEZ, it is of significant scale and appears to provide substantial returns. To put this proposal into perspective, a PV array of equivalent generation would need a capacity of over 400kW. CSE therefore recommends BCC continue to pursue this option; however, this is not included within the scope of the current study.

3.1.3 Water source heat pumps

The Department of Energy and Climate Change has recently published a map[18] indicating the location of urban rivers and estuaries that could provide large-scale renewable heating supplies to local communities through water source heat pumps. The River Avon in Bristol, along with the Frome and Chew, is listed as having "potential for water source heat pump deployment for heating and cooling, in areas of high heat demand". Further assessment of the potential within TQEZ is outside the scope of this study and would require a more specialist evaluation.

3.1.4 Biomass (woodfuel)

The potential for woodfuel from sustainably managed woodlands and from energy crop plantations such as Short Rotation Coppice (e.g. willow) or miscanthus was also assessed. Existing woodland types within a 20km radius of the TQEZ, their areas, sustainable yields, and the potential energy output are shown in the following table[19].

[18] www.gov.uk/government/publications/water-source-heat-map

[19] Felled, Ground prepared for planting, Shrub land, and Young trees were also present but have not been included here because of uncertain yield.

Type	Yield factor used [Tonnes/Ha/year]	Hectares	Yield: Tonnes/Ha at 30% moisture	Energy output[20] [MWh/yr]
Assumed woodland	3.86	224	864	3,024
Broadleaved	1.93	7,180	13,858	48,503
Conifer	6.43	780	3,009	10,532
Mixed - predominantly conifer	3.86	264	1,019	3,567
Mixed - predominantly broadleaved	1.93	275	531	1,859
Total			**19,281**	**67,485**

Table 5: woodland biomass resource within 20km of TQEZ

These figures represent the total technical potential from woodland within 20km of the TQEZ. The map below illustrates the location of this woodland resource.

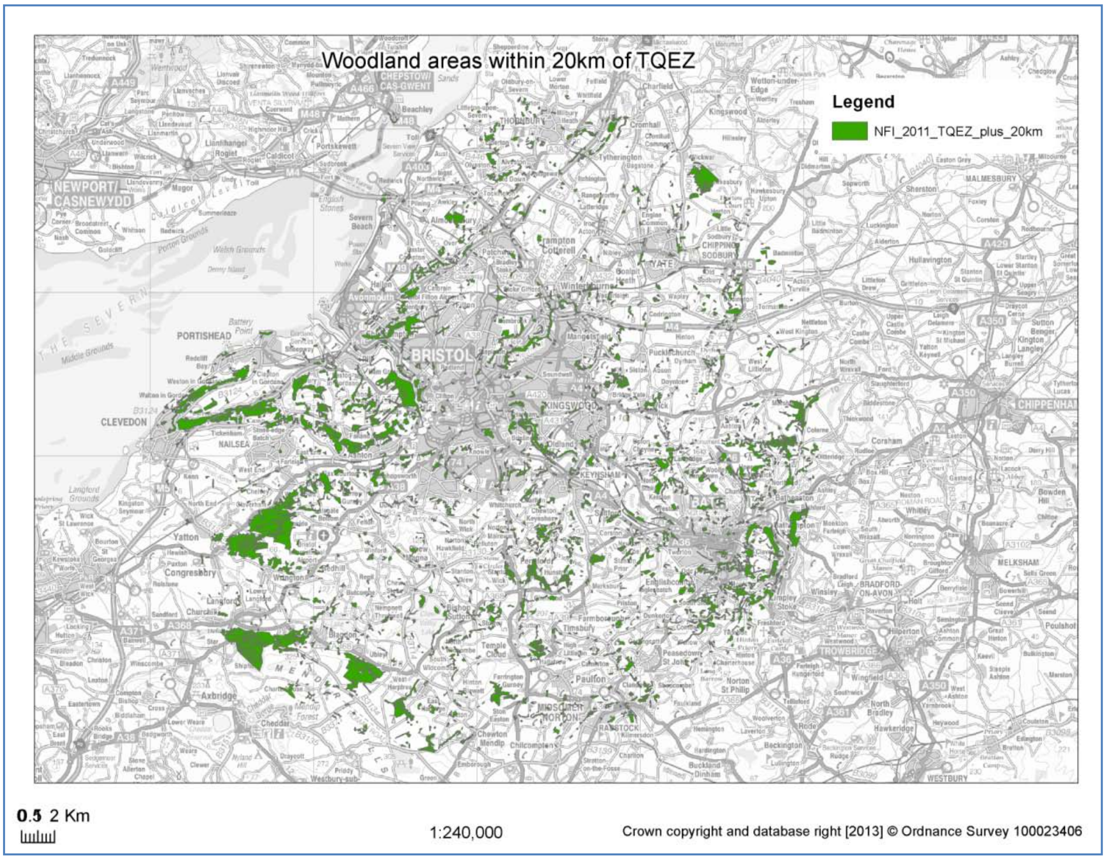

Figure 4: Map of woodland resource within 20km of TQEZ

64,215 hectares of agricultural land were also identified as potential sites for 'woody' energy crop production, 417 of which are not considered suitable for miscanthus. As most agricultural land will currently be in use, either for other crops or as set-aside, establishment of energy crops would require farmers to make the decision to switch to growing energy crops. The map below identifies land that could theoretically be suitable for growing energy crops.

[20] At 30% moisture content, one tonne can produce around 3,500kWh.

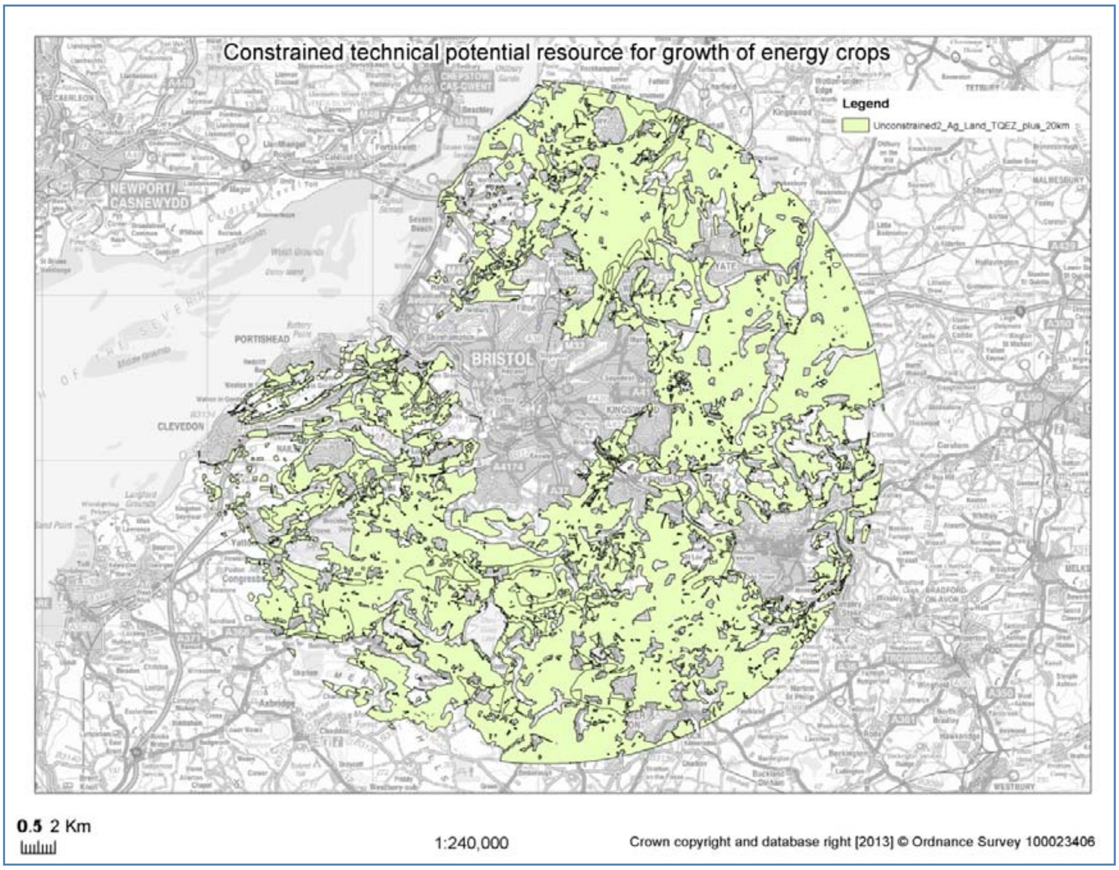

Figure 5: Map of constrained land potentially suitable for growing energy crops

In practice, however, it is likely that only a small proportion of this agricultural land would be switched to energy crops, at least in the short to medium term, and so small percentages of the land are used as examples to give a more realistic assessment of energy crop potential in the table below. This table shows the potential yields that could be obtained by growing different amounts of the crops, and to help illustrate scale, the amount of domestic biomass boilers that this could potentially fuel.

% of available land	Hectares	Yield [oven-dried tonnes]		Energy [MWh[21]]	
		Misccanthus	Using SRC	Miscanthus	Using SRC
100%	64,215 (99% suitable for miscanthus)	956,970	642,150	4,784,850	3,210,750
5%	3,211	48,161	32,108	240,806	160,538
2%	1,284	19,265	12,843	96,323	64,215
1%	642	9,632	6,422	48,161	32,108

Table 6: Energy crop production potential within 20km of TQEZ

Site-specific factors which should be considered when planting energy crops include whether or not the area is water-stressed and the potential (positive and negative) environmental impact of the crops. Energy crops are increasingly considered as multi-functional crops and evidence is emerging that they can be used for non-energy applications such as to help mitigate flood risk, increase biodiversity and for clean-up of waste water, but they may also have a visual impact on protected landscapes.

[21] Using a reference factor of 5MWh per oven dried tonne.

3.1.5 Building-integrated renewable heating

Existing buildings

The 35 existing dwellings within TQEZ were modelled for their gross renewable energy potential, with a minimum threshold of 10kW biomass boiler heating capacity, 3kW heat pump capacity and 0.5kW solar hot water panel capacity. The table below summarises this analysis. In each case, the average renewable energy heat loading was applied. Whilst biomass boilers contribute to both space heating and hot water demands; the modelling assumes that heat pumps contribute to space heating only and that solar hot water systems contribute to hot water, and thus could be combined together within buildings.

Renewable Heating	Peak load [kW]	Heating [kWh/yr]
Biomass boilers	63	96,163
Heat pumps	148	257,666
Solar hot water	44	177,515

Table 7: Renewable heating opportunities in existing TQEZ dwellings

The same analysis was conducted for non-domestic buildings, using the same heating capacity thresholds. The building categories from renewable heat loading figures were best-fit matched to the building types of existing buildings. This analysis is summarised below.

Renewable Heating	Peak load [kW]	Heating [kWh/yr]
Biomass boilers	13,049	12,177,844
Heat pumps	6,339	10,237,030
Solar hot water	1,287	664,670

Table 8: Renewable heating opportunities in existing TQEZ non-domestic dwellings

Future development

A very similar analysis to existing buildings was employed to estimate the renewable heating potential for TQEZ development sites, using the average modern renewable heat loading figures. As before, the capacity figures have been corrected using the ratio of heat consumption, to take account of the lower heating demands of modern buildings.

		Biomass boilers		Heat pumps		Solar hot water	
Phase	Sector	[kW]	[kWh/yr]	[kW]	[kWh/yr]	[kW]	[kWh/yr]
Phase 1 (2013-2018)	Non-domestic	1,372	2,017,373	1,226	1,959,671	318	203,276
	Domestic	651	957,761	582	930,367	151	96,507
Phase 2 (2018-2023)	Non-domestic	3,249	4,777,592	2,904	4,640,942	753	481,404
	Domestic	2,656	3,905,721	2,374	3,794,008	616	393,552
Phase 3 (2023-2036)	Non-domestic	103	152,003	92	147,656	24	15,316
	Domestic	1,141	1,677,618	1,020	1,629,634	264	169,042
	Total	**9,172**	**13,488,068**	**8,198**	**13,102,279**	**2,126**	**1,359,097**

Table 9: Renewable heating options for TQEZ development sites

3.1.6 Solar PV

The solar map shows that the total potential for solar power on buildings currently within the TQEZ is 12,735kWp. This is shown in Figure 6.

However, some of these existing buildings fall within the development sites and may be demolished. When buildings within the development sites are removed, the potential installed capacity on remaining existing buildings falls to 2,582 kWp. The buildings included in this calculation are shown in Figure 7.

Finally, in development sites TM07 and TM08 there are listed buildings which are certain not to be demolished and which have solar potential. These are shown in the map in Figure 8. Their potential installed capacity is 3,333kWp. This capacity is included in the assessment of capacity in development sites, rather than the existing buildings figure, due to an assumption that solar panels would be installed on the buildings on these sites during the redevelopment of the sites and not before. It should be noted that installing solar panels on listed buildings will be subject to listed building consent.

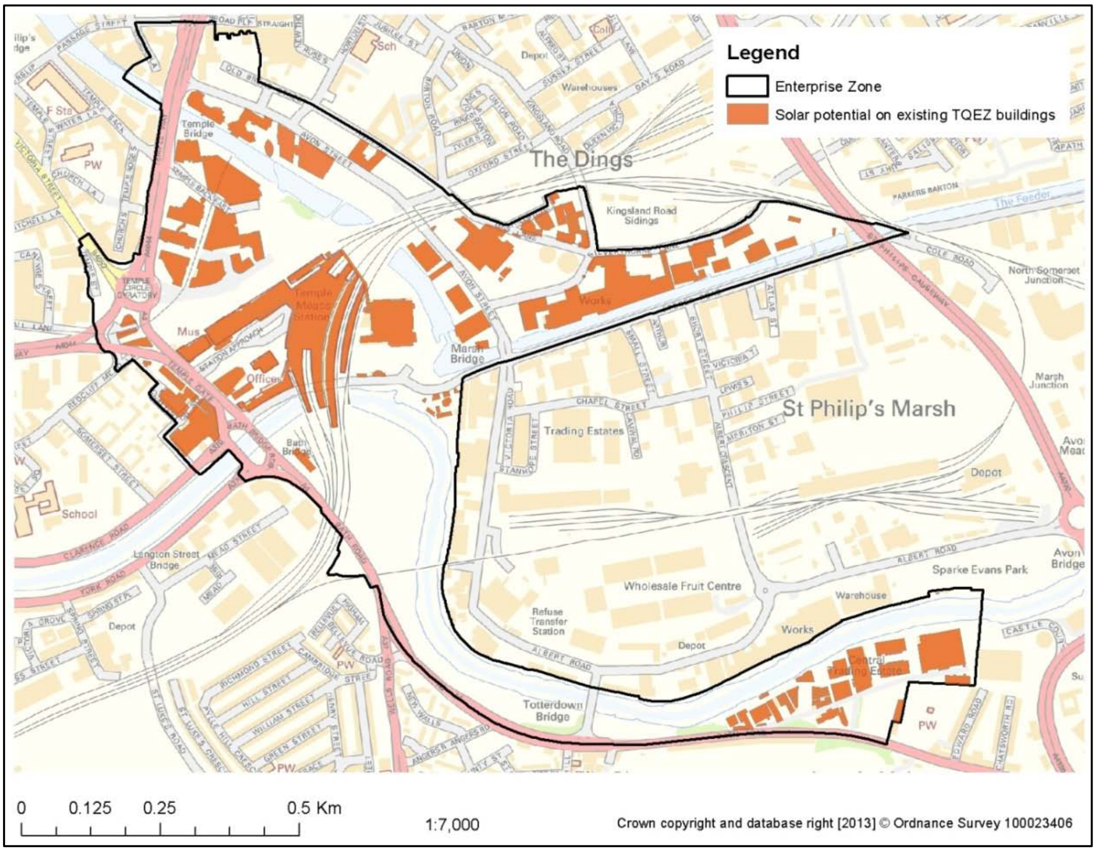

Figure 6: Solar potential on TQEZ existing buildings

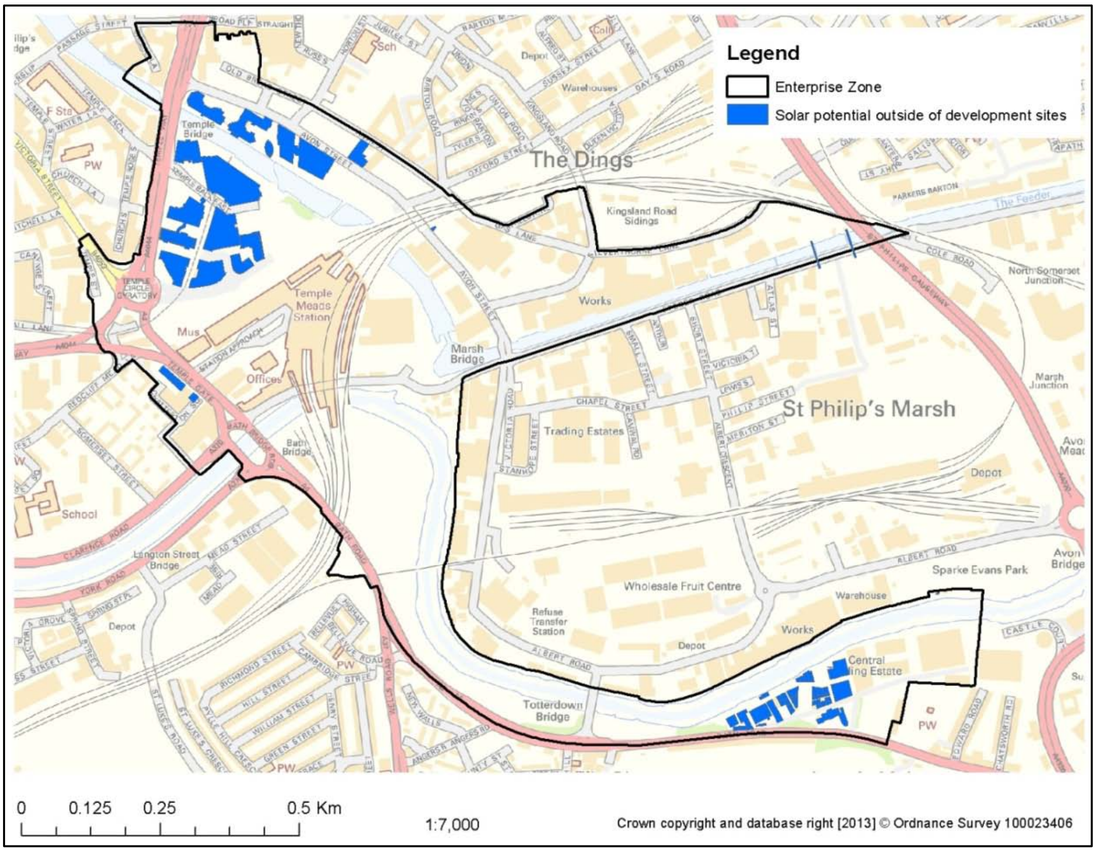

Figure 7: Solar potential on TQEZ existing buildings outside development sites

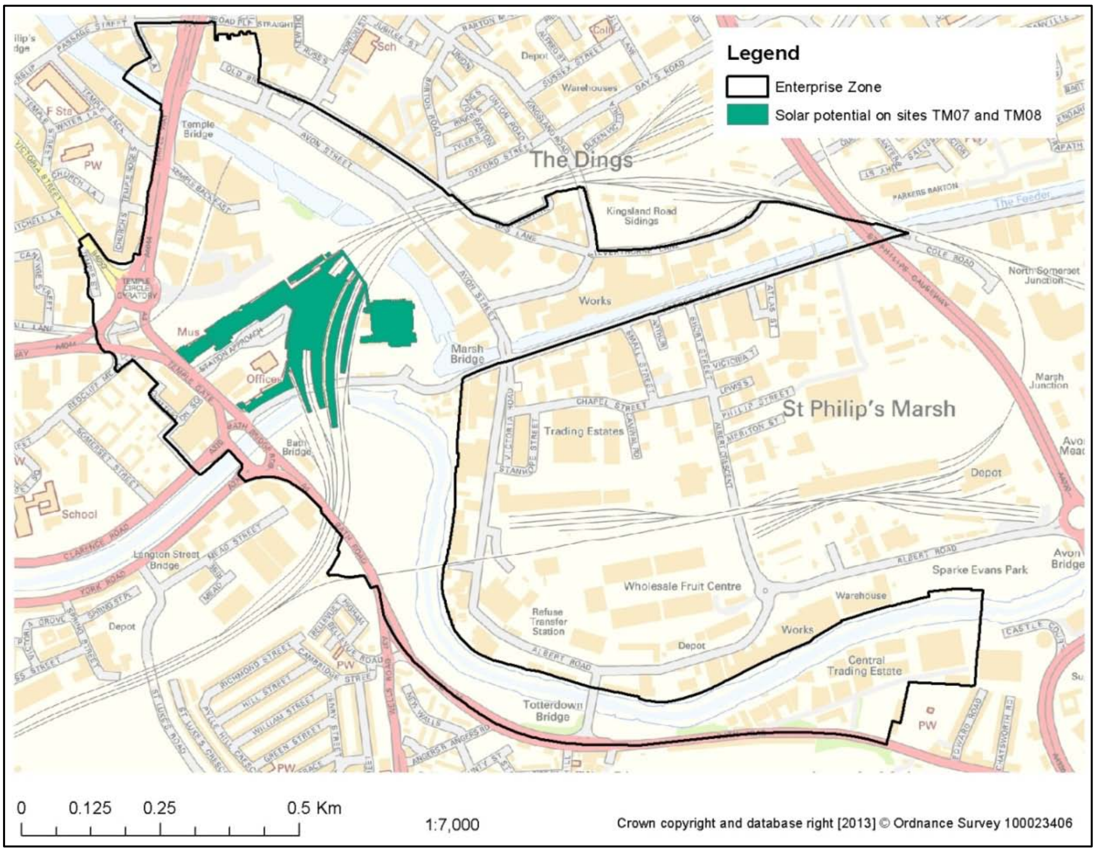

Figure 8: Solar potential on existing buildings within TM07 & TM08 development sites

The development site boundaries were used to estimate the solar potential within each site. Where development sites currently contain existing buildings which have solar potential, it is assumed that these will be replaced by new development or incorporated into it, such that it is more appropriate to base the solar potential on the size of the new development site than to use the figure for existing potential.

The exceptions to this are sites TM07 and TM08, where buildings are likely to be renovated rather than demolished and replaced, and so the roof areas, orientations and resulting solar capacity will remain valid. For these sites it has been assumed that panels would be installed during redevelopment in Phase 2, not before, which is why these figures are not included in the figures for existing potential.

The application of these assumptions resulted in the following maximum potential installed capacities per phase.

Phase	Sector	Capacity [kWp]	Generation [kWh/yr]
Phase 1 (2013-2018)	Non-domestic	1,280	896,706
	Domestic	550	385,173
Phase 2 (2018-2023)	Non-domestic	3,408	2,388,379
	Domestic	2,481	1,738,934
Phase 3 (2023-2036)	Non-domestic	151	105,981
	Domestic	1,137	796,481
	Total	**9,006**	**6,311,654**

Table 10: Solar PV potential for TQEZ development sites

3.1.7 Biogas

Decarbonisation of mains gas supplies through the injection of biogas into the gas grid is another potential option for Bristol, although outside the scope of this study. This requires production of biogas through processes such as anaerobic digestion and will for example help to increase the CO_2 savings associated with gas CHP.

3.2 Assessment of potential constraints

3.2.1 Existing utility infrastructure

The 'Utilities Strategy for Spatial Framework' study[22] provides a comprehensive review of the existing and future infrastructure. This identified existing 'utility corridors' (routes followed by several different utilities), which are located along Avon Street, Silverthorne Lane, Temple Gate, Bath Road, Cattle Market road and Feeder Road. If these utilities are being consolidated or renovated, there may be potential to install district heating or to future-proof them for district energy, by ensuring that suitable space is left for pipework.

The study also identified 'utility hot spots', where several utilities cross over, typically at major road junctions such as: Temple Gate, Bath Road bridge (Avon and Railway) and Marsh Bridge. These could act as constraints for potential district heating routes, and care will need to be taken if any new pipe routes cross these hotspots.

The study identifies several proposed highway improvement projects that could be used to reduce the cost of pipe-lays and have their service corridors future-proofed for district energy pipework. Proposed highway

[22] Mott MacDonald (2013-14) study for BCC. A map of utility corridors and hotspots can be found on page 35 of their report (existing utility corridors and 'hot spots', drawing number MMD-325452-C-DR-00-XX-0003)

improvements include bridges over the River Avon and Feeder Canal, and represent a valuable opportunity for future district energy schemes to link across waterways. These bridges should be future-proofed, so they have the space and structural integrity to carry district energy pipework. As with transport infrastructure improvements, further roll-out of communications infrastructure represents an opportunity for combined service or multi-utility ducts, thereby reducing the cost of district energy and communications cabling, including Gigabit Bristol and BNET.

The only significant constraints from existing energy infrastructure in the Enterprise Zone are Wales & West Utilities' medium-pressure gas main in Cattle Market Road, which crosses Marsh Bridge into Silverthorne Lane, and the fact that Western Power Distribution's power infrastructure is at full capacity in and nearby Silverthorne Lane. Neither of these would be a barrier to energy infrastructure, however grid connection of localised electricity generation in Silverthorne Lane might not be possible in the vicinity until the infrastructure is upgraded.

Mott MacDonald have not conducted or observed ground condition surveys within TQEZ, however they do recommend that ground condition surveys are conducted as further development occurs on a plot by plot basis. There may be economies of scale of conducting ground condition surveys for proposed district energy networks. Certainly the individual plot's ground condition surveys will inform the technical and financial details associated with district energy network routes within each development plot.

CSE agrees with Mott MacDonald's recommendations, and suggests the following additional points:

- Update the energy strategy and energy-related investment plans, when updating the Utility Strategy.
- Include district energy when 'reviewing the appetite' for multipurpose ducting.
- When conducting ground condition surveys, include investigation for proposed district heating routes and the potential for boreholes as a source for ground source heat pumps.
- When liaising with the Environment Agency include discussion of using the river as an energy source (for hydropower at Netham Weir and water-source heat pumps for heating/cooling, if relevant).

3.2.2 Development mix and phasing

The mix of development and estimated timescales for TQEZ are still very broad. BCC with input from other TQEZ stakeholders has split the development between:

- Development occurring in phase 1 (2013-18), phase 2 (2018-23) and phase 3 (2023-36)
- Broad use types of employment, residential and other.

When investigating building-integrated renewable energy opportunities, the potential for low and zero carbon energy generation can only be broadly investigated with the information currently available. Ideally, when more detailed information about the building and the design of its mechanical and electrical services becomes available, it would be imported into appropriate energy modelling software in order to fully confirm the size and viability of renewable energy opportunities.

As the details of each site become more refined, the low and zero carbon energy generation opportunities should be reviewed and any relevant implications considered as part of the going development of the TQEZ Sustainable Energy Masterplan.

3.2.3 Flood risk

The map below shows the area of TQEZ at high risk of flooding. As with any other development, energy infrastructure within these areas will need to be planned carefully to mitigate risk of flood-related damage. The Environment Agency and relevant BCC officers (acting as the Lead Local Flood Authority) should be consulted on energy infrastructure plans that could be at risk.

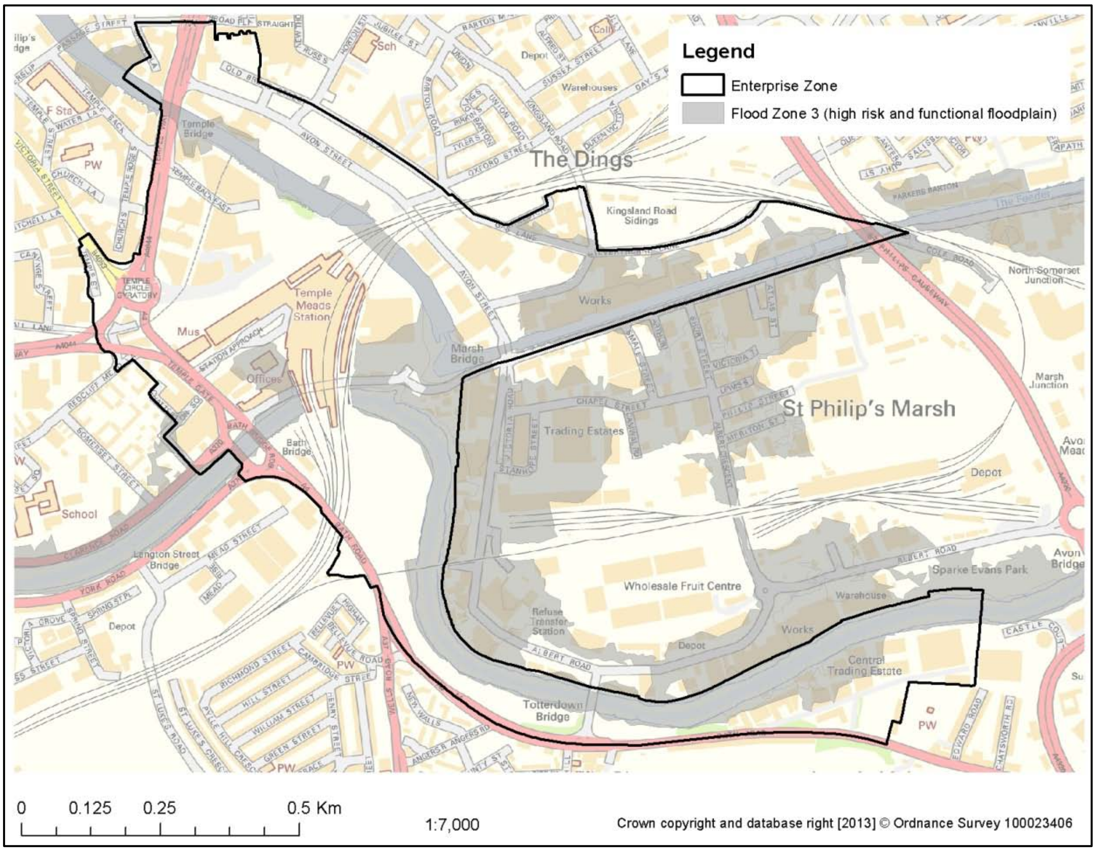

Figure 9: Bristol's Flood Zone 3 (high risk and functional floodplain – data provided by Bristol City Council)

3.2.4 Air Quality Management Areas

Most of the TQEZ is located within an Air Quality Management Area (AQMA), and the whole of Bristol is considered a smokeless zone under the Clean Air Act. This means that there are restrictions on the types of biomass boiler technology that can be used. The map below shows the extent of the AQMA. DEFRA publishes a list of biomass technologies that can be used within areas such as Bristol[23], providing it is operated in accordance with conditions (typically relating to fuel type and controls to prevent minimise air pollution). Any biomass installation within the AQMA requires assessment and/or dispersion modelling to establish its impact on air quality.

[23] DEFRA's list of approved technologies for use in England's smoke control zones: http://smokecontrol.defra.gov.uk/appliances.php?country=e

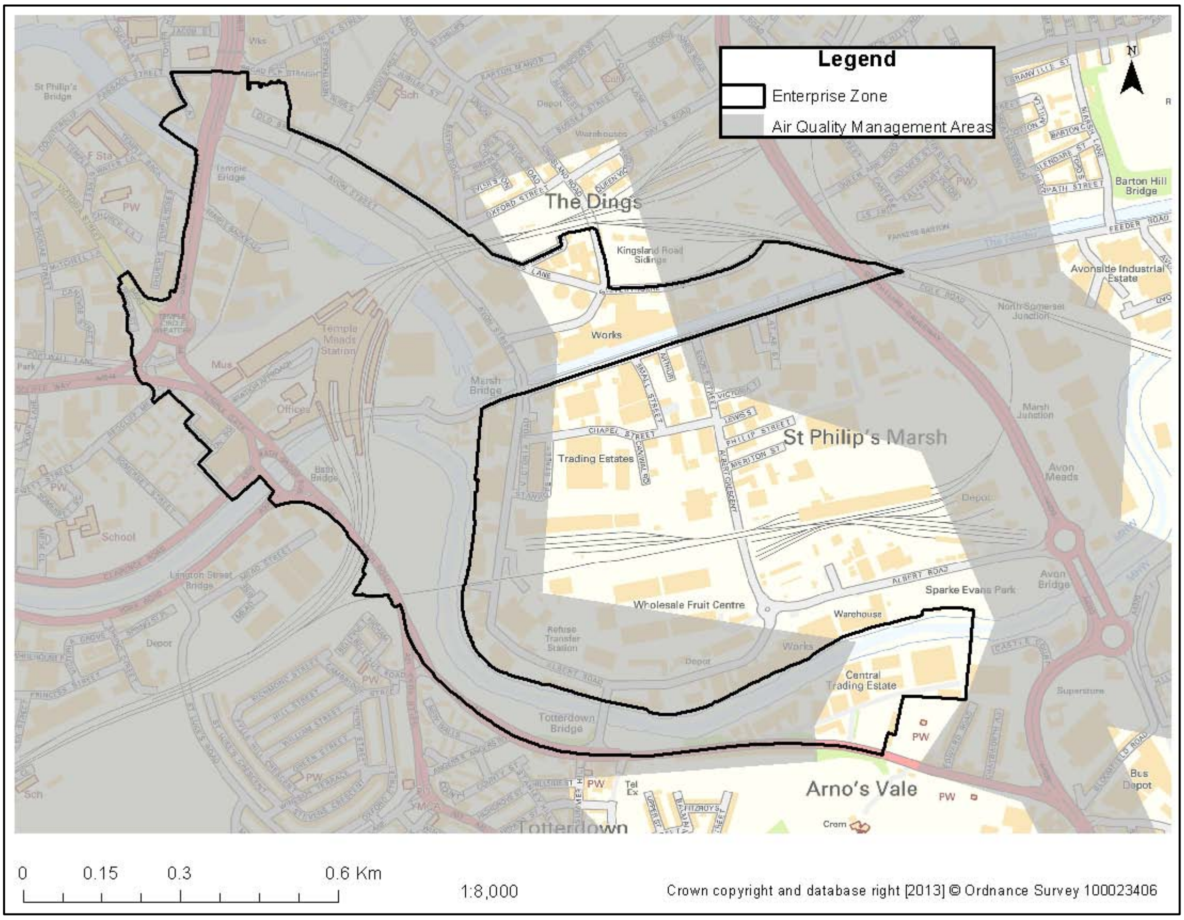

Figure 10: Bristol Air Quality Management Area

3.2.5 Building designation

There are several listed buildings in the TQEZ. These are shown in the table below.

Building	Grade
Bristol Old Station, Temple Meads	I
Temple Meads Station	I
Bristol And Exeter Building	II*
St Vincent's Works And Attached Front Area Railings	II*
Warehouse, Former Premises of Marble Mosaic Company	II
St Vincent's Works Factory	II
St Vincent's Works, Gateway and Attached Wall to South West	II
Warehouse, Premises of Clarks Wood Company	II
Gasworks Perimeter Wall	II
St Vincent's Works North Gateway and Attached Walls	II
The George Railway Hotel	II

Table 11: Listed buildings within TQEZ

Listed building consent is required for alterations and extensions to listed buildings. This would include installation of solar panels (all but three of the listed buildings in the TQEZ have been identified as suitable for solar panels) and any other works likely to impact the heritage significance of the building, such as upgrading heating systems or adding in heating plant.

Whilst low and zero carbon energy generation may still be approved for use in or near Listed Buildings, extra care must be taken to ensure there is no detrimental damage to its heritage value. The higher the listed grade, the greater the difficulty and potentially the cost associated with integrating energy generation. During the stakeholder engagement for this work, Network Rail highlighted a building's listed status as a constraint to the carbon-saving opportunities they are able to deploy. This has meant that energy efficient lighting has been the main focus for reducing carbon emissions under their refurbishment of Temple Meads. It is expected that this measure will reduce lighting-related electricity consumption at the station by 40%.

Developers and owners of TQEZ's listed buildings are recommended to pay close attention to English Heritage guidance on renewable energy[24], and to engage with BCC's conservation officers.

[24] Extensive English Heritage guidance on renewable energy within historic buildings is found on their website: www.english-heritage.org.uk/professional/advice/advice-by-topic/climate-change/renewable-energy/

4 Energy demand analysis

4.1 Existing demand

The energy demand attributable to existing buildings within the Temple Quarter Enterprise Zone was calculated in line with the methodology set out in Section 2 of this report. A summary of the results of this analysis is set out in the table below.

Sector	Regulated (non-heat) electricity [MWh/yr]	Regulated (heat) electricity [MWh/yr]	Unregulated electricity [MWh/yr]	Gas demand [MWh/yr]	Total energy demand [MWh/yr]	CO_2 emissions [tonnes/yr]
Offices	17,692	530	11,986	10,070	40,279	15,527
Industrial	159	44	108	830	1,141	309
Retail	2,244	237	1,520	4,505	8,505	2,708
Hotels	423	4	287	68	782	332
Domestic	66	68	34	383	550	74
Total	**20,584**	**882**	**13,935**	**15,857**	**51,257**	**18,950**

Table 12: Existing energy demand within TQEZ

The figure for gas consumption from existing buildings within the domestic sector is likely to decrease slightly over the next decade due to energy efficiency initiatives, although other changes in factors such as comfort levels and electricity consumption may reverse the effect on overall carbon emissions.

Some improvement in the performance of existing non-domestic buildings is also possible, however as a large proportion of buildings of this type within the Enterprise Zone have been constructed or refurbished fairly recently (i.e. within the last ten to fifteen years), and as many of the buildings are not owner-occupied, it is not thought that significant investment will be made in energy efficiency measures in this sector within the development timeframe.

For the purposes of this exercise, and for simplicity, it has been assumed that all gas consumed within the non-domestic sector is used for space heating and hot water production. Due to the nature of the non-domestic stock within the Enterprise Zone this is considered to be a reasonable assumption.

4.2 Future demand

4.2.1 Cumulative demand

The baseline demand for electricity and gas for each of the three development phases has been calculated, and a summary of results is set out in the table below. These figures represent a ‘business as usual’ scenario, assuming that all new developments shall be constructed to meet the minimum requirements of future versions of Building Regulations Part L.

For non-domestic buildings it was assumed that buildings constructed under 2013/14 Building Regulations would demonstrate a 9% reduction in regulated emissions over 2010 Part L (based on proposals set out within a press release regarding the Technical Housing Standards Review), with buildings under 2016 regulations demonstrating a further 10% reduction, and those constructed after 2020 demonstrating an additional 20% reduction.

In order to calculate the impact of future versions of Building Regulations on domestic properties, a sample dwelling was modelled to meet 2010 Part L standards using NHER software, and a percentage reduction of 6% was applied to the fuel consumption figures shown within the SAP output worksheet for all dwellings to be constructed under 2013/14 Part L. For the purposes of this study it was assumed that all planned domestic developments within the Enterprise Zone are likely to be flats. All domestic properties expected to be constructed after 2016 were assumed to be constructed in line with the government's zero carbon aspirations, taking into account the Zero Carbon Hub's proposals for a Fabric Energy Efficiency Standard and Carbon Compliance standard.[25]

Phase	Sector	Regulated (non-heat) electricity [MWh/yr]	Regulated (heat) electricity [MWh/yr]	Unregulated electricity [MWh/yr]	Gas demand [MWh/yr]	Total energy demand [MWh/yr]	CO_2 emissions [tonnes/yr]
Phase 1 (2013 - 2018)	Domestic	55	354	832	1,624	2,865	673
	Non-domestic	21,044	1,766	15,191	18,087	56,088	19,064
	Total	**21,099**	**2,120**	**16,023**	**19,710**	**58,953**	**19,737**
Phase 2 (2018 - 2023)	Domestic	395	1,247	4,436	6,682	12,760	2,789
	Non-domestic	26,121	2,092	18,372	24,275	70,860	16,838
	Total	**26,516**	**3,339**	**22,808**	**30,957**	**83,620**	**19,627**
Phase 3 (2023+)	Domestic	465	1,630	6,087	8,855	17,038	3,358
	Non-domestic	26,281	2,102	18,475	24,471	71,330	14,563
	Total	**26,746**	**3,733**	**24,562**	**33,327**	**88,367**	**17,921**

Table 13: TQEZ development sites' cumulative future energy demand

Note - regulated emissions are those limited by Building Regulations and relate to energy used by space and water heating, fixed lighting and pumps/fans. They do not include emissions from cooking or appliances and for dwellings typically represent around two-thirds of total emissions.

Figure 11 and Figure 12 below summarise the growing energy demands and corresponding CO_2 emissions from TQEZ through the build phases. In calculating CO_2 emissions, standard projected emission factors were used as described in Section2.2. Even though energy demand increases throughout the three phases of development, it can be seen that corresponding overall CO_2 emissions begin to decrease as a result of the expected decarbonisation of the UK's electricity supply mix over this period.

[25] www.zerocarbonhub.org/

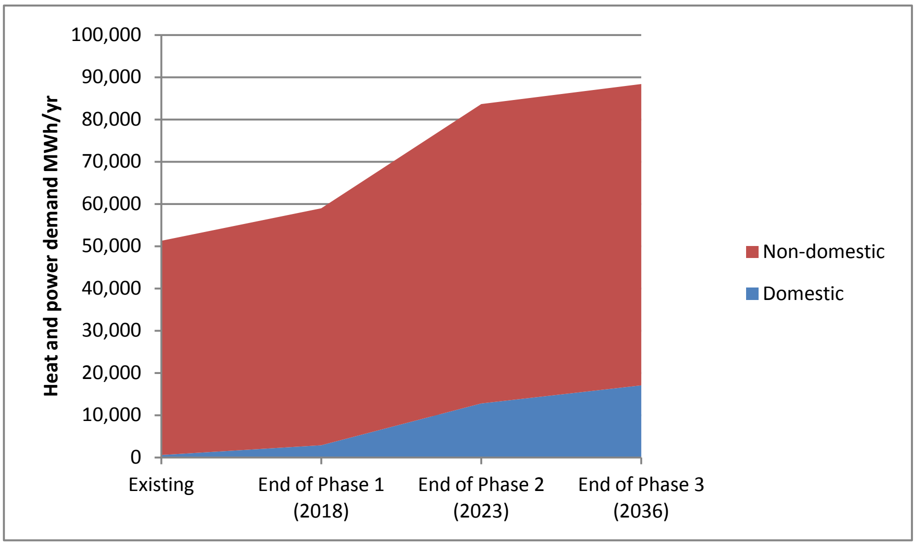

Figure 11: TQEZ energy demands over development phases

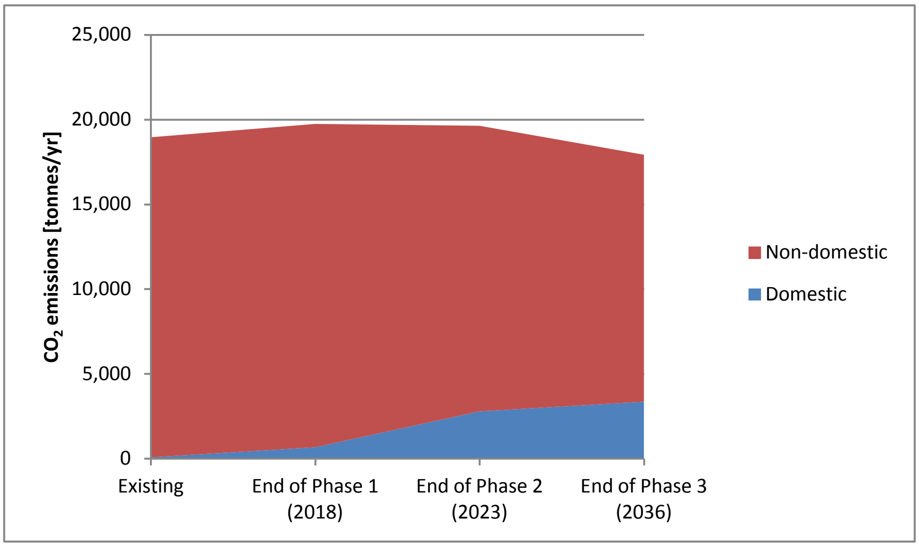

Figure 12: TQEZ CO_2 emissions over development phases

Heat demand maps

Existing heat loads located in development sites were removed as these are very likely to be replaced during the development of TQEZ. The resulting existing heat demand is shown in the maps below, for each of the three phases. The main cluster of existing heat demand is around Temple Back East where there are several large office blocks.

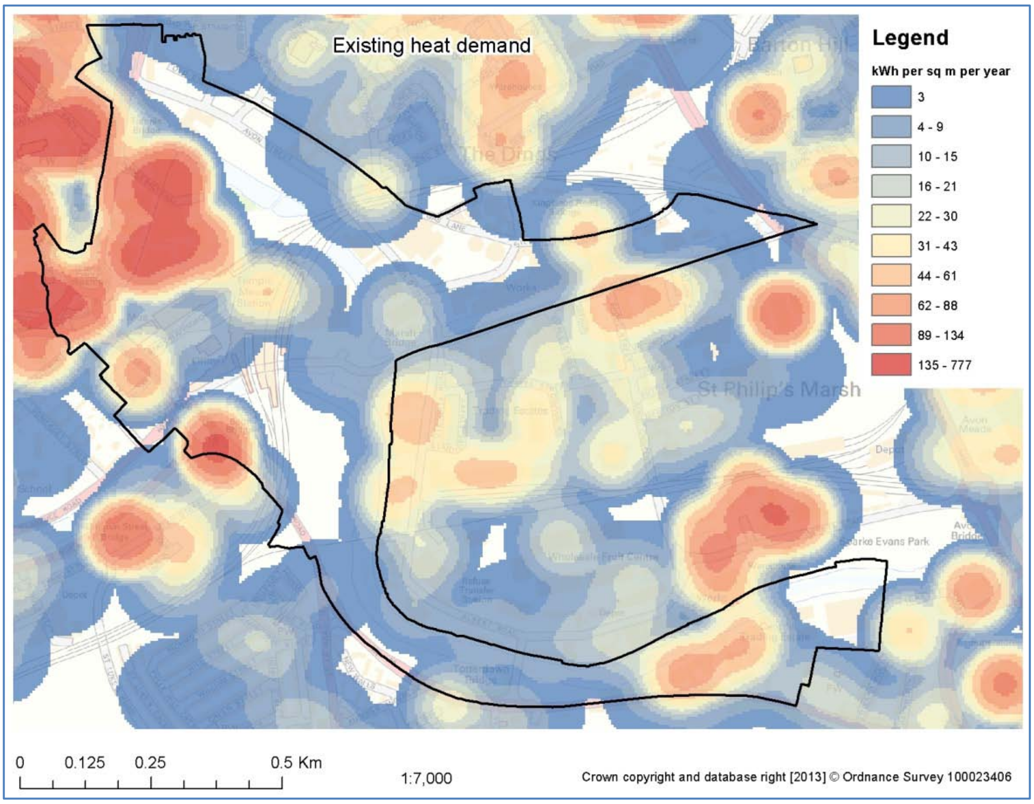

Figure 13: Heat demand map of existing buildings

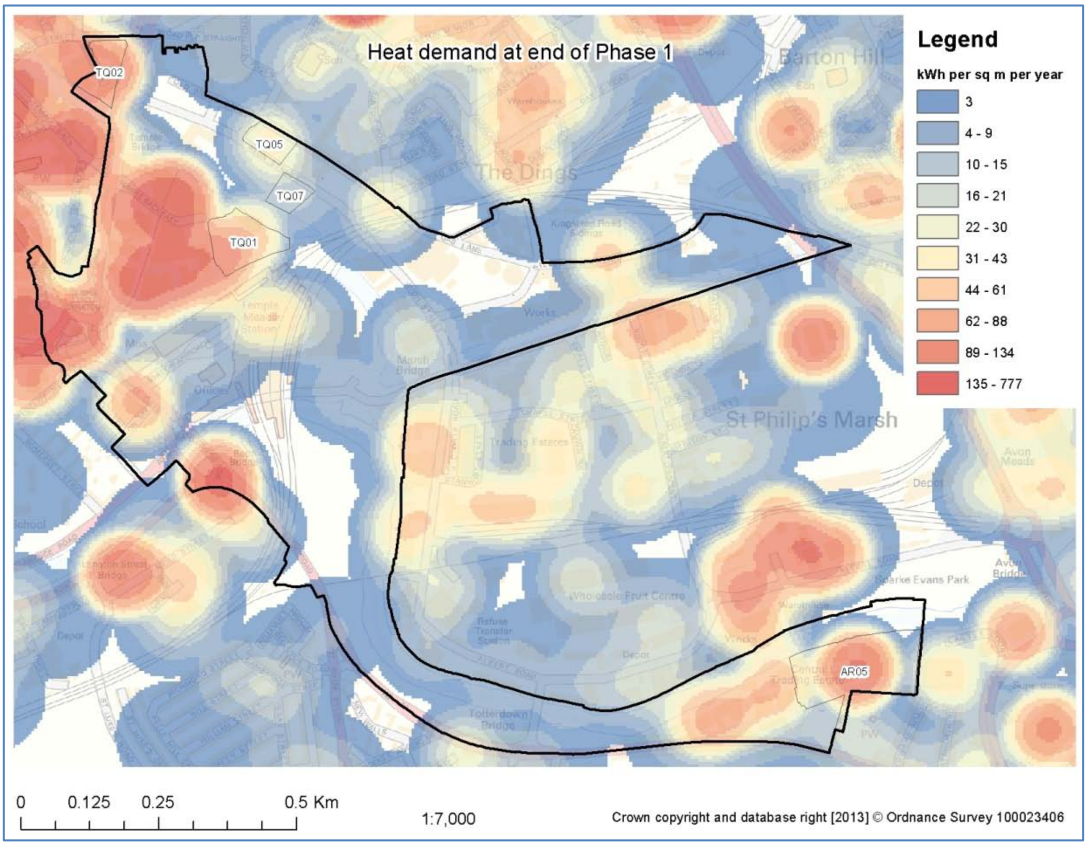

Figure 14: Heat demand map after phase 1 construction (2018)

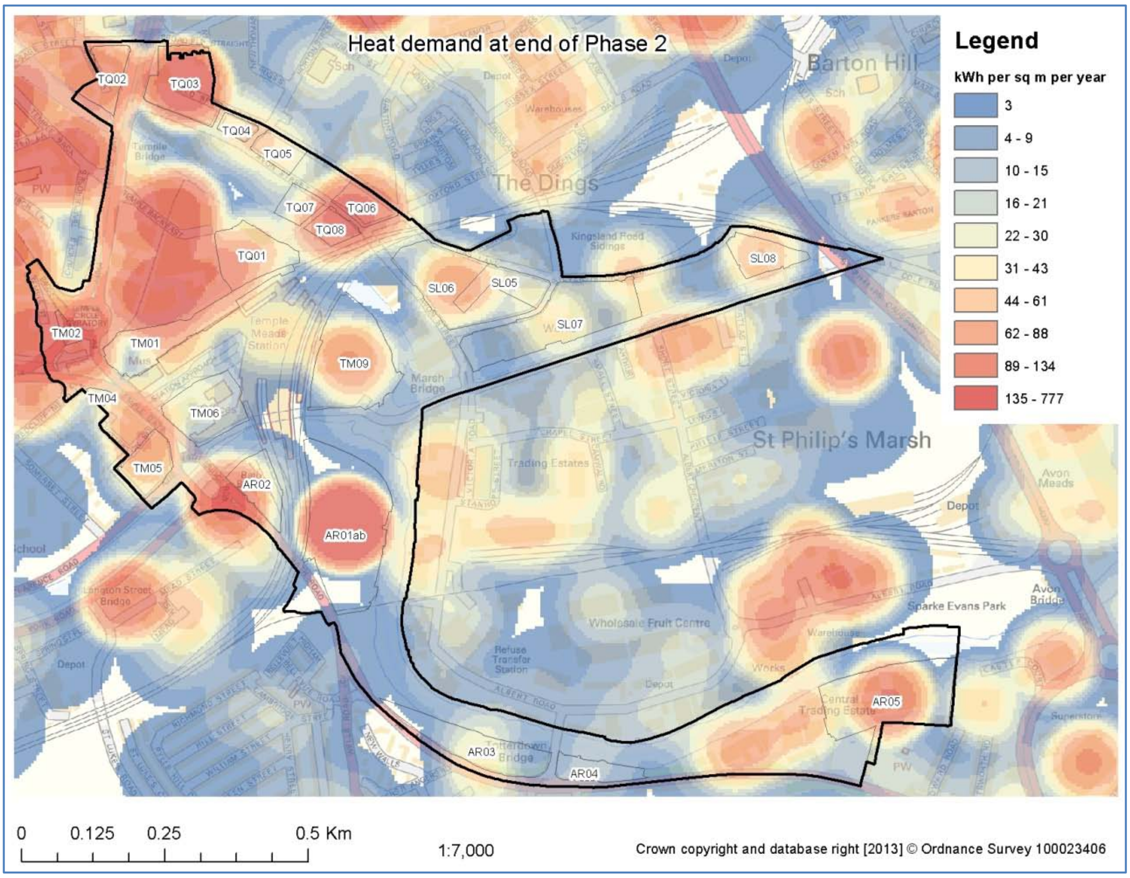

Figure 15: Heat demand map after phase 2 construction (2023)

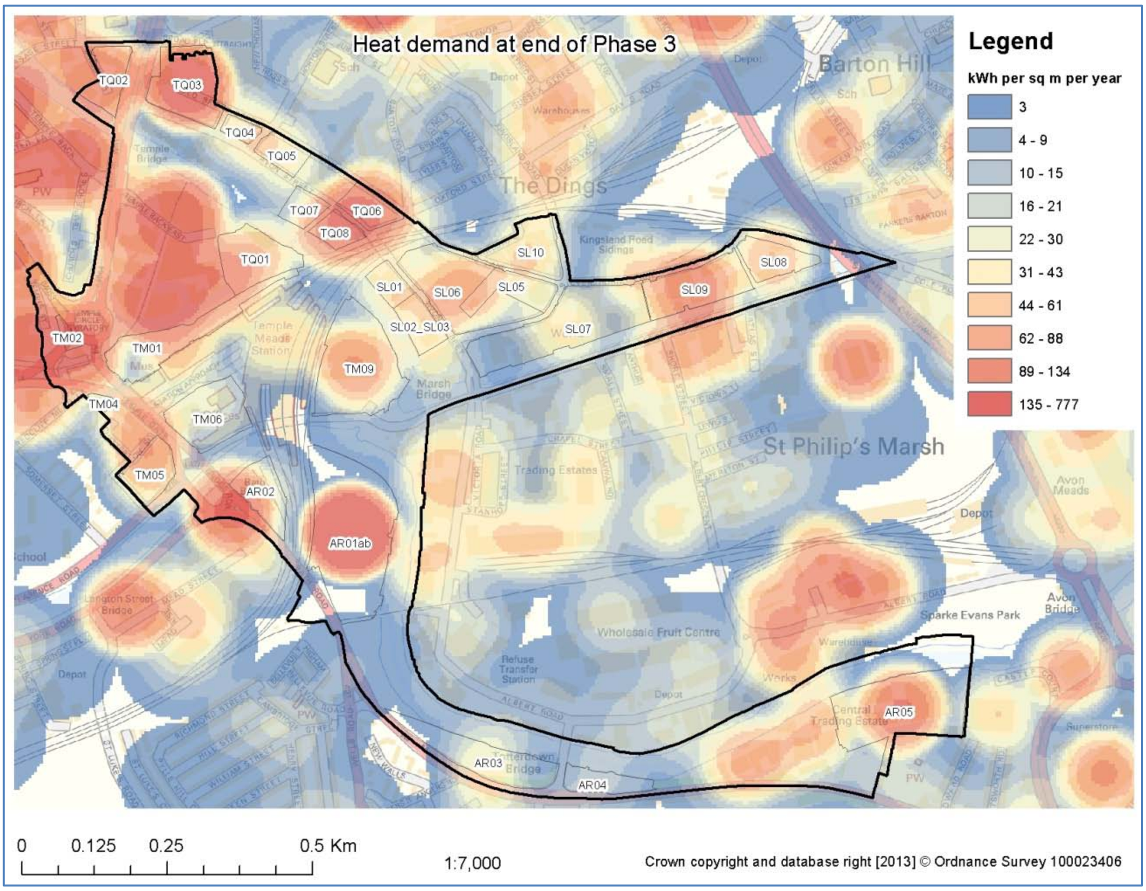

Figure 16: Heat demand map after phase 3 construction (post 2023)

5 Energy supply modelling

This section draws on the resources and constraints analysis and energy demand assessment described above then explores the impact of deploying various combinations of heat networks and building-integrated renewables in the context of achieving a Zero Carbon TQEZ.

5.1 Heat network options

In Section 4 heat demand across the TQEZ is mapped in four phases: as it is currently, and as it will be at the end of each of the three development phases leading up to 2036. This enables the identification of clusters of heat demand at different stages and allows us to see areas that could potentially be joined up as the developments progress.

5.1.1 Existing opportunities for district energy

There are seven existing office buildings located on Temple Back East, Rivergate, Temple Quay, The Square, and Friary, which could potentially be joined together in a heat network loop and serve as ‘anchor’ loads for an initial network for future expansion. The table below shows nine address points because these buildings contain many addresses and, where a building is large, there are two sets of coordinates representing different addresses within the same building. From the address data it is difficult to ascertain the exact addresses as most of the data only contains the street name.

Building	Annual heat demand [MWh]
1 Friary	117
1 Rivergate	833
2 Rivergate	1,282
3 Rivergate	254
1 Temple Back East	1,881
2 Temple Back East	1,049
Temple Quay House, 2 The Square	839
1 The Square	1,174
Total	**7,430**

Table 14: Existing heat loads that could serve as anchor loads for district heating

With the buildings joined in a loop as shown in Figure 17 below, the pipe length would be approximately 570 metres, giving a linear heat density of 13 MWh/m/yr. There is another cluster in the southeast of the Enterprise Zone, formed by The Paintworks where total annual heat demand is 1,746 MWh. A line from one end of the Paintworks to the other would be 170m (in reality it would have to be longer with spurs to meet each building), giving a linear heat density of around 10MWh/m/yr.

The other areas of high heat demand in the map are the industrial area around Albert Road, which is outside of the Enterprise Zone, and a point on Bath Bridge, which is the only high heat demand point in that area and so has not been considered for a heat network.

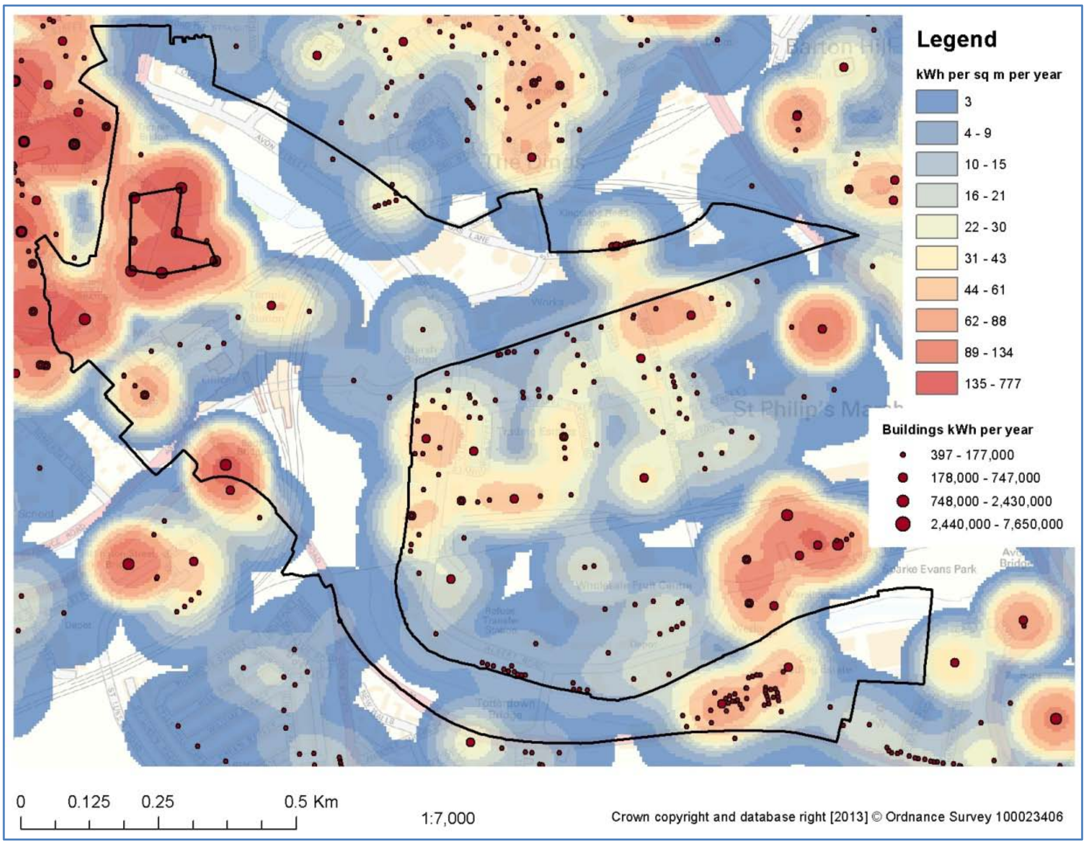

Figure 17: Existing heat demand showing point loads and potential network cluster (DH Network 1 – Temple Back East)

5.1.2 Phase 1 district heating opportunities

At the end of Phase 1 the area of high heat demand around Temple Back East has extended slightly to the east with the completion of site TQ01 and TQ05. There is also higher heat demand in the north west corner of the Enterprise Zone, with the building of site TQ02. However, these new sites alone are unlikely to provide a high enough heat demand to warrant extending the potential network at Temple Back East or creating a separate network.

5.1.3 Phase 2 district heating opportunities

By the end of Phase 2, sites TQ03, TQ04, TQ06, TQ08, AR01a & b and AR02 have been developed. Sites TQ06 and TQ08 could be linked up to the Temple Back network, going via TQ01 (which is completed in Phase 1 but of itself is unlikely to provide enough heat demand to extend the network this way).

The total annual heat demand from these three sites is 3,039 MWh, and a pipe run joining them to the Temple Back cluster would measure around 300m, giving a linear heat density on this section of around 10.1 MWh/m/yr. Simply linking sites TQ06 and TQ08 would give an annual heat demand of 2,338 MWh, and a minimum pipe run of approximately 170m (because the layout of the site is unknown, this distance has been obtained by measuring diagonally across the footprint of the two sites). This gives a linear heat density of around 13.8 MWh/m/yr, which is the highest of the options outlined up to this point.

Sites TQ02 (from Phase 1) and TQ03 (from Phase 2) now combine to create an area of relatively high heat demand in the northwest of the TQEZ. Together these sites have an annual heat demand of 3,595 MWh. Linking these sites with the Temple Back network would require a pipe run of at least 350m, giving a linear heat density on this section of 10.3 MWh/m/yr. It would also require the pipe to cross the river. Simply linking the two sites would require a shorter pipe run of around 245m (measuring diagonally from the corner of one site to another), giving a linear heat density of 14.7 MWh/m/yr.

Sites AR01a & b (the Diesel Depot, shown as one site on the map, labelled AR01ab) together have notable predicted heat demands and are close to an existing site which also has a relatively high demand, an engineering company on Mead Street. A pipe run of 215m would link the centres of both sites together, giving a linear heat density of 26 MWh/m/yr. However, this should be treated with caution as the modelled heat demand for the engineering company is based on an industrial benchmark and there can be wide variation in the actual heat demand on industrial sites. It is probable that the actual heat demand of this site is lower than the modelled heat demand and this would need to be checked in a pre-feasibility study. There are two other smaller, currently existing sites near to these two large heat demand points; one is site AR02, and the other is Fowler's of Bristol, the motorbike shop. Linking the centres of the four sites together would require a minimum pipe run of 275m, giving a linear heat density of 23 MWh/m/yr.

These linear heat densities are the highest found of the options considered, but it should be noted that they are based on two key estimated values: the first is the heat demand of the stadium proposed for site AR01ab, which in the absence of any detailed proposals for the site we have based solely on benchmarks related to the likely capacity of the stadium (i.e. no data is currently available about other mixed-use development that is likely to go ahead on this site); and the second is the estimated heat demand for the engineering company on Mead Street, which is based on an industrial benchmark.

More details about the proposed stadium and adjacent development, and actual heat demand for the engineering company would need to be known in order to be confident about the potential heat density in this cluster of buildings/ sites. The proposed stadium is unlikely to have a high heat demand; instead it will likely have a high electrical load when events are taking place.

The map below illustrates the additional heat loads, with points now representing development sites as well as buildings, with the network being extended to Temple Back (Phase 2a) and the additional network connected to the Diesel Depot (Phase 2b).

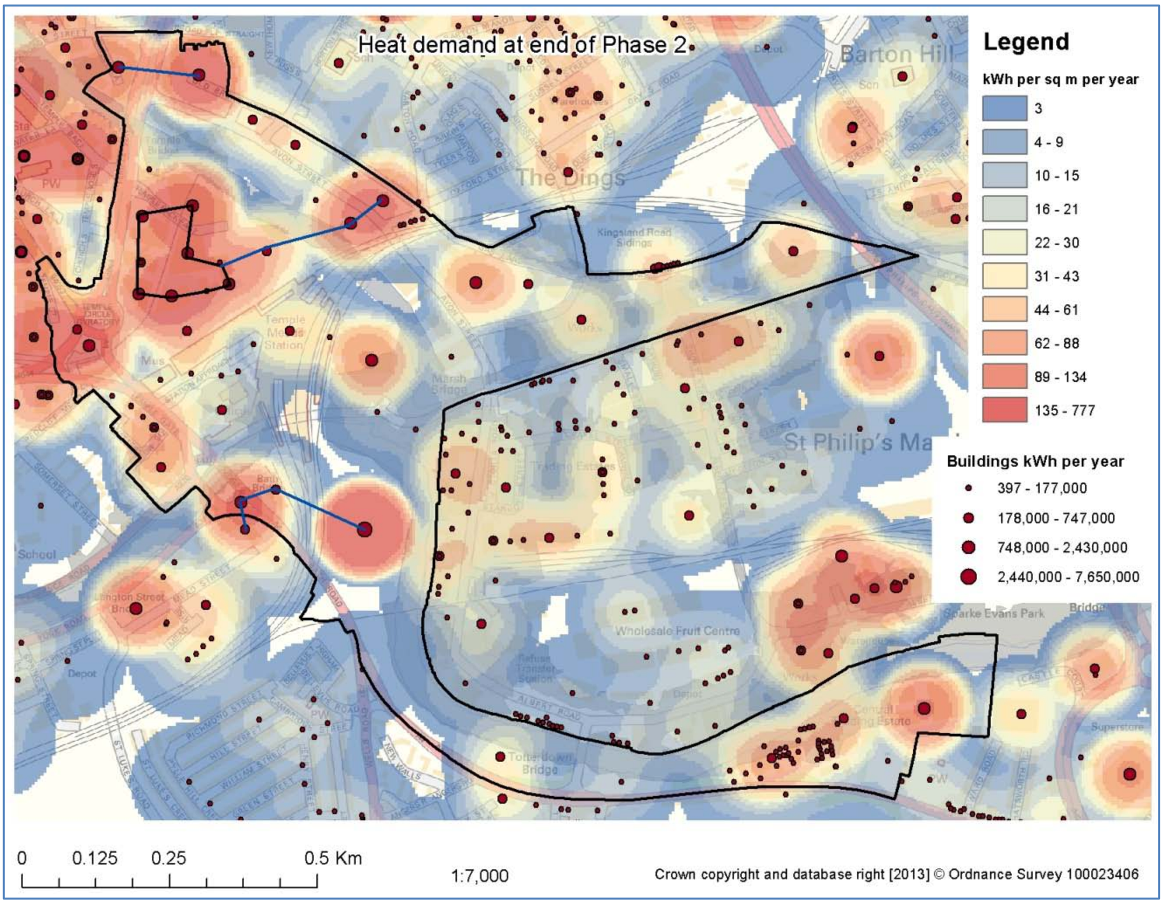

Figure 18: District heating opportunities within TQEZ at end of phase 2

5.1.4 Phase 3 district heating opportunities

The new sites which create heat demand in Phase 3 are SL01, SL02, SL03, SL04, SL09, and SL10. Of these, SL01, SL02, SL03 and SL04 do not have particularly high heat demand but do extend the area of higher heat demand which was created by SL06 in Phase 2. However, linear heat density is less significant; joining site SL06 and TM09, which have the highest heat demands and are close together, would give a linear heat density of around 5 MWh/m/yr.

The addition of SL09 in the northeast creates an area of high heat demand which merges with some smaller buildings just outside the TQEZ. The total annual heat demand of SL09 and the five address points just outside of the TQEZ boundary is 2,583 MWh, and a pipe route joining them would be approximately 300m, giving a linear heat density of 8.6 MWh/m/yr. However, the five address points are on Feeder Road, which is the other side of the Feeder Canal, and so the route would involve traversing the water way.

Joining SL09 to SL08 next to it would result in a lower linear heat density of 7.6 MWh/m/yr if the pipe had to run the whole length of site SL09. However, if a shorter pipe were possible, this figure would increase. However, without knowing the layout of buildings on the proposed sites, this is difficult to quantify.

Most of this analysis has looked at whether more than one development site could be joined together into a heat network. However, it is possible that many of the development sites have the potential to accommodate smaller heat networks *within* the individual site. As there is currently no information about the layout of buildings on sites, it is not yet possible to investigate this. However, sites AR05, SL09, TQ06, TQ02, and TQ08 are likely to offer the best opportunities as their projected heat demand would allow pipe runs of 50m or more with a linear heat density of 20 MWh/m/yr. Of course if the site comprises just one large building a heat network would not be necessary, but where there are several smaller buildings there could be potential.

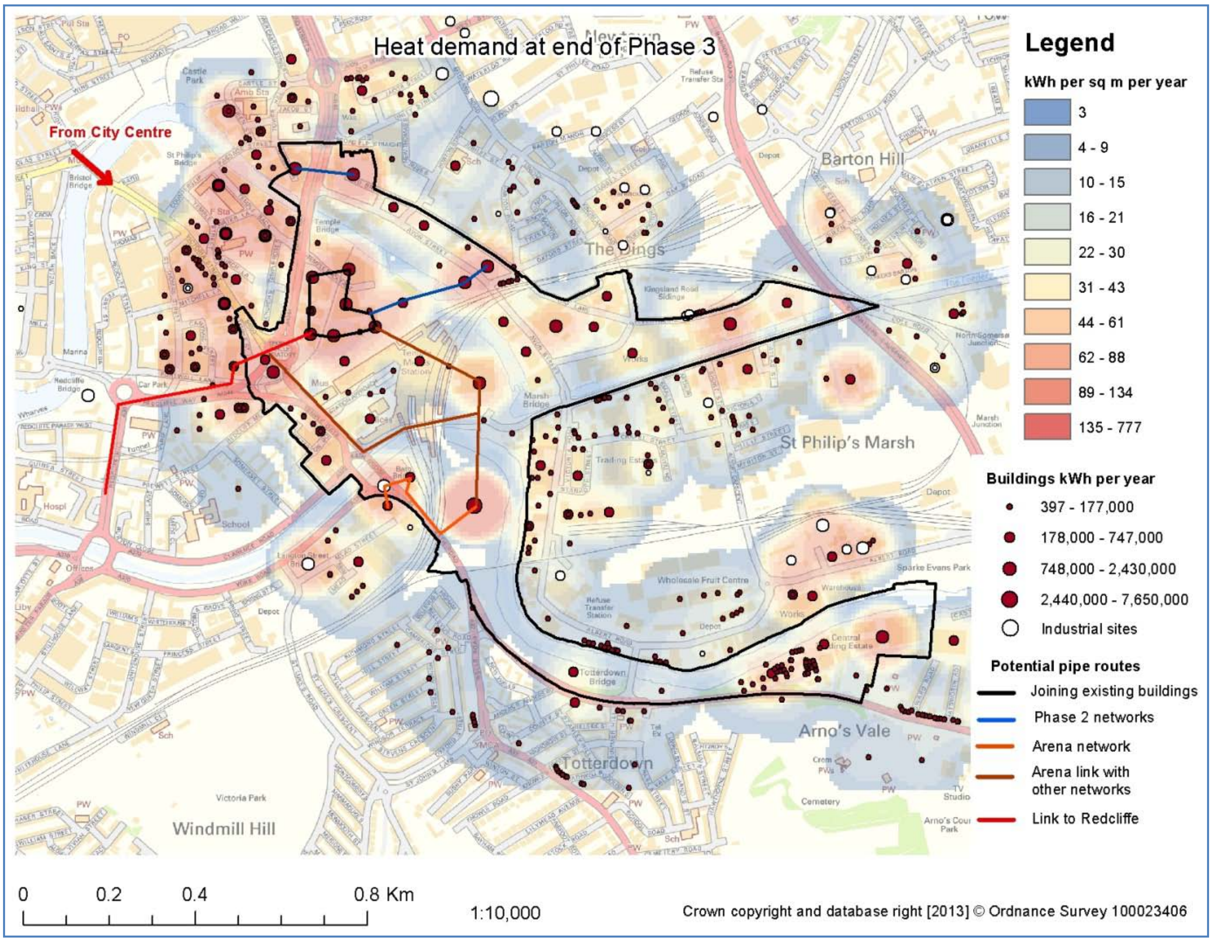

Figure 19: District heating opportunities within TQEZ at end of phase 3

Note that industrial sites are separately marked on the map above in order to represent the level of uncertainty associated with the benchmark figures for these buildings. The map also identifies potential links to two district energy schemes BCC is also investigating outside of TQEZ: the first is a potential scheme connecting residential high-rise flats in Redcliffe, and the second is a potential scheme in the City Centre.

5.2 Building-integrated options

5.2.1 New development

The following analysis of building-integrated options (i.e. systems that serve individual buildings, usually comprising micro-renewable technologies) is applied to the whole TQEZ site assuming district heating is not deployed. It assumes that:

- Biomass boilers (for space and water heating) with a capacity over 100kW are prioritised.
- Heat pumps and solar hot water systems, for space and water heating respectively, are deployed in development sites with lower heat demands.
- Large quantities of solar PV are deployed, leaving roof space for solar hot water collectors where required.

The table below estimates the maximum viable deployment of each technology within new development sites across each development phase.

Phase	Sector	Biomass boiler capacity [kW]	Biomass boiler heat generation [kWh/yr]	Heat pump capacity [kW]	Heat pump heat generation [kWh/yr]	Solar PV capacity [kW]	Solar PV generation [kWh/yr]	Solar hot water capacity [kW]	Solar hot water generation [kWh/yr]
Phase 1 (2013 - 2018)	Domestic	556	817,369	85	136,376	550	385,173	22	14,146
	Non-domestic	1,157	1,701,629	192	306,713	1,280	896,706	50	31,815
	Total	**1,713**	**2,518,998**	**277**	**443,090**	**1,829**	**1,281,879**	**72**	**45,962**
Phase 2 (2018 - 2023)	Domestic	2,501	3,677,389	139	221,801	2,481	1,738,934	36	23,007
	Non-domestic	2,235	3,286,343	906	1,448,596	3,408	2,388,379	235	150,263
	Total	**4,735**	**6,963,732**	**1,045**	**1,670,397**	**5,889**	**4,127,313**	**271**	**173,270**
Phase 3 (2023+)	Domestic	1,053	1,549,129	78	124,814	1,137	796,481	20	12,947
	Non-domestic	0	0	92	147,656	151	105,981	24	15,316
	Total	**1,053**	**1,549,129**	**170**	**272,469**	**1,288**	**902,462**	**44**	**28,263**
Total		**7,501**	**11,031,860**	**1,493**	**2,385,956**	**9,006**	**6,311,654**	**387**	**247,495**

Table 15: Building-integrated renewables opportunities (capacities) for new development sites

The above options represent what could be achieved by installing renewable heating options to meet an assumed level of demand, i.e. installing renewable heating to meet base heating requirements, with gas boilers installed to meet peak requirements and provide a back-up heating system (which developers and occupants often want, in case of a fault with the renewable heating system). The estimated capital costs of delivery and CO_2 saving from this scenario are summarised in Table 16.

The table below provides capital costs and CO_2 savings for these building-integrated renewable energy options.

Phase	Sector	CO_2 saving [tonnes/yr]	Biomass boiler CAPEX	Heat pump CAPEX	Solar PV CAPEX	Solar hot water CAPEX	Total CAPEX
Phase 1 (2013 - 2018)	Domestic	334	£115,605	£100,007	£444,571	£15,069	£675,253
	Non-domestic	733	£240,671	£285,156	£1,097,129	£74,191	£1,697,146
	Total	**1,067**	**£356,276**	**£385,163**	**£1,541,700**	**£89,260**	**£2,372,399**
Phase 2 (2018 - 2023)	Domestic	1,189	£271,502	£111,538	£1,340,040	£28,311	£1,751,392
	Non-domestic	1,529	£242,631	£859,980	£1,969,209	£187,283	£3,259,103
	Total	**2,718**	**£514,134**	**£971,518**	**£3,309,249**	**£215,594**	**£5,010,495**
Phase 3 (2023+)	Domestic	506	£97,217	£57,116	£434,501	£9,049	£597,883
	Non-domestic	55	£0	£74,656	£82,189	£22,313	£179,158
	Total	**561**	**£97,217**	**£131,773**	**£516,690**	**£31,362**	**£777,041**
Total		**4,345**	**£967,626**	**£1,488,453**	**£5,367,639**	**£336,216**	**£8,159,935**

Table 16: Building-integrated renewables opportunities (CO_2 savings and costs) for new development sites (non-cumulative)

Developers could exceed these levels of renewable energy deployment by installing renewable heating to meet full peak demands, and by designing the buildings to accommodate larger areas of roof space suitable for solar PV. However, installing renewable heating to meet peak heating demands will require significantly larger capacity renewable heating options which will potentially reduce financial viability as the installed costs are comparatively larger than the returns from heat generation.

An example of innovative building design around solar PV is Kaohsiung's National Stadium in Taiwan[26]. This stadium, completed in 2009, is the world's largest solar power stadium. Its spiral shape incorporates 8,444 solar panels, saving 660 tonnes of CO_2 and meeting 75% of the buildings demands[27]. Innovative approaches to building design could result in higher renewable energy deployment in TQEZ, but at a greater cost to developers.

Figure 20: Ariel photo of Kaohsiung World Stadium (world's largest solar-powered arena)

5.2.2 Existing development

Applying a similar set of assumptions as that for new development, whilst accounting for increased heat loads through lower insulation standards, an analysis of building-integrated renewables deployment on existing buildings (using appropriate benchmarks) identifies significant retrofit opportunities – especially in existing non-domestic buildings. The two tables below summarise this potential.

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26 Image sourced from Wikimedia Commons, user Peellden, uploaded Feb 2009 and page viewed June 2014: http://en.wikipedia.org/wiki/File:WorkdGame2009_Stadium_completed.jpg

27 Figures from Solar Energy World article (2011): www.solarenergyworld.com/2011/07/07/international-solar-kaohsiung-world-stadium-taiwan/

Existing buildings	Biomass boiler capacity [kW]	Biomass boiler heat generation [kWh/yr[	Heat pump capacity [kW]	Heat pump heat generation [kWh/yr]	Solar PV capacity [kW]	Solar PV generation [kWh/yr]	Solar hot water capacity [kW]	Solar hot water generation [kWh/yr]
Domestic	0	0	148	257,666	185	129,928	44	177,515
Non-domestic	11,640	10,402,648	885	1,956,865	1366	957,853	1,301	658,587
Total	**11,640**	**10,402,648**	**1,033**	**2,214,531**	**1,552**	**1,087,782**	**1,345**	**836,102**

Table 17: Building-integrated renewables opportunities (capacities) for existing sites

Sector	CO_2 saving [tonnes/yr]	Biomass boiler CAPEX	Heat pump CAPEX	Solar PV CAPEX	Solar hot water CAPEX	Total CAPEX
Domestic	147	£0	£268,200	£197,864	£30,127	£496,191
Non-domestic	3,102	£2,533,943	£1,567,548	£1,080,728	£1,345,748	£6,527,966
Total	**3,249**	**£2,533,943**	**£1,835,748**	**£1,278,592**	**£1,375,875**	**£7,024,158**

Table 18: Building-integrated renewables opportunities (CO_2 savings and costs) for existing sites

5.2.3 Combined potential

The chart below summarises the potential deployment capacity of building-integrated renewables across existing buildings and development phases within TQEZ, assuming no district energy system is deployed.

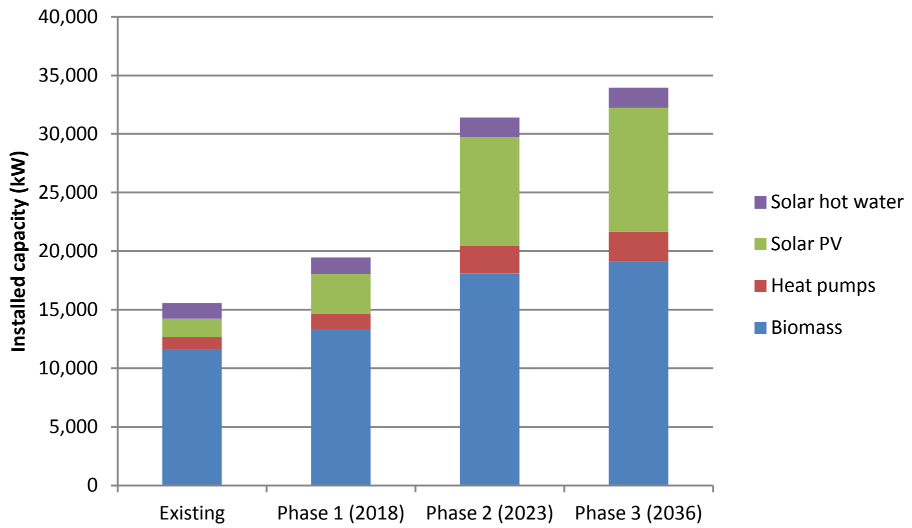

Figure 21: Potential cumulative integration of building-integrated renewables within TQEZ

5.3 Deployment scenarios

Having looked separately at the potential for district heating networks and building-integrated renewables, a set of scenarios can now be examined which attempts to evaluate the options for achieving Zero Carbon in the TQEZ both in terms of new development only and then considering all existing and future buildings.

5.3.1 Base Scenario: National standards plus 20% onsite generation requirement

Government's proposals for zero-carbon buildings suggest all new homes built from 2016 must have zero regulated emissions; however, developers will have the option of offsetting carbon emissions offsite via the Allowable Solutions scheme (see Section 6.2). Building regulations will control this and set improved standards for fabric energy efficiency; this has been incorporated into the energy demand modelling discussed in Section 4.2.

The Government also intends to set a zero carbon standard for non-domestic development by 2019. Whilst there are few details currently available as to how the government will implement zero carbon non-domestic standards, it is assumed for the purposes of this study that it will follow a similar approach to the domestic sector. In other words, this assumes that minimum energy efficiency performance standards are set via building regulations, with developers being given the choice as to how much of their remaining carbon reduction target they will meet onsite via low and zero carbon energy generation or offsite through the Allowable Solutions mechanism.

In addition to national improvements, BCC have a local planning policy target for a 20% CO_2 saving beyond building regulations via onsite renewable energy (Policy BCS14). This requires that new development in TQEZ incorporates, as a minimum, onsite renewables to reduce residual CO_2 emissions (after Building Regulations have been applied) by 20%. Whilst, in practice, developers will decide how they meet their targets, the scenarios below provide an example of generation capacities achieved across new development in the TQEZ and indicative additional costs if these targets were to be met using two of the most cost-effective solutions: biomass heating and solar PV, where biomass is prioritised.

Phase	Sector	Biomass boiler capacity [kW]	Biomass boiler heat generation [kWh/yr]	Biomass boiler CAPEX	Solar PV capacity [kW]	Solar PV generation [kWh/yr]	Solar PV CAPEX	Total CAPEX
Phase 1 (2013 - 2018)	Domestic	221	325,142	£45,987	27	19,113	£39,294	£85,281
	Non-domestic	869	1,278,630	£180,844	119	83,526	£171,718	£352,562
	Total	**1,091**	**1,603,772**	**£226,830**	**146**	**102,639**	**£211,012**	**£437,843**
Phase 2 (2018 - 2023)	Domestic	973	1,431,535	£156,949	41	29,014	£37,623	£194,572
	Non-domestic	1,523	2,239,686	£180,810	497	348,580	£452,644	£633,455
	Total	**2,496**	**3,671,221**	**£337,759**	**539**	**377,595**	**£490,268**	**£828,027**
Phase 3 (2023+)	Domestic	348	511,512	£42,436	21	14,491	£14,071	£56,506
	Non-domestic	0	0	£0	37	26,255	£26,085	£26,085
	Total	**348**	**511,512**	**£42,436**	**58**	**40,746**	**£40,155**	**£82,591**
	Total	**3,935**	**5,786,505**	**£607,025**	**743**	**520,979**	**£741,435**	**£1,348,461**

Table 19: Estimated capacities of building-integrated renewables (biomass heating & solar PV) deployed to meet 20% onsite CO_2 reduction target for new development

The following scenarios illustrate how building-integrated renewables and district energy solutions could improve TQEZ's energy performance above and beyond that of the base case ('business as usual') scenario.

5.3.2 Scenario 1: Building-integrated renewables

Maximising building-integrated renewables within TQEZ will require the delivery of all the renewable energy measures identified in Section 5.2. Table 20 and Table 21 below summarise capacities, yield, costs and emissions from these measures when deployed across the whole of TQEZ, including existing buildings and future development sites, if there were no district heating networks implemented between sites.

Sector & phase		Biomass boiler capacity [kW]	Biomass boiler heat generation [kWh/yr]	Heat pump capacity [kW]	Heat pump heat generation [kWh/yr]	Solar PV capacity [kW]	Solar PV generation [kWh/yr]	Solar hot water capacity [kW]	Solar hot water generation [kWh/yr]
Existing domestic		0	0	148	257,666	185.4	129,928	44	177,515
Existing non-domestic		11,640	10,402,648	885	1,956,865	1366.8	957,853	1,301	658,587
Phase 1 (2013-2018)	Domestic	556	817,369	85	136,376	550	385,173	22	14,146
	Non-domestic	1,157	1,701,629	192	306,713	1,280	896,706	50	31,815
Phase 2 (2018-2023)	Domestic	2,501	3,677,389	139	221,801	2,481	1,738,934	36	23,007
	Non-domestic	2,235	3,286,343	906	1,448,596	3,408	2,388,379	235	150,263
Phase 3 (2023-2036)	Domestic	1,053	1,549,129	78	124,814	1,137	796,481	20	12,947
	Non-domestic	0	0	92	147,656	151	105,981	24	15,316
Total		**19,142**	**21,434,508**	**2,526**	**4,600,486**	**10,559**	**7,399,436**	**1,732**	**1,083,597**

Table 20: Estimated capacities from maximising building-integrated renewables across existing and future TQEZ development

Sector & phase		CO_2 saving from RE installed [tonnes/yr]	Biomass boiler CAPEX	Heat pump CAPEX	Solar PV CAPEX	Solar hot water CAPEX	Total CAPEX
Existing domestic		147	£0	£268,200	£197,864	£30,127	£496,191
Existing non-domestic		3,102	£2,533,943	£1,567,548	£1,080,728	£1,345,748	£6,527,966
Phase 1 (2013-2018)	Domestic	334	£115,605	£100,007	£444,571	£15,069	£675,253
	Non-domestic	733	£240,671	£285,156	£1,097,129	£74,191	£1,697,146
Phase 2 (2018-2023)	Domestic	1,189	£271,502	£111,538	£1,340,040	£28,311	£1,751,392
	Non-domestic	1,529	£242,631	£859,980	£1,969,209	£187,283	£3,259,103
Phase 3 (2023-2036)	Domestic	506	£97,217	£57,116	£434,501	£9,049	£597,883
	Non-domestic	55	£0	£74,656	£82,189	£22,313	£179,158
Total		**7,595**	**£3,501,569**	**£3,324,201**	**£6,646,231**	**£1,712,091**	**£15,184,093**

Table 21: Building-integrated renewable opportunities (capacity and generation) across TQEZ

By Phase 3, this option would save approximately 57% of the total annual CO_2 emissions arising from new development, or 34% of total annual emissions from all existing and future TQEZ buildings, at an estimated total additional cost of £15.2m.

Figure 22 estimates the annual CO_2 savings achievable with this scenario. The total of each column represents total baseline TQEZ emissions at each phase and shows the proportions then saved by deployment of these scenarios.

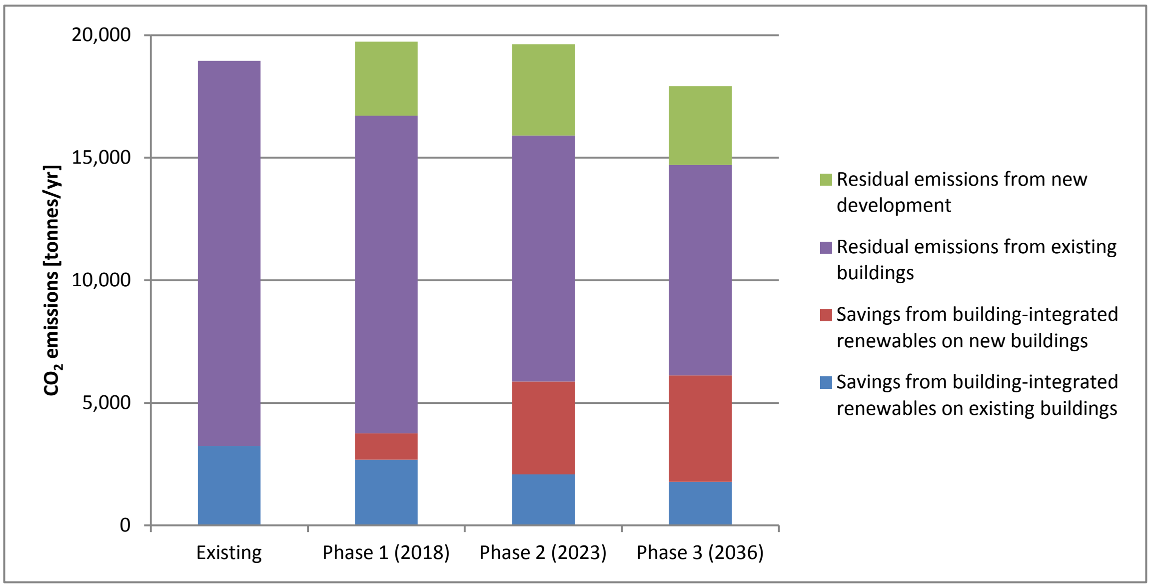

Figure 22: Scenario 1: Saved and remaining CO_2 emissions by deploying all building-integrated renewables

5.3.3 Scenario 2a: Small-scale biomass CHP heat network with building-integrated renewables

This scenario assumes that a relatively small-scale biomass CHP plant is implemented together with building-integrated renewables across the TQEZ from Phase 1.

The CHP plant is modelled using estimated heat loads from the illustrative heat network shown in Figure 17 (Network 1 – Temple Back East) involving existing buildings only. The table below shows the modelled results of an initial high level financial appraisal, using a biomass CHP plant theoretically-sized at 1.4 MWth as the energy centre technology to supply all the predicted heat demand to the existing buildings on the network.

DH Network 1 (small biomass CHP) – Temple Back East		
Full load equivalent run hours	6,000	Hrs
Rated heat output	1.40	MW
Annual heat output	8,400	MWh
Annual heat delivered (after pipe losses)	7,980	MWh
Rated elec output	0.70	MW
Annual elec output	4,200.00	MWh
Annual woodfuel tonnage	4,337	tonnes
Annual CO_2 saving (2013)	3,131	tonnes
Energy centre capex	£5,600,000	
Heat network capex	£353,746	
Total capital cost	£5,953,746	
NPV	-£263,776	
IRR	5.53%	
NPV/capital ratio	0.04	

Table 22: Modelled results of small-scale biomass CHP network under Scenario 2a

The modelled impact of the CHP plant is that the number of building-integrated renewable heating systems will be reduced in the area served by the CHP heat network. This only impacts the existing non-domestic sector due to the location of the network. Table 23 and Table 24 below show the resulting capacities of building-integrated renewables and CO_2 savings with capital costs under Scenario 2. The shaded cells indicate the changes compared to Scenario 1.

Sector & phase		Biomass boiler capacity [kW]	Biomass boiler heat generation [kWh/yr]	Heat pump capacity [kW]	Heat pump heat generation [kWh/yr]	Solar PV capacity [kW]	Solar PV generation [kWh/yr]	Solar hot water capacity [kW]	Solar hot water generation [kWh/yr]
Existing domestic		0	0	148	257,666	185.4	129,928	44	177,515
Existing non-domestic		8,128	6,330,988	885	1,956,865	1366.8	957,853	1,078	545,486
Phase 1 (2013-2018)	Domestic	556	817,369	85	136,376	550	385,173	22	14,146
	Non-domestic	1,157	1,701,629	192	306,713	1,280	896,706	50	31,815
Phase 2 (2018-2023)	Domestic	2,501	3,677,389	139	221,801	2,481	1,738,934	36	23,007
	Non-domestic	2,235	3,286,343	906	1,448,596	3,408	2,388,379	235	150,263
Phase 3 (2023-2036)	Domestic	1,053	1,549,129	78	124,814	1,137	796,481	20	12,947
	Non-domestic	0	0	92	147,656	151	105,981	24	15,316
Total		**15,630**	**17,362,847**	**2,526**	**4,600,486**	**10,559**	**7,399,436**	**1,509**	**970,495**

Table 23: Estimated capacities of building-integrated renewables under Scenario 2a

Sector & phase		CO_2 saving from RE installed [tonnes/yr]	Biomass boiler CAPEX	Heat pump CAPEX	Solar PV CAPEX	Solar hot water CAPEX	Biomass CHP Capex	Total CAPEX
Existing domestic		147	£0	£268,200	£197,864	£30,127	–	£496,191
Existing non-domestic		2,242	£1,803,425	£1,567,548	£1,080,728	£1,193,634	£5,953,746	£11,599,081
Phase 1 (2013-2018)	Domestic	334	£115,605	£100,007	£444,571	£15,069	–	£675,253
	Non-domestic	733	£240,671	£285,156	£1,097,129	£74,191	–	£1,697,146
Phase 2 (2018-2023)	Domestic	1,189	£271,502	£111,538	£1,340,040	£28,311	–	£1,751,392
	Non-domestic	1,529	£242,631	£859,980	£1,969,209	£187,283	–	£3,259,103
Phase 3 (2023-2036)	Domestic	506	£97,217	£57,116	£434,501	£9,049	–	£597,883
	Non-domestic	55	£0	£74,656	£82,189	£22,313	–	£179,158
Total		**6,735**	**£2,771,051**	**£3,324,201**	**£6,646,231**	**£1,559,977**	**£5,953,746**	**£20,255,206**

Table 24: Estimated savings and capital costs of biomass CHP network and building-integrated renewables under Scenario 2a

Implementing a 1.4MWth biomass CHP network alongside compatible building-integrated renewables throughout TQEZ would by Phase 3 save approximately 57% of the total annual CO_2 emissions arising from new development, or 43% of total annual emissions from all existing and future TQEZ buildings, at an estimated total additional cost of £20m.

Figure 23 estimates the CO_2 savings achievable with this scenario. The total of each column represents total baseline TQEZ emissions at each phase and shows the proportion then saved by the technologies under this scenario.

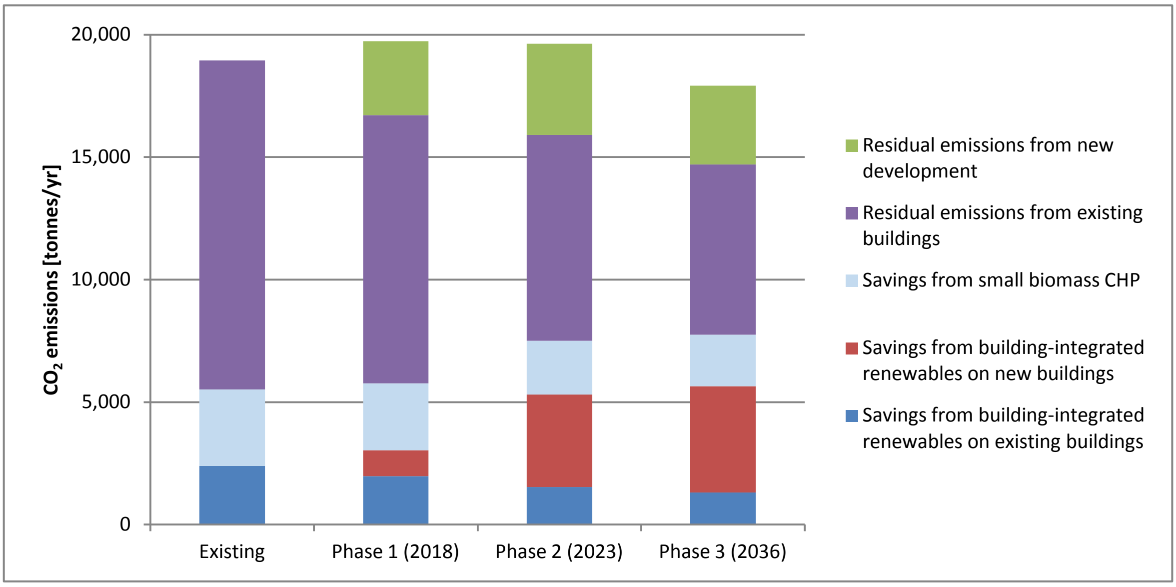

Figure 23: Scenario 2a: Saved and remaining CO_2 emissions by deploying small-scale biomass CHP & building-integrated renewables

5.3.4 Scenario 2b: Small-scale gas CHP heat network with building-integrated renewables

This scenario assumes a similar-sized CHP plant is implemented to Scenario 2a, but using gas-fired technology instead of biomass. The plant is assumed to serve the same heat network, alongside the same building-integrated renewable energy deployment options as in Scenario 2a.

The table below therefore shows the modelled results of an initial high level financial appraisal, using a gas CHP plant theoretically-sized at 1.4 MWth as the energy centre technology to supply all the predicted heat demand to the existing buildings on the network.

DH Network 1 (Gas CHP) – Temple Back East		
Full load equivalent run hours	6,000	Hrs
Rated heat output	1.40	MW
Annual heat output	8,400	MWh
Annual heat delivered (after pipe losses)	7,980	MWh
Rated elec output	0.70	MW
Annual elec output	4,200.00	MWh
Annual CO_2 saving (2013)	274	tonnes
Energy centre capex	£919,800	
Heat network capex	£353,746	
Total capital cost	£1,273,546	
NPV	-£321,515	
IRR	3.01%	
NPV/capital ratio	0.25	

Table 25: Modelled results of gas CHP network under Scenario 2b

Capacities of building-integrated renewables under this scenario would therefore be the same as those shown in Table 23.

Table 26 below shows CO_2 savings with capital costs under Scenario 2b, with the shaded cells indicating the changes compared to Scenario 1.

Sector & phase		CO_2 saving from RE installed [tonnes/yr]	Biomass boiler CAPEX	Heat pump CAPEX	Solar PV CAPEX	Solar hot water CAPEX	Gas CHP Capex	Total CAPEX
Existing domestic		147	£0	£268,200	£197,864	£30,127	–	£496,191
Existing non-domestic		2,242	£1,803,425	£1,567,548	£1,080,728	£1,193,634	£1,273,546	£6,918,881
Phase 1 (2013-2018)	Domestic	334	£115,605	£100,007	£444,571	£15,069	–	£675,253
	Non-domestic	733	£240,671	£285,156	£1,097,129	£74,191	–	£1,697,146
Phase 2 (2018-2023)	Domestic	1,189	£271,502	£111,538	£1,340,040	£28,311	–	£1,751,392
	Non-domestic	1,529	£242,631	£859,980	£1,969,209	£187,283	–	£3,259,103
Phase 3 (2023-2036)	Domestic	506	£97,217	£57,116	£434,501	£9,049	–	£597,883
	Non-domestic	55	£0	£74,656	£82,189	£22,313	–	£179,158
Total		**6,735**	**£2,771,051**	**£3,324,201**	**£6,646,231**	**£1,559,977**	**£1,273,546**	**£15,575,006**

Table 26: Estimated savings and capital costs of gas CHP network and building-integrated renewables under Scenario 2b

Implementing a 1.4MWth gas CHP network alongside compatible building-integrated renewables throughout TQEZ would by Phase 3 save approximately 57% of the total annual CO_2 emissions arising from new development, or 27% of total annual emissions from all existing and future TQEZ buildings, at an estimated total additional cost of £15m.

Figure 24 estimates the CO_2 savings achievable with this scenario. The total of each column represents total baseline TQEZ emissions at each phase and shows the proportion then saved by the technologies under this scenario.

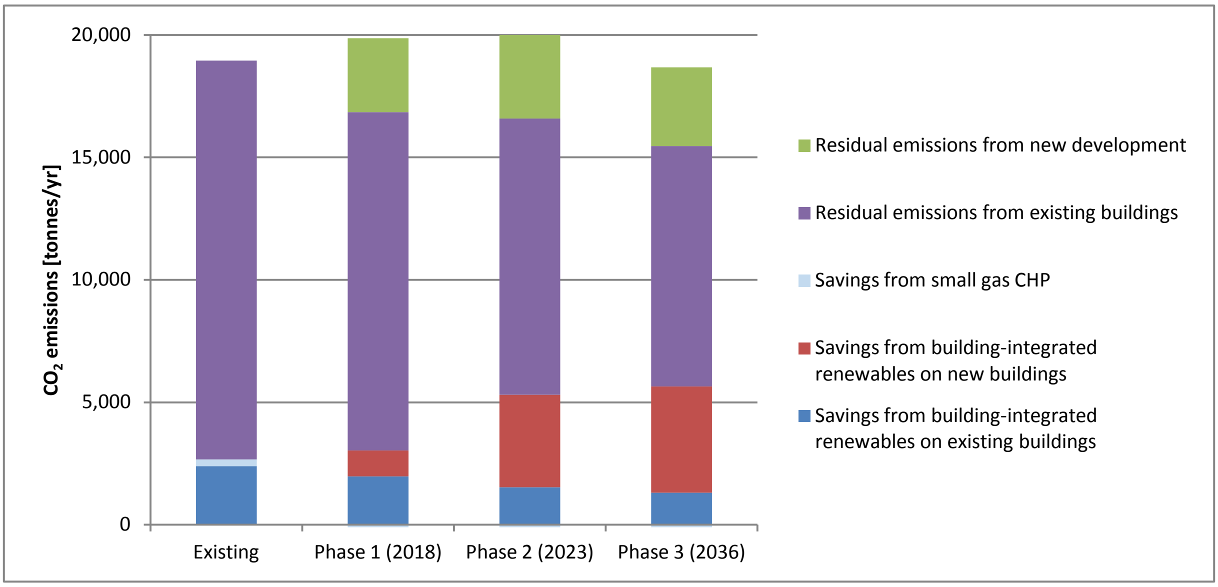

Figure 24: Scenario 2b: Saved and remaining CO_2 emissions by deploying gas CHP & building-integrated renewables

5.3.5 Scenario 3: Large-scale biomass CHP heat network with building-integrated renewables

This final scenario assumes a hypothetical 5MWth biomass CHP plant is installed where the maximum amount of its energy output is used within the TQEZ, with any surplus being exported. This scenario is not based on a defined heat network; it simply explores the impact of a larger biomass CHP plant on the TQEZ's total emissions.

The heat output from this size plant would marginally exceed that delivered by the total amount of building-integrated renewable heating in Scenario 1, and so is assumed to replace this, leaving only solar PV to contribute to the building-integrated renewables element of this scenario (i.e. using the solar PV figures shown in Table 20 and Table 21 .

The table below therefore shows the modelled results of an initial high level financial appraisal, using a biomass CHP plant theoretically-sized at 5MWth. As a heat network has not been defined, parameters such as 'heat network capex' have been broadly estimated by scaling up figures from the CHP/DH analysis in Scenarios 2a and 2b; as such, the financial indicators are broad estimates only.

DH Network (large biomass CHP) – unspecified location		
Full load equivalent run hours	6,000	Hrs
Rated heat output	5.00	MW
Annual heat output	30,000	MWh
Annual heat delivered (after pipe losses)	28,500	MWh
Rated elec output	2.50	MW
Annual elec output	15,000	MWh
Annual woodfuel tonnage	15,491	tonnes
Annual CO_2 saving (2013)	11,184	tonnes
Energy centre capex	£20,000,000	
Heat network capex	£990,488	
Total capital cost	£20,990,488	
NPV	-£1,762,214	
IRR	5.10%	
NPV/capital ratio	0.08	

Table 27: Modelled results of large-scale biomass CHP network under Scenario 3

Implementing a 5MWth biomass CHP network alongside compatible building-integrated renewables (in this case solar PV) throughout TQEZ would by Phase 3 save approximately 52% of total emissions from all existing and future TQEZ buildings, at an estimated total additional cost of £27m.

Figure 25 below estimates the CO_2 savings achievable with this scenario. The total of each column represents total baseline TQEZ emissions at each phase and shows the proportion then saved by the technologies under this scenario.

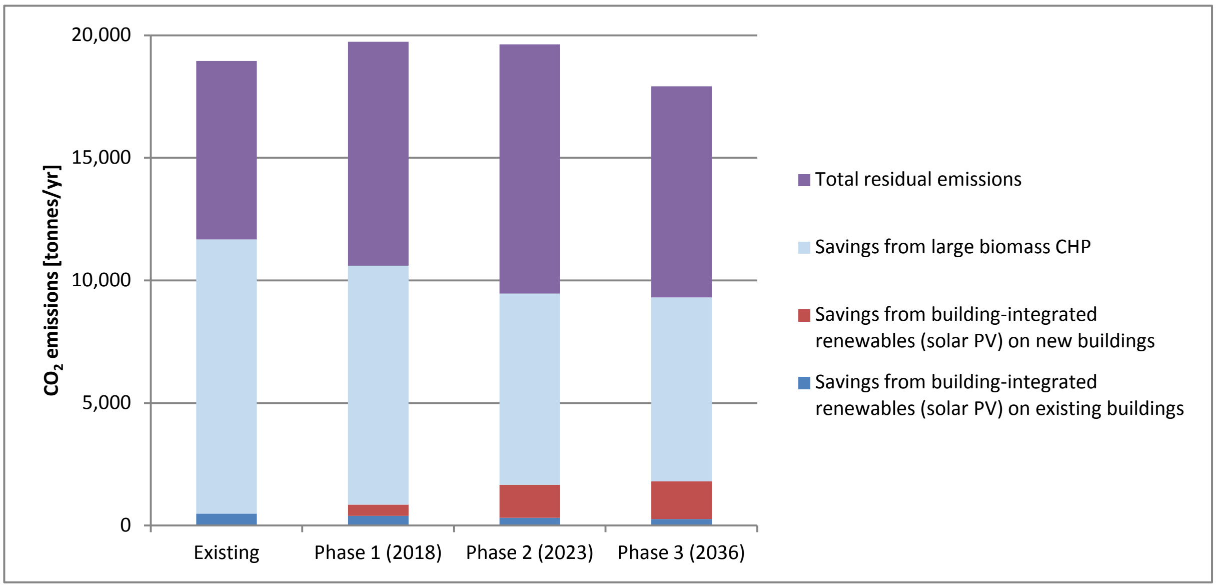

Figure 25: Scenario 3: Saved and remaining CO_2 emissions by deploying large-scale biomass CHP & building-integrated renewables

6 Planning considerations and delivery options

This section reviews the planning policy considerations, how they interact with building regulations, and options for delivering the low and zero carbon energy scenarios via an Energy Services Company (ESCo).

6.1 National planning policy, Bristol planning and building regulations

National planning policy is governed by the National Planning Policy Framework (NPPF)[28], supported via the online national planning practise guidance[29]. These provide several powers to local authorities in developing localised energy planning policy, with the overarching policy contained in paragraph 97:

97. To help increase the use and supply of renewable and low carbon energy, local planning authorities should recognise the responsibility on all communities to contribute to energy generation from renewable or low carbon sources. They should:

- *have a positive strategy to promote energy from renewable and low carbon sources;*
- *design their policies to maximise renewable and low carbon energy development while ensuring that adverse impacts are addressed satisfactorily, including cumulative landscape and visual impacts;*
- *consider identifying suitable areas for renewable and low carbon energy sources, and supporting infrastructure, where this would help secure the development of such sources;*
- *support community-led initiatives for renewable and low carbon energy, including developments outside such areas being taken forward through neighbourhood planning; and*
- *Identify opportunities where development can draw its energy supply from decentralised, renewable or low carbon energy supply systems and for co-locating potential heat customers and suppliers.*

Additionally, the Planning and Energy Act 2008[30] allows local planning authorities within local planning policies to require a proportion of energy supplied to new development in their area to be from renewable and/or low-carbon sources in the locality of the development; and comply with energy efficiency standards that exceed the energy requirements of building regulations.

Central government is in the process of revoking local authorities' ability to set energy efficiency standards exceeding building regulations for new or refurbished dwellings following the outcomes of a recent consultation on housing standards[31]. This may have an impact on new developments within the TQEZ, especially if similar changes are introduced to the non-domestic sector. However, local authorities' ability to apply onsite renewable energy ('Merton') targets and requirements on developers to investigate and apply feasible energy infrastructure (district energy) has been maintained.

BCC's energy-related policies are included within their Core Strategy policies BCS13-15[32]. Whilst these contain requirements for new homes to exceed building regulations, several important policy requirements still stand:

[28] Department for Communities and Local Government (DCLG), 2012: www.gov.uk/government/publications/national-planning-policy-framework--2
[29] DCLG 2014: http://planningguidance.planningportal.gov.uk/
[30] Planning and Energy Act 2008: www.legislation.gov.uk/ukpga/2008/21/contents
[31] Government's response to the Housing Standards Review, published 13 March 2014. Legislative changes to the Planning and Energy Act are being brought forwards through additions to the Deregulation Bill: www.gov.uk/government/news/stephen-williams-announces-plans-to-raise-housing-standards
[32] Adopted November 2011: www.bristol.gov.uk/page/planning-and-building-regulations/planning-core-strategy

- [Development should include] *High standards of energy efficiency including optimal levels of thermal insulation, passive ventilation and cooling, passive solar design, and the efficient use of natural resources in new buildings.*
- [Development should include] *The use of decentralised, renewable and low-carbon energy supply systems.*
- *development will be expected to provide sufficient renewable energy generation to reduce carbon dioxide emissions from residual energy use in the buildings by at least 20%.*
- *Within Heat Priority Areas* [which includes TQEZ], *major development will be expected to incorporate, where feasible, infrastructure for district heating, and will be expected to connect to existing systems where available.*
- *New development will be expected to demonstrate that the heating and cooling systems have been selected according to the following heat hierarchy:*
    1. *Connection to existing CHP/CCHP distribution networks*
    2. *Site-wide renewable CHP/CCHP*
    3. *Site-wide gas-fired CHP/CCHP*
    4. *Site-wide renewable community heating/cooling*
    5. *Site-wide gas-fired community heating/cooling*
    6. *Individual building renewable heating*

Building regulations sit outside of the planning policy framework, and set the minimum construction standards for new and refurbished buildings. New or refurbished buildings must meet the most up-to-date regulations applicable at the start of construction, currently defined as the point at which construction work on the site starts (not when it is complete). Minimum energy standards within Building Regulations are governed by 'Part L' (Conservation of Fuel and Power). The government tightens building regulations every few years; however, the dates and degree of tightening are not known for certain until near to their implementation, as they are subject to consultation.

6.2 Carbon offsetting and Allowable Solutions

The consultation on allowable solutions for zero carbon homes[33] states that "house builders decide how they meet their obligation" and, in addition to onsite solutions, can meet it offsite in one of four ways:

1. House-builder 'Do it yourself', where the developer has complete control over which carbon saving initiatives they fund.
2. Contracting with a third party Allowable Solutions private sector or local authority delivery partner on a bilateral agreement.
3. One-off investments via an Allowable Solutions brokerage or matching system.
4. Developers invest in a national funding programme, similar to the Green Investment Bank.

[33] 'Next steps to zero carbon homes: allowable solutions', DCLG consultation, 6 August 2013: https://www.gov.uk/government/consultations/next-steps-to-zero-carbon-homes-allowable-solutions

Each of these routes could provide investment towards delivering carbon saving solutions within the TQEZ. These may include retrofitting other buildings with energy saving, low or zero-carbon energy systems, or investing in larger stand-alone energy generation and/or their associated energy distribution infrastructure.

The most significant consideration is that, for each development, developers would have a choice as to how to meet their carbon saving obligation. Therefore, if BCC want developers to invest in a certain technology or project, they will need to make it an attractive opportunity. Within the consultation's 'central price cap option', the upper limit for allowable solutions obligations is £60 per tonne of CO_2 saved. However the outcome of this consultation has not yet been announced, so the price may alter in practice.

Whilst this consultation focused on zero carbon homes, the approach to Allowable Solutions and carbon offsetting for zero carbon non-domestic developments is likely to follow a similar process of allowing developers the freedom to choose where they invest.

6.3 Grant funding opportunities

6.3.1 Community Infrastructure Levy (CIL)

The majority of developments within the TQEZ will be liable to pay a contribution to the Community Infrastructure Levy (CIL)[34]. BCCs current Regulation 123 list, setting out where BCC can invest CIL funds, does not currently include investments into energy services. BCC may want to look to modify their Regulation 123 list if they decide their CIL funding priorities have changed, however this may need to be within a comprehensive review if it is to have a significant impact on development viability.

If BCC did choose to change Regulation 123 priorities, CIL funding could fund low carbon infrastructure, to facilitate development being acceptable in planning terms. There is no CIL charge for commercial development[35], so funding secured from development in the TQEZ will be limited to housing, retail and other non-commercial developments. CIL funding secured from outside TQEZ could be invested within the area.

6.3.2 Grant funding opportunities

Currently, the majority of grant funding opportunities for sustainable energy developments in the UK are overseen by DECC. They currently have £7m of development funding to award to local authorities before March 2015, and a dedicated team to support local authorities in developing district energy schemes[36]. Whilst this funding will help cover development costs, there are no obvious specific grant funding opportunities to help cover the capital costs of district energy systems.

Small-scale renewable energy generation is subsidised through the Feed in Tariff (known as the 'FiT', for renewable electricity schemes) and the Renewable Heat Incentive (RHI). These subsidies are needed to make renewable energy financially viable in the short term whilst these technologies still have high capital costs, but are set to drop in parallel with falling capital costs.

[34] Developments with a floor area <100m^2 are excluded from CIL obligations. BCC guidance: http://www.bristol.gov.uk/page/community-infrastructure-levy-cil

[35] BCC CIL Charging Schedule, September 2012: http://www.bristol.gov.uk/sites/default/files/documents/planning_and_building_regulations/planning_applications_and_process/CIL%20Charging%20Schedule.pdf

[36] Further information on DECC's Heat Network Delivery Unit and funding support for local authorities is here: www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies/supporting-pages/heat-networks

Previously, the Homes and Communities Agency (HCA) has invested in district energy schemes in other areas via their Low Carbon Infrastructure Fund. For example, this included a £1.5m contribution to Phase 1 of a scheme in Nottingham, where the remaining £0.4m came from the council's prudential borrowing. Their funds for this programme have now been fully allocated[37].

Private Finance Initiatives (PFIs) have also in the past helped deliver energy centre and district energy solutions. The Barkantine CHP scheme capital cost was £6m, and Tower Hamlets BC obtained £5m PFI credit from the Department of the Environment, Transport and the Regions (DETR). However, the Treasury Committee now views PFI funding as rarely providing good value for money for taxpayers. PFI finance for energy services infrastructure may therefore be difficult to obtain.

6.4 Energy Services Company (ESCo) delivery options

Developers within TQEZ will need to invest in carbon saving measures to meet low-carbon energy requirements of future building regulations. Whilst they may achieve much of this via onsite measures, such as high levels of energy efficiency and integrating low and zero-carbon energy measures, they may need to invest in off-site carbon saving measures. Offsite solutions are termed as 'Allowable Solutions'. Developers could choose to invest using their own capital investment and/or through off-balance-sheet financing via an Energy Services Company (ESCo).

ESCos are often synonymous with district energy operators. However, there are three other delivery structures used for setting up district energy networks[38], summarised in the table below.

Delivery structure	Description of undertaking
ESCo	A single entity is procured or set-up for the supply of heat to customers, and to build and operate the DH system. ESCos can form partnerships, so that different organisations are responsible for separate work elements and services. This could be set up with a defined set of consumer buildings to be connected, or to provide the service to developments within a defined area.
Wholesale energy supplier	A single contractor is appointed to design, build and operate the system. The organisation procuring the contractor buys the energy, and sells the energy to other consumers (as the wholesaler).
Network delivery and operation	One or more contractors are procured to design, build, operate and maintain a network on behalf of the procuring organisation, who remains the asset owner.
Network operation	An organisation is procured on behalf of the asset owner to operate an existing distribution network, which may include metering and billing.

Table 28: District energy delivery structures

TQEZ has no existing distribution networks but does have the potential for one to be set-up. If one were to be set-up, there would be multiple stakeholders with different interests in the scheme. These stakeholders would include TQEZ landowners, developers, building occupiers and BCC.

Based on discussions with TQEZ stakeholders, including the council, it is unlikely that one organisation would want to have the overarching responsibility for assets or for the supply of energy. The network composition will also change as new construction takes place and more buildings connect to the network. These factors suggest that an ESCo may be the most viable structure to deliver district energy in the TQEZ. An ESCo also has potential to supply other energy services, such as energy efficiency and renewable energy retrofit under Allowable Solutions.

[37] More information can be found here: www.homesandcommunities.co.uk/ourwork/low-carbon-infrastructure-fund-0
[38] Further information can be found in Chapter 5 (Contract Structure and Management) within the District Heating Manual for London, February 2013: www.londonheatmap.org.uk/Content/uploaded/documents/DH_Manual_for_London_February_2013_v1.0.pdf

ESCos can have four broad structures; wholly public sector, a public-private sector partnership, stakeholder owned or wholly private sector. These structures are explained in more detail in the following sections. BCC are in the process of setting up a Bristol-wide ESCo, as part of their ELENA-funded strategic energy unit's work[39]. With input from TQEZ stakeholders, the Council will need to decide whether TQEZ warrants its own ESCo; or whether the Bristol-wide ESCo would meet the decarbonisation needs of TQEZ.

6.4.1 Wholly-owned public sector ESCo

Local councils and some other public sector organisations do have the capability to set up an ESCo themselves. The ESCo can be operated 'in-house' within the organisation, or via an arms-length Special Purpose Vehicle (SPV) delivery structure. Many older district energy networks in the UK operate using this model, or those wholly within a single public-sector organisations estate.

Examples of this approach include:

- Nottingham CC Energy from Waste CHP scheme. Nottingham CC own this scheme in-house, although the EfW plant is operated by private contractor WRG and Enviroenergy operate the CHP and district heating infrastructure and manage distribution, metering and billing: http://www.local.gov.uk/web/guest/climate-change/-/journal_content/56/10171/3511234
- Aberdeen CC set up the Aberdeen Heat and Power Company as an arms-length SPV in 2002: http://www.aberdeenheatandpower.co.uk/
- Pimlico District Heating Undertaking: this scheme is considered the UKs first CHP disrict heating scheme. The scheme is owned by Westminser Council and operated by the housing association CityWest Homes: http://www.cwh.org.uk/locations/churchill-gardens/the-pimlico-district-heating-undertaking-pdhu-/

6.4.2 Public-private partnership ESCo

Many of the older wholly-owned public sector ESCos have formed partnerships, especially when having their networks expanded. Similarly, new schemes being set up by local authorities are often tendered out to partner with private firms capable of technically developing, delivering and operating the firm and, more often than not, who are able to secure financial investment for the networks.

Many of these partnership tenders have been won by organisations such as Cofely (GDF Suez)[40]. Examples of this approach include:

- Southampton geothermal and gas CHP scheme. The council partnered with Utilicom[41] to develop and run the Southampton Geothermal Heating Company (SGHC): https://www.southampton.gov.uk/s-environment/energy/Geothermal/
- Barkantine CHP scheme in Tower Hamlets, London. Barkantine Heat and Power Company (BHPC), a subsidiary of EDF, own and manage the scheme on a 25-year contract with the borough council until 2026: http://www.local.gov.uk/web/guest/climate-change/-/journal_content/56/10171/3510422
- Woking gas CHP: Woking BC set up Thameswey Ltd, an arms-length venture set up to enter public-private sector partnerships. Thamesway Ltd then set-up the joint venture Thamesway Energy Ltd, a

[39] BCC Strategic Energy Unit: www.bristol.gov.uk/page/environment/strategic-energy-unit
[40] Including schemes in: Manchester, Leicester, Coventry, Birmingham, Portsmouth and London. A full list of their schemes can be found here: www.cofely-gdfsuez.co.uk/solutions/district-energy/district-energy-schemes
[41] Utilicom and its subsidiaries was acquired by GDFSUEZ Energy Services on 30 April 2010 and is now known as Cofely District Energy Limited

joint-venture with Danish firm ESCO International A/S. The council maintains 19% via shareholding capial, with ESCO International A/S holding the remaining 81%: http://www.thamesweyenergy.co.uk/pages/about_us.php?id=12

6.4.3 Private sector ESCo

Not all ESCos in the UK have needed public sector involvement. There are examples of the private sector and communities developing district energy networks, however professional ESCos have been brought in to run and maintain the networks.

Examples of this approach include the City of London's combined heat and power system, which was initially developed by the City Corporation before the ESCo operation was awarded to Citigen (now a subsidiary of EON): http://217.154.230.218/NR/rdonlyres/62844866-7207-483A-ADFD-C07C385B9628/0/SUS_casestudyheatandpower.pdf

6.4.4 Stakeholder ESCo

As district heating networks become larger and the size of local authorities (in terms of their estate and access to capital) decreases, the importance of forming large partnerships – or 'stakeholder ESCos' – becomes ever more important. These schemes are owned by several organisations who, in partnership, typically then procure an organisation to run their network.

An example of this is the Cranbrook and Skypark Energy Centre, operated by EON but originally part-owned by Devon County Council, The Growth Point, Homes and Communities Agency (HCA), South West Regional Development Agency, St. Modwen. Further details on this scheme are found here: www.exeterandeastdevon.gov.uk/Energy-Centre--District-Heating-Network/

7 Stakeholder engagement

This section summarises CSE discussions with:

- Peter Holloway, Area Manager for Homes and Communities Agency (HCA)
- Mathew Fox, Project Manager for PSK – representing Salmon Harvester developments
- Andy Fant, Western Route Area Mechanical and Electrical Asset Engineer at Network Rail

7.1 Homes and Communities Agency

HCA are a major landowner within the zone, with two of their existing plots of land covered by Local Development Order's for their temporary use. These temporary uses are expected to cease in late 2014, following which these sites will progress to development. CSE conducted a telephone interview with Peter Holloway on 25 September 2013.

HCA's process for developing sites is to prepare 'development briefs', for developers to bid for. Whilst HCA broadly agree with BCC's TQEZ Spatial Framework, they believe higher densities should be delivered on sites close to Bristol Temple Meads station. HCA have conducted some preliminary studies into what could be delivered on each plot. These studies will be refreshed over the next 6 months to reflect national and local policy and market changes; the outcomes of these refreshed studies should be considered, for their impact on the potential decarbonisation opportunities.

HCA do not have any proposed sustainable energy initiatives, nor do they prescribe any environmental or sustainability requirements beyond those which are applied via building regulations, national planning policy or local council policies.

They would however adopt BCC standards and support BCC ambitions towards sustainable energy within TQEZ, providing they do not delay or unduly burden development of HCA sites. This includes any proposals for the development of district energy schemes in the area.

Additionally, HCA recognise the large opportunity the TQEZ represents for setting up shared operational and management arrangements. This could include the provision of energy services, alongside the provision of other utilities, waste, marketing and maintenance of shared infrastructure. Peter gave an example of the potential for shared purchasing power in achieving lower energy costs.

7.2 PSK – representing Salmon Harvester

PSK are project managing three major development sites on behalf of Salmon Harvester, a landowner within TQEZ. CSE conducted a telephone interview with Mathew Fox on 26 September 2013.

Three of Salmon Harvester's developments within TQEZ are buildings with prior planning permission and, in some cases, are required to meet a previous standard of building regulations – due to construction work already having started. Where this is the case, PSK (on Salmon Harvester's behalf) have improved the energy performance through low-cost interventions such as energy-efficient lighting throughout and HVAC improvements (such as heat recovery).

PSK and Salmon Harvester are highly unlikely to implement sustainable energy measures beyond building regulation requirements, national planning policy or local council policies. Within these requirements, they expect to implement PV and dock-water-cooling systems where needed and viable.

In theory, PSK and Salmon Harvester could be supportive of district energy solutions within the TQEZ. However, they see this as 'new ground" for private developers of commercial buildings. There would need to be an in-depth investigation into the implications to occupants and appropriate guarantees, especially if occupants are reselling their building, if they were to seriously consider connecting to a communal heating (and power) system. For instance, "*what if new occupants do not want to be part of this shared heating network and there is no heating-plant delivered as part of the development?*"

7.3 Network Rail

Network Rail is a major landowner within the Enterprise Zone, with ownership of Bristol Temple Meads train station and the supporting railway infrastructure. The train station is operated by First Great Western, and there are a number of commercial tenants also on site who have sub-lease agreements through First Great Western.

CSE conducted a telephone interview with Andy Fant on the 27th September 2013. Andy not only manages mechanical and electrical engineering work within Network Rail's buildings, he is also responsible for their Carbon Reduction Commitment (CRC) strategy and its reporting requirements.

Bristol Temple Meads rewiring of internal electrical systems will occur by May 2016. Due to the Grade I listing of this building and others within the site of Bristol Temple Meads, approaches to sustainable energy refurbishment currently focus on efficient lighting. Previously, Network Rail has found the listed building status of Bristol Temple Meads and other listed buildings to be a barrier for installing other low-carbon solutions, with allowable improvements varying between different local authority areas. This work will have negligible impacts on energy master-planning, but the difficulty in refurbishing and doing works in listed buildings has a bearing on other TQEZ listed buildings (identified in Table 11).

In addition to rewiring the existing station, the Great Western Line from London to Bristol is due for electrification by 2016, and it is proposed that Brunel's Old Station will be refurbished and returned to use for this purpose. If senior officials in the Department for Transport agree with the proposals, the refurbishment work will occur 2016-18. This will include a similar approach to fitting energy efficient lighting.

Discussions with Andy highlighted two key considerations for any proposed district heating networks:

1. Pipe-runs should avoid crossing railway tracks unless using existing crossings points such as subways, tunnels or bridges.
2. Due to the permissions required for access, only Network Rail and their subcontractors can gain easy access. Network Rail would resist external organisations using this land for installing infrastructure for this reason, and in addition to this, they consider there is limited space available for further infrastructure.

8 Conclusions & recommendations

8.1 Meeting the current 20% target

The analysis of low and zero carbon energy supply opportunities suggests that BCC's 20% onsite renewable energy target should be technically achievable through the use of building-integrated technologies. It is estimated that this would increase capital costs for new development sites by a total of approximately £1.3m across all sites, and would focus primarily on the installation of a combination of biomass boilers and solar PV.

8.2 Towards zero carbon

A number of carbon reduction scenarios have been modelled on TQEZ using combinations of building-integrated renewables and combined heat and power (CHP) district energy systems to explore on-site Zero Carbon concepts. Table 29 describes the scenarios considered and their key impacts on emissions using a 'business as usual' Phase 3 CO_2 emissions baseline of approximately 18,000 tonnes per year. Figure 26 illustrates the Phase 3 CO_2 reductions for all TQEZ existing and future buildings.

Scenario	Phase 3 CO_2 reduction on new development	Phase 3 CO_2 reduction on all existing and new development	Approx additional capital cost	Description
Scenario 1: BIR only	57%	34%	£15m	Solar PV, biomass boilers for larger buildings and a combination of heat pumps and solar thermal systems for smaller buildings. The heat technologies have been modelled as meeting optimum base heat loads as a minimum whilst remaining within the realms of technical and financial viability. Renewable electricity BIR comprises solar PV only and is based on estimates of roof area and orientation.
Scenario 2a: BIR + small biomass CHP	57%	43%	£20m	As per Scenario 1, but with a relatively small district heating network of existing buildings served by a 1.4MWth biomass CHP plant. This is assumed to displace some of the BIR heating renewables throughout the buildings served by the CHP.
Scenario 2b: BIR + small gas CHP	57%	27%	£15m	As per Scenario 2, but with a 1.4MWth gas CHP plant instead of biomass.
Scenario 3: BIR + large scale biomass CHP	(Not modelled)	52%	£27m	A theoretical 5MWth biomass CHP plant supplying a non-defined heat network, but where use of its heat and electricity output is prioritised within the TQEZ. This is assumed to displace all of the BIR heating within the TQEZ as modelled in Scenario 1, leaving just solar PV as the BIR element of this scenario.

Table 29: Scenario descriptions and headline findings

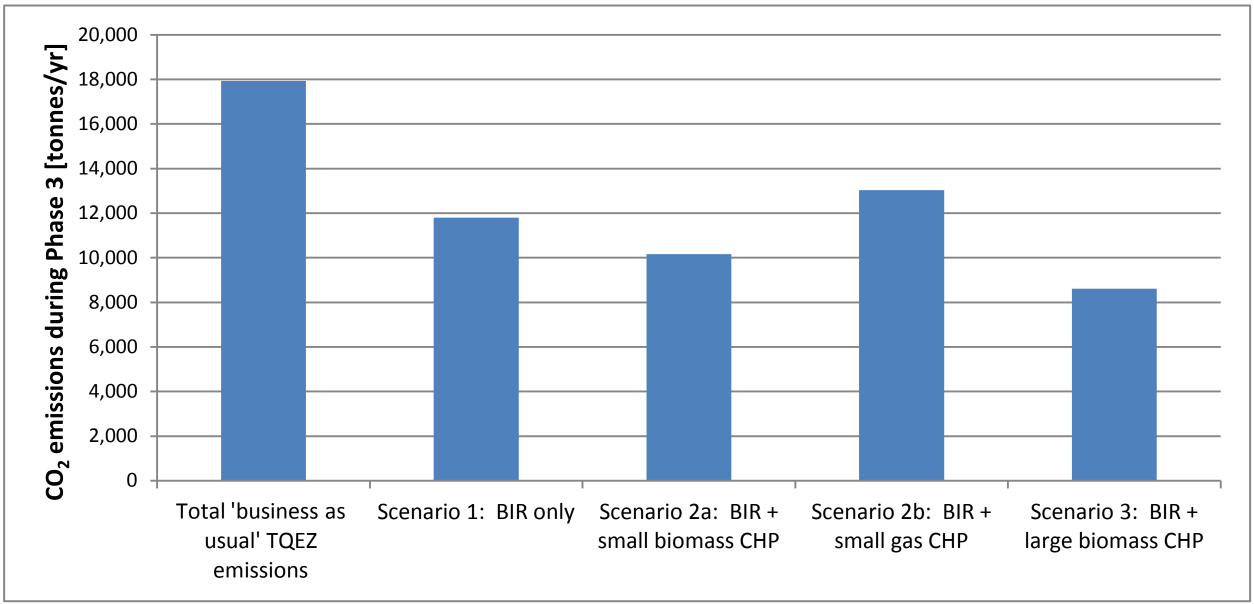

Figure 26: Summary of total CO_2 reduction potential (all existing and future TQEZ development) from modelled scenarios involving building-integrated renewables (BIR) and combined heat and power (CHP) district energy systems

It should be noted that during the three phases of development, overall energy demand will increase, but the increase in electricity demand will be proportionally greater than the increase in heat due to progressively tighter building regulations concerning building insulation. Additionally, CO_2 emissions associated with mains electricity demand will gradually decrease due to the expectation that the UK's electricity generation mix will progressively decarbonise over the three phases, but emissions from gas use will remain constant. Thus any CO_2 reduction benefits enjoyed by gas CHP now will significantly decrease into the future.

Although Scenario 3 may approach on-site Zero Carbon for new development, it is still some way off from achieving on-site Zero Carbon for the TQEZ as a whole. If all emissions from existing and future TQEZ buildings are to be fully mitigated on-site, renewable heating would in some cases need to be sized to meet peak heating requirements, and significantly more renewable electricity generation would be needed within the TQEZ. Solar PV deployment in new development sites could further contribute through innovative building design and/or the use of ground-mounted solar PV arrays in dead-space (strips or parcels of land without another use). Whilst increasing the size of biomass CHP may close the gap, the corresponding heat generated would most likely exceed the demand of TQEZ and so would need to be exported in order to maintain value and plant financial viability. Other 'off-site' options, such as Allowable Solutions also remain, but will depend on the agreed definition of Zero Carbon.

8.3 District energy opportunities

This high level analysis suggests that, like for like, biomass CHP would provide greater returns than gas CHP and lower emissions. Viability, however, will need deeper analysis and careful monitoring to account for future changes in technology, subsidies, fuel costs, obligations on developers, etc.[42] To maximise carbon savings however, district energy schemes should be rolled out in conjunction with compatible building-integrated renewable solutions across the whole site.

A key advantage of district energy solutions over building-integrated renewables is that pipe systems can typically last sixty years or more if properly maintained. Like most building-integrated renewables, the energy

[42] In Sept 2014 CIBSE and CHPA consulted on a Heat Networks Code of Practice which aims to enhance the quality of heat networks across the UK. www.cibse.org/HeatNetworksConsultation

plant would also reach the end of its operational life after 15-20 years, but can potentially be replaced with the most appropriate low or zero carbon technologies available in the future. For example, gas CHP energy centres of today could be replaced with lower carbon biomass (or biogas) CHP plants in the future.

Although use of gas CHP plant instead of biomass CHP will increase emissions, there are certain benefits associated with this technology. Gas CHP plants are much more adept at being installed in a modular format, so the energy centre's capacity can be increased in line with expanding developments' energy demands. Additionally, gas CHP plants are significantly cheaper than biomass CHP as the technology is more mature; developers are likely to perceive it as a less-risky option compared to biomass. Other issues regarding biomass CHP technology include the following:

- There are few examples of successfully installed and operating biomass CHP plants in the UK, with very few manufacturers capable of producing/installing plant below 5MWth[43]. Appendix 4 of this report provides examples of current deployment of biomass CHP systems in the UK.
- Compared to gas, biomass is a more complex fuel to burn and thus will require more complex monitoring and mitigation measures to comply with Bristol's Air Quality Management Zone requirements.
- The energy centre needs to be sited on or near to the heat network, otherwise the additional cost of heat mains will certainly lower (if not prevent) financial viability. Delivery and storage of biomass fuel to the energy centre will need to be adequately considered and contracts for fuel supply will be needed to ensure investor confidence.

There may be opportunities in the future to expand a first-phase district heating network to additional existing or future development sites within TQEZ, as well as potentially linking up to networks being developed elsewhere in Bristol. This will require a strategic view of Bristol's future energy infrastructure and is very much dependent on the appetite of developers and others to invest in these solutions. It should also be noted that a number of the buildings planned for development in TQEZ over the next few years have already submitted outline or detailed planning applications, and so it is possible that it may not be feasible to request them to significantly alter their servicing strategies at this late stage.

8.4 Assumptions to be reviewed as TQEZ develops

This study required the use of a number of assumptions to overcome unknowns. As these unknown characteristics are refined, BCC may want to reassess the modelling and preferred low and zero carbon energy solutions for the TQEZ. These assumptions have included:

- The energy demand of existing buildings: energy demand figures were based on industry-standard benchmarks, building floor areas and usage types. In reality these may differ from actual demand, and they do not take into account any plans their owners or occupiers might have to refurbish or alter these buildings.
- Phasing, usage, sizes, developers, occupants and energy demands of future development. Currently, BCC and others only know broad details such as rough timescales of when development will occur, and a breakdown of building usage categories between Domestic, Employment and Other. As development site characteristics become refined, the energy demands and potential low and zero carbon energy solutions will alter.

[43] Carbon Trust (2012, CTG012) states "Across Europe, a number of biomass CHP plants fuelled by solid biomass are in operation. Plant sizes vary but most installations have a rated boiler output of more than 5MWth"

- The cost, location and scale of low and zero carbon energy technologies have been modelled based on the best information currently available. However, the only accurate way to assess the viability of energy technologies is to use building-specific data and to obtain capital cost, operating cost and revenue figures shortly before deciding to commission the technology.
- The building-integrated renewable heating options have been sized based on future development site characteristics, and assume that a communal heating system is used for each usage type within each development site. Developers may choose to install different heating systems within different buildings and units, which would lead to higher capital costs and potentially lower deployment of biomass heating, as heat pumps are favourable in buildings with smaller heat loads.
- The planning policy framework and building regulations are constantly evolving. This study incorporates the existing framework and regulations, with estimates as to how building regulations and the approach to zero carbon buildings may occur. As these regulations and policies alter, so too will the appropriate scale and type of low and zero carbon energy solutions.
- Developers within the zone are unlikely to choose to exceed sustainable energy requirements set within planning policy or building regulations without sufficient incentive. District heating systems in particular are not particularly common in the UK, and the stakeholder engagement process indicated that developers are unlikely to link their buildings to a district energy network unless there is a requirement to do so through local planning policy and/or the benefits of connecting their buildings to a district energy network outweigh the risks of limiting future building occupants' choice of how to heat their buildings. Developers may require appropriate guarantees to be in place in order to encourage them to invest in district heating systems.

8.5 Funding opportunities

The Allowable Solutions framework puts developers in control of how they can achieve zero-carbon standards, either through the use of additional onsite low and zero carbon energy or energy efficiency measures, or via offsite carbon saving initiatives. Allowable Solutions could form an integral funding mechanism for onsite low and zero carbon energy solutions, making it possible to retrofit existing buildings with sustainable energy measures and deliver a TQEZ district energy network. BCC and other local authorities have the ability to develop their own framework for developers to use in delivering this type of carbon offsetting, but there will be no requirement for them to do this.

Other potential funding routes for delivering sustainable energy within the TQEZ include the Community Infrastructure Levy (CIL), and the use of renewable energy generation subsidies such as the Feed in Tariff (FiT) and Renewable Heat Incentive (RHI).

8.6 Key recommendations

In further developing and refining the TQEZ energy masterplan, BCC need to prioritise continuing stakeholder engagement, and to set an Allowable Solutions framework and Energy Services Company (ESCo) that developers find attractive enough for investment and delivery of the decarbonisation requirements. In order to achieve this, CSE recommends that BCC:

2. **Facilitate a more detailed energy masterplanning process** - coordinate further energy masterplanning activities with the STEEP project[44] (Systems Thinking for comprehensive city Efficiency Energy Planning) to engage stakeholders in the masterplanning process, and thereby develop a

[44] http://www.smartsteep.eu/

process model which reflects a shared vision and strategy of a sustainable TQEZ. This should include achieving a consensus on an overarching aim or target regarding energy use and/or emissions such as one of the scenarios considered in this report, but one which also has stakeholder buy-in, is clear in its scope and can be monitored

3. **Define and further investigate the most suitable district heating network option** - using the preliminary heat mapping work and network options presented in this report, investigate further the potential for a district energy scheme which initially connects TQEZ existing buildings. This investigation should:
    - Obtain actual heating demand data for the existing buildings that would potentially connect to the network (shown in Table 14), whilst checking the appetite of stakeholders and testing viability to connect to the district heating network.
    - Examine in more detail the potential network routes and the position of the energy centre, taking regard of the infrastructure constraints in the TQEZ and possibilities for a cooling network.
    - Take into account opportunities to link up with district heating options being considered for areas adjacent to the TQEZ such as the proposed scheme in the Redcliffe area and/or an energy centre in St Phillips.
    - With potential customers of the network, decide upon a suitable delivery model.
4. **Provide 'Zero Carbon' support to developers by**:
    - Providing developers with more clarity on which policies they will need to comply with, especially policies BCS13-15 within the Bristol Core Strategy and how 'Zero Carbon' should be interpreted.
    - Providing developers with details of how the Council will work with them to achieve Zero Carbon developments through the creation of a shared ESCo and Allowable Solutions framework.
    - Developing a design guide on how buildings can meet Zero Carbon standards through measures such as passive solar design, natural ventilation, super-insulation, on-site generation and, where available, ways to fully benefit from local district heating/cooling networks e.g. provision for future connection, incorporation of low temperature heat distribution systems and building-wide cooling circulation loops.
    - Ensuring that any emerging ESCo delivery vehicle can benefit developers by maximising potential subsidies for zero carbon development such as the Community Infrastructure Levy, Allowable Solutions or other sources of finance. It should also encompass a structure which allows different levels of ownership and risk management between the council, customers (TQEZ developers, building occupants and residents) and investors. BCC will need to consider whether TQEZ needs a specific ESCo, or whether a Bristol-wide ESCo will be sufficient.
5. **Embed Zero Carbon infrastructure across all TQEZ developments** - embed sustainable energy considerations within other development work for the TQEZ such as:
    - Consideration of proposed energy network routes when specifying infrastructure for utility service corridors e.g. use of multipurpose ducting which could accommodate district heating pipes.
    - When conducting ground surveying, include investigation of ground conditions for proposed district heating routes and the potential for boreholes as a heat/cooling source for ground source heat pumps.

6. **Maximise use of local sustainable energy resources -** investigate further the opportunities to utilise the area's sustainable energy resources to help achieve a Zero Carbon TQEZ. This might include:

   - District or single building cooling/heating using technology such as water source heat pumps in conjunction with the area's waterways.
   - District or single building cooling/heating using waste water systems.

Appendix 1: Map and key of TQEZ development sites

The map and table below provides the development site names and reference numbers used in this study, given to CSE by BCC.

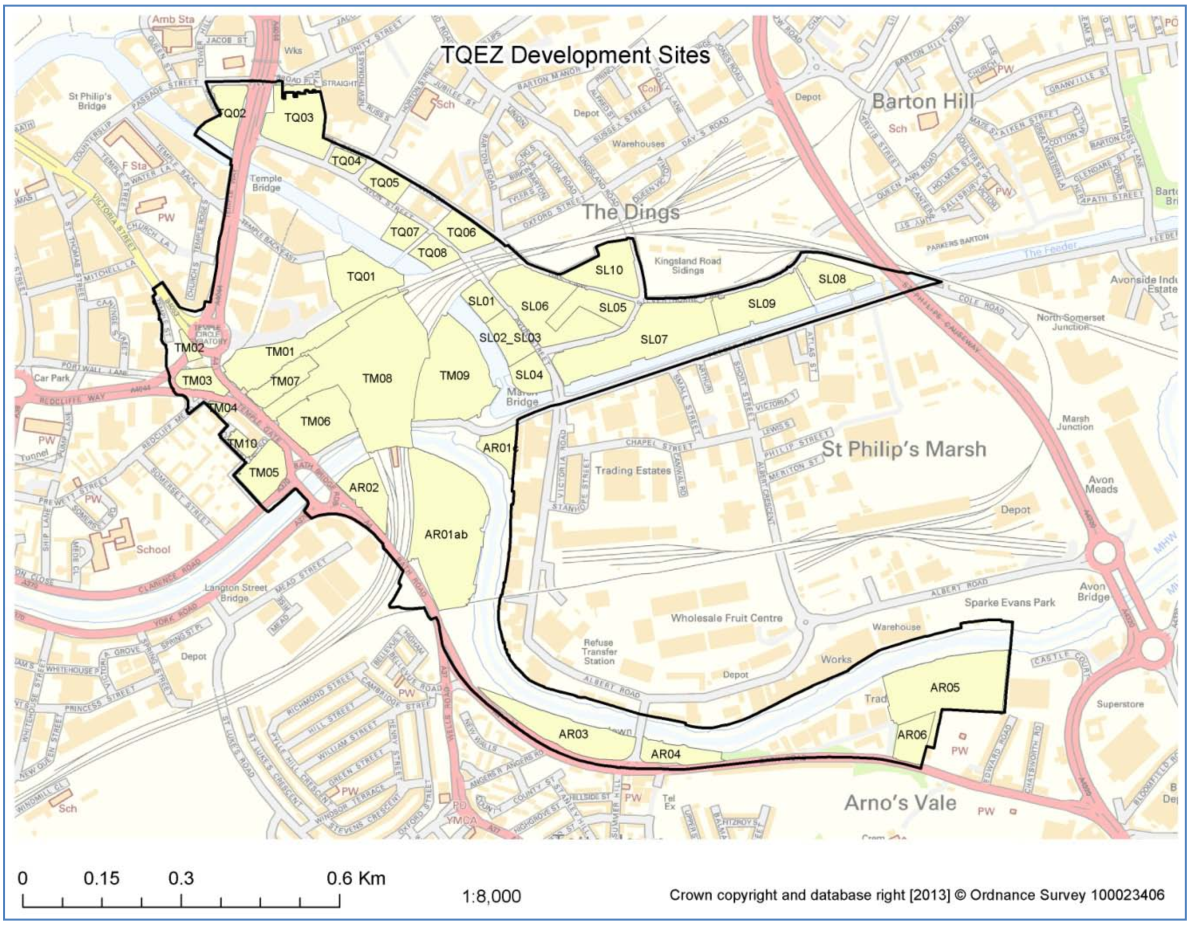

Figure 27: Map of development sites and their reference numbers within TQEZ

Site reference	Name of site
BCC PHASE 1: 2013 - 2018	
TQ01	Plot 3, The Friary
TQ02	Bank Place, Temple Way
TQ05	Plot ND7, Temple Quay North
TQ07	2 Glass Wharf, Temple Quay North
TM07	Brunel Engine Shed and Passenger Shed
TM08	Temple Meads Joint Station
AR05	Paintworks Phase 3
AR06	Bath Road Wine Warehouse
BCC PHASE 2 - 2018 - 2023	
TM01	Plot 6, The Friary
TM02	Temple Circus Site
TM03	The Island Site
TQ03	Glassfields, Temple Way
TQ04	Plot ND6, Temple Quay North
TQ06	Plot ND9, Temple Quay North

TQ08	3 Glasswharf, Temple Quay North
TM04	Petrol Station site
TM05	Peugeot garage
TM06	Bristol & Exeter Yard
TM09	Former PO site
AR01a and b	Diesel Depot
AR02	Fish Quay/Kwikfit sites
AR03	Avon Riverbank
AR04	Bath Road petrol station site
SL05	Former gas works site
SL06	Vauxhall Drive Motor site
SL07	St Vincent's Works
SL08	Silverthorne Lane East
BCC PHASE 3: 2023 onwards	
SL01	Avon Street South(1)
SL02 and 03	Avon Street South (2) + (3)
SL04	Avon Street South (4)
SL09	Silverthorne Lane
SL10	Kingsland House block

Table 30: TQEZ site references and site names split between development phases

Appendix 2: List of stakeholders and structure for interviews

The table below sets out the TQEZ development stakeholders (i.e. organisations involved in developing sites within the area) in their order of priority for involvement in this study, as agreed with BCC.

Organisation	Notes	Status
HCA	Largest landowner in the zone and also included in the planning consent list as having two sites that are currently covered by an LDO for temporary use	Paper and Email copies of BCC and CSE letters sent 23rd August 2013
Network Rail	Third largest landowner and is listed on the planning consents spreadsheet with the note ‘masterplanning underway'	Email copy of BCC and CSE letters sent 23rd August 2013
Verve Investments	(i.e. paintworks development) large landowner and have outline permission for a development which includes a number of different usage categories	Paper and Email copies of BCC and CSE letters sent 23rd August 2013
Kian Gwan Ltd.	Large landowner (derelict Parcel Force building by the station). Seems to be a Chinese-owned company based in Taiwan (but with Jersey PO box as Shepherdess Holdings), which has now been dissolved. High profile site due to location. Need new contact for site if possible.	In administration - BCC to confirm status of land?
Salmon Harvester	Own quite a bit of land and have 3 separate applications in (two detailed and one with reserved matters)	Paper and Email copies of BCC and CSE letters sent 23rd August 2013
The Carlyle Group	Have detailed planning applications in for 2 developments which both include office and retail/food, plus a public plaza and an underground car park	Paper and Email copies of BCC and CSE letters sent 23rd August 2013
Paul Tolley/DPM Ltd.	Have an application in for 2 big office buildings inc. a café/bar between Temple Way and Victoria street	Paper and Email copies of BCC and CSE letters sent 23rd August 2013
Crown Estate	Fourth largest landowner (no planning applications)	Paper and Email copies of BCC and CSE letters sent 23rd August 2013
Jon Lysaght Properties Ltd.	Significant landowner (no planning applications)	Paper and Email copies of BCC and CSE letters sent 23rd August 2013
AGM City Space	Have a planning application in for a mixed-use building	Appear to be disolved: http://opencorporates.com/companies/gb/04122810
Peugeot Motor Company	Own quite a lot of land and are listed on the planning consent list, but no information has been provided and there are ‘sensitivities around the existing workforce’	Consider removing - unclear who is responsible for developing this site
Andrew and Nick Smart	listed on the planning consents table but there’s no information in the columns except for the location of the site (vacant B8 site on Bath Road). Plans at very early stage. Mixed-use development, linking up to paintworks.	Development still at 'embryonic' stage, so no detailed understanding of what's going where. land adjacent to majestic wine/paintworks.
Trammel Crow Nedland	Also listed on planning table but no information except for site name (Temple Gate), so again not sure whether they are of interest or not	Paper and Email copies of BCC and CSE letters sent 23rd August 2013
Drive Motor Retail Ltd	Fairly significant landowner, no planning applications	Paper and Email copies of BCC and CSE letters sent 23rd August 2013
Royal London Asset Management	Fairly significant landowner, no planning applications	Paper and Email copies of BCC and CSE letters sent 23rd August 2013

Ron Lewis Holdings Ltd.	landowner, no planning applications	Unknown contact details
Prudential Annuities Ltd.	landowner, no planning applications	Unknown contact details
Deborah Services	landowner, no planning applications	Unknown contact details
Burges Salmon	landowner (owner occupier), no planning applications	Unknown contact details

Table 31: Main TQEZ stakeholders identified

Developers were asked a series of questions, based on the topics and information needed outlined in the table below. The focus of these discussions were on 'sustainable energy initiatives', as stakeholders rarely had information to share under the other headings.

Topic	Requested information
1. Building ownership, type, form and use	• Brief description of building including type, use, number of occupants, age, fabric (incl. roof) and general condition • Floor areas • Typical hours of occupancy • Land ownership and potential for wayleaves
2. Energy use	• Historical energy use ideally consisting of two recent full years worth of monthly data for electricity, gas or other fuels • Type/size/location of energy metering and utility billing information
3. Heating/cooling systems	• Brief description of space and water heating and cooling systems in building(s) including kW rating, age, location, condition and any current operational issues • Brief description of any process heating/cooling energy use including catering • Plans and timescales for refurbishment of heating or cooling systems
4. Electricity use	• Brief description of electricity use throughout building e.g. normal office-type use vs other loads
5. Future plans for existing buildings	• Brief description of any future plans for general refurbishment, expansion or additional building works. • Awareness of future building regulations and Bristol policies on carbon/sustainability targets for new build
6. Future plans for development sites	• Expected floor areas and corresponding use-classes • Corresponding timescales for development • Where available quantities and locations of buildings and corresponding infrastructure (transport links, etc)
7. Sustainable energy initiatives	• Details of any current organisational policy on sustainability, carbon or energy targets • Brief description of any energy efficiency or low/zero carbon generation initiatives that have taken place or are planned for the future, including appetite or capacity for investing in this sector* • Initial views on TQEZ proposals* • Initial views on shared energy networks and approaches to the supply of energy services – key expectations and concerns*

Table 32: Scope of discussions held with stakeholders

Appendix 3: Detailed methodology for estimating biomass resource

To estimate the woodland residues available, the latest Forestry Commission National Forest Inventory (2011) was used. This classifies woodland into the following 'interpreted forest types', so called because they are interpreted from aerial photographs, remote sensing and other information sources:

- Broadleaved
- Conifer
- Felled
- Ground prepared for new planting
- Mixed - predominately broadleaved
- Mixed -predominately conifer
- Young Trees
- Coppice
- Coppice with standards (standards are larger broadleaved trees amongst the coppice)
- Shrub land
- Low density
- Assumed woodland: based on information about new planting schemes rather than aerial photos

Not all of these types were present in the area within a 20km radius of the TQEZ. Different types of woodland have different levels of sustainable yields. To calculate the yield from each type, the following yield factors were used:

Type	Yield: Tonnes per Hectare at 30% moisture[45]
Broadleaved	1.93
Coniferous	6.43
Coppice	3.86
Mixed	3.86

Table 33: Woodland biomass yield ratios

The total technical potential resource for energy crops[46] can be assessed by looking at the total amount of suitable agricultural land within a 20km radius of the TQEZ. Short rotation coppice (SRC) and miscanthus are the most common form of energy crops in the UK, and can be grown on agricultural land of grades 1-3 (arable land). The Department for Environment, Food and Rural Affairs (DEFRA) provides a dataset showing agricultural land grades[47].

A number of constraints have been applied in order to exclude areas of agricultural land where energy crops are unlikely to be grown. For example, Miscanthus does not grow well in exposed areas, which for the purposes of this resource assessment are defined as areas where the wind speed is over 7m/s at 10m above ground level.

The Environmental Impact Assessment (Agriculture) (England) Regulations 2006 control activity on uncultivated land and semi-natural areas. The Department for Energy and Climate Change (DECC) suggest that this is likely to constrain cultivation of energy crops on permanent pasture and moorland[48]. For this reason, available data on grassland and common land has been added as a constraint to the use of energy crops.

[45] Plan LoCaL Biomass Woodfuel Estimator: www.planlocal.org.uk/downloads/group/further-resources
[46] crops grown for the specific purpose of energy generation
[47] Available from www.magic.gov.uk
[48] DECC 'Renewable and Low-carbon Energy Capacity Methodology: Methodology for the English Regions', January 2010. Available from https://www.gov.uk/government/news/decc-publishes-methodology-for-renewable-and-low-carbon-capacity-assessment

The agricultural land classification identifies urban areas but does not identify villages and hamlets and so some areas are labelled as agricultural land when in fact they have buildings in them. To remove these areas, Ordnance Survey's Strategi dataset was used to remove built-up areas. A full list of constraints is set out in the table below.

Constraint	Details	Data source
Land grade	Exclude agricultural land grades 4 and 5 and urban areas.	Defra[49]
Protected land	Grassland types: lowland heathland, upland heathland, lowland meadows, coastal and floodplain grazing marsh, lowland dry acid grassland, lowland calcareous grassland	Natural England
Protected woodland	Ancient woodland	Natural England
Forest use	National Forest Inventory	Forestry Commission
Heritage sites	Scheduled monuments	English Heritage
Parks and gardens	Historic Parks and Gardens	English Heritage
Built up areas	Strategi dataset	Ordnance Survey
Wind speed	Areas where wind speed is above 7 metres per second at 10m above ground level are not suitable for miscanthus, but are suitable for SRC	NOABL[50]

Table 34: Constraints applied to energy crop production

The following yield factors were used in calculating the potential resources on appropriate agricultural land, based on oven dried tonnes (0% moisture content):

Crop	Yield (oven-dried tonnes) per hectare
Miscanthus	15
SRC (Short Rotation Coppice)	10

Table 35: Energy crop yield factors

[49] GIS data for agricultural land classifications is available from www.magic.gov.uk.
[50] DECC national wind speed database (NOABL): http://webarchive.nationalarchives.gov.uk/20121217150421/http://decc.gov.uk/en/content/cms/meeting_energy/wind/onshore/deploy_data/windsp_databas/windsp_databas.aspx

Appendix 4: Biomass CHP capacity in the UK

Biomass CHP is an emerging renewable energy technology for the UK. The graph below shows the growth in the technology, since the first nationally recorded installation in 2004[51]. The majority of these installations will use conventional steam turbine technology, although the technology used in smaller biomass CHP systems is diversifying in attempts to improve system efficiencies.

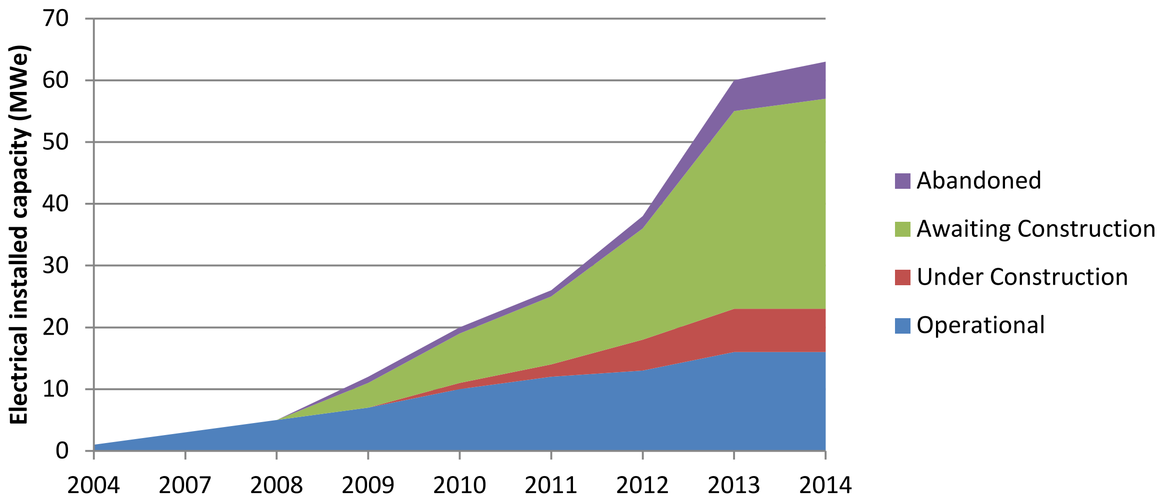

Figure 28: Graph showing proposed and installed capacity of biomass CHP in the UK

The number of proposed and operating biomass CHP plants in the UK is growing, suggesting the technology is becoming more widespread. The graph below shows the number of applications for projects below and above the 5MW (large-scale) biomass CHP threshold that have not been abandoned, highlighting the increased deployment of large-scale systems compared to smaller projects.

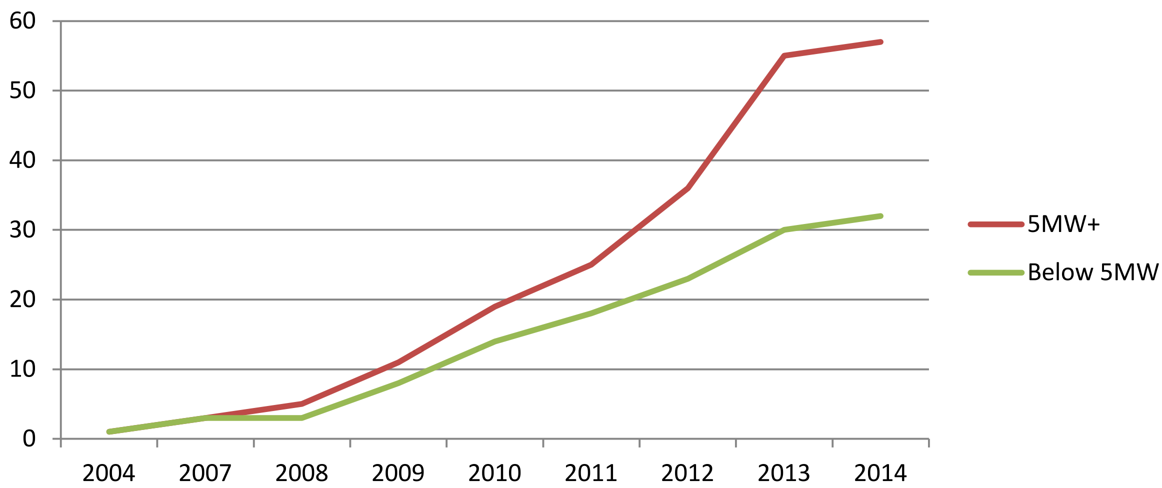

Figure 29: Graph showing quantity of UK <5MW & >5MW biomass CHP proposed or delivered projects

The Forestry Commission and Biomass Energy Centre provide further guidance on small-scale biomass CHP in their "Information Sheet No. 5", including examples of systems up to $2MW_e$:
www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/RESOURCES/REF_LIB_RES/PUBLICATIONS/4.%20CHP%20V5.1%209-2009%20DRAFT.PDF

[51] Statistics on biomass CHP deployment in the UK from DECC's Planning Database reports: https://restats.decc.gov.uk/cms/planning-database/