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ENERGY INDEPENDENCE 2025

Roadmap to city-scale Energy Independence

A REPORT FOR EXETER CITY FUTURES

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FOREWORD

The last 10 years have seen profound change in our city. I have been proud to witness the transformation of Devon's capital from a provincial administrative town to a thriving, cosmopolitan centre of business and culture. Exeter has grown rapidly and is now the fastest growing city in the UK by population. The accompanying economic development, the creation of over 30,000 new jobs and the emergence of new knowledge-based industries speak to the achievements of the past decade.

However, our future success cannot be taken for granted. As we look towards the next 10 years and beyond, many wonder what our city will become. Our continued growth presents considerable challenges – impacts on the urban and rural environment, the affordability of housing and increased demand on services and infrastructure. To make our city stronger we must support economic development - to improve wage levels and create new opportunities. But that growth must not conflict with enhanced quality of life.

Energy is essential to modern cities. It provides heat for our homes, supplies our food, enables our mobility and keeps our healthcare system running. A resilient, clean and affordable supply of energy is a prerequisite for both economic development and quality of life. In a world where natural resources are limited, successfully dealing with growing demand for housing, transport and other essential services demands leadership and long-term solutions.

Exeter City Council is strongly committed to renewable energy and to playing our part in pushing the boundaries of what local authorities can do to deliver a low carbon future. Over the past decade we have pioneered Passivhaus standards in the UK, deployed renewable generation across our public sites and delivered large-scale district heating networks. On our own estate we have reduced energy consumption by 37% and are on track to deliver an energy-neutral council by 2022. However, as this report shows, the wider city region has a tremendous opportunity to go so much further.

Greater Exeter consumes 10 TWh of energy every year - enough to make 368 trips to the moon or to drive around the Earth 1.5 million times. This use is set to grow. Existing energy consumption patterns already cost our residents and businesses over £900m each year, money which is lost to the region. This is a significant cost to many families and a particular burden to those in fuel poverty. I want to ensure that more of that money is retained in our local economy to be reinvested in its infrastructure, its people and their future.

In 2014, the resilience of our infrastructure was tested by the worst storms the UK has seen for 20 years. Extreme weather threatened properties, businesses and lives, demonstrating our region's vulnerability to external events. Greater Exeter's vibrant energy sector has also experienced adverse impacts from developments outside our control – constraints imposed on our energy distribution grid present a major barrier to our dynamic regional renewables industry as well as the many businesses and citizens who are striving to live more sustainably. I want to ensure that we become more resilient in the face of an uncertain future, facilitating regional energy security that also grows our economy.

Our environment is our greatest asset. The beauty of our city and its surrounding area attracts many people to the region. It's a big part of why more and more people choose to live, invest and do business here. The planning choices we make, choices which impact that environment, are incredibly important. Decisions we make today reach far beyond the immediate present – they will shape the way we live and its environmental impact for decades to come. I want to ensure that we minimise our impact while creating a sustainable basis for future development.

Our city already has a world-class reputation in climate and environmental research. The Met Office and the University of Exeter inform the international response to climate change every day. We have an ambition to make Exeter globally-recognised for a wider contribution to environmental futures too. That means we must collaborate across the region to embrace the industrial opportunities this new energy system presents – positive-energy buildings, smart grids, low-emission vehicles, battery technology, hydrogen use and the many generation options discussed in this report. All the resources, skills and expertise needed to lead this energy transition are within our grasp.

This report, commissioned by Exeter City Futures, presents a road map for delivering the ambitious goal of making Greater Exeter energy independent by 2025. This vision pioneers a model for inclusive, sustainable growth and builds on our unique assets, strengths and capabilities. The magnitude of the task is immense, but the timing of this report, published as we embark on the preparation of the Greater Exeter Strategic Plan, will enshrine sustainability and a high quality of life at the heart of our next phase of growth.

I am hugely optimistic that we will make the right choices over the next 10 years to deliver a smarter, healthier, happier and more prosperous city and I look forward to the many discussions this report will stimulate.

Karime Hassan
Chief Executive and Growth Director
Exeter City Council

EXECUTIVE SUMMARY

Cities and the unprecedented growth of urban environments present both the greatest challenge and opportunity of our lifetime. As drivers of economic growth, cities are essential to modern life. But unsustainable trends in energy use, congestion and associated negative consequences threaten their health and the health of their residents and workers. Exeter City Futures has commissioned a series of three reports to examine the potential options and roadmaps that would enable Greater Exeter to develop a path towards a sustainable future. The stated goal of Exeter City Futures - an energy independent and congestion-free city region by 2025 - is without precedent in the UK.

Robust evidence is required to demonstrate whether this ambition is achievable and, if successful, what its economic impact might be. This first report undertakes a detailed assessment of potential energy resources and uses in Greater Exeter and across the wider South West region. The second report assesses the transport situation and the options available to alleviate congestion and deliver further efficiency. The final report pulls together economic evidence to provide an independent analysis of the impact of the programme's goals and proposed delivery plans.

This report examines the current energy consumption profile for Greater Exeter across domestic, industrial, commercial and transport sectors and develops three potential scenarios for the 2025 reference year. The first scenario, Business As Usual, projects 2025 energy consumption based on forecast growth rates. Potential energy demand reduction and energy generation measures are then explored in detail across a range of technologies and settings. In each case political, financial, social and other non-physical or landscape constraints are initially set aside in order to ambitiously assess overall resource availability. This Maximum Technology scenario demonstrates what is possible if current barriers can be overcome. These barriers are then discussed in detail for each technology and further major constraints applied to identified onshore generation measures. This produces the Maximum Deployment scenario which is then compared to the Business As Usual projection to determine the extent to which Exeter City Futures' energy independence target can be realised. A series of recommendations, governed by identified barriers, that would unlock the path towards the desired ambition are then presented.

By 2025, annual energy consumption in Greater Exeter is expected to grow to 11.3 TWh from the current 10.0 TWh. This is predominantly due to forecast household and business growth and the associated increase in transportation demand. Excluding transportation, it is anticipated that 2.6 TWh of demand reduction is possible. This estimate is based largely on reductions in domestic space heating demand. For existing properties, the installation of an ambitious suite of retrofit energy efficiency measures (including insulation and electrification of heat using heat pumps) would reduce demand by an estimated 1.8 TWh/year (60%). Tightening building regulations to Passivhaus standards and adopting heat pumps for the additional 29,600 properties expected by 2025 would limit energy consumption by a further 161 GWh compared with the Business As Usual scenario. A further 104 GWh could be saved in the domestic sector through upgrading appliances to the most efficient models.

Commercial demand is currently responsible for 1.3 TWh (13%) of energy consumption, forecast to increase to 1.5 TWh by 2025 at current sector growth rates. The variety of commercial businesses and building types means there are wide variations in energy end uses. Space heating, as in the domestic sector, is thought to represent a significant level of demand (36%), with lighting being the next largest end use (27%). Building fabric efficiency retrofit measures, similar to those applied in the domestic sector, would address space and water heating and lighting energy use. However several sector-specific issues would also need to be addressed, for example, refrigeration in supermarkets. Based on available data, a saving of 359 GWh is estimated to be achievable with the net resultant demand 9% lower than 2014 levels.

Industrial demand is responsible for 1.6 TWh (16%) of current energy consumption. As in the commercial sector, patterns of energy consumption vary significantly according to the the type of industry. Consequently, potential energy savings are highly sensitive to the mix of industries in the region and the specific operational processes in each. For example, 2020 carbon reduction targets set under the Climate Change Agreements for different industrial sectors range from about 5% for non-metallic minerals (cement, ceramics, glass) to 11.3% for chemicals, to about 15% for food and drink. Several assessments have been produced at national level which identify efficiency roadmaps on a sector-by-sector basis, developed from detailed work involving specialists in their respective sectors. This report suggests that Greater Exeter could reduce industrial energy consumption by 250 GWh (16% of industrial demand) by 2025, in line with national studies.

Greater Exeter has access to abundant natural energy resources due to its position in the South West. Analysis indicates that 153 TWh/year of unconstrained low carbon energy resource remains untapped in the region, comprised mostly of solar (111.1 TWh) and wind (41.6 TWh). A geothermal hotspot with an energy potential of 139.0 TWh per year is believed to extend through much of Cornwall and Dartmoor National Park and into the western fringe of the study area. Further assessment would be required to quantify to what extent this could be exploited for use in Greater Exeter. After applying major constraints such as those entailed by sensitive landscape designations, radar areas, urban development and roads it is estimated that the Maximum Technology Potential, i.e. the potential energy which could be captured, is 16 TWh.

Comparing the anticipated 2025 Business As Usual energy demand of 11.3 TWh with the Maximum Technology potential of 2.6 TWh of demand reduction and 16.0 TWh of new generation suggests that energy independence at regional level is possible. However, the inclusion of further non-physical constraints, in particular those associated with cumulative visual impact, means that the Maximum Deployment scenario is expected to be limited to 6.5 TWh, due principally to removal of onshore wind generation potential. Considering only the Greater Exeter area, this constraint results in a residual energy requirement of 4.8 TWh per annum from 2025 onwards. This estimate of residual energy requirement is pessimistic in that it does not include any energy saving potential from the 4.4 TWh annual transport demand anticipated by 2025, which is the focus of another report. It also excludes potential technology efficiency improvements, such as in solar cells. Energy from other large regional sources, such as the Alderney tidal stream interconnector that is proposed to land in East Devon, is also excluded from the analysis as it originates from outside the Greater Exeter boundary.

The barriers that must be overcome to achieve both proposed energy savings and new generation are significant and are reviewed in detail throughout this report. Political barriers, particularly in relation to planning consent, are likely to have the greatest impact on the region's ability to achieve energy independence. Planning policy related to local generation, particularly approaches to cumulative impact of large-scale installations, removes 12.1 TWh of potential generation between the Maximum Technology and Maximum Deployment scenarios in this analysis. For example, cumulative impact policies materially affect the available onshore wind resource, which could range from 157 GWh, when cumulative impact is assumed to be based on a 15 km offset between each 10 MW wind farm, to 1,479 GWh, when a 5 km offset is assumed. It is also likely that cumulative impact considerations would feature in applications for new development of onshore solar generation. In this context policy should be directed towards advancing demand reduction initiatives. These are already viewed positively from a planning perspective but the code should be improved to establish the highest energy efficiency standards as the norm.

Financial barriers are also widespread. While the costs of more mature generation technologies and components are falling and considered likely to fall further to 2025, techno-financial barriers are especially high for demand reduction initiatives. Supply chains are insufficiently mature to deliver components at low enough prices to enable cost-effective retrofit roll-out at the levels required to deliver the proposed savings. Significant co-ordinated responses are required to create viable business models and stimulate the market for retrofit products to make inroads in energy demand reduction. Financial barriers are also acute for technologies still at the demonstration stage in the UK, particularly those where regional resources are plentiful: tidal range and geothermal. The financial issues here are complex and closely linked to high levels of technology and deployment risk, the continued fall in the price of alternatives (wind and solar) and long-term energy policy at national level. Significant public and private investment in these technologies will be needed to reach commercial viability.

While the Maximum Technology scenario assesses Greater Exeter's potential position without technology constraints, the reality is that considerable technical barriers remain, most notably the South West regional grid infrastructure. This constraint impacts the majority of generation options reviewed in this study as well as the electrification of heat using heat pumps across all sectors. National government could choose to see this issue either as a costly barrier or as an industrial innovation challenge that would enable the UK to take a leadership role. Smart grid concepts have been around for a long time, but city-scale solutions have yet to be demonstrated. Greater Exeter, with leadership, investment and national assistance, could embrace new technologies and models to unlock the grid. A further technical barrier is posed by radar interference from onshore wind generation. This should not be an impediment to change: a co-ordinated approach linking strategic land use and consultation with air traffic users can achieve a framework in which safety is maintained while generation is accelerated.

Based on a quantified assessment of the barriers that currently stand in the way of delivering the Maximum Technology scenario, this study proposes a series of recommendations. These define a set of actions that should be progressed across the range of options available to Greater Exeter to maximise the likelihood of achieving energy independence by 2025.

RECOMMENDATIONS

1.1 | RECOMMENDATION 1:

FACILITATE THE DEVELOPMENT OF NET ENERGY POSITIVE BUILDINGS

The development of a supply chain and policy environment that ensures the delivery of net positive energy buildings is an urgent priority. New developments that positively contribute to city energy use will mean that less onshore generation development and retrofitting of older building stock will be required. Greater Exeter already benefits from progressive local authorities which actively pursue building energy efficiency objectives, in particular in their own properties. The next steps are to further encourage innovative solutions, combine insights and analysis to support tighter planning policy and develop mechanisms to significantly expand the project base.

1.2 | RECOMMENDATION 2:

DEVELOP CREDIBLE ROADMAPS TO LARGE-SCALE DOMESTIC RETROFIT

A key assumption in the Maximum Technology scenario is that viable business models which deliver large-scale retrofit will be developed over the time horizon. The development of credible roadmaps that deliver comprehensive intervention in this area is essential. This is a challenging undertaking which requires significant investment in skills, new solutions and the development of businesses that can integrate, finance and deploy the roll-out of multiple technologies at scale.

1.3 | RECOMMENDATION 3:

ENCOURAGE AND DEMONSTRATE INNOVATIVE SOLUTIONS TO REDUCE DOMESTIC APPLIANCE ENERGY USE

While space and water heating consume the largest proportion of domestic energy, appliance use represents 0.5 TWh of Greater Exeter demand. The benefits of upgrading to the highest efficiency appliances should be promoted and systems developed which enable and manage behavioural change to both optimise use and reduce overall cost. Identified technologies should be trialled and best practice fostered.

1.4 | RECOMMENDATION 4:

DEVELOP COMMERCIAL AND INDUSTRIAL CASE STUDIES

This study identifies 359 GWh of potential savings from commercial buildings and 250 GWh of potential savings from industrial processes, based on current understanding of technical opportunities. More specific demonstrator projects are required to advance and promote greater understanding of what is achievable across a varied range of end users. A diverse group of local commercial and industrial partners should be brought together to develop leading-edge strategies to encourage potential energy savings.

1.5 | RECOMMENDATION 5:

DEVELOP CREDIBLE ROADMAPS TO CUT TRANSPORT CONSUMPTION

Transportation is expected to represent 4.4 TWh of annual energy consumption by 2025. Developing roadmaps to significantly address this consumption is an essential priority, and is the focus of a forthcoming report. In this context, wider participation in the development of various options should be encouraged, in particular through Exeter City Futures' innovation programme.

1.6 | RECOMMENDATION 6:

CO-ORDINATE SOLUTIONS TO ADDRESS GRID CONSTRAINTS

The grid is a critical technical constraint that impedes the viability of projects across the region. Moving past this barrier is essential if the regional energy industry is to thrive. Several options exist including capacity amnesties, the socialisation of upgrade costs and technology-led options such as smart grid infrastructure. All would need considerable co-ordination with the local grid operator to progress, but should be seen as a pivotal issue for the South West economy and Exeter City Futures' goals. If this barrier can be overcome, Greater Exeter could play a key role in stimulating a regional approach to energy independence, drawing on the skills, expertise and innovation of local research and industry. Close collaboration with the Department for Business, Energy and Industrial Strategy (BEIS) and other national stakeholders is required to develop policy and technology mechanisms to realise the potential local benefits of regional generation.

1.7 | RECOMMENDATION 7:

STIMULATE ONSHORE GENERATION

In the face of considerable planning barriers, improved stakeholder understanding of the impact of onshore generation options - principally wind and solar - is required. Co-ordinated Greater Exeter multi-authority strategic planning is needed to optimally locate new generation and work openly and collaboratively with the public to identify solutions that would be acceptable in the context of the energy choices available. Furthermore, the exploration of generation technologies that achieve higher levels of aesthetic acceptability should be encouraged. This is already happening within the solar industry, with the introduction of technology integrated into rooftops and roads. Further integration into other standard infrastructure could achieve both new generation and cost reduction without facing political barriers.

1.8 | RECOMMENDATION 8:

PROVIDE AN ECONOMIC EVIDENCE BASE

Evidence for the economic benefits of the proposed approach to energy independence and the opportunities afforded by being at the forefront of integrated smart energy infrastructure development should be provided, and is the focus of a forthcoming report. Demonstrating significant potential for increased local productivity, jobs and growth will enable the development of a wider network of support for this approach.

1.9 | RECOMMENDATION 9:

ENCOURAGE AND SUPPORT RESEARCH INTO ENHANCED GENERATION EFFICIENCY

Estimates of generation made here are potentially conservative. While they are based on widely accepted methodologies, the efficiency of many technologies can be expected to improve with time. Extrapolating the historical trends in technology efficiency would increase the estimates of generation made in this report. Research into areas with the potential to improve natural energy resource conversion efficiency, for example, solar cell technology, should be prioritised.

1.10 | RECOMMENDATION 10:

ENCOURAGE INVESTMENT IN MARINE AND GEOTHERMAL TECHNOLOGIES

In the wider South West region, geothermal and marine technologies offer sizeable generation potential in the Maximum Technology scenario. These capital-intensive sectors require significant levels of investment to reach commercial viability. High technology and deployment risk, alongside falling substitute technology prices, mean public sector support is likely to be required to achieve long-term market development. Private investment and innovation in these sectors should be supported and promoted, alongside strategic engagement with policy-makers at national level.

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1 INTRODUCTION

Cities are the drivers of change in a global transition to new energy systems. Consuming between two thirds and three quarters of the world's energy, cities are the primary driver of how much energy is used, how it is used and, to a growing extent, which sources it comes from.

1.1 | GLOBAL CONTEXT

There is little doubt that urbanisation has been accelerating ever since the Industrial Revolution.

In 2008, the world passed a significant milestone when for the first time more than 50% of the global population was recorded as living in urban areas. More recent figures[1] show that the urban population has already grown to 54% of the total. Cities are clearly the predominant spatial structure in which people choose to live. In North America, for example, 82% of the population is urban. With this trend expected to continue, 70% of the world's population could reside in cities by 2050. 90% of urban growth is occurring in the developing world[2] and it is expected that this is where a significant proportion of urban expansion will continue. Here, the size and pace of urbanisation and associated economic growth has been astounding. For example, China's 90 largest cities have already surpassed the size of the national economies of Germany and France combined[3]. Asia and Africa are urbanising fast, with 64% and 56%[1] respectively of the population expected to be urban by 2050.

Cities are synergistic hubs of innovation and enterprise, as well as critical centres of government, trade and knowledge. They create efficiencies of scale[4], provide agglomeration effects for the economy[5] and demonstrate super-linear scaling for positive outcomes such as income, productivity and innovation[6]. Cities represent more than 60% of global Gross Domestic Product (GDP)[7] and in many instances a much higher proportion of national GDP, tax revenues and jobs[8]. However, negative consequences such as crime, disease, congestion and air pollution all increase faster than the rate of population growth.

50%

In 2008, the world passed a significant milestone, when for the first time more than 50% of the global population was recorded as living in urban areas.

[1] United Nations (2014). World Urbanisation Prospects: 2014 Revision, [online]. Available at: https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.Pdf | [2] E. Moir, T. Moonen and G.Clark (2014). Future of Cities: What is the Global Agenda?, [online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/429125/future-cities-global-agenda.pdf | [3] From analysis by LSE Cities using data from Oxford Economics (as cited by New Climate Economy | [4] Kuhnert, Helbing & West (2003). Physica A363, pp96-103 [5] Krugman (1991). Geography and Trade, Cambridge. MA: MIT Press | [6] Arbesman, Kleinberg & Strogazt (2008). Superlinear scaling for innovation in cities. Physics Review 79 (1), 016115 | [7] LSECities (2014). Cities and the new climate economy, [online]. Available at: LSE Cities work for the New Climate Economy, | [8] Mckinsey Global Institute (2010). India's urban awakening: Building inclusive cities, sustaining economic growth. Available at: http://www.mckinsey.com/~/media/mckinsey/global%20themes/urbanization/urban%20awakening%20in%20india/mgi_indias_urban_awakening_full_report.ashx,

- Cities are vast draws on resources and have a considerable impact on the natural environment. Greenhouse gases produced by cities represent between 70%-80% of global totals[9]. Given the historic evolution of cities around sea trade[10] many are likely to be the hardest hit by the effects of climate change.

- Cities are often places of poor health. A considerable percentage of urban dwellers worldwide are exposed to dangerous levels of air pollution, with total suspended particles (TSPs), plus fine particle emissions (PM-10s) continuing their upward trends[11]. Some of China's cities (e.g. Xingtai, Shijiazhuang, Baoding, Handan, Hengshui and others) have air pollution more than 10 times worse than World Health Organisation recommended levels[12].

- Cities themselves often mask great inequality, with the poorest living in homes without adequate insulation or, depending on climate, air conditioning. The connection between crime and inequality is as strong in urban areas as it is across countries[13].

- As urbanisation occurs faster than the growth in capacity of roads, rail and other types of transportation[14] cities often exhibit that most conspicuous sign of a system under strain - congestion. With road users in cities spending, on average, 36 hours in gridlock every year[15] there is a clear case for change.

This is all before an expected further 2.5 billion people[1] join the world's urban population by 2050.

70-80%

Greenhouse gases produced by cities represent between 70%-80% of global totals[9].

[9] Arup (2016). Five minute guide to Energy in Cities, [online]. Available at: http://publications.arup.com/publications/e/5_min_guide_energy_in_cities, | [10] Over 90% of all urban areas are coastal acc. C40 Cities | [11] IIASA (2016). Urban Energy Systems, [online]. Available at: http://www.iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/GEA_Chapter18_urban_lowres.pdf,
[12] Forbes (2013), Xingtai leads list of China's cities with with worst air pollution in 2013, [online]. Available at: http://www.forbes.com/sites/russellflannery/2014/01/13/xingtai-leads-list-of-chinas-cities-with-the-worst-air-pollution-in-2013-list/#295ba0854bf2, | [13] Glaeser, Resseger, and Tobio (2009). Inequality in Cities. Journal of Regional Science, 49(4), pp617-646 | [14] Deloitte (2015). Transportation in the Digital Age, [online]. Available at: https://www2.deloitte.com/uk/en/pages/business-and-professional-services/articles/transport-in-the-digital-age.html
[15] Cebr (2014). The future economics and environmental costs of gridlock in 2030, [online]. Available at: http://inrix.com/wp-content/uploads/2015/08/Whitepaper_Cebr-Cost-of-Congestion.pdf,

Today's cities are a consequence of geographic, social, economic and political factors, shaped by the technologies, industries, policies, consumer trends and preferences of multiple generations. Given that the lifespan of urban infrastructure such as roads and buildings typically ranges from 30 to 100 years, cities can find themselves locked in by choices that are being made every day. The fact that future infrastructure in emerging economies has not yet been designed nor built might be of comfort. For example, 70-80% of urban infrastructure that will exist in India in 2050 has not yet been developed[8]. However, without clear case studies of how urban form should be designed to enhance the positive aspects of urban growth, while minimising the considerable negative impacts, it is unclear how cities can be designed differently. The legacy of our existing structures, compounded by the trend of urbanisation, presents a significant challenge to cities across the world.

Fortunately, there is growing recognition among city leaders in developed and developing economies that new approaches are needed to address such challenges. The aim of these is to improve the efficiency of public service delivery, the sustainability of the urban environment, and the quality of city life. However, recognition is not nearly enough. The challenge presented by the re-imagining of our large-scale infrastructure systems is extensive. Cities are very large and complex systems, operated by multiple agencies across the public, private and third sectors and shaped by decisions at both macro and micro levels. It is the combined decisions of these agencies that shape urban form, transport systems and energy use. In a democratised world of individual decision-making, no single agency has a holistic view of, nor total control over, the precise direction in which a city will evolve. The legacies of labour specialisation, market deregulation and privatization – a core part of the evolution of cities to date – have created a complex web of interactions. Co-ordinated approaches to urban infrastructure are certainly difficult to design and may prove yet more difficult to realise[11].

Cities do, however, possess considerable power as vision holders, points of convergence and alignment, and as sources of significant innovation and finance. As local champions with growing levels of political and fiscal decentralisation, cities have expanding powers and their importance in national structures is increasingly recognised. It is cities, more than national governments, that can and do choose to adopt inventive responses to the specific local challenges they face. For example, a growing number of cities are planning to switch to 100% renewable energy, with zero net carbon emissions. Some small towns in the United States are already running entirely on renewable power, including Aspen, Colorado and Burlington, Vermont. Larger cities have set ambitious goals, with Copenhagen aiming to be carbon neutral by 2025, San Diego targeting 100% renewable power by 2035 and many cities adopting 2050 targets. Helsinki has adopted a plan to roll out Mobility as a Service by 2025, with the aim of making car ownership redundant. Global networks of cities, such as the C40, the Compact of Mayors and the Resilient Cities initiatives, demonstrate how cities can take co-ordinated global action and share best practice. National and local planning decisions, when aligned and working collaboratively towards a common goal, can have a significant impact on driving change.

100%

A growing number of cities are planning to switch to 100% renewable energy.

1.1.1 ENERGY IN CITIES

Cities are the drivers of change in a global transition to new energy systems. Consuming between two thirds and three quarters of the world's energy[16], cities are the primary driver of how much energy is used, how it is used and, to a growing extent, what sources it comes from. Energy is vital to a city's economy. It powers transportation systems, enables the production of goods and services, provides heating to homes and is essential to the function of modern appliances and technology. Energy is fundamental across urban infrastructure, from the supply of water, the disposal of waste and the provision of modern communications and healthcare systems to the creation and operation of the built environment. A secure, affordable supply of energy is a prerequisite to the provision of basic city functions and a key pillar in the delivery of economic growth.

The share of global energy used by cities is rising fast. In the early 1990s, cities used less than half of the global energy supply. Today, it is nearly two-thirds. In fact, according to some sources, the share of urban energy use is increasing faster than the global share of urban population[17]. Given forecast levels of urban population growth, urban primary energy demand under a "do-nothing" scenario would increase by 70% to about 172 Petawatt hours in 2050[18], with some forecasts of global energy demand growth suggesting an even higher figure[19]. At the same time, the way we generate, distribute and consume energy is changing. This change is being provoked by the emergence of new generation technologies, the digitisation of infrastructure and, at a political level, the global regulatory responses to climate change. Over the past 10 years the global growth of installed solar[20] and wind capacity has been exponential and with technology improvements and cost reductions continuing at pace, these technologies are playing an increasingly important role in modern and future energy systems. This presents a significant obstacle for legacy energy infrastructure designed around centralised generation. For example, South West England (the area covered by this study) has already reached the grid-constrained limit of new distributed generation. Other technologies – most notably electric vehicles, batteries and heat pumps – are radically changing the mix of energy demand towards electricity rather than gas. Under a range of scenarios, existing systems may not be fit for the future. The 2016 Paris agreement, negotiated by representatives of 195 countries, further embeds decarbonisation into global and national energy policy. As the deployment of new technologies expands, policy and regulation that encourages collaboration and innovation while retaining predictability, reliability and protection is essential.

Moving past the policy responses to date means rethinking the entire urban energy landscape – commercial and industrial sectors, buildings, transportation, generation technologies and integration with existing grid infrastructures. The bulk of the legacy built environment, for example, is energy inefficient, a situation which is costly, contributes heavily to climate change, and often results in fuel poverty and poor health. By lowering energy use and eliminating waste, cities can reduce energy bills and make their energy systems more sustainable and secure. Cities create synergies, whether it be the opportunity to deliver networked solutions, such as district heat, or the possibility of developing local expertise and supply chains. Innovation and new technology in the built environment will also have a significant role to play in the global context: the way new cities in emerging economies are built will be crucial to meeting global carbon targets[18]. This growing demand-side focus at urban scale represents a paradigm shift compared to traditional, supply-side energy policy focus at national scale[11]. As the International Energy Agency (IEA) concludes, support for urban energy transition is one of the key levers available to governments wishing to address climate change[18].

16 IRENA – Renewable Energy in Cities, IEA - Energy Technology Perspectives, Arup – Energy in Cities, IIASA – Urban Energy Systems. A range of values represents the range of accounting approaches in determining the urban share of consumption. | 17 IRENA (2016). Renewable Energy in Cities, [online]. Available at: http://www.irena.org/DocumentDownloads/Publications/IRENA_Renewable_Energy_in_Cities_2016.pdf, | 18 IEA (2016). Energy Technology Perspectives, [online]. Available at: https://www.iea.org/publications/freepublications/publication/EnergyTechnologyPerspectives2016_ExecutiveSummary_EnglishVersion.pdf | 19 Arup – Energy in Cities / World Energy Council scenarios
20 CleanTechnica (2014). The continuing exponential growth of global solar PV production and installation, [online]. Available at: https://cleantechnica.com/2014/07/22/exponential-growth-global-solar-pv-production-installation/

To enable a cost-effective low carbon transition, more advanced local area energy planning is needed to identify the right technologies in the right place at the right time[21]. City-scale energy independence roadmaps are critical to meet national and global low-carbon ambitions. The longer action is delayed, the greater the chance that inefficient choices will be made and locked in for decades to come[22]. While much has been written about the rise of mega-cities, most urban growth will continue to occur in small- to medium-sized urban centres[11], such as Greater Exeter. Alongside a growing number of cities, Exeter City Futures has set an ambitious target to transform the region's energy infrastructure by 2025, developing and demonstrating new solutions to the challenge of becoming energy independent. This report develops detailed evidence assessing possible pathways to achieving that goal, analysing the barriers that must be addressed if cities like Exeter are to achieve such objectives. While this report is focussed on Greater Exeter, the challenges, barriers and constraints are global.

1.2 | REPORT AIM

This report presents an objective assessment of the technical potential to achieve Exeter City Futures' goal of an energy independent Greater Exeter by the reference year of 2025, alongside the key barriers identified in each sector which need to be overcome to meet this target.

1.3 | METHODOLOGY

The findings of this study are based on a series of energy resource and efficiency assessments that have been conducted across a wide range of sectors and technologies, each of which is considered to play an important potential role in achieving the energy independence goal. Where available, industry recognised methodologies have been used to complete each assessment and are highlighted in the relevant chapter. Each section concludes with an evaluation of the maximum technical contribution towards the energy independence goal, alongside the actions required to achieve it. The sum of the contributions from each analysis is then defined as the Maximum Technology scenario for low carbon intervention. Finally, a roadmap of energy choices is presented and discussed, highlighting the key areas of opportunity and barriers that need to be overcome to achieve the desired change. Certain barriers are deemed so significant that a further Maximum Deployment scenario is presented.

To assess the possibility of reaching Exeter City Futures' goal, a Business As Usual energy demand forecast has been produced for 2025 based on a 2014 baseline. This allows the anticipated energy demand to be assessed against the Maximum Technology and Maximum Deployment scenarios. The assumptions for the Business As Usual scenario are defined as follows for each sector:

- **Domestic sector:** existing dwelling figures are taken from live stock tables[23]. Growth in dwelling figures is assumed according to local development plans for each authority in Greater Exeter[24]. New houses are initially assumed to have a consumption equal to the current average consumption of households; building regulations are assumed to be tightened in 2020, and then in 2023, leading to reductions of 15% each time in the energy uses covered (space heating, hot water and lighting); these energy uses are estimated to account for over 80% of total energy use in the household[25]. Overall this leads to energy use increasing by 13% in the sector by 2025.

[21] Gas Power Heat Systems Network (2016). The heat is on: the smart systems and heat programme, [online]. Available at: https://networks.online/gphsn/technology-focus/1000128/heat-smart-systems-heat-programme/page/2 | [22] International Energy Agency (2016). Energy Technology Perspectives 2016, [online]. Available at: https://www.iea.org/publications/freepublications/publication/EnergyTechnologyPerspectives2016_ExecutiveSummary_EnglishVersion.pdf | [23] DCLG (2016). Live tables on dwelling stock (including vacant), [online]. Available at: https://www.gov.uk/government/statistical-data-sets/live-tables-on-dwelling-stock-including-vacants
[24] DCA (2015). Exeter Housing Market Area – Strategic Housing Marketing Assessment, [online]. Available at: http://eastdevon.gov.uk/media/1008081/exeter-shma-final-report-16-03-15.pdf | [25] BEIS (2016). Energy consumption in the UK (ECUK) 2016 Data Tables, [online]. Available at: https://www.gov.uk/government/statistics/energy-consumption-in-the-uk

- **Commercial sector:** commercial floor space area is assumed to increase at the same average rate of growth seen between 2000 and 2012 (1.7% pa.). It is assumed that, on average, new buildings might have about half of the measures identified for existing buildings implemented, which gives a reduction in energy use per m^2 of 11% for new buildings compared to the average for existing buildings. This saving is assumed to rise over time, giving a reduction in energy use per m^2 of 22% in 2025, and an overall increase in energy use in the sector of 15%.

- **Industrial sector:** energy use is assumed to expand in line with GDP growth of 3.0% p.a.. However, continuing improvements in energy efficiency mean that energy consumption only rises at a quarter of this rate. Overall industrial energy use is projected to grow by 9%.

- **Transport sector:** transport energy use is assumed to be proportional to number of households and therefore grows as the number of households increases, rising by 15% by 2025.

Based on these assumptions, total energy consumption across all end users and sectors in the region could increase by up to 13% by 2025, to 11.3 TWh (Figure 1.1). This figure forms the basis of the target for energy independence. In practice, existing national policies to improve energy efficiency and decarbonise the electricity, heat and transport sectors could help to offset this projected increase. UK Government projections suggest that existing policies and measures could reduce energy consumption in 2025 by approximately 6%[26]. However, projections after this date subsequently increase, and certainty around policies at national level is unclear.

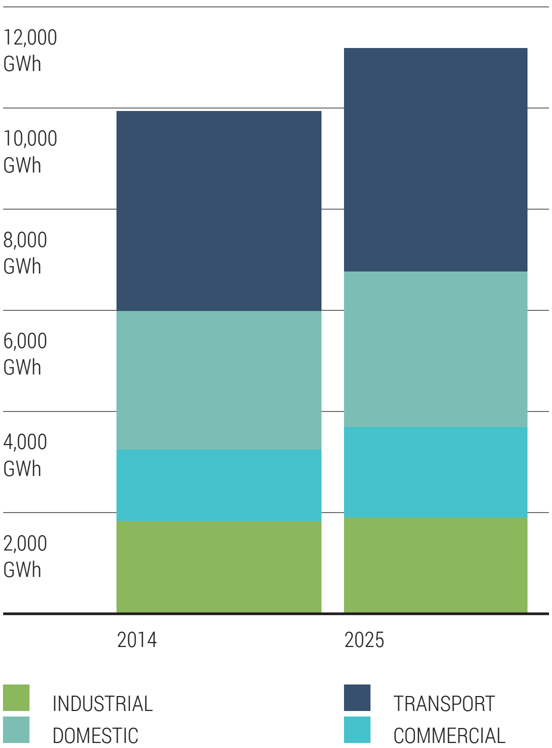


FIGURE 1.1: Projected 2025 Greater Exeter energy use under a Business As Usual scenario

[26] DECC (2016). Updated energy and emissions projections: 2015, [online]. Available at: https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2015

1.4 | DEFINITION OF ENERGY INDEPENDENCE

The goal of Exeter City Futures is energy independence by 2025 for the Greater Exeter region. Exeter City Futures defines energy independence as a net operating balance of energy generation and consumption within the geographic area identified across all fuels. This definition excludes the current energy used in the wider consumption footprint of the city, for example, foreign energy used and transportation energy that forms part of the existing food supply chain. It also excludes energy used in the extraction of materials, for example, energy embedded in the built environment or used in the production of fuels themselves. It is recognised that the resulting carbon emissions and savings of the discussed measures are important.

However underlying energy use was considered more appropriate and relevant in the context of quantifying and achieving energy independence and security. Where appropriate, the implications for carbon emissions are discussed in the relevant section, especially for electrification of heat.

1.5 | REGIONAL DEFINITION

The geographic regions assessed are defined as follows:

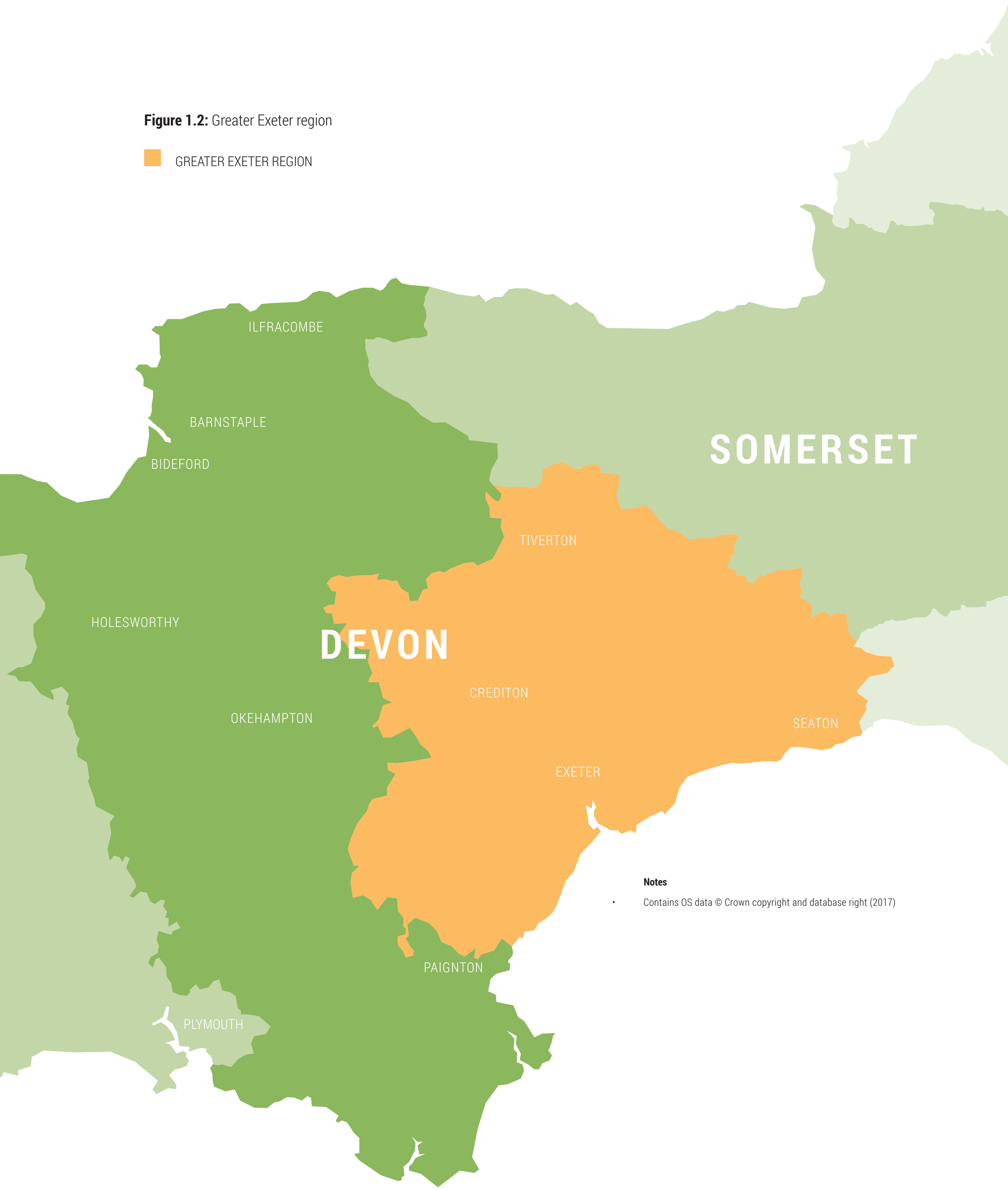
GREATER EXETER:
The region covered by Exeter City Council and the three adjoining local authority areas of Mid-Devon, Teignbridge and East Devon district councils.

DEVON:
The administrative area of Devon County Council – covering the county of Devon, excluding Torbay and Plymouth.

WIDER REGION:
This includes Devon, Plymouth, Torbay and the geographic areas covered by the Heart of the South West, Cornwall and Isles of Scilly Local Enterprise Partnerships (LEPs).

SOUTH WEST:
As defined at national level, representing one of nine UK regions.

Figure 1.2: Greater Exeter region



Notes

- Contains OS data © Crown copyright and database right (2017)

2

THE CURRENT SITUATION

In 2014, energy consumption in the Greater Exeter region was almost 10 TWh and had a net cost of £0.9bn.

2.1 | CURRENT ENERGY SUPPLY

In 2014, energy demand in the Greater Exeter region was almost 10 TWh[27] (Table 2.1). By sector, the main energy uses are transport (38%) and domestic (30%). Industrial and commercial energy use combined is approximately equal to that of domestic (29%). By specific fuel type and end use, petroleum based transport is the highest energy consumer (34%), followed by domestic gas (27%), then domestic electricity (8.8%). Collectively this consumption accounts for approximately 70% of the total annual energy requirement for the region.

Fuel Type	**Industrial** (GWh)[28]	**Commercial** (GWh)	**Domestic** (GWh)	**Transport** (GWh)	**Unspecified** (GWh)	**Total** (GWh)
Coal[29]	123 (1.2%)	2 (0.1%)	48 (0.5%)	3 (0.1%)	-	175 (1.8%)
Petroleum products	419 (4.2%)	157 (1.6%)	290 (2.9%)	3,822 (33.9%)	-	4,688 (47.0%)
Gas	473 (4.7%)	489 (4.9%)	1,761 (17.6%)	-	-	2,723 (27.3%)
Electricity	614 (6.2%)	643 (6.4%)	875 (8.8%)	-	-	2,132 (21.4%)
Bioenergy & wastes	-	-	-	-	252 (2.5%)	252 (2.5%)
All fuels	1,628 (16.3%)	1,292 (13.0%)	2,973 (29.8%)	3,825 (38.4%)	252 (2.5%)	9,971

Table 2.1 Greater Exeter energy consumption in 2014

Energy use overall in Greater Exeter has shown a general downward trend over time, falling by 8% between 2006 and 2014. However, inter-annual temperature variations can cause significant fluctuations in energy use especially in the domestic sector. 2011 was the second hottest year ever recorded[30], which may account for lower energy use in that year (Figure 2.2).

27 BEIS (2016). Sub-national total final energy consumption in the United Kingdom (2003 – 2014), [online]. Available at: https://www.gov.uk/government/collections/total-final-energy-consumption-at-sub-national-level | 28 Industrial and commercial energy use are not disaggregated in regional energy statistics, and are done so here based on national statistics on use of energy in industrial and commercial sectors | 29 Coal includes manufactured fuels | 30 Met Office (2011). Warm autumn weather 2011, [online]. Available at: http://www.metoffice.gov.uk/about-us/who/how/case-studies/warm-autumn-weather

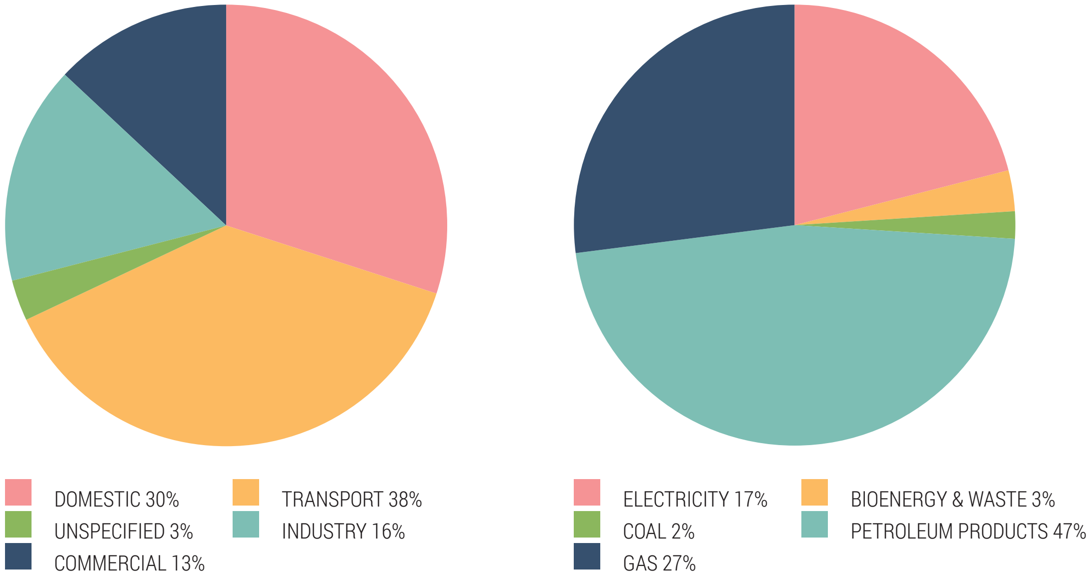


Figure 2.1: Greater Exeter energy consumption in 2014 by fuel and end use[31]

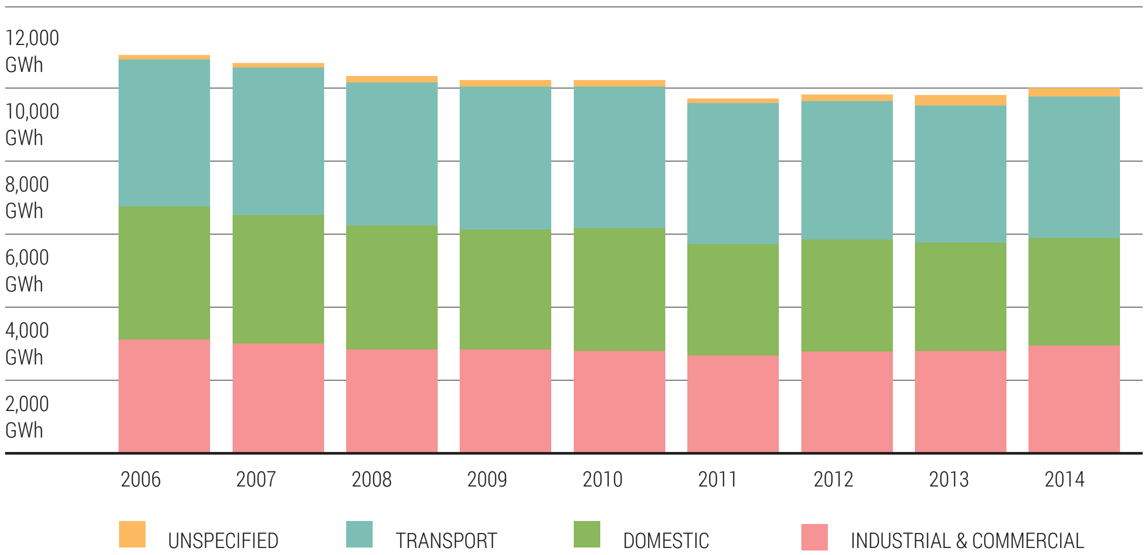


Figure 2.2: Trends in energy consumption

31 BEIS (2016). Total final energy consumption at regional and local authority level, [online. Available at: https://www.gov.uk/government/statistical-data-sets/total-final-energy-consumption-at-regional-and-local-authority-level-2005-to-2010

2.2 | COST

The estimated current cost of energy consumption in Greater Exeter is £0.9bn (Figure 2.3). This estimate is based on domestic and non-domestic gas and electricity consumption at standard costs, plus the recorded energy use of the transport sector, based on average pump prices in 2015. This analysis indicates that energy consumption in the transport sector costs in the region of £467m annually (51% of total), energy in the domestic sector costs in the region of £236m (26% of total) and the remainder – energy in the industrial and commercial sectors – costs £211m annually (23% of total). Current levels of energy consumption and imports represent a sizeable expenditure for the regional economy.

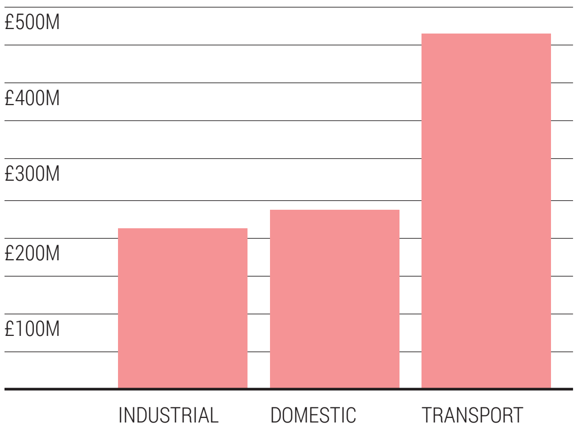


Figure 2.3: Estimated current annual cost of energy by sector

£914M

The estimated current cost of energy consumption in Greater Exeter is £0.9bn.

2.3 | CO_2 EMISSIONS

CO_2 emissions associated with energy use in 2014 in the Greater Exeter region were 2.82 Mt CO_2, and accounted for 0.7% of national emissions[32]. Between 2006 and 2014, a decrease in total CO_2 emissions for Greater Exeter is observed, falling by approximately 18%[32] (Figure 2.4). The decrease in emissions in Greater Exeter has not been as great as the national average (23%), or as in other large conurbations in the South West such as Bristol (28%) over this period. Since 2006, emissions in Greater Exeter have been driven by a reduction of 28% in the domestic sector while transportation emissions have only fallen by 9%.

Emissions reductions have exceeded the 8% fall in energy use (Figure 2.2) over the same period, with changes to the mix and carbon intensity of fuels accounting for the remainder of the saving. The reduction in petroleum products has been a key driver of this change. Electricity use, however, has increased over the period. The carbon intensity of grid electricity (gCO_2e/kWh) has not consistently fallen resulting in additional carbon emissions from electricity. Annual fluctuations in grid carbon intensity depend heavily on the relative prices of coal and natural gas as well as fluctuations in peak demand and renewables. This demonstrates that a range of factors need to be taken into account if Greater Exeter is to take a proactive approach towards meeting its share of national carbon targets.

32 DECC (2016). UK local authority and regional carbon dioxide emissions national statistics: 2005-2014, [online]. Available at: https://www.gov.uk/government/statistics/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics-2005-2014 | 33 BEIS (2016). Government emission conversion factors for greenhouse gas company reporting, [online]. Available at: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting

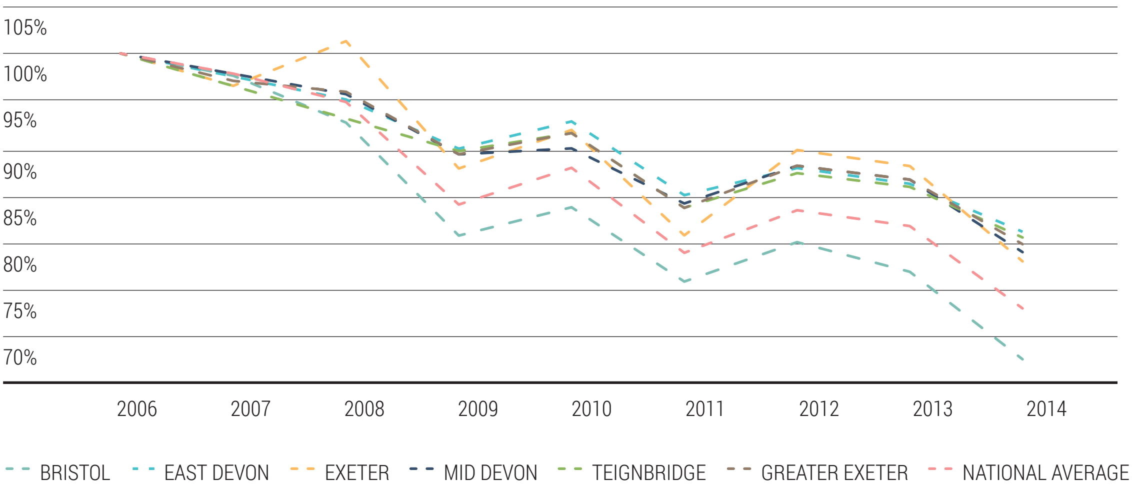


Figure 2.4: Trend in CO_2 emissions, expressed as a percentage of 2006 CO_2 emissions

2.3.1 RENEWABLE ENERGY GENERATION

In 2015, renewable energy technologies generated 213 GWh of electricity in Greater Exeter[36], equivalent to 2.1% of total energy consumption or 10.0% of electricity consumed in the Greater Exeter region[34]. The potential to increase supply from renewable resources (excluding landfill gas) is considered in Section 4. Most existing renewable electricity is generated by solar photovoltaics and landfill gas (Figure 2.5), the former being significantly incentivised in recent years by the UK Government Feed in Tariff (FiT). Generation from landfill gas is expected to decrease significantly in the future, as quantities of waste going to landfill have been declining rapidly where waste is managed via other options such as anaerobic digestion, composting and combustion in energy from waste plant. This trend is set to continue, with the Department for Environment, Food and Rural Affairs (Defra) estimating that quantities of municipal waste sent to landfill, which could degrade to form landfill gas, could fall by 60% between 2012 and 2020[35].

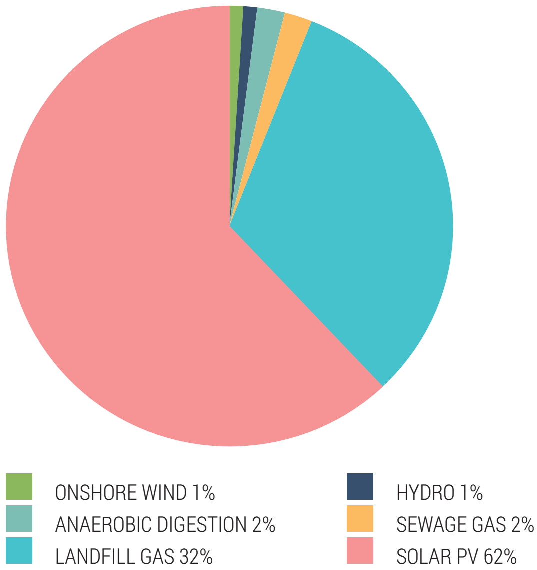


Figure 2.5: Sources of renewable electricity in Greater Exeter in 2015[36]

34 BIES (2016). Total final energy consumption at regional and local authority level, [online]. Available at: https://www.gov.uk/government/statistical-data-sets/total-final-energy-consumption-at-regional-and-local-authority-level-2005-to-2010 | 35 Defra (2014). Forecasting 2020 waste arisings and treatment capacity: Analysis to inform the review of Defra financial support for the Hertfordshire County Council residual waste treatment project. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/364243/forecasting-2020-hertfordshire-analysis-20141016.pdf | 36 BIES (2016). Regional Renewable Statistics: Renewable electricity by local authority, [online]. Available at: https://www.gov.uk/government/statistics/regional-renewable-statistics

REDUCING DEMAND

3

The bulk of the legacy built environment is energy inefficient, a situation which is costly, contributes heavily to climate change, and often results in fuel poverty and poor health.

3.1 | DOMESTIC SECTOR

The energy consumption of the domestic sector accounts for approximately 30% (2.97 TWh) of Greater Exeter's overall demand (Table 3.1), the majority of which is for space and water heating (Table 3.2). Based on 2014 housing levels[24], new development is expected to add 29,600 dwellings to the region's stock by 2025 (representing a 14% increase from 204,086 dwellings in 2014), which could see domestic energy demand grow by up to 384 GWh (13%). Therefore, if Exeter City Futures is to achieve its goal of energy independence (Section 1.4), energy use in both existing buildings (using retrofit measures) and new buildings will need to be reduced significantly.

Fuel Type	**Domestic** (GWh)	**Total** (GWh)
Coal[37]	48 (0.5%)	175 (1.8%)
Petroleum products	290 (2.9%)	4,688 (47.0%)
Gas	1,761 (17.6%)	2,723 (27.3%)
Electricity	875 (8.8%)	2,132 (21.4%)
Bioenergy & wastes	-	252 (2.5%)
All fuels	2,973 (29.8%)	9,971

Table 3.1: Extract from total energy consumption figures for Greater Exeter (Table 2.1)

30%

(2.97 TWh) of Greater Exeter's overall energy demand is consumed by the domestic sector.

Fuel Type	**Space Heating**	**Hot Water**	**Cooking**	**Lighting and Appliances**
Solid fuel	88.2%	11.8%	0.0%	0.0%
Gas	84.6%	13.6%	1.8%	0.0%
Electricity	19.3%	9.0%	4.8%	66.9%
Oil	91.3%	8.7%	0.0%	0.0%
Heat sold	100.0%	0.0%	0.0%	0.0%
Bioenergy & wastes	77.1%	22.9%	0.0%	0.0%
Total	70.3%	12.6%	2.2%	14.8%

Table 3.2: Breakdown of domestic energy consumption by fuel and end use (2012)

38 Coal includes manufactured fuels

Heating, cooling and fixed lighting (known as 'regulated loads') account for much of this domestic energy demand. Heating and cooling comprises approximately two thirds of an average domestic building's overall energy consumption[25]. Appliances (or 'unregulated loads') typically account for the remaining energy demand.

Detailed building physics models have been developed to help understand the heating and cooling load of a dwelling, which allow the potential impact of a range of measures to be estimated. These measures relate to the thermal envelope of the building and the efficient delivery of heat, where significant reductions in heating and cooling demand are likely to be technically achievable. However, considerable barriers still stand in the way of mass deployment.

The remaining domestic demand, which can be largely attributed to appliances, is an area that has typically been overlooked by building modelling practitioners and consumers alike[38]. It is an area that covers a diverse and disparate set of individual components and occupant choices, and has historically been addressed through targeted campaigns and appliance-level regulation.

Collectively, however, this area: a) represents approximately 0.48 TWh (4.8%) of Exeter's current demand[25,29] b) is susceptible to consumer demand changes, particularly where new consumer electronics (e.g. computer consoles) are concerned, and c) is an area of demand that does not fall within the scope of building regulations. More research is needed to understand the patterns of component use, and the mechanisms that can achieve increased component efficiency and long-term behaviour change.

3.1.1 RETROFIT

In Greater Exeter, the bulk of the challenge in the domestic sector relates to the existing building stock. The clear majority of properties in the region have an EPC rating between band C and E (Figure 3.1), with an average dwelling total consumption of 14 MWh per annum[40].

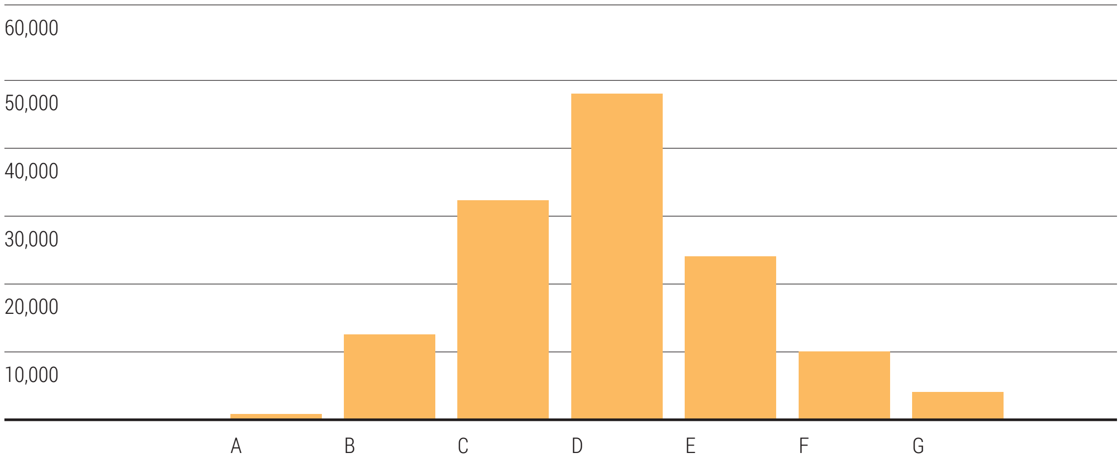


Figure 3.1: EPC lodgements in Greater Exeter 2008-2016[41]

[38] Smart-meters, while being rolled out, provide only a course level of information. Non-Intrusive Load Monitoring or "Disaggregation" might improve this, but further work is required to improve the accuracy of current algorithms. | [39] BEIS (2016). Energy Consumption in the UK, [online]. Available at: https://www.gov.uk/government/collections/energy-consumption-in-the-uk | [40] DCLG (2016). Live tables on dwelling stock (including vacants), [online]. Available at: https://www.gov.uk/government/statistical-data-sets/live-tables-on-dwelling-stock-including-vacants | [41] DCLG (2016). Live tables on Energy Performance of Buildings Certificates, [online]. Available at: https://www.gov.uk/government/statistical-data-sets/live-tables-on-energy-performance-of-buildings-certificates

Retrofit measures which can be applied to existing properties include enhanced thermal insulation and the replacement of existing heating systems with heat pumps. However, a prerequisite for domestic dwelling heat pump retrofits is a better-performing thermal envelope that retains building heat more efficiently. Otherwise, an increase in heating energy carbon emissions may arise if gas is displaced with electricity in an inefficient manner. There has been good uptake of some insulation measures, particularly those with short payback periods, and these have been encouraged by schemes such as the Energy Company Obligation (ECO – ending March 2017), the (no longer financed) Green Deal cashback and the Green Deal Home Improvement Fund. In total, 1.35M UK households have installed measures under these schemes[42]. Projects such as the Energy Alton Local Energy Assessment Fund (LEAF) also demonstrate that large scale retrofitting is achievable. However, to reduce energy demand further, Greater Exeter will require mechanisms to both stimulate the retrofit of measures with a higher thermal performance and efficiency in each property and increase penetration across housing stock in the region[43]. Much improved thermal performance of dwellings could be achieved through the administration of existing standards, such as Passivhaus' EnerPHit. The UK's first such retrofit project is already taking place in Greater Exeter with East Devon District Council making significant upgrades to a Victorian terraced dwelling[44]. Exeter City Council has also made significant progress towards its ambition for its social housing stock to be Passivhaus' certified[45]. If Greater Exeter could deliver this degree of improvement across a large proportion of its stock, it is estimated that energy demand in 2025 could be reduced by up to 60%. This saving would be in comparison to the 2014 baseline and is subject to the significant barriers discussed in Section 6 being overcome. If the full potential could be realised, annual cost savings in the domestic sector for gas and electricity would be approximately £129m per year. To achieve this, however, a move beyond local authority-led schemes will be critical.

3.1.2 NEW DEVELOPMENT

With an estimated 29,600 new properties to be constructed in Greater Exeter by 2025 (14% increase from 204,086 in 2014), new development will play an important role in overall energy demand. New housing, while providing more energy-efficient space- and water-heating than older properties, could increase energy demand in Greater Exeter by a further 13% (384 GWh) by 2025 if built to existing standards.

Increasingly stringent building regulations will help drive down the energy consumption of new buildings over time by ensuring that energy efficiency measures such as insulation, efficient glazing, low energy lighting and efficient heating systems are incorporated into the design and build of new houses. However, the extent and timing of these regulations is determined centrally by government, leaving regional policy-makers with only limited additional local influence through the planning system.

If, for example, all new housing (from 2018) were built to more exacting standards (such as Passivhaus Standard[46]) and heat pumps were installed on all newly-built dwellings, then the forecast additional demand could be reduced by 86% (299 GWh). Allowing for a more gradual rate of introduction of low-energy housing (due to, for example, the need to incentivise developers in this direction), the energy demand from new housing stock in 2025 could be reduced by 32% (110 GWh).

There may also be options to integrate energy independence through design. This is particularly applicable in large developments, where shared schemes are likely to be viable. For example, through the use of district heating schemes based on renewable sources such as biomass or large scale heat pump ground arrays.

[42] DECC (2015). Green Deal and Energy Company Obligation (ECO): headline statistics (November 2015), [online]. Available at: https://www.gov.uk/government/statistics/green-deal-and-energy-company-obligation-eco-headline-statistics-november-2015
[43] The incentives discussed resulted in improvements across an approximated 5% of the UK housing stock | [44] Midas (2016). Mi-space commences UK's first Passivhaus 'EnerPHit' standard social housing project, [online]. Available at: http://www.midasgroup.co.uk/news/?id=633 | [45] http://www.houseplanninghelp.com/wp-content/uploads/2016/09/Exeter-City-Council-Scheme-Information.pdf | [46] The Passivhaus standard requires a space heating demand in properties of ≤15 kWh/m2 per yr which represents a reduction of over 80% compared to typical current heating loads. See www.passivhaus.org.uk/

3.1.3 HEAT PUMPS

Heat pumps absorb heat from the outside air, ground or water in the same way that a fridge extracts heat from the air inside. Electricity is then used to pump heated fluid through a compression cycle, which raises the grade of heat. This heat can then be transferred to radiators, underfloor heating systems or warm air convectors, and be used to provide hot water. Ground-based heat pumps typically produce about three times as much heat as the electricity they consume, and consequently require approximately a third of the energy required to heat a property using traditional systems such as natural gas boilers or electric resistance heaters.

The Bromford Housing Association case study highlights the opportunities and potential for retrofitting heat pumps into dwellings[47]. 16 off-gas grid properties in Shropshire were converted from electric hot water and heating systems to individual ground source heat pump systems saving between £300-350 per year in heating bills. The scheme attracted the non-domestic RHI and ECO funding.

It is estimated that heat pumps could reduce domestic energy consumption in Greater Exeter by up to 860 GWh (or 28% of the domestic energy use in 2014) if powered by the grid. The transmission and distribution losses of imported electricity are higher than those of gas, which will reduce energy savings if converting from a gas heating system to a heat pump – in practice, up to 7% of electricity is typically lost between power station and property[48]. Taking this into account, further additional savings could be offered if powered using locally-generated electricity (such as solar PV), which negates transmission and distribution losses. Heat pumps could therefore make a large contribution to overall demand reduction, although there are significant challenges to be considered, in particular the change in heating energy mix towards electricity from gas.

Heat pumps deliver heat at lower temperatures over much longer periods than gas or oil boilers, and are more suitable for underfloor heating or larger radiators. Installing heat pumps might therefore also require radiator systems to be changed, causing household disruption, which can present a behavioural barrier to uptake. The increase to the cost of the system is also worth considering. The efficiency of a heat pump can also fall at very low ambient temperatures, increasing the grid demand in winter months when it is typically already strained. Hybrid heat pumps, where a heat pump is used in tandem with a gas boiler, can help to overcome some issues and remove the need to replace radiator systems – although the benefits are then reduced.

Space requirements may also prove problematic. Air source heat pumps need to be installed outside a property and either fitted to a wall or on the ground with plenty of space around the unit to get good air flow. Ground source heat pumps, meanwhile, require a ground loop that needs to be buried in a garden. These requirements mean that heat pumps may not be suitable for all existing dwellings. When calculating the deployment and savings potential offered by heat pumps, their physical dimensions and the electricity source used to power them are important considerations. Due to the space requirements, it is assumed in the estimates above that all properties off the gas grid (typically in rural areas) would have space for a heat pump while, for the remaining stock, it is assumed that 75% of detached and semi-detached properties are suitable, along with 50% of terraced properties and 25% of flats[49].

[47] Kensa Heat Pumps (2016). Case Study: Bromford Housing Association, [online]. Available at: http://www.kensaheatpumps.com/bromford-housing-association/, | [48] BEIS (2016). Digest of United Kingdom Energy Statistics (DUKES) 2016: main chapters and annexes, [online]. Available at: https://www.gov.uk/government/statistics/digest-of-united-kingdom-energy-statistics-dukes-2016-main-chapters-and-annexes [49] DECC (2010). Renewable and low-carbon energy capacity methodology; Methodology for the English Regions, [online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226175/renewable_and_low_carbon_energy_capacity_methodology_jan2010.pdf

3.1.4 APPLIANCE DEMAND

The remaining non-heating demand for energy comprises consumption from a diverse range of appliances. There have been considerable efforts to increase the energy efficiency of these appliances in recent years, led at European level by the Ecodesign Directive and Energy Labelling Directive (established in 1992). These two subsequently updated directives now address the energy performance of 27 different appliances including:

- Air conditioners and comfort fans
- Circulators
- Computers
- Domestic cooking appliances
- Electric motors
- External power supplies
- Household dishwashers
- Household tumble dryers
- Household washing machines
- Industrial fans
- Lighting products in the domestic and tertiary sectors
- Local space heaters
- Heaters and water heaters
- Power transformers
- Professional refrigerated storage cabinets
- Refrigerators and freezers
- Simple set-top boxes
- Solid fuel boilers
- Standby and off mode power consumption of household and office equipment
- Televisions
- Vacuum cleaners
- Ventilation units
- Water pumps

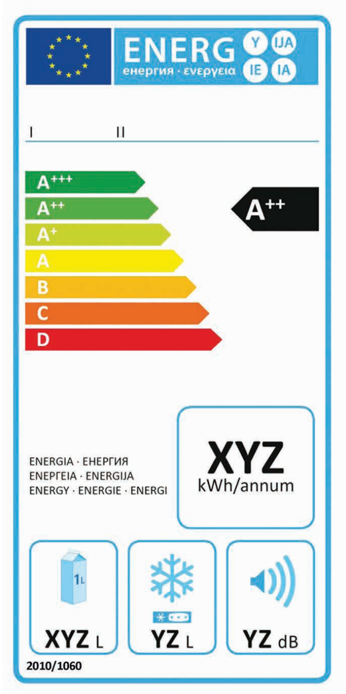


Figure 3.2: Domestic cold appliance energy label, 2010 regulation[50]

The energy label with which most consumers are likely to be familiar is relevant to 15 appliance groups. It is intended to educate at the point of purchase, so consumers can make an informed choice. The energy label shown in Figure 3.2 applies to cold appliances such as fridges, fridge-freezers etc. and contains information on the appliance's energy efficiency, the likely energy consumption, its fridge and freezer capacity, and noise levels.

In addition, the Ecodesign Directive defines Minimum Energy Performance Standards (MEPS). These prevent the lowest performing appliance models remaining on the market once a certain date has passed. For example, the updated 2009 Cold Appliances Regulation established that only new refrigerator models that complied with energy class A+ or higher could be placed on the market by 2014[51]. The sale of all models from G to A was no longer permitted (Table 3.3). The evidence-gathering phase of the next revision of domestic cold appliances is currently underway, with further, stricter, MEPS requirements expected soon.

[50] The European Commission (2010). COMMISSION DELEGATED REGULATION (EU) No 1060/2010 of 28 September 2010 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of household refrigerating appliances, [online]. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010R1060 | [51] Models of lower performance, for example A+, can still be sold as existing stock, but cannot be manufactured for sale on the European market any longer.

Energy label	A+++	A++	A+	A	B	C	D	E	F	G
EEI*	<22	<33	<42/44	<55	<75	<95	<110	<125	<150	<150
2010 reg			<44 removed 2012 <42 removed 2014	<55 removed 2010						

*The EEI is the Energy Efficiency Index, a detailed calculation for each appliance type, and standardised so comparisons across the appliance type can be made.

Table 3.3: Domestic Ecodesign Directive requirements for refrigerators and freezers

The government has estimated that, by 2020, the annual net savings to the UK economy resulting from the Ecodesign and Energy Label directives will be more than £850 million per year, with reductions in greenhouse gas emissions of more than seven million tonnes per year[52]. At EU level this translates to a saving of 17% of electricity and 10% of heat by 2020 compared to the start year[53]. Average home energy demand in England and Wales decreased by 22.3% between 2005 and 2011. However regional variations occur: the South West was lowest for every year between 2005 and 2011.

To fully understand household appliance energy usage, the Powering the Nation study (2012)[55] produced data from 259 dwellings over the course of a year. Summary data for different categories of appliance (Table 3.4; Figure 3.3) demonstrates that energy use is widely distributed across several essential activities. It also highlights that while the number of appliances in a 1970s home was about a dozen, the average in 2011 was 41, and 21% of households owned over 51 appliances. While significant energy savings have been made at the appliance level (and at the dwelling level), it must also be acknowledged that the energy share of appliances has tripled in the past 40 years, from less than 5% to nearly 14%[54].

Appliance category	**Demand** %
Cold appliances	16.20%
Cooking	13.80%
Lighting	15.40%
Audio-visual	14.40%
ICT	6.10%
Washing/drying	13.60%
Water heating	7.10%
Other	3.70%
Not known	9.70%
Total	100%

Table 3.4: Energy consumption by appliance category

52 Energy Efficient Products – helping us cut energy use https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/328083/Energy_efficient_products_-helping_us_to_cut_energy_use_-_publication_version_final.pdf | 53 Economic benefits of the EU Ecodesign Directive (2012)., http://www.ecofys.com/files/files/ecofys_2012_economic_benefits_ecodesign.pdf | 54 Household Energy Consumption in England and Wales, 2005–11, http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/dcp171766_321960.pdf | 55 Energy Saving Trust, DECC, Defra (2012). Household Electricity Survey; A study of domestic electrical product usage, [online]. Accessed: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/208097/10043_R66141HouseholdElectricitySurveyFinalReportissue4.pdf

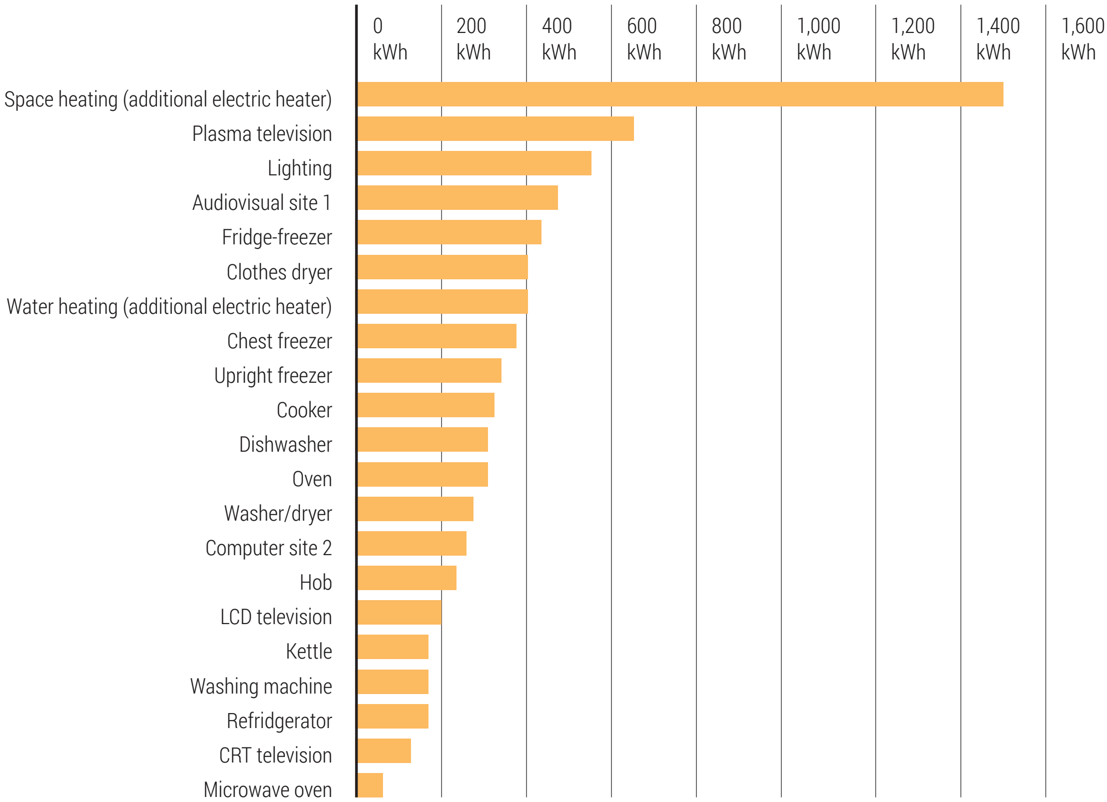


FIGURE 3.3: Annual energy usage by specific appliance

Taking the example of fridges and freezers, the above report identified the following energy demands for the monitored cold appliances (Table 3.5; Table 3.6).

Cold appliance	Annual kWh/yr	Running cost/yr (£)
Refrigerator	162	£23.50
Fridge-freezer	427	£62.00
Upright freezer	327	£47.50
Chest freezer	362	£52.50

Table 3.5: Typical yearly running costs for monitored cold appliances for monitored households

Annual kWh/yr	BAT kWh/yr*	Energy saving %	Top ten listed inefficient product kWh/yr
162	88	46%	178
427	172	60%	280
327	228	30%	326
362	178	51%	278

*BAT, Best Available Technology, taken from the top ten lists of A+++ cold appliances, averaging the energy consumption of the listed appliances, accessed 15.11.16

Table 3.6: Typical yearly energy consumption compared to average BAT energy consumption

Table 3.6 demonstrates that significant energy savings can be made at the appliance level through simply buying the best available technology in the marketplace. It has been reported that one in five households (19%) still own a fridge or freezer that is at least 15 years old[56]. A similar exercise (using a TopTen 'inefficient product' by comparison) gives potential savings for TVs at 42% (sizes 40"-49") and washing machines at 45% (9 kg capacity). A study for DECC[57] in 2012 identified that for the UK, electricity demand could be reduced by 26.3 TWh per year by 2030 if consumers purchased the most efficient appliances. To put this into context, that is more electricity than will be produced by the nuclear power station at Hinkley Point C.

To realise the potential energy savings, there are challenges that need to be tackled with respect to consumer behaviour and purchasing; the number of appliances is proliferating and the size of some appliances is increasing. This is particularly true for TVs and fridges, and it negates the energy savings made through efficiency improvements. Consider how high household energy consumption would be without the energy efficiency measures discussed above. One recognised consequence of increased energy efficiency is the financial saving made by consumers, and the fact that some of this saving is being spent on further appliances and further energy consumption. This is known as the rebound effect, and its impact can be recognised here.

The 4E Report[58] identifies that global energy efficiency programmes deliver, on average, a technology efficiency improvement of 3-4% each year over a long period from commencement. Therefore, we can expect further energy efficiency improvements from the appliances covered by the Ecodesign and Energy Label regulations as standards continue to push for improvements and producers respond to this. Over the eight years to 2025, this could be expected to provide a theoretical saving of 24-36%, assuming the UK adopts this legislation following exit from the EU. Whether 3-4% is realistic for an already established long term scheme is unclear, and replacement rates, appliance size and number growth are uncertain.

To achieve the 20% saving identified in this study, a focus on consumer behaviour and consumer purchasing could also yield results. The information on which appliances are most energy efficient needs to be ubiquitous and fully reliable. Usefully, the information relating to growth in appliance size and number is well researched and available, hence a focus on how to realise reductions with the public, through education and demonstration of the benefits (both financial, environmental, and in terms of energy security), is a very real possibility at a city level.

Monitoring and the provision of digital information to home-owners offers a further potential technological solution to reduce both costs and energy use through behaviour change. Granular monitoring could be enabled by technologies such as Non-Intrusive Load Monitoring, a process where energy readings are disaggregated over a period using individual appliance energy signatures[59]. However, it is difficult to predict what might be achievable in the absence of large scale behavioural trials.

56 Energy Saving Trust (2016). Brits could save £1.7 billion a year by switching appliances off standby, [online]. Available at: http://www.energysavingtrust.org.uk/about-us/news/brits-could-save-%C2%A317-billion-year-switching-appliances-standby, | **57** Capturing the full electricity efficiency potential of the UK, McKinsey & Co report for DECC 2012, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/66564/7035-capturing-full-elec-eff-potential-edr.pdf | **58** IEA (2015). Achievements of appliance energy efficiency standards and labelling programs: A global assessment, [online]. Available at: https://www.iea.org/publications/freepublications/publication/4E_S_L_Report_180915.pdf | **59** Clean Technica (2015). Non-Intrusive Load Monitoring can enhance smart meters, save energy and money, [online]. Available at: https://cleantechnica.com/2015/06/10/non-intrusive-load-monitoring-can-enhance-smart-meters-save-energy-money/

3.1.5 SAVINGS

The total technical energy savings potential for existing Greater Exeter housing stock has been estimated as a function of each energy saving measure, with a total reduction of approximately 60% achievable when all the savings are applied and accounting for interactions between each measure (Table 3.7).

Fuel Type	**Applicability %**	**Saving %**	**Gas/Oil/ Coal saving** (GWh/yr)	**Electricity saving** (GWh/yr)	**Total saving** (GWh/yr)	**Savings as % of domestic demand**
INSULATION MEASURES						
Cavity wall insulation (easy to treat)	17%	14%	45.6	4.2	49.8	1.68%
Cavity wall insulation (hard to treat)	12%	14%	32.2	3.0	35.2	1.18%
External wall insulation (all properties with cavity walls, after all filled, easy to treat)	60%	15%	173.1	16.8	189.9	6.39%
External wall insulation (all properties with cavity walls, after all filled, hard to treat)	10%	15%	28.8	2.8	31.7	1.06%
Solid wall insulation (easy to treat)	15%	20%	57.6	5.6	63.2	2.13%
Solid wall insulation (hard to treat)	15%	20%	57.6	5.6	63.2	2.13%
Loft insulation (from zero)	1%	18%	3.3	0.3	3.6	0.12%
Loft insulation (top-up)	23%	8%	30.9	2.9	33.8	1.14%
Loft insulation (hard to treat)	7%	8%	11.1	1.0	12.1	0.41%
Floor insulation	18%	3%	8.8	0.9	9.7	0.33%
Window upgrade (single to double glazing)	6%	8%	8.8	0.8	9.7	0.32%
Window upgrade (pre-2002 double to standard double, coming to end of life by 2025 and replaced)	53%	6%	56.7	5.2	61.9	2.08%
Window upgrade (pre-2002 double to standard double, those not coming to end of life by 2025)	9%	6%	9.6	0.9	10.5	0.35%

Fuel type	**Applicability %**	**Saving %**	**Gas/Oil/ Coal saving** (GWh/yr)	**Electricity saving** (GWh/yr)	**Total saving** (GWh/yr)	**Savings as % of domestic demand**
Window upgrade (post-2002 double to standard double)	31%	3%	13.7	1.3	15.0	0.50%
Window upgrade (standard double to Passivhaus)	99%	4%	67.3	6.6	73.9	2.48%
Draft Proofing	25%	4%	15.3	1.5	16.8	0.56%
Hot water tank insulation (top-up)	18%	15%	8.3	0.8	9.1	0.30%
Hot water pipe insulation	80%	2%	2.5	0.2	2.7	0.09%
IMPROVED HEATING SYSTEMS						
Improved space heating controls	10%	2%	3.8	0.4	4.2	0.14%
Gas boiler upgrade (from D or worse)	25%	17%	59.4	0.0	59.4	2.00%
Heat pumps (off gas grid)*			545.8	-181.9	363.8	12.23%
Heat pumps (on gas grid)*			1212.7	-404.2	808.4	27.18%
OTHER						
Smart metering	89%	2%	31.3	15.6	46.9	1.58%
More efficient lighting	100%	21%	0.0	50.1	50.1	1.69%
Appliance demand reduction	100%	20%	0.0	105.0	105.0	3.53%
Total individual savings (GWh)			2484.4	-354.8	2129.6	71.6%
Total savings (GWh allowing for interaction between measures)					1782.2	59.9%

*Heat pumps typically run on electricity – hence the negative number in the table to indicate increased demand, but deliver heat more efficiently than other heating systems resulting in substantial overall energy savings.

Table 3.7: Potential savings from individual measures in domestic sector for existing dwellings

The total energy savings potential across the domestic sector for existing properties and new builds, allowing for interactions between the measures applied, is shown in Figure 3.4.

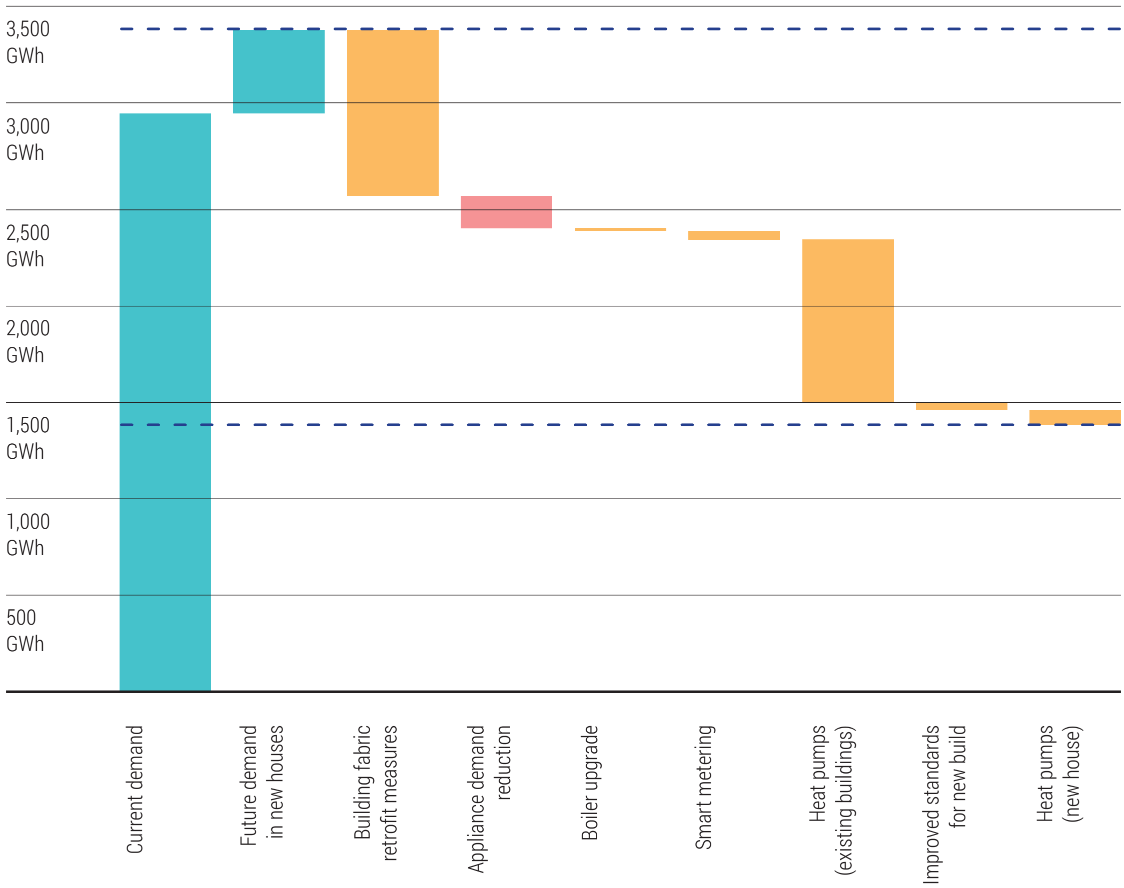


Figure 3.4: Reduction from energy efficiency measures in domestic sector

3.1.6 BARRIERS

Achieving the identified potential will require existing barriers, in particular those relating to thermal efficiency, to be overcome. The main barriers to this retrofit activity fall into three categories: financial, behavioural and supply chain. From a financial perspective, looking across a range of measures, the payback of individual interventions varies to a wide degree and is dependent on several variables. So, while more holistic and cost-effective strategies for achieving retrofit to EnerPHit standards (such as Energisprong) are being developed, improved and trialled, only a few have entered the mainstream. Component manufacturing and installation costs will need to be reduced further, and new financing mechanisms will need to be made available to encourage widespread uptake.

Traditionally, behavioural barriers have been significant. These barriers generally prevent uptake and could reflect a lack of awareness and understanding of technologies, the effort required to arrange for the implementation of measures, and possible disruption and inconvenience. Aesthetics and perceived value are also important considerations in the design phase of any intervention – measures that adversely impact the aesthetics or use of a property are likely to see more restrained growth.

One route to overcome these barriers may be to offer homeowners a comprehensive service from a single contractor that would assess and undertake all measures. However, sufficient technical knowledge and capability across a full range of interventions presents a challenge and would require significant upskilling and coordination of the existing supply chain. The sheer scale of a retrofit ambition of this size also needs to be appreciated in the context of the existing workforce. With 204,086 households in Greater Exeter (2014), the labour required to deliver the retrofit over the time given would require an estimated 2,500 people. Scaling an organisation or series of organisations to implement this would be a material challenge.

Achieving the identified potential will require existing barriers, in particular those relating to thermal efficiency, to be overcome. The main barriers to this retrofit activity fall into three categories: financial, behavioural and supply chain.

3.2 | COMMERCIAL SECTOR

In Greater Exeter, almost 9000 commercial properties consume approximately 13% (1,292 GWh) of the region's energy demand (Table 3.8). Many commercial buildings now have Energy Performance Certificates (EPCs) which allow potential tenants or purchasers to make an informed choice in terms of the energy efficiency of the building. Revisions to Part L of the buildings regulations will also contribute to future energy efficiency and carbon savings under a Business As Usual scenario. There are several additional legislative measures in place that encourage commercial organisations to reduce operational energy use, such as the Climate Change Levy (CCL) and, in the short term, the Carbon Reduction Commitment (CRC). Many commercial organisations will also have been captured by the Energy Savings Operational Scheme (ESOS) which should help these organisations identify and implement energy efficiency measures.

Unlike the domestic housing stock, which is relatively homogeneous, there are many types of commercial premises (for example retail, catering, office, warehouse, sport and leisure), each with differing energy needs and divergent energy use patterns. A retail unit, for example, will on average use a relatively higher proportion of energy for lighting than an office property (Figure 3.5). The potential for energy savings also varies significantly between types of building. A full assessment of any potential energy savings therefore requires a more detailed breakdown of a building's energy use.

Fuel type	**Commercial** (GWh)	**Total** (GWh)
Coal[60]	2 (0.1%)	175 (1.8%)
Petroleum products	157 (1.6%)	4,688 (47.0%)
Gas	489 (4.9%)	2,723 (27.3%)
Electricity	643 (6.4%)	2,132 (21.4%)
Bioenergy & wastes	-	252 (2.5%)
All fuels	1,292 (13.0%)	9,971

Table 3.8: Extract from total energy consumption figures for Greater Exeter (Table 2.1)

60 Coal includes manufactured fuels

Of the commercial properties in Greater Exeter, just over half are in the retail sector, almost one third are offices and the remainder are other types of premises. Based on the available data, an initial assessment of efficiency savings has been made, with applicable measures discussed both in the general sense and as applicable to building types where relevant (Table 3.9).

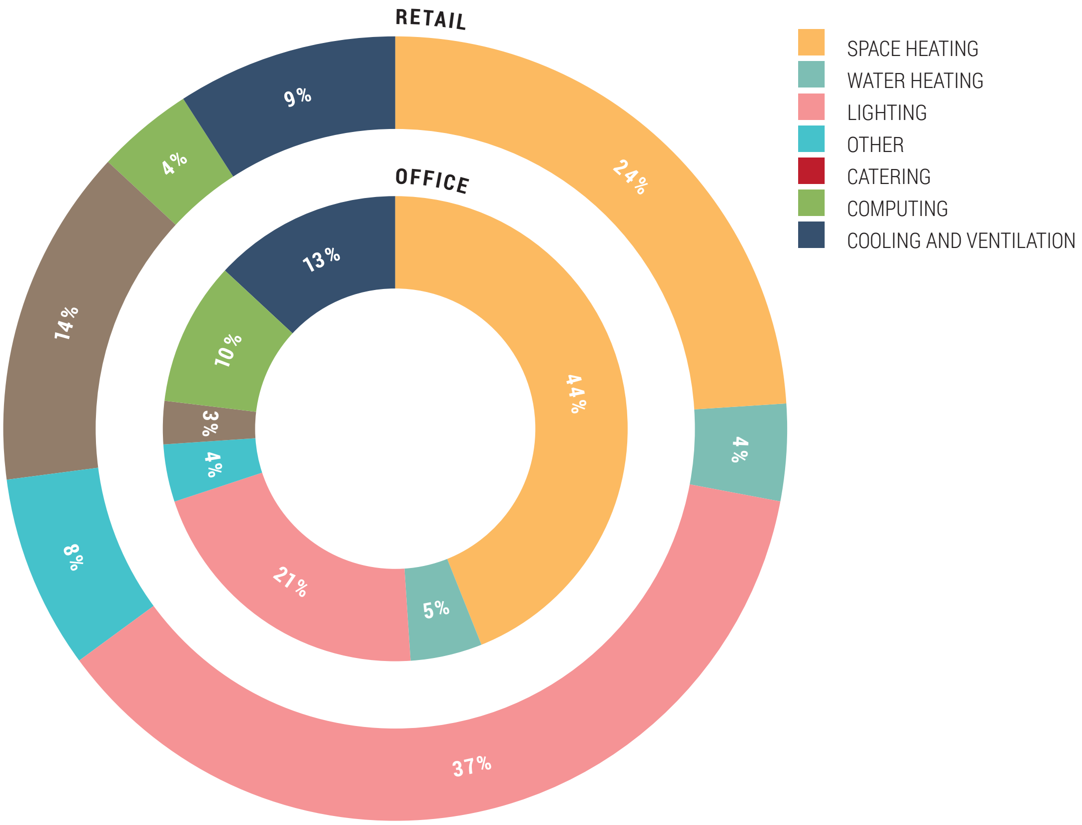


Figure 3.5: Comparison of energy use between commercial office and retail[25]

3.2.1 GENERAL MEASURES

While acknowledging different energy usage patterns between retail, restaurant, offices and other commercial properties, there are a range of energy efficiency measures which can be applied generally to most buildings regardless of use. These are discussed below:

- **Building fabric:** As in the domestic setting, space heating represents a lesser but significant level of demand in commercial properties (36%). Draught-proofing and loft insulation can be low cost measures, while insulation to walls and improved glazing may be required for older properties to attain baseline standards. As with the domestic sector, more advanced standards such as Passivhaus[61] and "BREAM Outstanding" can be adopted, however these standards are currently used only for new builds. Alterations to the building fabric of commercial properties may be restricted where the building is leased (as is often the case in a commercial setting).

- **Heating, Ventilation and Air Conditioning (HVAC):** Beyond insulation improvements, changes to the system of generating and providing heat can achieve substantial savings. Alongside technical improvements, 'soft measures' such as reducing set points for heating and behavioural initiatives can offer savings at low capital cost. Measures include:

  - Heating system improvements
    - Updated fossil fuel boilers
    - Replacing fossil fuel boilers with heat pumps
    - Radiant heating (typically in industrial settings)
    - Air-distribution fans
  - Optimising set points for heating and cooling such as through occupancy monitoring and ensuring suitable dead-bands to prevent simultaneous heating and cooling
  - Improved ventilation equipment (fans/pumps)
  - Heat recovery – refrigeration/building extraction

- **Lighting:** Savings can be made from reduced lighting hours, the utilisation of daylight and reducing lighting intensity where appropriate. Measures include:

  - LED lighting (and other energy-efficient lighting)
  - Occupancy sensors
  - Daylight sensors
  - Zoning of lighting

- **Energy management and behaviour:** Most organisations can benefit from improved energy management and it is conservatively estimated that this can save around 5% of overall energy use[62]. Improvements can be delivered through better organisation, by employing designated energy managers, creating energy teams, improving communications and education among staff, and the use of energy data. Further savings can be made in some buildings using (or through improved understanding of) Building Energy Management Systems (BEMs).

[61] The Canolfan Hyddgen project in Powys was the first Passivhaus certified offices in the UK in 2009. | [62] Based on experience of Ricardo Energy & Environment auditing of buildings for compliance with ESOS

3.2.2 RETAIL-SPECIFIC MEASURES

As the largest proportion of commercial stock in Greater Exeter, achieving low energy use in retail units is a key consideration in the delivery of regional energy independence. There are also economic benefits for retailers in addressing the energy efficiency of their operations – the Carbon Trust estimates that a 20% saving in energy is equivalent to a 5% increase in sales[63].

- **Lighting:** Lighting accounts for a much larger proportion of energy use in retail than in other sectors. Here, lighting is used both for general purposes but also for displays, signage and for the provision of customer car parks. Occupancy sensors for storerooms and internal meeting rooms and daylight sensors for external areas can provide a simple way to ensure that lights are turned off when not in use. The largest saving however would likely be made by using low energy light bulbs to replace large areas of customer lighting and display. The conversion from traditional lighting to Compact Fluorescent Lamps or LEDs could result in savings of up to 75%[64].

- **Space heating:** In a retail setting, there are slightly different considerations with regards to space heating.

  - Customers are likely to dress appropriately for the external temperature and time of year, meaning that with appropriate staff uniforms, internal temperatures can be comfortable at lower settings. This is an important consideration since a 1°C reduction in demand temperature can reduce energy consumption by 8%.
  - Shop fronts and large openings can lead to a loss of internally generated heat and so automatic and revolving doors should be used to minimise losses.
  - Building fabric considerations may be different – for example, single skin construction and uninsulated roofs (sometimes found in retail warehouses) can lose a lot of heat.

- **Refrigeration:** Refrigeration is an important driver of demand in food and restaurant retail uses. In UK supermarkets, for example, more than 70% of the energy consumed is electricity, most of which is used to power refrigeration equipment in store[65]. Efficiency improvement options are:

  - Technical efficiency – improvements to technical elements of modern refrigeration systems, such as motor optimised controls, have the potential to reduce energy consumption by 15%–40%[66].
  - If the cooling temperature can safely be increased, every 1°C increase would equate to 2% savings[67].
  - Free cooling – utilising low external air temperatures to assist with chilling processes.

- **Catering:** Cooking plays a significant role in the energy consumption of commercial restaurants. Energy dissipation in kitchens can be high with cooking processes creating waste heat that does not directly contribute to food preparation. The Carbon Trust assesses that savings of up to 20% are achievable in most catering environments[68]. Efficiency improvement examples are:

  - Induction hobs – these work via magnetic fields and transfer heat directly to food preparation. They can use 15-20% less energy than conventional gas and do not release water vapour as a by-product of combustion (as with gas hobs), thereby reducing heat and dehumidification loads.
  - Combi-steam/convention ovens can reduce the amount of energy required by 25%-50%.
  - Additional measures such as switch-off policies for catering equipment and full-lifetime equipment cost considerations in upgrade cycles.

[63] Carbon Trust (2016). Retail and distribution; energy efficiency advice for retail businesses, [online]. Available at: https://www.carbontrust.com/resources/guides/sector-based-advice/retail-and-distribution/ | [64] Carbon Trust, Energy Management – the new profit centre for retail businesses | [65] S.A. Tassou et al (2011). 'Energy consumption and conservation in food retailing', Applied Thermal Engineering, vol 31, p.147-156, [online]. Available at: http://www.spiral-freezers.co.uk/articles/eccfr.pdf | [66] Sustainability Victoria (2009) – 3 Energy Efficiency Best Practice Guide: Industrial Refrigeration, [online]. Available at: http://www.sustainability.vic.gov.au/-/media/resources/documents/services-and-advice/business/srsb-em/resources-and-tools/srsb-em-best-practice-guide-refrigeration-2009.pdf?la=en | [67] Carbon Trust (2016). Refrigeration, [online]. Available at: https://www.carbontrust.com/resources/guides/energy-efficiency/refrigeration/ | [68] Carbon Trust (2008). Food preparation and catering: Increase carbon savings without compromising on quality


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Image Credit: Neale Smith Photography, Hoskins Architects

CASE STUDY

The Bon Accord and St Nicholas Shopping Centre in Aberdeen boasts 70,000 square metres of floor space and is a popular destination with shoppers (Figure 3.6). Following an extensive refurbishment, the shopping precinct is one of the first retail destinations in the UK to feature LED-only lighting. The conclusion of an energy appraisal that compared the existing lighting to the proposed scheme with the inclusion of lighting controls, found an annual saving of approximately 117 MWh. This equates to a predicted annual carbon reduction of 49 TCO_2[69].

Figure 3.6: Bon Accord and St Nicholas Shopping Centre, Aberdeen

69 Zumtobel (2012). Aberdeen leads way with complete LED shopping experience, [online]. Available at: https://www.zumtobel.com/media/downloads/PR-ZT_BonAccord_Shoppingcentre_UK.pdf

Measure	Applicability %	Savings % of energy use in that equipment	Fossil fuel saving (GWh/yr)	Electricity saving (GWh/yr)	Total saving (GWh/yr)	Saving as % of commercial demand
ENERGY MANAGEMENT						
Energy management (Behavioural)	80%	5%	16.6	1.8	18.4	1.4%
BEMS (Building Energy Management System)	10%	5%	2.9	3.6	6.5	0.5%
SPACE HEATING - BUILDING FABRIC						
Loft/roof insulation	20%	5%	4.2	0.5	4.6	0.4%
Wall insulation	10%	10%	4.2	0.5	4.6	0.4%
Floor insulation	5%	12%	2.5	0.3	2.8	0.2%
Replacement windows	10%	11%	4.6	0.5	5.1	0.4%
Draught proofing	20%	5%	4.2	0.5	4.6	0.4%
Additional measures to achieve EnerPhit standards	10%	20%	8.4	0.9	9.3	0.7%
SPACE HEATING – HEATING SYSTEMS						
Optimisation of heating hours and set points	50%	8%	16.6	1.8	18.4	1.4%
Gas boiler upgrade	25%	15%	15.6	1.7	17.3	1.3%
Heat pumps[(a)]	25%		103.7	-34.6	69.2	5.4%
Zoning	5%	5%	1.0	0.1	1.2	0.1%
TRVs	5%	10%	2.1	0.2	2.3	0.2%
Heat recovery from outlet air	20%	10%	8.3	0.9	9.2	0.7%

Measure	**Applicability %**	**Saving % of energy use in that equipment**	**Fossil fuel saving** (GWh/yr)	**Electricity saving** (GWh/yr)	**Total saving** (GWh/yr)	**Savings as % of commercial demand**
COOLING AND VENTILATION						
Fan efficiency and natural ventilation	40%	6%	0.0	1.8	1.8	0.1%
LIGHTING						
Higher efficiency lighting (LEDs)	90%	25%	0.0	77.9	77.9	6.0%
Occupancy and daylight sensors	90%	15%	0.0	46.7	46.7	3.6%
CATERING EQUIPMENT						
Miscellaneous measures	90%	20%	13.3	13.3	26.5	2.1%
OFFICE EQUIPMENT						
Miscellaneous measures	20%	10%	0.0	1.0	1.0	0.1%
Total Individual Savings (GWh)					360	28.0%

Notes

(a) Heat pumps typically run on electricity – hence the negative number in the table to indicate increased demand – but deliver heat more efficiently than other heating systems, resulting in substantial overall energy savings.

(b) There are many ways to improve refrigeration, including updated, more efficient compressors, the use of free cooling, and alternatives to refrigeration in the form of evaporative cooling.

(c) From outlet air in mechanically ventilated buildings.

(d) Measures include 'power-downs' and timers on printers and photocopiers, timers on vending machines, power-downs on computers, laptops instead of desktops, improved efficiency hand-dryers, improved efficiency white goods.

Table 3.9: Potential savings from individual measures in commercial sector

3.2.3 SAVINGS

The total technical energy savings potential for the Greater Exeter commercial building stock has been estimated for each individual measure and could lead to total savings of 359 GWh – 28% of current commercial energy demand. Demand from future commercial buildings has been estimated based on historic rates of growth in commercial sector floor space and the assumption that new buildings will achieve at least half of the energy savings identified for the current stock from 2013 onwards, rising to 100% implementation of identified measures by 2025. This would lead to an increase in demand of 231 GWh (18%).

However, if efforts are made to ensure that all new buildings achieved these savings by 2020, then demand could be reduced to 222 GWh. Overall, it is therefore estimated that demand in commercial buildings in 2025 could be reduced to 1,155 GWh, a reduction of 9% compared to current energy consumption (Figure 3.7).

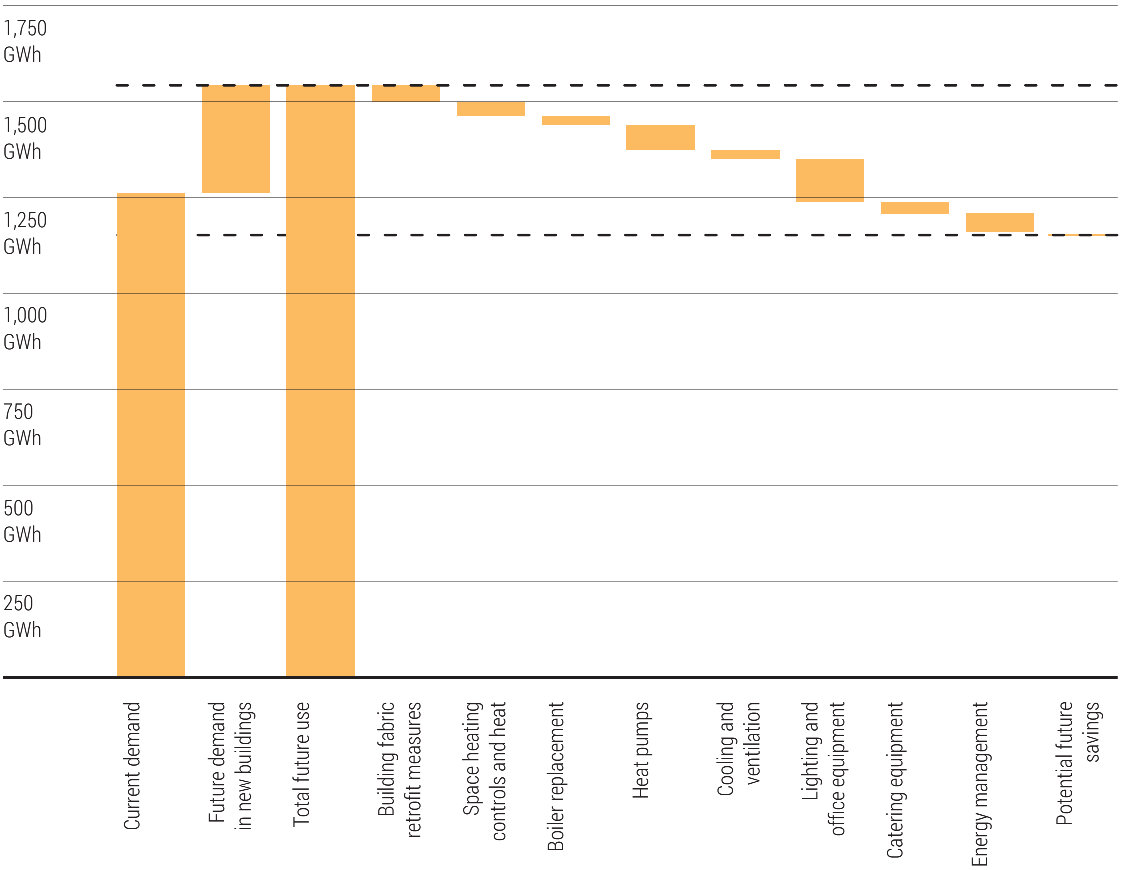


Figure 3.7: Reduction from energy efficiency measures in commercial sector

3.2.4 BARRIERS

One of the key barriers is that many commercial buildings are leased, making the implementation of energy-saving measures complex as capital costs may fall to the owner while cost savings accrue to the tenant. The Green Lease Toolkit, published by the Better Buildings Partnership in August 2013, provides best practice guidance and recommendations encouraging landlords and tenants to work together to increase the sustainability of commercial buildings.

The case studies detailed in the Green Lease Toolkit highlight the potentially significant benefits for both owners and occupiers who wish to collaborate to improve energy performance and waste management, both from a cost reduction perspective and to fulfil corporate social responsibility objectives. Green lease strategies have been adopted by large organisations in the UK such as Marks & Spencer and Legal & General. However, green leasing is far from commonplace. Green leases have a role to play in ensuring flexibility in commercial leases to enable landlords and tenants to actively respond to sustainability and efficiency opportunities. By prioritising sustainability and energy efficiency during leasehold negotiations, owners and occupiers have the opportunity to agree how they might share the cost of improving commercial property energy standards.

Financial barriers, particularly in relation to component costs and the financing of broad packages of measures, are also important to consider. While businesses will have clear incentives to invest so that they might reduce costs, they will often have strict internal rates of return and borrowing limits. Consequently financing energy efficiency measures may not be a core business strategy. Similarly, while several incentives exist, for example in the tax code, for businesses to adopt energy-efficient plant and machinery, these are often not the key financial consideration. Trusted options to finance improvements off the balance sheet might be helpful, but would involve a much greater understanding of the real-world savings and capital cost by the financial community.

A further barrier relates to the low number of real-world demonstrations of best practice across a range of different commercial environments. Certainly, there are few examples of Passivhaus office or retail units. Exemplary demonstrators which push the boundaries of technology across a range of commercial buildings might help increase the potential saving estimates further.

3.3 | INDUSTRIAL SECTOR

There are 1,010 industrial enterprises operating in Greater Exeter[70] with a combined annual energy demand of 1,628 GWh (Table 3.10) or 1,881 GWh if including consumption classed as "unspecified". As in the case of the commercial sector, patterns of energy consumption vary significantly according to end use. Consequently, potential energy savings are highly sensitive to the mix of industries in the region and on the specific operational processes in each. For example, 2020 carbon targets set under the Climate Change Agreements (CCAs) for different industrial sectors range from about 5% for non-metallic minerals (cement, ceramics, glass), to 11.3% for chemicals, to about 15% for food and drink. Several assessments have been produced at national level which identify efficiency roadmaps on a sector-by-sector basis, and build from detailed work involving specialists in their respective sectors. The results presented below provide an estimate of the provisional order of magnitude of a Maximum Technology scenario in Greater Exeter based on these national studies. These have been validated against a bottom-up intervention-based analysis.

1,010

There are 1,010 industrial enterprises operating in Greater Exeter[70] with a combined annual energy demand of 1,628 GWh.

Fuel type	**Industrial** (GWh)[71]	**Unspecified** (GWh)	**Total** (GWh)
Coal[72]	123 (1.2%)	-	175 (1.8%)
Petroleum products	419 (4.2%)	-	4,688 (47.0%)
Gas	473 (4.7%)	-	2,723 (27.3%)
Electricity	614 (6.2%)	-	2,132 (21.4%)
Bioenergy & wastes	-	252 (2.5%)	252 (2.5%)
All fuels	1,628 (16.3%)	252 (2.5%)	9,971

Table 3.10: Extract from total energy consumption figures for Greater Exeter (Table 2.1)

[70] NOMIS Business Information by SIC Code | [71] Industrial and commercial energy use are not disaggregated in regional energy statistics, and are done so here based on national statistics on use of energy in industrial and commercial sectors | [72] Coal includes manufactured fuels

The assessment suggests that under a Maximum Technology scenario, Greater Exeter could reduce industrial energy consumption by 250 GWh, or 15% of industrial demand, by 2025. This level of saving is comparable with those identified in national studies. For example, a 2012 study identified that savings of 45 TWh might be possible in UK industry by 2025[73], equating to 16% of national industrial energy consumption. A subsequent 2015 report for DECC and BIS[74] assessed the likely savings under a Maximum Technology scenario to 2050. It presented a possible 73% reduction in CO_2 emissions. However, once adjusted to remove external actions such as grid decarbonisation and CCS, the resultant reduction in CO_2 emission is estimated to be approximately 16%[75].

Low temperature processes, those requiring high temperatures, and motor usage make up the majority of demand in the region (Figure 3.8). A number of interventions and technologies applying to these and more industrial processes are discussed below. However, the diverse and specialised nature of industrial processes presents a significant barrier to developing both the required holistic expertise and solution packages to deliver efficiencies at scale.

In general, most sectors will benefit from improved energy management, with additional savings available in common processes such as steam, hot water and compressed air generation, and electrical transmission developments. Lighting improvements will be applicable to most sectors, but will have a proportionally higher energy saving contribution in sectors that are less energy intensive. Heat-recovery measures will benefit more energy-intensive sectors such as chemicals, metals, minerals and food and drink. Refrigeration improvements will be most applicable to the food and drink sector, but will also have an impact in other sectors such as chemicals.

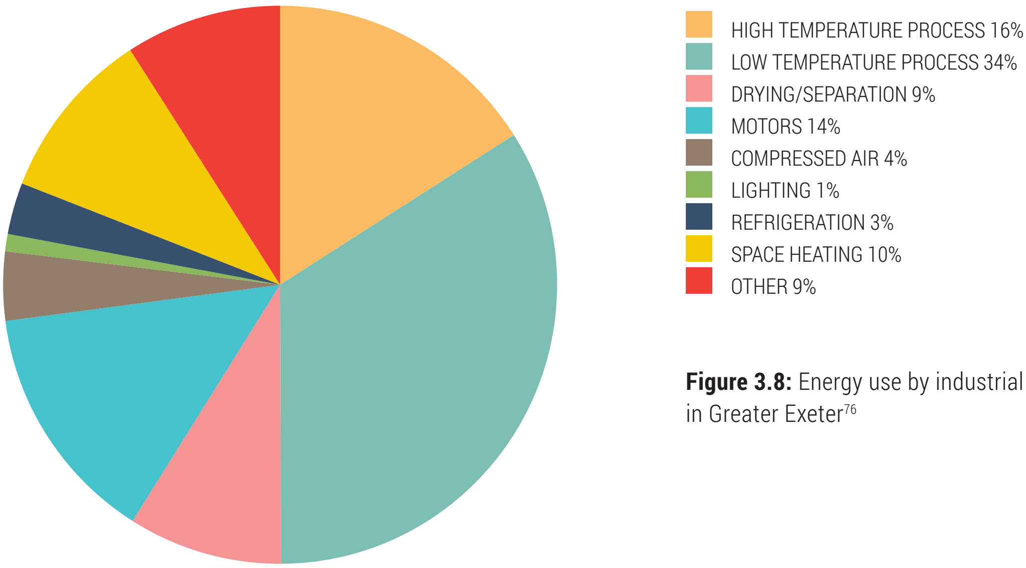


Figure 3.8: Energy use by industrial process in Greater Exeter[76]

[73] DECC (2012). The Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK Strategy and Annexes, [online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65602/6927-energy-efficiency-strategy--the-energy-efficiency.pdf | [74] WSP et al (2015). Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050, [online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/419912/Cross_Sector_Summary_Report.pdf
[75] The 73% scenario required a significant contribution from carbon capture and storage technology, grid decarbonisation, and the use of biomass as an energy source. The saving identified from remaining technologies implied a carbon saving of 16% under this scenario which, assuming a constant energy mix, would imply a similar level of energy saving. | [76] Re-weighted for regional industrial distribution based on data provided by ONS

3.3.1 GENERAL MEASURES

The main potential actions include:

- **Steam and hot water generation and distribution (temperature processes):** Steam is used in a wide range of industrial processes and broadly accounts for around 20 to 25% of industrial energy use. However, it is very sector-specific with the pulp and paper, chemical, refining, and food and drink sectors being the main users. There are a broad range of measures which can improve the efficiency of steam generation and distribution including the use of economisers to recover waste heat, new and optimised burners, instrumentation, recuperators and regenerators, condensate return, insulation of boilers and steam lines, and blowdown heat recovery. Depending on the measures taken, savings of around 5% to 25% can be achieved.

- **Electrification of heat:** Space heating, while lower than in other sectors, still accounts for 10% of industrial energy use. Industry can therefore obtain some benefit from measures to electrify space heating, such as heat pumps. Low temperature processes used, for example, in food and drink and pulp and paper sectors, will also be able to shift towards electrification with existing technologies. Other technologies such as electric melting, electric kilns and electric arc furnaces offer the opportunity to electrify higher temperature processes, but lower efficiencies can result because equipment is not developed at scale[74].

- **Motor efficiency improvement and Variable Speed Drives:** Electric motors are one of the biggest users of electricity in industrial sectors. Approximately 7% of energy savings can be achieved using higher efficiency motors (on replacement of existing motors), and the use of Variable Speed Drives (VSDs). Savings from VSDs will be determined on a case by case basis, but can be up to 50%. Additional savings can be achieved through better sizing of motors and rationalising processes to minimise motor and pump requirements.

- **Waste heat recovery:** There are many opportunities for waste heat recovery and use in industry. In addition to opportunities around boilers, heat can be recovered from equipment used in process operations such as air compressors and refrigeration equipment. Opportunities tend to be site-specific as there needs to be a use for the waste heat reasonably near the source. Larger industries can use process integration analysis to identify opportunities for waste heat recovery and use. Low-grade industrial waste heat could also be used in district heating schemes to provide heat to local housing or non-domestic buildings.

- **Refrigeration:** Refrigeration efficiency can be improved through the purchase of newer, more efficient equipment, through free cooling, and through alternative cooling processes such as evaporative cooling. Use of VSDs and heat recovery can also improve the efficiency of refrigeration. Again, depending on measures taken, the savings can be from 5% to 50% (evaporative cooling).

- **Compressed air:** Production of compressed air is an energy-intensive process. Substantial savings can be made through the elimination of leaks, the eradication of misuse, reduction of compressed air pressure and the use of more efficient air compressors. Savings can be in the region of 10%, depending on the age and state of repair of the current system.

- **Energy management and efficiency:** There are many opportunities to manage energy more systematically on sites, including state-of-the-art automation, process control, monitoring, planning and maintenance. Interventions can also be considered in organisational terms creating operational efficiencies in addition to energy savings. Most industries can benefit from improved energy management and it is conservatively estimated that this can save around 5% of overall energy use. Improvements can be made through better organisation, employment of designated energy managers and energy teams, the use and analysis of energy data and through improved communication with staff.

- **Improved lighting:** Energy use in lighting is less significant in industry compared to the commercial sector. As in commercial buildings, savings of up to 75% can be made from replacement of existing lighting with LED (and other energy efficient) lighting which can also be enhanced through the addition of occupancy and daylight sensors, and appropriate zoning.

- **Longer-term savings:** Process intensification of unit operations used in industry (such as reactors, distillation and other separation processes) could lead to savings in the longer term. Also, changes to process flowsheets to prompt a move to less energy-intensive process steps can lead to substantial savings. Both process intensification and changes to process flowsheets are highly process specific. It is difficult to give specific savings, but a change to the process flowsheets could, in some limited cases, remove up to 50% of energy requirements.

- **Clustering:** The integration between industrial sites to achieve synergies can also create efficiencies over the long term. Many of the energy efficiency measures identified could be enhanced through further industrial clustering.

As well as the measures outlined here, there are several technologies featured later in this report that may have direct implications on the industrial sector. These include:

- **Combined Heat & Power (CHP):** CHP is a viable energy-efficiency technology that is applicable in most industrial sectors. This is discussed further in Section 5.4.2.

- **Biomass:** Use of biomass by industry, if sourced locally, could contribute towards the goal of energy independence. This is discussed further in Sections 4.6 and 4.7.

- **Carbon Capture & Storage (CCS):** While not contributing towards energy independence, CCS is a notable decarbonisation technology that warrants consideration – for example, in the 2050 roadmaps prepared for DECC, CCS is the largest single contributor to industrial decarbonisation under the maximum technology scenario in that study. CCS in both generation and industry is considered in Section 5.6.

3.3.2 BARRIERS

The barriers discussed under commercial buildings are mirrored, and in some cases, exacerbated in industrial settings. The complexity and uniqueness of particular industrial processes means they are more difficult to tackle, and homogeneous solutions more difficult to develop. They are also closely linked to the output and growth of a region making it difficult to find ways to reduce overall demand. More research and demonstrable real-world case studies would help push forward a range of measures and spread best practice.

INCREASING LOW CARBON SUPPLY

4

Greater Exeter has access to abundant natural energy resources due to its position in the South West. Analysis indicates that 153 TWh/year of unconstrained low carbon energy resource remains untapped in the region.

4.1 | RENEWABLE ENERGY

There is considerable unconstrained low-carbon energy resource potential in Greater Exeter and the surrounding region. The following sections estimate the potential renewable resources in the region across a range of technologies under the Maximum Technology scenario and compare this estimate to what is currently installed. It follows that the difference is the potential for new generation. The key barriers currently preventing further deployment are identified, together with potential actions which could help to realise these resources.

Resource estimates follow the principles (and where applicable, the detailed guidance) outlined in the methodology developed for DECC for regional renewable energy assessments[77]. This first estimates the theoretical potential or unconstrained resource, and then considers the physical environmental constraints which apply – large wind turbines cannot be installed in urban or designated areas, for example. Other potential constraints are then identified and added to the analysis. Existing studies were used to provide a resource assessment if they were sufficiently detailed in terms of spatial definition, broadly followed the DECC methodology allowing the impact of constraints to be considered and underlying data sources were considered unlikely to have changed significantly since the study was undertaken.

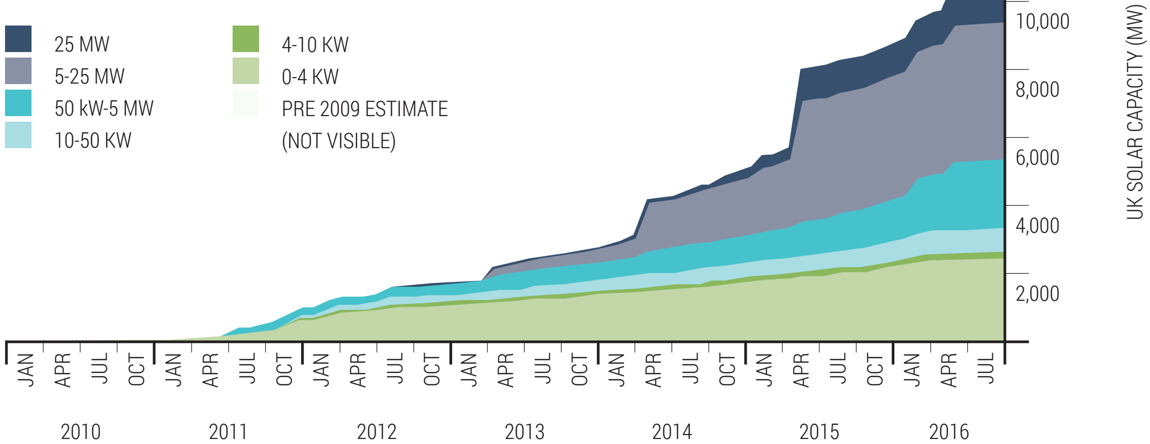
4.2 | SOLAR

Solar Photovoltaic (PV) systems are an established renewable generation technology that convert sunlight into electricity. Since 2011, the PV capacity installed in the UK has seen rapid growth, driven in part by subsidy support. At the end of August 2016 it stood at 11,131 MW across 886,948 installations[78] (Figure 4.1). This is an increase of 32% (2,677 MW) compared to August 2015. PV panels were previously typically mounted on domestic or commercial rooftops, but over the past three years ground-mounted PV farms have dominated new installations. To date, approximately 49% (5,462 MW) of the total installed solar PV capacity comes from large-scale installations greater than 5 MW, with 22% (2,431 MW) coming from small scale 0-4 kW installations, which are typical of domestic systems. As the market has matured, the cost of solar cells has consistently fallen.

Solar panel technology continues to advance, with Swanson's Law[79] predicting a further 20% cost reduction for every doubling of volume. Since solar is a global market that continues to grow, especially where cost parity is being reached, it is likely that panel prices will continue to fall during the 2025 time horizon. Today's typical panels operate with an efficiency of about 10-15%, with the most efficient panels reaching efficiencies of 21%. Of the two main panel types, monocrystalline are more expensive but also more efficient, typically 13-17%. Polycrystalline are cheaper to make, but have lower efficiency, usually 11-15%. New materials, such as Perovskite, may offer higher efficiencies at lower production costs[80] over a near-term time horizon. Certainly, some start-up companies are aiming to market Perovskite modules in 2017.

77 SQWenergy (2010). Renewable and Low-carbon Energy Capacity Methodology: Methodology for the English Regions, [online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226175/renewable_and_low_carbon_energy_capacity_methodology_jan2010.pdf | 78 BEIS (2016). Solar photovoltaics deployment, [online]. Available at: https://www.gov.uk/government/statistics/solar-photovoltaics-deployment | 79 Swanson's Law is the solar analogue to Moore's Law in semi-conductors based on the fact that photovoltaic cell prices have fallen from $76.67 per watt in 1977 to $0.36 per watt in 2014. | 80 Perovskite is the fastest-advancing solar technology to date.

Figure 4.1: UK SOLAR DEPLOYMENT BY CAPACITY (MW)



As costs fall, solar technology is increasingly being integrated into building components such as roof tiles or other pre-fabricated products[81]. This trend is likely to continue as the technology develops – thin-film Perovskite, for example, offers the potential for being printed directly on to glass or other surfaces[82]. There is little doubt that further cost decreases, efficiency improvements and aesthetic design enhancements make solar a very attractive technology for inclusion in a future renewable generation mix.

The South West has considerable solar resources, given the abundance of sunlight in relation to the rest of the UK. Greater Exeter has a total unconstrained solar resource as high as 111 TWh with opportunities to capture up to 2.5 TWh across ground mounted arrays, commercial and domestic rooftops and over car park canopies. Each option, and the level of energy that could realistically be captured from this resource, is considered in detail below.

4.2.1 ROOF MOUNTED SYSTEMS

Roof mounted PV systems are a mature and proven technology, and are one of the most well-developed and economically viable forms of renewable energy in the UK. Potential generation from roof mounted systems has been estimated based on the number of existing and forecast new buildings, using the DECC methodology to estimate installation capacity, and the methodology in the Standard Assessment Procedure[83] for buildings to estimate the amount of electricity generated. It is estimated that roof mounted PV systems on existing buildings in the Greater Exeter area could potentially generate 440 GWh (Table 4.1), representing 4% of current energy demand in the region. The clear majority would come from installations on commercial buildings due to the large system sizes which are possible. Installation on new houses and commercial properties to 2025 could add a further 115 GWh, giving a total potential generation of 555 GWh (almost 6% of current energy demand in the region).

Information on current installations is available from Feed in Tariff (FiT) data. This suggests that around 42% of the potential identified in domestic buildings has already been installed, reflecting tremendous growth in small and medium scale renewable energy capacity since the FiT incentive was introduced in April 2010, with more than 100,000 roof mounted solar PV installations in the South West region[84]. However, for commercial buildings, only 6% of potential capacity appears to have been installed.

81 Most notably Tesla's recent announcement but also early-stage companies in the UK such as ZED Factory and Minus7.
82 Oxford Photovoltaics Ltd | 83 Generation is calculated following the methodology described in the "SAP 2012 version 9.92" assuming panels are south facing, unshaded, and have an inclination of 30 degrees | 84 Ofgem database on FiT

Region Potential installed capacity	Greater Exeter (MWp)	Devon (MWp)	Wider Region (MWp)	SW Region (MWp)
Existing dwellings	101	167	538	1,175
Commercial properties [a]	349	576	1,993	4,104
New developments - domestic	28	39	93	211
New developments - commercial	91	150	511	1,060
Total	569	932	3,135	6,550
Current installed capacity	63	132	399	658
Commercial (FiT)	21	53	180	287
Domestic (FiT)	42	79	219	371
As % of current potential resource	14%	18%	16%	12%
Commercial	6%	9%	9%	7%
Domestic	42%	47%	41%	32%
POTENTIAL GENERATION	(GWh)	(GWh)	(GWh)	(GWh)
Existing dwellings	99	163	525	1,148
Commercial properties	341	563	1,946	4,007
New developments - domestic	27	38	91	206
New developments - commercial	88	146	499	1,036
Total	555	910	3,061	6,397

(a) Commercial properties include retail, offices and industrial

Table 4.1: Potential generation from rooftop PV systems

4.2.2 BARRIERS

The barriers to deployment of roof mounted PV have been mainly legal, particularly with regard to the leasing of commercial properties and the fact that under the FiT tariff regime, equipment can be registered only once. This means that tenants have been unable to take solar panels with them or sell them on at the end of a lease. It is anticipated that as solar installations become viable without tariffs, commercial rooftop activity will increase, as long as no further barriers, such as increased business rates on rooftop arrays, are introduced.

4.2.3 CARPORTS

Installing solar systems above surface and multi-storey car parks is becoming increasingly common in Europe and is starting to be considered in the UK. In fact, the first car parks in Britain to be fitted with solar car port frames were in Exeter, where the John Lewis and Mary Arches Street Car Parks have each been fitted with 150kWp systems[85]. There are currently many options available to suit different car park layouts. The configuration that is most suited to low-cost solar installation is long double rows of car parking adjacent to high energy users where electricity can be consumed directly rather than being exported to the grid. Potentially suitable sites include hospitals, airports, retail parks, schools and large commercial premises[86].

No estimate was available of the total number of suitable car parking spaces in the Greater Exeter area, although it contains many of the types of sites where installation is more favourable. An order of magnitude estimate of the potential has been made based on the total number of motor vehicle commuters visiting the city every day. Based on this we estimate the existence of at least 15,000 low-rise parking spaces (Exeter City Council alone is estimated to provide almost 4,000 public parking spaces[87]). It is considered that each parking bay can host between 2-3kWp, generating between 2-3 MWh per year depending on the orientation and inclination of the arrays. If 15,000 parking bays were covered with solar ports, this would give between 30-45 MWp of installed capacity generating approximately 29-44 GWh per year.

85 Western Morning News (2015). Exeter's solar powered car parks a UK first, [online]. Available at: http://www.westernmorningnews.co.uk/exeter-s-solar-powered-car-parks-uk/story-28034838-detail/story.html | 86 BRE (2016). Solar Car Parks: A guide for owners and developers, [online]. Available at: http://www.r-e-a.net/upload/rea-bre_solar-carpark-guide-v2_bre114153_lowres.pdf | 87 Exeter City Council (2016). Find a car park, [online]. Available at: https://exeter.gov.uk/car-parking/car-parks/find-a-car-park/

4.2.4 GROUND MOUNTED SYSTEMS

Ground mounted solar farms have become more common in recent years due to improving technology, falling costs and the lower likelihood of severe landscape and visual impacts. Solar farms are typically large, constructed on hectares of agricultural land and generate multiple MWs of electricity at peak times of operation. The potential generation from solar farms has been estimated with the following considerations in addition to the practices given in regional assessment methodology[77]:

- Only lower grade agricultural land should be used (Grade 3b, 4 and 5 are considered suitable for PV installations).
- Land with a landscape designation should not be used.
- Slope consideration is a key requirement for ground mounted PV systems. For inclinations of 0-3° from the horizontal, all orientations are considered suitable. For inclinations between 3-15° only southwest to southeast facing areas are considered suitable. Slope inclinations above 15° are considered unsuitable.

The total potential for ground mounted solar in the Greater Exeter region – after exclusion of areas unsuitable for development such as built-up areas, roads, areas with landscape designations, areas with unsuitable inclination and orientation, and high grade agricultural land – is 51.5 TWh. The database of land use does not distinguish between the various sub-grades, so it is not possible to exclude only Grade 3a land.

If all Grade 3 land is excluded, then the potential area and generation is reduced by over 80% to 9.7 TWh. However, it is unrealistic to consider that all of this could be developed for solar farms. Overall, this study assesses that no more than 20% of the remaining land area would be available without displacing food supply chains so the maximum technical potential considered is 1,938 GWh. A more detailed survey of the production supply chain, visual impact, shading, connection distance and access for construction would need to be undertaken to increase the confidence in this figure. An element of conservatism is built into this figure since a typical solar PV panel at today's efficiency of 15% has been used whereas the technology efficiency could be expected to increase by up to 5% by 2025.

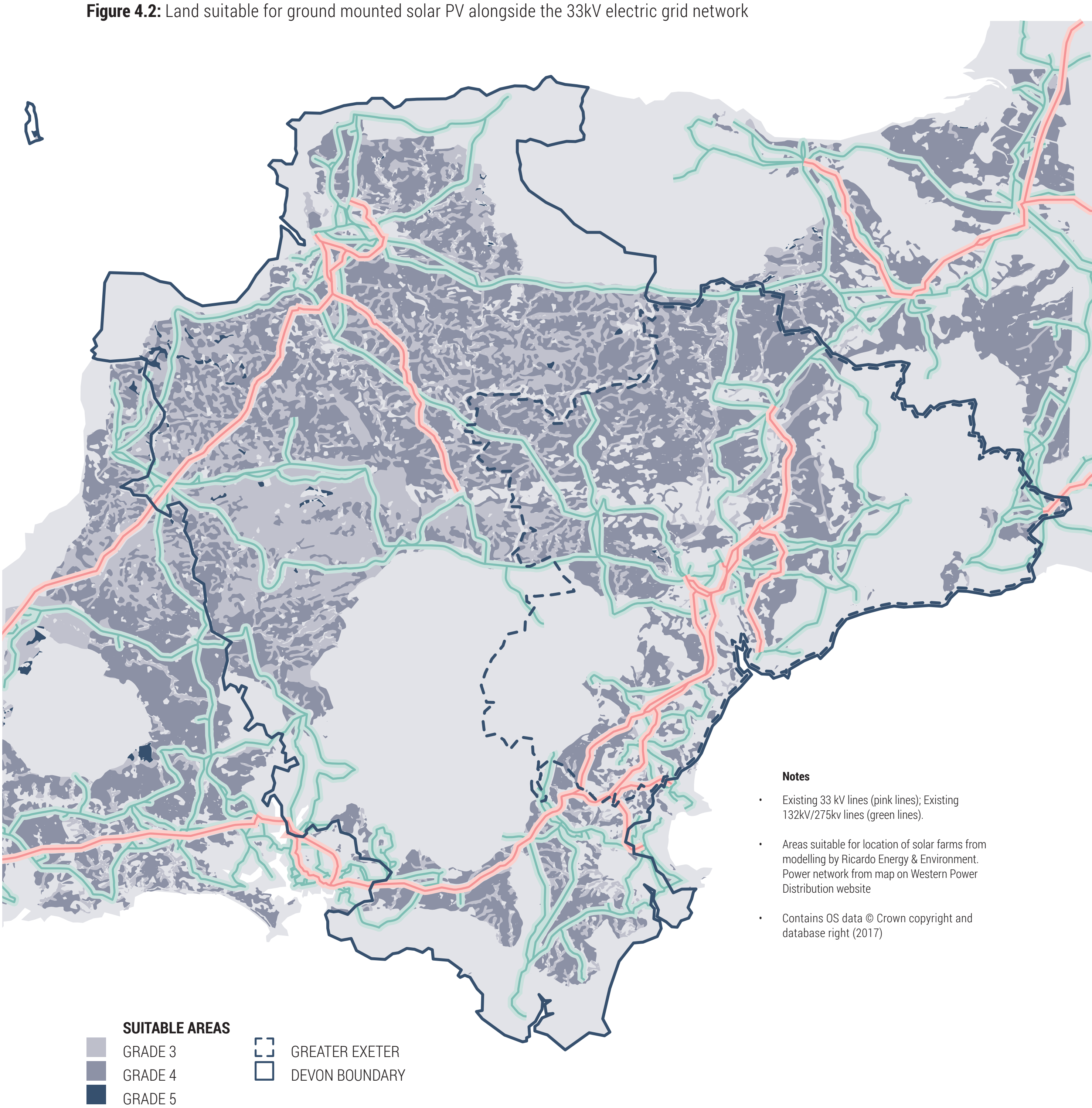
4.2.5 BARRIERS

The main barriers to deployment of ground mount solar are technical, political and financial, although financial constraints related to panel prices are expected to lessen over time. The key technical barrier that currently restrains deployment is the grid – in particular, the current capacity restrictions in the South West region and the cost of connection to the grid when capacity is available. The cost of grid connection means that a solar farm will typically need to be located within 2 km of the 33 kV (or higher) network[88], which could substantially reduce again the potential shown in Table 4.2. The location of land suitable for solar PV farms and the location of the network lines above 33kV are shown in Figure 4.2, but it should be noted that in some areas there may already be grid capacity constraints. A study by WPD/Regen SW estimated that there could be about 1000 km^2 (equivalent to approximately 40GW of solar PV capacity) of land suitable for PV development (of Grade 3a or below) in the South West Region which was also within 2 km of the network[88]. This is about 20% of the capacity indicated in Table 4.2. Energy storage or the use of physical private wire systems to connect solar farms directly to suitable demand loads could help overcome these constraints in some instances (as further discussed in Section 5.1).

A further key issue is the political response to ground mounted solar. While the lower visual and environmental impact of solar farms (compared to wind turbines) means that they are generally more acceptable, there are potential concerns about cumulative impacts, which mean that development in any single area is likely to be limited. The SQW methodology does not provide any guidance on cumulative impact for ground mounted solar and local consultation is likely to be required.

88 WPD and Regen South West (2016). Distributed generation and demand study – Technology Growth Scenarios to 2030, [online]. Available at: https://www.regensw.co.uk/distributed-generation-and-demand-study-technology-growth-scenarios-to-2030

Figure 4.2: Land suitable for ground mounted solar PV alongside the 33kV electric grid network



Notes

- Existing 33 kV lines (pink lines); Existing 132kV/275kv lines (green lines).
- Areas suitable for location of solar farms from modelling by Ricardo Energy & Environment. Power network from map on Western Power Distribution website
- Contains OS data © Crown copyright and database right (2017)

	Greater Exeter GWh	Devon GWh	Wider Region GWh	SW Region GWh
Unconstrained	111,118	303,927	414,353	842,306
After exclusion of areas with landscape	71,186	189,027	415,213	614,471
After exclusion of unsuitable slopes and orientations	66,469	177,015	260,923	261,009
After exclusion of higher grade (1 and 2) agricultural land	51,563	157,728	227,574	227,574
After exclusion of agricultural grade 3 land	9,688	55,157	85,339	85,367

Table 4.2: Potential generation from ground mounted PV systems

4.2.6 SOLAR THERMAL

Although unlikely to change the overall picture significantly, solar thermal collectors offer an alternative option to solar PV systems. Unlike solar PV systems that convert sunlight into electricity at up to 20% efficiency, solar thermal panels convert sunlight directly into heat with system efficiencies in excess of 60%[89]. Evacuated tube systems are best suited to industrial applications where high temperatures are required[90], however they can also be used alongside advanced flat plate collectors in domestic applications. Hybrid panels, such as the Solar Angel PV-T, offer combined solutions that deliver both thermal and electrical power and are well suited to integrated energy solution applications. By way of example, a hybrid PV-T panel can produce hot water at up to 45 degrees Celsius which is well matched to the pre-heat requirement of heat pumps, increasing their operating efficiency. Solar thermal systems may also be able to link into district heating networks (discussed further in Section 5.4). The UK's first demonstrator project, located in Cranbrook, near Exeter, will utilise 2,000 square metres of solar thermal collectors linking into a district heating system supplying heating and hot water to 3,500 homes as well as 130,000 square metres of industrial space at Skypark[91].

Solar thermal may also play a role in other sectors such as agriculture, especially the dairy industry, where large volumes of water tend to be heated by immersion elements and could benefit from energy savings if such systems were adopted. Planning and other practical considerations should be fairly straightforward to overcome.

89 University of Strathclyde (2016). Domestic solar water heating, [online]. Available at: http://www.esru.strath.ac.uk/EandE/Web_sites/09-10/Hybrid_systems/solar-thermal.htm, | 90 Viridian Solar (2016). A guide to solar energy, [online]. Available at: http://www.viridiansolar.co.uk/Solar_Energy_Guide_3_3.htm, | 91 University of Exeter (2015). UK-first renewable heat network demonstration secures research funding, [online]. Available at: http://www.exeter.ac.uk/news/research/title_431154_en.html

4.3 | WIND

Wind power accounted for 47% of total UK renewable generation in 2015[36]. Since 2009, the installed capacity for both onshore and offshore wind has seen rapid growth (Figure 4.3). At the end of July 2016, installed capacity stood at 14,653 MW. 2016 energy generation from wind turbines is likely to exceed 40 TWh, representing the energy demand of four regions of similar size to Greater Exeter. While onshore wind capacity is almost twice that of offshore wind, offshore contributes 43% of the wind generation mix due to higher wind speeds out at sea meaning that offshore wind installations tend to have a higher capacity factor than onshore.

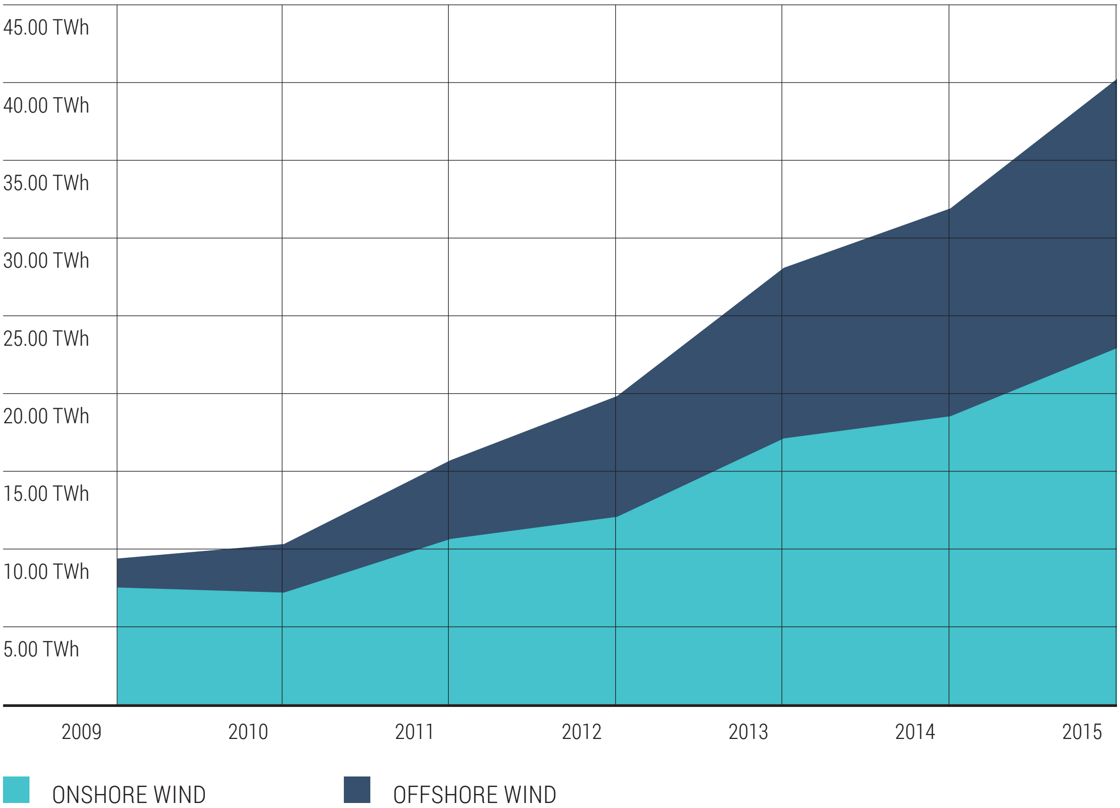


Figure 4.3: Annual generation from UK wind power

4.3.1 ONSHORE WIND

Onshore wind energy technology ranges from small wind turbines with a rated output ranging from 0.05-50 kW, medium turbines ranging from 50-500 kW, and large turbines rated above 500 kW. Large wind turbines are a mature and proven technology, and are one of the most developed and economically viable forms of renewable energy in the UK. Some types of small wind technology have also matured and newer turbines in the small- to medium-size range are increasingly being deployed.

The total unconstrained potential for wind in the Greater Exeter region – after the removal of areas unsuitable for development such as built-up areas, roads and areas of low wind speed – is 41.6 TWh[92]. This potential is reduced by about 40%, to 26.2 TWh if areas with a landscape designation are excluded. Excluding areas where there may be interference with radar used at airports or by the Ministry of Defence (MOD) has an even more substantial effect, reducing the remaining potential by 96% to 1.2 TWh or 12% of current energy demand (Table 4.3; Figure 4.4). This is due to the proximity of airports at Exeter, Farway Common, Yeovil/Westland and Yeovilton (MOD), and National Air Traffic Services (NATS) radar sites at Burington and Hartland Point. However, the high quantity of wind turbines already deployed in these constrained areas indicates that radar should not be considered as a blanket constraint to wind energy development.

Research into the impacts of, and methods to reduce, clutter effects of wind turbines on radar signals conclude that clutter suppression techniques and advanced digital tracking may reduce the effects on radar using Doppler technology. This may allow wind turbines to be situated within radar constrained areas. However, such techniques cannot be used on radar systems which do not utilise Doppler processing[93]. Mitigation measures are also available to wind farm developers for installation on their sites to ensure they meet the requirements set out by radar operators. The key to overcoming this is consultation with relevant authorities to determine the potential that could be realised. Similarly, the installation of wind farms on some landscape-designated areas might be permitted depending on the reason for the site designation. This would need to be established through consultation with the various stakeholders.

Wind generation in Greater Exeter and Devon currently occupies a tiny fraction (0.2 and 1.3%) of the areas identified as having no landscape or aviation constraints, which suggests that significant future development could be possible. However, the levels of deployment to date may indicate the existence of some sizeable barriers such as planning, cumulative impact and grid constraints. Recently there has been increased interest in installing turbines on existing solar farm sites since the typical seasonal variation between the two generation profiles means that a connection can be shared without major power curtailment making the schemes economically viable. Under the Business As Usual scenario, 2025 generation is forecast to be only 3.4 GWh. Assuming radar constraints can be overcome through technology and consultative measures, the maximum potential for wind generation in Greater Exeter could be up to 13.1 TWh (Table 6.1).

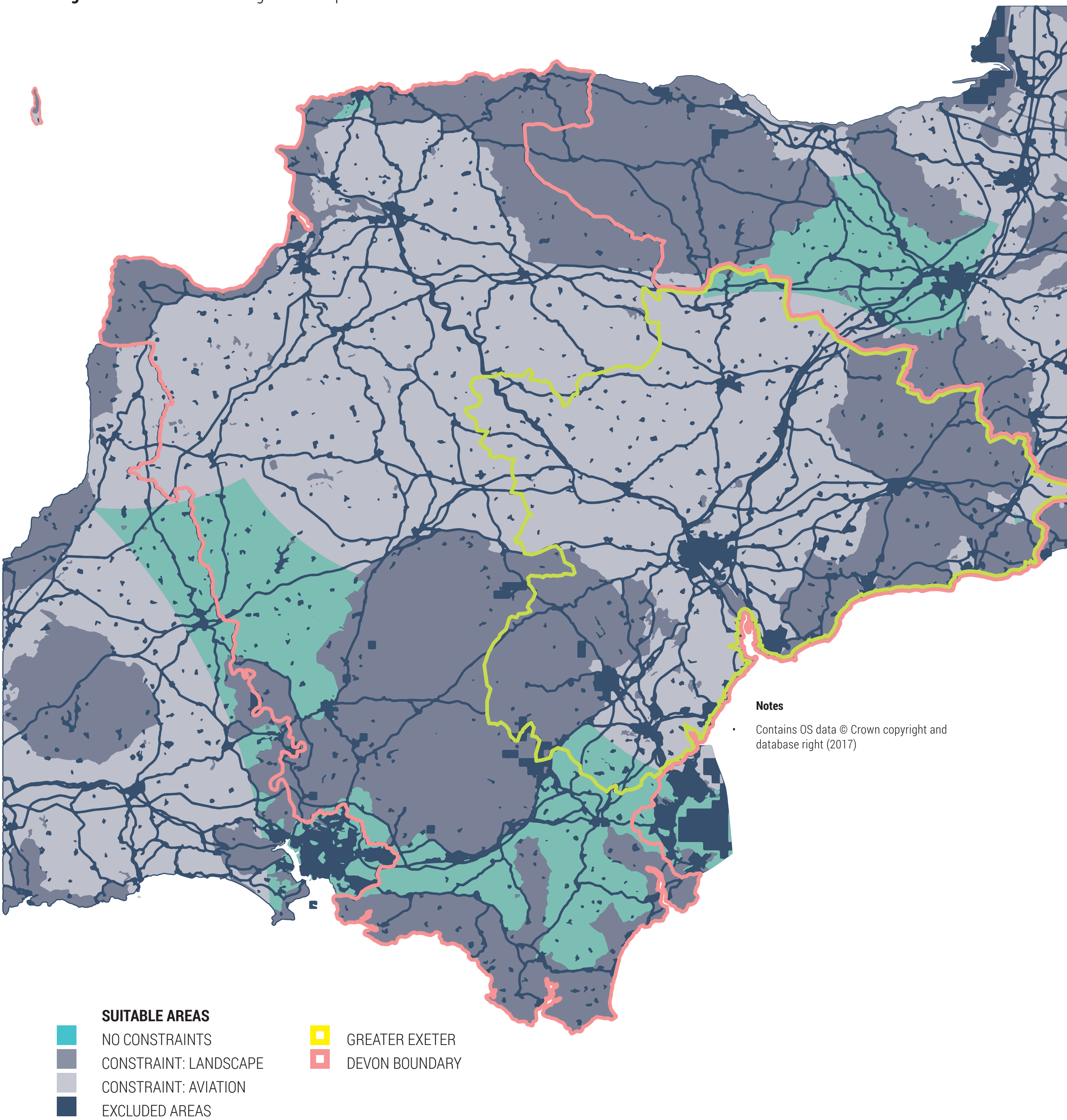
Potential generation (GWh per year)	**Greater Exeter** GWh	**Devon** GWh	**Wider Region** GWh	**SW Region** GWh
Unconstrained	41,643	116,947	237,684	404,720
After exclusion of areas with a landscape designation	26,171	71,178	148,656	225,175
After exclusions of areas with radar restrictions	1,242	13,283	20374	21,309
Generation in 2014	2	167	383	456

Source: Modelling by Ricardo for potential generation and RESTATs for current generation

Table 4.3: Potential wind generation

92 As estimated using the SQW guidance for DECC on regional renewable energy assessments, but with an updated capacity factor based on an average factor for the last five years for the South West region of 26.3%. | 93 L. Rashid and A.Brown (2010). Radar and Wind Farms, [online]. Available at: https://community.dur.ac.uk/supergen.wind/docs/presentations/2010-09-24_8_2_Rashid_radar.pd

Figure 4.4: Areas with wind generation potential in Devon



Notes

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4.3.2 BARRIERS

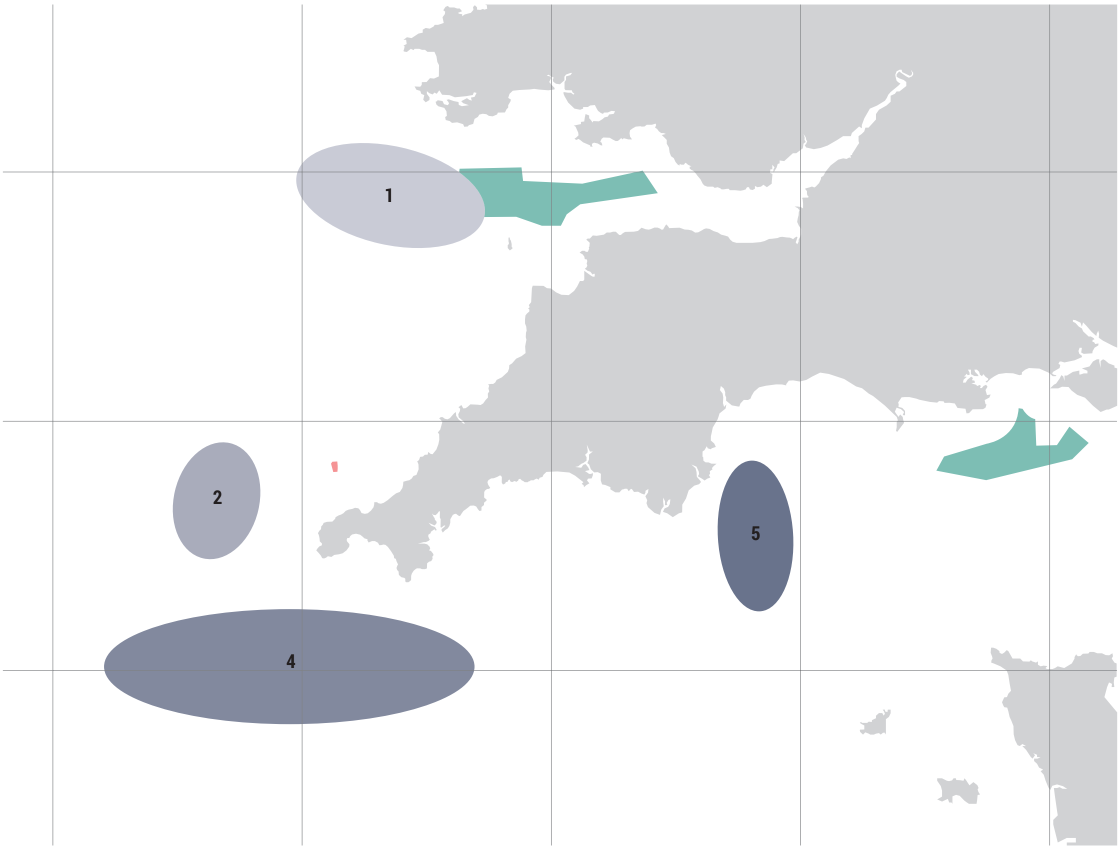
The technical barrier of radar has been discussed in detail. Assuming this can be remedied giving an annual resource potential of 26.2 TWh, the remaining barriers to onshore wind would be mainly political and to a lesser extent, grid-related. Financial barriers exist and will be site dependent, but the base case of this study is that price falls will make wind increasingly attractive over the time horizon. Political issues, in particular the cumulative impact of wind, could play a major role in limiting Maximum Deployment potential. The estimates performed by this study suggest that if the distance between wind farm sites was 15 km, a maximum of 5.7% of available land would be usable in practice for wind farms of average capacity 10 MW. This would reduce the level of generation achievable to 157 GWh. If impact constraints were to be relaxed to 5 km between farms, the achievable generation would increase to 1.5 TWh. To put this in context, this level of deployment would equate to 3% of Greater Exeter's unconstrained land area.

4.3.3 OFFSHORE WIND

The UK had 5.1 GW of offshore wind installed as of July 2016 which is likely to generate 17.4 TWh in 2016. Further capacity is under construction, and the industry is on track to deliver 10 GW by 2020[94], potentially generating 34 TWh in total[95]. An assessment for the South West[96] estimated potential for 6.9 GW within 50 km of regional shores (Figure 4.5), with one potential indicative area with a capacity of 1 GW identified as outer Lyme Bay (to the south east of Exeter). However, the South West has no existing or planned capacity, and two proposed projects in the region, the Atlantic Array Wind Farm (1.2 GW) in the Bristol Channel and the 970 MW Navitus Bay project (to the west of the Isle of Wight) have now been withdrawn[97].

4.3.4 BARRIERS

The deep water surrounding much of the South West coast presents considerable challenges for offshore wind, and other approaches such as floating platforms may be necessary to unlock the energy potential. Demonstration and pilot projects for floating platform technology and new foundation and installation concepts could help to unlock more sizeable opportunities for wind farm development in deeper water in the outer Bristol Channel, Celtic Sea and off the south coast. Deployment and maintenance costs for offshore arrays are higher than their onshore equivalents, which certainly impacts the viability of smaller schemes. Offshore schemes also give rise to significant political barriers, with the potential for coastal and marine environmental impacts causing concern.



INDICATIVE POTENTIAL DEVELOPMENT FOR OFFSHORE WIND DEVELOPMENT

1 OUTER BRISTOL CHANNEL
2 NORTH OF THE ISLE OF SCILLY
3 WEST OF THE ISLE OF SCILLY (EXCLUDED)
4 SOUTH CORNWALL OFFSHORE
5 OUTER LYME BAY
ROUND 3 ZONES
WAVE HUB

Figure 4.5: Indicative potential development areas for offshore wind 2010-2030

[94] UK Trade and Investment (2015). UK Offshore Wind: Opportunities for Trade and Investment, [online]. Available at: http://www.greeninvestmentbank.com/media/44638/osw-pitchbook_ukti_june-2015.pdf | [95] Based on existing 5 GW generating 17 TWh | [96] PMSS (2010). Offshore Renewables Resource and Deployment Report, [online]. Available at: http://www.wavehub.co.uk/downloads/Resource_Info/offshore-renewables-resource-assessment-and-development-(orrad)-october-2010.pdf | [97] Western Power Distribution and RegenSW, (2016). Distributed generation and demand study – Technology growth scenarios to 2030, [online]. Available at: https://www.westernpower.co.uk/docs/About-us/Our-business/Our-network/Strategic-network-investment/WPD-Regen-DG-Growth-Scenario-Report-RevisionA.aspx

4.4 | HYDRO

The unconstrained potential for small and micro (<50 kW) scale hydropower in the Greater Exeter region is estimated to be 42.4 GWh (Table 4.4), which is equivalent to 2% of the region's current electricity consumption. This is based on a resource assessment conducted by the Environment Agency[98] which identified sites where there was enough potential difference in river levels to generate power.

In 2014, only 5% of this potential was actually being exploited, although across the wider region this rises to 22%[36]. Hydropower is a mature, proven and effective technology, and although upfront costs are high, support for micro-hydro schemes is available under the Feed in Tariff scheme. Each potential site will need further evaluation to ensure it is suitable for generation, and that environmental concerns such as protecting fish and wildlife can be met.

Capacity	Greater Exeter GWh	Devon GWh	Wider Region GWh	SW Region GWh
Total potential generation	42.4	77.4	113.8	172.7
Current generation (2014)	2.0	16.7	22.8	24.6

Notes: Potential generation from spreadsheet 'Potential Sites of Hydropower Opportunity' accompanying the report Opportunity and Environmental sensitivity mapping for hydropower, Environment Agency, undated. Current generation from RESTATS 2015.

Table 4.4: Hydropower potential

Even if the potential contribution from hydro power is small, the availability of energy from hydro would typically fit well with periods of low solar or wind resource and could still be an important element of the overall energy mix.

4.5 | BIOENERGY: FORESTRY RESIDUES AND OTHER CLEAN WOOD RESIDUES

4.5.1 OVERVIEW

Forestry residues and other 'clean' waste woods could provide up to 352 GWh (Table 4.5) of heat fuel in Greater Exeter area (9% of non-transport fuel use in 2013) or 106 GWh if used to generate electricity (5% of electricity use in 2013). The main barriers to use of the largest part of this resource (forestry residues) relate to customer awareness, the acceptance of biomass as heat source and committed, long-term policy support for biomass technologies. The former could be addressed by supplying reliable independent information on how to install and operate biomass systems and their costs and benefits.

98 Environment Agency (undated). Opportunity and Environmental Sensitivity Mapping for Hydropower. [online]. Available at https://ea.sharefile.com/share?#/view/se5dc68954964d548

4.5.2 POTENTIAL RESOURCE

Wood suitable for combustion in boilers, CHP plant or dedicated biomass power plant includes:

- **Forestry residues:** the estimate of 'thinnings' and residues from forestry and woodland management is based on the National Inventory of Woodland and Trees (NIWT). This is the 'operationally available' resource, i.e. it does not consider the cost of extraction of the wood, or issues of access to the woodland, and is based on the sustainable biomass yield from forestry, including sawmill residues from the harvested timber. More recent Forestry Commission data reported by South West Electric Co-operative (SWEC) in 2014 suggests that woodland areas, and hence the resource available in Greater Exeter and Devon, may be higher than shown in Table 4.5.

- **Arboricultural arisings:** these arise from management of gardens and parks and other public spaces, tree surgeon waste and from roadside management such as hedge trimming. About 55% of the resource identified is higher quality stem wood and 45% is lower quality wood, suitable only for larger scale combustion plant. An additional resource could be coppiced wood from hedgerow management of wood fuel. Early estimates from Devon Hedge Group[99] suggest that changing hedge management to encourage coppicing of suitable species could result in around 300 odt/y wood resource, approximately 7% of the estimated arboriculture arisings.

- **Clean waste wood:** Clean waste wood includes untreated ('clean') waste wood from timber-consuming industries such as the furniture industry and waste wood from construction sites. Much of the former may already be utilised for on-site power production.

[99] Barnes S et al, 2013. Tamar Valley Area of Outstanding Natural Beauty Significant Hedge Survey

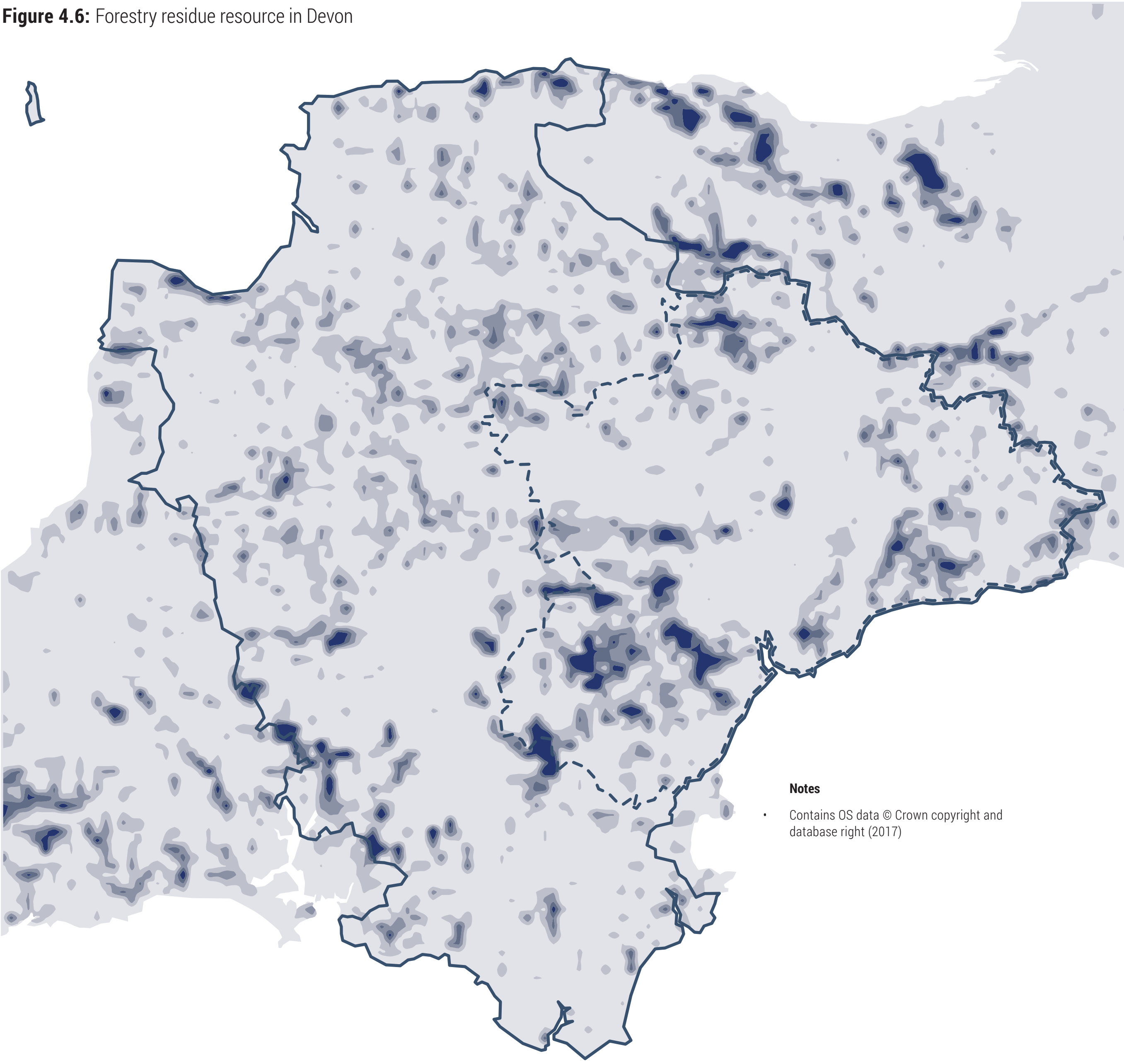
odt (of fuel)	**Greater Exeter**	**Devon**	**Heart of SW**	**SW Region**
Forestry residues	56,528	131,957	252,181	429,884
Arboricultural arisings	2,869	4,791	16,271	33,437
Clean waste wood	7,338	12,541	41,049	83,603
Total	66,735	149,289	309,501	546,924
Resource in woodlands currently managed	26,694	64,269	164,036	289,870
GWh (of fuel)				
Forestry residues	298	696	1,331	2,269
Arboricultural arisings	15	25	86	176
Clean waste wood	39	66	217	441
Total	352	788	1,633	2,887
GWh (of electricity if used for generation)				
Forestry residues	90	209	399	681
Arboricultural arisings	5	8	26	53
Clean waste wood	12	20	65	132
Total	106	236	490	866

Notes: Based on estimates of the fraction of woodland managed in SWEC (2014) for Devon (43%) and Greater Exeter (40%) and a national average value for the wider region and the South West (53%)[100].

Table 4.5: Unconstrained potential resource: forestry residues and 'clean' wood wastes

[100] AEA (2010). Regional Potential for sustainable renewable energy: biomass south west- stage 1 Resource quantification. EA Science report SC090009

Figure 4.6: Forestry residue resource in Devon



Notes

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FORESTRY (odt/km^3)

- 0 - 25
- 26 - 50
- 51 - 75
- 76 - 100
- 101 - 243

GREATER EXETER

DEVON BOUNDARY

4.5.3 BARRIERS

The key barriers for wood fuel supply are outlined below:

- For **forestry residues** the main supply side barriers relate to the small size and inaccessibility of individual woodlands, and the need to ensure a forestry products market which can ensure woodland management is economically-motivated. Devon is making good progress with these issues already, working with the Forestry Commission. For the future, this initiative needs to be maintained and expanded.
- For **arboricultural arisings** the issue is in ensuring the material is separated at collection, and is of sufficient quality for use as wood fuel. This will require public education and provision of suitable collection points.
- For **clean waste wood** the supply-side issue is again to ensure that clean wood waste is kept separate from other wastes. This will require staff education, staff incentives and provision of suitable containers.

The demand-side barriers for small scale heat from biomass relate to potential customer awareness and acceptance of renewable energy in general and biomass in particular. In addition to committed, long-term policy support for biomass technologies, customers have highlighted the need for reliable independent information on how to install and operate biomass systems and the costs and benefits of these systems. The barriers to use of clean waste wood are assessed as lower than for forestry residues. This is because the clean waste wood fuel supply is of consistent quality and often available on the site where heat is required. Utilisation of waste wood is also a waste disposal solution and heat production is often economic without further support.

> *The demand-side barriers for small scale heat from biomass relate to potential customer awareness and acceptance of renewable energy in general and biomass in particular. In addition to committed, long-term policy support for biomass technologies, customers have highlighted the need for reliable independent information on how to install and operate biomass systems and the costs and benefits of these systems.*

4.6 | BIOENERGY: CROPS

4.6.1 POTENTIAL RESOURCE

Perennial bioenergy crops suitable for cultivation in Devon on arable land or reasonable quality permanent pasture are Miscanthus (a woody rhizomatous grass) and Willow or Poplar grown using a Short Rotation Coppice (SRC) technique. The planting, cultivation and harvesting of these crops requires specialised equipment, techniques and planting material, but once established they require less input in agrochemicals and labour than annual crops. Once they reach maturity (up to four years) they are harvested at regular intervals - typically every year for Miscanthus and every four years for Willow SRC. After about 20 to 25 years the crop is removed and replanted, and then the harvesting cycle begins again.

Wood from SRC is suitable for use in small scale boilers to produce heat, or in a dedicated biomass CHP or power plant to produce electricity as well as co-firing in existing power plants. Miscanthus however, while suitable for combustion in purpose-designed plant for power generation, must be briquetted or pelleted for use in small scale boilers.

The South West has had one of the highest planting rates for Miscanthus in England - 23% of Miscanthus planted for energy purposes in England is in the South West. Likely reasons include the suitability of the region for Miscanthus as a crop, both climatically and in terms of soil type, and the influence of Bical who were located in the region and helped to pioneer use of the plant. However, the total planted area and the annual rates of planting for both Miscanthus and SRC are slowly declining from a maximum in 2009[101], with plantations being replaced with conventional crops suggesting there are problems in the ongoing development of energy crops, both in Devon and England as a whole.

The unconstrained resource from energy crops (Miscanthus and SRC) for the Greater Exeter region is estimated to be 745 GWh of fuel (7.5% of fuel use in 2014). However, the need to restrict planting of these crops to land not required for food or feed, and to avoid areas of permanent grassland and landscape-designated areas could reduce this to 91 GWh (or 0.1% of current energy use). Improving the productivity of food and feed production, or producing foodstuffs with a lower land footprint could allow more land to be available for energy crop production.

Estimated quantities of SRC and Miscanthus which could be grown, the amount of solid fuel they could replace (in boilers) and the electricity they could produce are shown Table 4.6 based on AEA (2010)[102]. The estimates include the following constraints:

- Removal of areas such as urban land, water bodies, roads and other infrastructure
- Removal of areas with sites of cultural heritage, designated areas, landscape sensitivity
- Removal of grade 1 and 2 agricultural land
- Areas where yield was considered too low (less than 9 odt/ha) to make cultivation economically viable.

This leads to the estimate of unconstrained potential in Table 4.6. In addition, it was considered that it might not be desirable to grow energy crops in designated landscape areas, or on permanent grasslands, which reduces the potential resource still further. The use of permanent grassland was excluded as ploughing up permanent grassland to allow cultivation of energy crops typically causes a large carbon emission. However, the cultivation of energy crops requires no tilling during the lifetime of the plantation, and plant root structures rebuild the soil carbon store[103]. It is not clear how this new carbon store is affected when the plantation is grubbed up at the end of its lifetime for replanting, so there is some uncertainty over the net carbon emissions over the plantation life cycle. Authoritative evidence on this issue could help to identify where conversion of permanent grassland to energy crops should be encouraged.

Finally, it is also necessary to take account of the need to use land for existing uses, such as food and feed production[104]. The AEA study assumed that up to 90% of suitable land would be needed for these uses, leaving 10% for energy crops. This report takes a more optimistic view of potential improvements in food and feed production efficiency, as well as the reduction in food and feed production land use which could be achieved through dietary changes. Vegetarian diets typically require smaller areas of land to support them than diets including meat (particularly beef)[105]. It is therefore assumed that up to 20% of the arable land might be available for growing energy crops.

[101] Defra (2015). Area of Crops Grown for Bioenergy in England and the UK: 2008 – 2014, [online]. Available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483812/nonfood-statsnotice2014-10dec15.pdf | [102] AEA (2010). Regional Potential for sustainable renewable energy: biomass south west- stage 1 Resource quantification. EA Science report SC090009 | [103] See for example, Behongaray B et al, 2016. Soil carbon and belowground carbon balance of a short rotation coppice: assessments from three different approaches. | [104] Displacing food and feed production form the UK to release land for energy crop production could have undesirable impacts, causing food production to be expanded in other countries, resulting in land use change and associated carbon emissions. It is therefore important that energy crop production is restricted to areas of agricultural land not required for food and feed production. | [105] See for example https://www.sciencedaily.com/releases/2007/10/071008130203.htm. GCB Bioenergy

Typical locations where Miscanthus and SRC could be grown in Devon are shown in Figure 4.7.

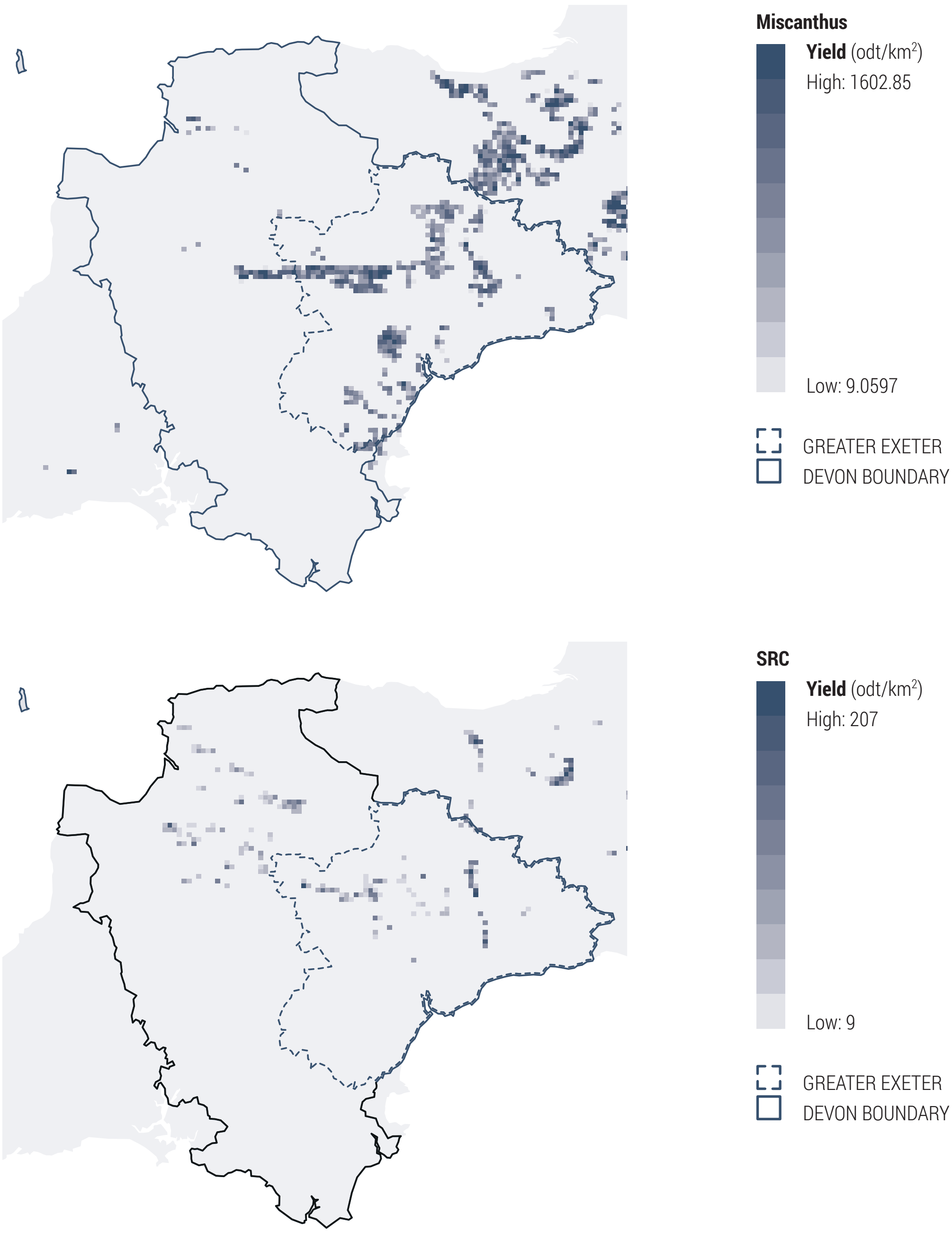

Figure 4.7: Areas suitable for growing energy crops in Devon

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odt (of fuel)		Greater Exeter	Devon	Wider Region	SW Region
Unconstrained potential - all suitable lower grade arable land	**Miscanthus**	124,510	147,199	398,629	974,422
	SRC	22,068	40,860	71,640	291,984
	Total	146,578	188,059	470,269	1,266,406
Remaining suitable arable land after major constraints - permanent grassland and landscape designated areas	**Miscanthus**	77,509	89,994	244,906	448,279
	SRC	12,384	21,528	39,780	128,328
	Total	89,893	111,522	284,686	576,607
After allowing for food and feed production (assumed to require 80% of land)	**Miscanthus**	15,502	17,999	48,981	89,656
	SRC	2,477	4,306	7,956	25,666
	Total	17,979	22,304	56,937	115,321
Estimated area growing in 2013	**Miscanthus**				16,000
	SRC				1,270
	Total				17,270
GWh (of fuel)					
Unconstrained potential - all suitable lower grade arable land	**Miscanthus**	633	748	2,026	4,953
	SRC	112	208	364	1484
	Total	745	956	2391	6438
Remaining suitable arable land after major constraints - permanent grassland and landscape designated areas	**Miscanthus**	394	457	1,245	2,279
	SRC	63	109	202	652
	Total	457	567	1447	2931
After allowing for food and feed production (assumed to require 80% of land)	**Miscanthus**	79	91	249	456
	SRC	13	22	40	130
	Total	91	113	289	586
GWh (of electricity if used for generation)					
Unconstrained potential - all suitable lower grade arable land	**Miscanthus**	190	224	608	1486
	SRC	34	62	109	445
	Total	224	287	717	1931
Remaining suitable arable land after major constraints - permanent grassland and landscape designated areas	**Miscanthus**	118	137	373	684
	SRC	19	33	61	196
	Total	137	170	434	879
After allowing for food and feed production (assumed to require 80% of land)	**Miscanthus**	24	27	75	137
	SRC	4	7	12	39
	Total	27	34	87	176

Table 4.6: Renewables potential from energy crops

4.6.2 BARRIERS

Farmers in the South West have been willing to grow energy crops, so the recent slowdown of production and planting needs understanding and addressing if there is to be future expansion of these crops. Barriers to realising the energy crop potential (in addition to the major constraints discussed previously) include:

- **Market:** There are economic barriers related to the up-front costs of establishing energy crops and the delay before the crops become productive, which can lead to cash flow problems. There are also issues with immature supply chains. However, these issues can be addressed. The main outstanding issue is the perceived market failure for energy crops: it is currently not easy to find energy markets for SRC and Miscanthus, and there is no secure long-term energy crop market to give farmers the confidence to invest.

- **Technical:** There is considerable experience in the South West in growing and harvesting Miscanthus, so production is not seen as a barrier. However, there are issues with the specialist equipment needed for SRC production and the disease/pest issues associated with SRC. For both SRC and Miscanthus, the variability of the physical and chemical composition of the product needs to be addressed, as it has an impact on combustion.

- **Environmental:** Energy crops can have an impact on the landscape, water availability and soil quality. These issues are modelled in this study through the constraints applied to development potential. However, impacts at very local level should be assessed and managed on a case by case basis using existing guidelines. One key area of uncertainty is the long-term carbon implications of converting permanent pasture to perennial energy crop production. There is some evidence that the release of carbon involved in initial tilling of the grassland will outweigh the carbon benefits energy crops can deliver, and for this reason, use of permanent pasture has been excluded. However, it is possible that no/low till methods could reduce carbon fluxes, and as conversion of 10% of permanent pasture land is permitted under CAP, this could release further land for energy crops.

- **Social:** This relates to the attitudes of both farmers and the wider public to production of energy crops. For the public, the main issues are competition for current agricultural land with food production, and conversion of high biodiversity land to crop production. The land conversion issue relates mainly to imported biomass, so emphasising the advantages of local bioenergy production may address this. The estimates of land use in the South West in this study are made on a 'food first' basis, so this issue can be addressed through public education which provides reassurance about land use concerns and emphasises the socio-economic benefits of local energy crop production and use.

4.7 | BIOENERGY: WASTE

Wastes of biological origin which can provide a bioenergy resource fall into two main categories:

- **Wet wastes suitable for anaerobic digestion to produce biogas.** Biogas is a mixture of methane and carbon dioxide (CO_2). Biogas can either be combusted directly to produce heat and power, or upgraded (by removing the CO_2 and other impurities) into bio-methane. This can be injected into the natural gas grid, and substituted for fossil-derived natural gas in a variety of applications. Alternatively, it can be used directly as a vehicle fuel. Wet wastes suitable for anaerobic digestion include animal manures and food waste from households, commercial premises, and from the food processing industry, as well as sewage sludge from waste water treatment plants. Anaerobic digestion plant can either be based on a single type of feedstock, or can co-digest various feedstocks. This can have advantages as feedstocks are often dispersed spatially and combining feedstocks can allow economies of scale in plant without the need to transport feedstocks long distances. The biogas yield can also be increased by using energy crops, for example maize, which are grown specifically for use as an anaerobic digestion feedstock.
- **Dry wastes suitable for combustion to produce heat and/or power.** These include waste wood, either extracted from the municipal solid waste stream (as collected at civic amenity sites, for example) and waste wood from demolition. As these wastes are contaminated they need to be burnt in plant which meet pollution abatement requirements[106]. Finally, the residual waste – waste which is left after recyclables and fractions like food and waste wood have been extracted from the waste stream – can be combusted in an incinerator to produce heat and power. It should be noted however that incineration with energy recovery sits low down on the waste hierarchy and it is possible that options higher up the waste hierarchy could offer greater carbon benefits.

The waste hierarchy dictates a preference order for dealing with waste arisings.

1. The preferred means of handling waste, at the top of the hierarchy, is simply to prevent it from arising in the first instance. It can be expected that efforts such as the Love Food, Hate Waste campaign[107] will continue to aim to reduce arisings.
2. The second preference is reuse. This is more likely to be employed for wood products but could also be exemplified by food bank programmes.
3. Recycling and composting (including digestion) are next in line. With the impending exit from the EU, it is not clear what (if any) UK targets will be set for recycling and composting. However rates such as those in Devon, where over 50% of waste is already being diverted, typically plateau, so it is to be expected that recycling and composting in Devon will level off somewhere near the current diversion rates.
4. Recovery is the penultimate option, turning the material into energy, whether through conventional incineration or more advanced gasification or pyrolysis technologies. There have been debates in the press for several years about whether too many incinerators are being built in the UK. What does seem certain is that a tipping point is near, so fewer new waste incinerators should be expected in years to come.
5. The final option is landfill. This is also becoming a less prevalent approach as sites fill and are closed to new intake. The landfill tax is designed to price out landfill and help make other technologies more attractive.

[106] Industrial Emissions (integrated pollution and control) Directive (2010/75/EU) | [107] Love Food Hate Waste (2016), [online]. Available at: http://www.lovefoodhatewaste.com/ http://www.lovefoodhatewaste.com/

4.7.1 BIOGAS

The potential biogas resource in the region, together with the quantity of electricity that could be produced from it, is shown in Table 4.7. The estimated breakdown of sources of biogas are based on a 2010 resource study[108] which assessed the resource based on Defra livestock numbers for animal slurries, Defra waste statistics (WasteDataFlow) for food waste in the municipal waste stream, a 2009 study by ADAS for commercial organic waste[109] and information from Environment Agency pollution inventory returns for industrial food wastes. Estimates for food waste arisings in Greater Exeter and Devon have been updated based on more recent waste collection statistics. Biogas from sewage sludge was estimated based on Environment Agency data on sewage treatment works, combined with estimates from company returns to the Water Services Regulation Authority (Ofwat) on quantities of sewage waste entering plants. Overall, it is believed that 43 GWh (0.4% of energy consumption in Greater Exeter in 2014) could be generated from biogas, predominantly from animal slurries (Figure 4.8). As of 2014, only about 14% of this potential is utilised in Greater Exeter, although levels are higher (42%) in the wider Devon region.

POTENTIAL RESOURCE - GWh	**Greater Exeter** GWh	**Devon** GWh	**Heart of SW** GWh	**SW Region** GWh
Biogas from animal slurries	74	153	328	561
Biogas from food wastes	16	37	141	283
Biogas from sewage sludge	34	57	177	317
Total	124	247	646	1,161
POTENTIAL RESOURCE - GWh OF ELECTRICITY (IF USED FOR GENERATION)				
Biogas from animal slurries	26	54	115	196
Biogas from food wastes	6	13	49	99
Biogas from sewage sludge	12	20	62	111
Total	43	87	226	406
CURRENT GENERATION FROM BIOGAS (2014) - GWh OF ELECTRICITY				
Biogas from anaerobic digestion (including food waste and slurries)	3	33	61	132
Biogas from sewage sludge	2	3	5	61

Table 4.7: Unconstrained potential resource for biogas

[108] AEA (2010). Regional Potential for sustainable renewable energy: biomass south west- stage 1 Resource quantification. EA Science report SC090009 | [109] ADAS (2009). National Study into Commercial and Industrial Waste Arisings. Available at: http://www.eera.gov.uk/publications-and-resources/studies/topic-based-studies/wastestudies/national-study-into-commercial-and-industrial-waste-arisings/

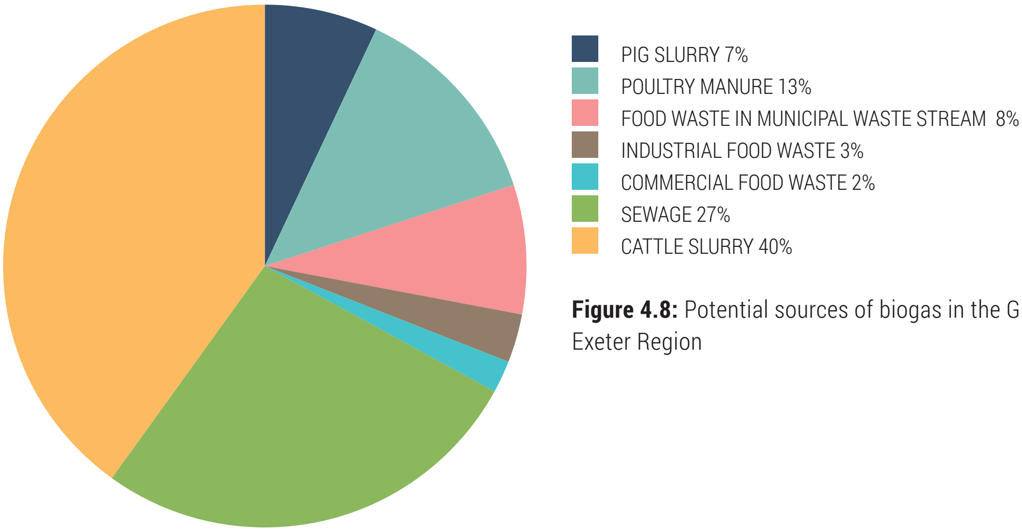


Figure 4.8: Potential sources of biogas in the Greater Exeter Region

4.7.2 BARRIERS

Some barriers to anaerobic digestion differ by feedstock type while others, such as integration into existing gas supply markets and planning issues in relation to plant, cut across all developments. The competing uses for food wastes influence the financial viability of use in anaerobic digestion plant. For animal waste inputs, the dispersed nature of waste, often spread across several small farms and having a high liquid content, can be a challenge.

[110] Only contaminated waste wood (from the municipal solid waste stream and demolition is considered here). Clean waste wood was considered together with other sources of wood in Section 5.5 and could generate an additional 12 GWh | [111] AEA (2010). Regional Potential for sustainable renewable energy: biomass south west- stage 1 Resource quantification. EA Science report SC090009 | [112] Defra (2016). Waste Statistics, [online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/142046/2011-12_ANNUAL_publication_LA_level_WITHOUTLINKS.xls | [113] Resource (2016). Controversial Plymouth incinerator hits full operation, [online]. Available at: http://resource.co/article/controversial-plymouth-incinerator-hits-full-operation-10758

4.7.3 SOLID WASTE

Waste wood[110] and residual waste arising in the Greater Exeter area could generate an estimated 45 GWh of electricity (Table 4.8), equivalent to 0.5% of total energy consumption in Greater Exeter in 2014. Estimates on quantities of waste wood are based on a 2010 resource study for the South West[111], while residual waste quantities are based on the most recent Defra data on regional waste arisings[112] and information on waste composition, to allow estimation of the biogenic content.

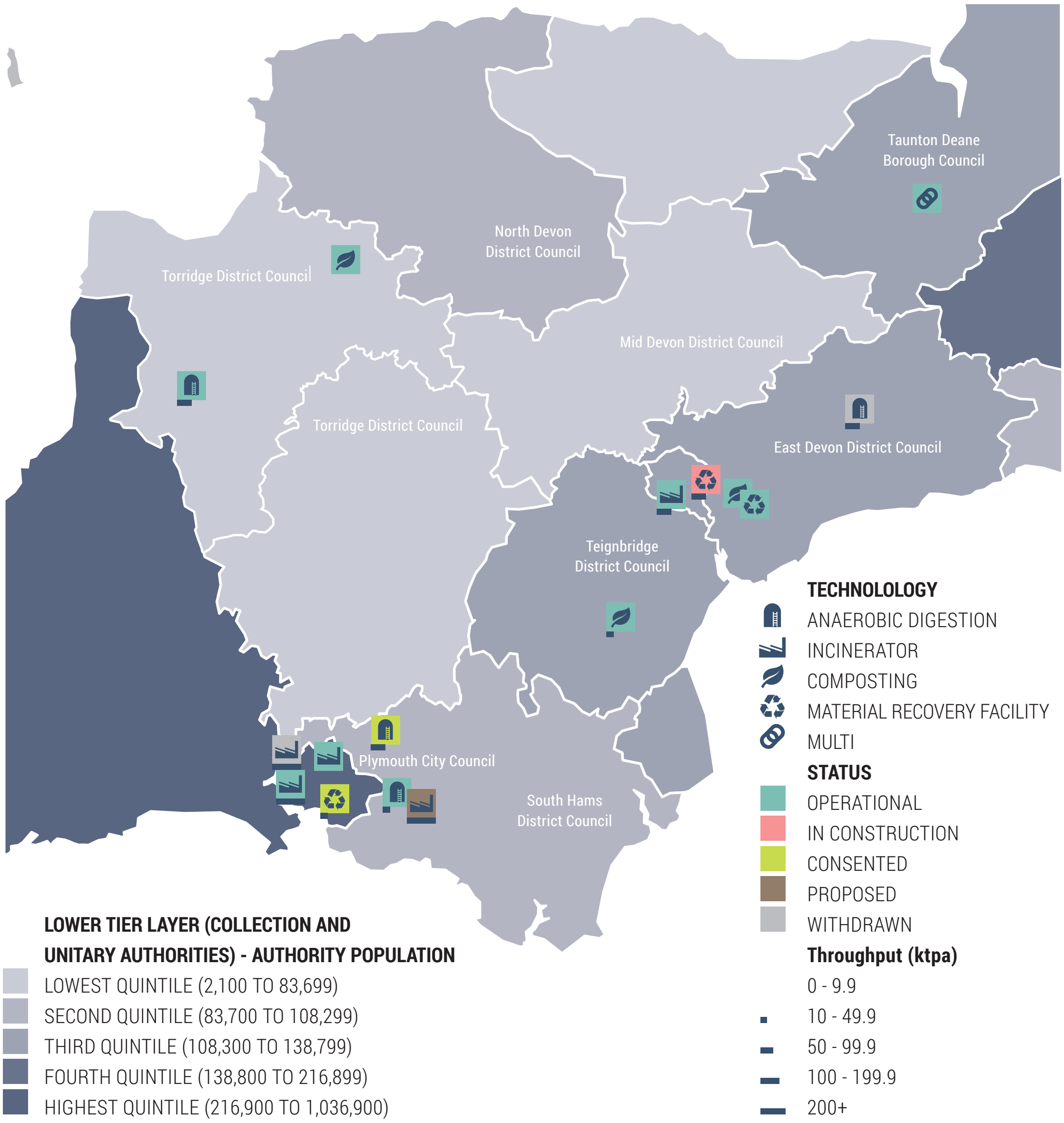
Much of this residual waste may already be utilised in energy from waste plant. Devon has incinerators in Exeter (owned by Viridor and with a capacity of 60,000 tonnes per annum) and Devonport (owned by MVV, and with a capacity of 245,000 tonnes per annum). The latter is contracted to accept around 163,000 tonnes of waste per annum from Devon, Torbay and Plymouth[113]. Existing waste facilities are shown in Figure 4.9.

ODT OF WOOD	Greater Exeter	Devon	Heart of SW	SW Region
Waste wood from municipal waste stream	11,307	18,882	47,474	82,590
Waste wood from demolition	4,815	8,041	26,136	56,117
Total	16,122	26,922	73,610	138,707
GWh AS A FUEL				
Waste wood (all)	85	142	388	732
GWH OF ELECTRICITY (IF USED FOR GENERATION)				
Waste wood (all)	26	43	117	220
TONNES OF WASTE				
Biogenic fraction residual waste	45,922	61,362	Not estimated	Not estimated
GWh AS A FUEL				
Biogenic fraction residual waste	65	87	Not estimated	Not estimated
GWh OF ELECTRICITY (IF USED FOR GENERATION)				
Biogenic fraction residual waste	19	26	Not estimated	Not estimated
Total residual waste and waste wood	45	69	Not estimated	Not estimated

Table 4.8: Unconstrained potential resource for solid wastes

4.7.4 BARRIERS

As Figure 4.9 shows, there are many competing technologies in the county already at various stages of development. Furthermore, the UK waste industry is perceived by many to be near capacity for thermal treatment. The presence of incinerators at Exeter, Devonport and in Cornwall suggests that any new facility may struggle to secure the necessary waste. Waste should also be treated respecting the waste hierarchy, under which bioenergy is less preferred to minimisation and reuse, and combustion is inferior to composting.



Notes: This composite screenshot from Ricardo's FALCON[114] software shows waste management facilities in Devon, Torbay and Plymouth, also conveying their size and development status.

Figure 4.9 : Existing waste facilities in Devon

114 Ricardo (2016). Waste market research, [online]. Available at: http://ee.ricardo.com/cms/waste-market-research-2

4.8 | MARINE: WAVE AND TIDAL STREAM

Marine energy has the potential to be a key renewable energy source given the substantial energy resources present in the oceans. The UK has an abundance of marine energy, having around 50% of Europe's tidal energy resource. Recent estimates of UK deployment of marine technologies in the period 2002 to 2025 range from 56 to 1000 MW, with estimates for 2050 as high as 27.5 GW[115, 116, 117]. However, the potential of these technologies has proven difficult to realise, with studies often overestimating the rate at which developments can be made. For example, a 2009 study estimated that by 2016 there would be as much as 600 MW of installed marine capacity[118]. However installed capacity at the start of 2015 was only 1.5% of this (9 MW) highlighting the uncertainty in forecasting potential capacity of an unproven technology so far in advance[38].

The South West has a unique advantage in the development of marine energy technologies with extremely viable energy resources, port infrastructure, research facilities and industrial talent. Initiatives in the South West to support marine technology development include the North Devon Demonstration Zone[119], the Perpetuus Tidal Energy Centre (on the Isle of Wight), the FABtest site at Falmouth and the Wavehub site off Hayle in North Cornwall. These offer developers access to sites that have been consented for development and are grid connected, partly addressing some potential barriers. Access to sites for small scale demonstration has also been improved by the recent introduction by the Crown Estate of an open leasing system allowing anyone to apply for a lease for a site of less than 3 MW for development without the need to wait for leasing rounds. While this does provide access to more sites, these small-scale sites will be challenging to make financially viable given the fixed costs such as development, grid connection and installation for such small sites. This makes the demonstrator sites important for these first years of deployment of both tidal and wave.

Despite these initiatives, the levels of capital required to progress technology towards commercialisation still presents a major obstacle. The Offshore Renewables Energy Catapult (OREC) estimated in 2014 that the wave sector will require £200 million and the tidal sector £100m of investment[120] to drive the industry along a path to commercial readiness, with further investment necessary above this figure to deploy the first arrays of both technologies[121]. Although large arrays (greater than 10 MW) could be financially viable, it will not be possible to raise finance for them until demonstrator arrays have been completed to provide the performance guarantees and warranties necessary to make the large arrays investable[122].

This section discusses the unconstrained resource, status and potential of the three technologies used to harness marine energy:

- Tidal stream
- Wave
- Tidal barrages and lagoons

The South West has a unique advantage in the development of marine energy technologies with extremely viable energy resources, port and grid infrastructure, research facilities & industrial talent.

115 BEIS (2013). Wave and tidal energy: part of the UK's energy mix, [online]. Available at: https://www.gov.uk/guidance/wave-and-tidal-energy-part-of-the-uks-energy-mix | 116 Carbon Trust (201x). Marine Renewables Green Growth Paper, [online]. Available at: https://www.carbontrust.com/media/597981/marine-green-growth-carbon-trust.pdf https://www.gov.uk/guidance/wave-and-tidal-energy-part-of-the-uks-energy-mix | 117 RenewableUK (2013). Working for a Green Britain and Northern Ireland 2013-23, [online]. Available at: http://www.renewableuk.com/news/293536/Working-for-a-Green-Britain--Northern-Ireland.htm | 118 MEG (2010). Marine Energy Road Map, [online]. Available at: http://www.marineenergypembrokeshire.co.uk/wp-content/uploads/2010/03/Scottish-RM-09.pdf | 119 WaveHub. North Devon demonstration zone, [online]. Available at: http://www.wavehub.co.uk/downloads/North_Devon_Site/wave-hub-north-devon-demonstration-zone-leaflet.pdf | 120 OREC (2014). Financing Solutions for Wave and Tidal Energy | 121 The Scottish Parliament (2015). Meeting agenda and submissions, [online]. Available at: Renewablesminuteshttp://www.parliament.scot/S4_EconomyEnergyandTourismCommittee/Meeting%20Papers/20150422_Public_Papers.pdf | 122 Cornwall Council et al. Cornwall & Isles of Scilly Marine Renewables Roadmap 2015 – 2025, [online]. Available at: http://www.cioslep.com/assets/file/Marine%20Renewables%20Roadmap.pdf

4.8.1 TIDAL STREAM

Tidal streams are caused by large bodies of water moving under the gravitational pull of the moon. Energy can be extracted from the flowing stream (which increases in speed depending on the topology of the ocean floor). Tidal turbines can be installed at locations with high tidal current velocities or with strong continuous ocean currents, extracting energy from the current and converting it to electricity. The technology is still at the demonstration stage, with current designs focussed on seabed-mounted two or three blade horizontal axis turbines, floating platform mounted turbines and open axis turbines. Although as the technology develops further towards commercialisation, designs are likely to centre on the approach which proves to be the most successful. The turbines typically range in size from 50 kW to 1.5 MW[123], but the high fixed costs of sites (development, installation and grid connection) mean that when deployed commercially, sites would be much larger. Typically, large arrays of devices would be installed at a location giving a generating capacity of up to 100 MW per site.

To maximise economic viability, the first tidal arrays are likely to be installed in areas where the tidal stream is greater than 2 m/s. At this speed, a 1 km^2 area could contain a turbine array of 60 MW[124]. As the technology matures (e.g. post 2025), arrays in areas where the tidal stream is above 1.75 m/s may become viable. The areas in the South West with flows of this strength are given in Table 4.9. In addition, there is the North Devon demonstration zone, a 35 km^2 Crown Estate-leased area with a tidal stream of 1.5 m/s, for array demonstrators.

In the UK, 8.7 MW of demonstration devices are installed (principally at the European Marine Energy Centre in the Orkneys) which generated 2.2 GWh in 2014. Other pre-commercial turbines are currently being installed (for example Atlantis, Andritz Hammerfest Hydro, Tocardo, Schottel) and many full-scale prototypes have secured finance, including grant funding, for installation over the next few years. Projects such as MeyGen highlight the potential of the technology, with up to 398 MW planned by 2020. Closer to Exeter, the FABLink project aims to develop the marine grid infrastructure to connect both Britain and France to marine renewable energy planned for the seas around Alderney. This subsea interconnector is currently planned to land in East Devon. Connection to renewable marine development around Alderney alone has the potential to supply 6 TWh[125] of energy annually. Additionally, if the North Devon demonstration zone was to be fully utilised by 2025 then 60 MW could potentially be installed, generating around 158 GWh per year[126]. Table 4.9 demonstrates the available resource in the wider region. However, for all these projects, technical barriers still need to be overcome. Improving the performance, reliability and survivability of devices in operation is critical to larger scale deployment.

Region	Greater Exeter	Devon	Wider Region	SW Region
Areas with suitable tidal flow greater than 1.75 m/s[(a)]	None[(b)]	Hartland Peninsula, Exmoor Heritage Coast to the Bristol Channel, and around Isle of Lundy	Penwith Heritage Coast; Lizard Heritage Coast	
Potential generation capacity	**MW**	**MW**	**MW**	**MW**
Unconstrained resource	0	210	360	960
Potential generation[(c)]	**GWh**	**GWh**	**GWh**	**GWh**
Unconstrained resource	0	552	946	2,523

(a) Areas with tidal flow greater than 1.75 m/s shown on the UK Marine Energy Atlas Map (http://www.renewables-atlas.info/)which has a 200m resolution
(b) While there may be some very localised areas where tidal stream velocity is sufficient for development, no significant areas were identified
(c) Based on an assumed capacity factor for demonstration projects of 0.3 and for fully developed commercial arrays installed of 0.4

Table 4.9: Tidal stream potential in the South West

123 Some devices might be up-scaled e.g. to 2 MW when fully commercialised. | 124 Based on data in in Offshore Renewables Resource and Deployment Report, PMSS, 2010 which estimate that the array density would give a capacity of 30 MW for a 0.5 km2 area for a tidal stream of 2 m/s | 125 Alderney Renewable Energy | 126 Assuming a capacity factor of 0.3 for demonstration projects

4.8.2 WAVE

There are several different designs for devices to capture and convert wave energy into electricity[116]. However, there are still fundamental technical challenges to overcome to get wave technologies operating successfully, with only a small number of companies (such as Oyo, Carnegie Wave Power and Seatricity) currently testing scaled prototypes. At current rates of investment, innovation and testing, full scale wave prototypes are unlikely before 2020[127]. The first commercial developments are likely to be in areas of high wave energy density[128] (greater than 20 kW/m[96]) to maximise economic viability. As the technology develops, areas of lower wave energy density (e.g. 15 kW/m) are likely to become viable.

In Devon, wave energy density is greater than the minimum (20 kW/m) considered necessary for financial viability around the Hartland peninsula and Isle of Lundy. Across the wider region, the whole of Cornwall's north coast, and most of its south coast also have the necessary wave energy density. The unconstrained potential this leads to is shown in Table 4.10. However by 2025, at current rates of investment, development is likely to be limited to the Wavehub demonstration site which has obtained the necessary consents and grid connection, and potential small scale demonstration arrays licenced under the 3 MW Crown Estate demonstration zone licences[129]. This could give 23 MW of capacity installed in the wider region, delivering 50 GWh[130].

Region	Greater Exeter	Devon	Wider Region	SW Region
Areas with suitable resource (wave energy density >20 kW/m[(a)])	None[(b)]	Around Isle of Lundy	North Cornish coast Most of south Cornish coast	
Potential generation capacity	**MW**	**MW**	**MW**	**MW**
Unconstrained resource	0	100	1,240	1,240
Potential generation[(c)]	**GWh**	**GWh**	**GWh**	**GWh**
Unconstrained resource	0	219	2,715	2,715

(a) As shown on the UK Marine Energy Atlas Map which has a 200m resolution
(b) While there may be some very localised areas where wave power is sufficient for development, no significant areas were identified
(c) Based on an assumed capacity factor in early years of development of 0.25 and for fully developed commercial arrays of 0.45

Table 4.10: Wave energy potential

127 South West Marine Energy Park (2015). Outlook and statement of ambition to 2030. | 128 Wave energy density is a function of the wave height and wave period, which varies significantly depending on the wave fetch | 129 To open access to sites, the Crown Estate recently introduced an open leasing system allowing anyone to apply for a lease for a site less than 3 MW for development, without the need to wait for leasing rounds. 130 Assuming that the 20 MW potential of the Wave Hub site is fully utilised and that one other 3 MW demonstration array is licensed and assuming a capacity factor for early years of development of 0.25.

4.8.3 BARRIERS

Physical barriers restrict the availability of development zones to some extent. Some offshore areas are specifically likely to be considered unsuitable for marine technologies and would be excluded from development[131]. The impact of these barriers can only be evaluated fully on a site-by-site basis (through an Environmental Impact Assessment). With consideration of the specific technology to be deployed, further restrictions to the unconstrained resource may apply. These barriers include:

- Areas within five nautical miles of the entry and exit points of International Maritime Organisation (IMO) Traffic Separation Schemes (TSS)
- Areas subject to zone development agreements under Crown Estate offshore wind farm licensing rounds
- Areas with alternative uses such as aggregate extraction, dumping or anchorages (as defined on admiralty charts).

As discussed, wave and tidal energy have a high level of associated technological uncertainty, which presents difficulties forecasting the likely deployment to 2025. Considerable innovation is required to bring the technologies to commercial deployment, but financial constraints remain one of the biggest obstacles to accelerated development of marine technologies. Funding of demonstration projects is a high-risk activity and will likely require some form of public support. Once tested, technologies then need to demonstrate cost reduction sufficient to compete commercially – the success of marine technologies will also depend closely on the cost trajectory of substitute low carbon technologies such as solar, further adding to investment uncertainty.

131 These constraints are mapped in the Offshore Renewables Resource and Deployment Report, PMSS, 2010 | 132 Renewable and Sustainable Energy Reviews | 133 IRENA (2014). Tidal Energy Technology Brief, [online]. Available at: http://www.irena.org/documentdownloads/publications/tidal_energy_v4_web.pdf

4.9 | MARINE: TIDAL RANGE

Tidal range technologies use a dam or other barrier to generate electricity from the height difference between high and low tide. Resources exist in locations where large water masses flow into compounded areas, bays or estuaries. Barrage technologies have been well established through the operation of several plants globally with the earliest being La Rance in 1967. Advancements in turbine technologies and design have since resulted in a plethora of new, exciting turbine designs for tidal energy[132] including tidal 'lagoons', tidal 'reefs', tidal 'fences' and low-head tidal barrages[133].

4.9.1 TIDAL BARRAGE

Tidal barrage, where water is impounded behind an artificial estuary barrage and then used to drive turbines, is an established technology. There are a number of installations around the world, including a 240 MW example in La Rance, France and a 254 MW example in the Sihwa Lake in South Korea. Power can be generated on both the ebb and flow tides, offering generation for approximately 14 hours a day. Since power output is highly predictable, tidal range technologies can provide balancing services to the grid.

In the Greater Exeter region, the Exe has a tidal range of only 3.8 m at spring tide. This means that a barrage across the mouth of the Exe from Exmouth to Cockwood, would only support an installation of 34 MW, generating 83 GWh[134]. This is below the smallest size of installation currently being considered and is unlikely to be viable. In addition, there could be significant environmental constraints in the area, particularly around the Dawlish Warren nature reserve.

In the wider South West region, the Severn Estuary has long been discussed as a potential site for tidal barrage. In 2008/09 several exploratory studies were undertaken but the government decided that the barrage would be too risky in 2010 due to cost and concerns over environmental impacts. In 2013, DECC published guidance noting that their feasibility work had not identified a strategic case for public investment in a Severn tidal scheme. More recently, tidal lagoons have been proposed for the Severn Estuary area, including Swansea Bay and Bridgewater.

4.9.2 TIDAL LAGOON

Tidal lagoon power uses a similar concept: an artificial lagoon is constructed using a bund wall connected to the shore, and the differential between water levels inside and outside the lagoon created by the tides is used to drive turbines installed in the perimeter. The government has recently completed an independent review assessing the feasibility and practicality of tidal lagoon energy in the UK[135], concluding that tidal lagoons at scale could deliver low carbon power in a way that is very competitive with other low carbon sources. The report opens the way for a sub-500 MW pathfinder project to inform potential wider development.

Current technology requires a tidal range of approximately 6m and a minimum water depth of 5m, so the only suitable areas in Devon are on the north coast. In the wider region, the Somerset coast and most of the North Cornwall coast (down to Godvery) could offer opportunities. Estimates of the unconstrained potential tidal range resource in the wider region are shown in Table 4.11. The underlying data does not allow the specific resource in Devon to be identified, but it does indicate that a substantial resource is available in the region and at least some of that resource would lie on the Devon coastline. Not all this potential resource would be realised, as it would not be desirable to cover the whole coast in lagoons or barrages, and there may be areas which should be excluded because of environmental impacts.

Tidal lagoon development is being considered at Bridgewater Bay in Somerset, and the developers Tidal Lagoon Power are currently in a community engagement phase, consulting with nature conservation bodies and environmental experts about the various options for a lagoon in what is an environmentally-sensitive region[136]. While the design of the lagoon is still under consideration, a 16 km long bund wall around the bay, giving a generation capacity of 3.6 GW, generating up to 9 TWh annually, has been discussed[137].

134 Based on an approximate estimate of impoundment area of 11.25 km2, a power density of approximately 3W/m2 for a 4m tidal range, and a capacity factor of 0.28 | 135 BEIS (2017). Independent review into the strategic role of Tidal Lagoons in the UK published, [online]. Available at: https://www.gov.uk/government/news/independent-review-into-the-strategic-role-of-tidal-lagoons-in-the-uk-published [accessed: 12/01/2017] | 136 Tidal Lagoon Power (2016). Bridgewater Bay, [online]. Available at: http://www.tidallagoonpower.com/lagoons/bridgwater-bay/143/ | 137 The Engineer (2014). Tidal lagoons touted as Somerset flooding solution, [online]. Available at: https://www.theengineer.co.uk/issues/february-2014-online/tidal-lagoon-touted-as-somerset-flooding-solution/ [accessed: 09/11/2016]

Potential Tidal Range Resource	Calculated Value
Potential impoundment area with a tidal range > 6 m [a]	3,708 km2
Potential unconstrained resource – capacity [b]	26 GW
Potential unconstrained resource – generation [c]	64 TWh

(a) Based on data in Offshore Renewables Resource and Deployment Report, PMSS, 2010, excluding areas unsuitable because of other uses
(b) Based on a power density of 7 W/m2
(c) Based on the capacity factor for La Rance tidal barrage of 0.28 as no operational data available for tidal lagoons

Table 4.11: Potential tidal range resource

4.9.3 BARRIERS

Depending on the scale of the lagoon, construction can take between three and seven years[138], but a significant development phase precedes this in which an Environmental Impact Assessment must be completed and the necessary consents obtained. All the barriers identified for wave and tidal stream technologies also apply to tidal range technologies, but the most significant potential barriers to development are upfront construction costs and environmental impacts, including:

- **Sedimentation:** tidal range schemes could result in loss of large areas of intertidal habitats and salt marshes as a result of a change in water levels and sediment transport in an estuary or river basin. This will be affected significantly by the design, siting and mode of operation (e.g. two-way operation may reduce the scale of impact). As there are no current designs to base any estimates of these impacts, further development of the technology is required to understand how much sedimentation is likely.
- **Biodiversity:** The potential impact on birds, particularly waders such as oystercatcher, ringed plover and sanderling, will be site specific and is unknown. This could also lead to changes in fauna and flora and changes in local tidal regimes.

138 Cebr (2014). The Economic case for a tidal lagoon industry in the UK, [online]. Available at: http://www.tidallagoonpower.com/storage/documents/The-Economic-Case-for-a-Tidal-Lagoon-Industry-in-the-UK_final.pdf

4.10 | GEOTHERMAL

Geothermal energy is stored in the form of heat within the earth's surface[139]. There are various types of geothermal energy source that can be exploited. Depending on the nature of the geothermal source and its extraction, it can be used for heat only applications and power generation[140]. To generate power, the geothermal source needs to be of sufficient temperature and volume to turn a turbine and associated electrical generator[141]. At a global level, this form of energy is largely associated with areas of volcanic activity although, as the UK does not have any such sources, the focus for UK geothermal energy is in the following areas[142]:

- **Aquifer geothermal** opportunities result from the heating of groundwater stored and trapped in aquifers by the heat conducted from the Earth's core and mantle. The extent of these opportunities will depend on the level of this heat flow and the ability to extract water from the aquifer.

- **Hot rock sources** utilise heat from rocks beneath the surface which are heated to higher levels than normal because of increased heat flow gradients caused by concentrated radiothermal elements in granite. Where hydraulic simulation of the rock is required, these are also known as Engineered Geothermal Systems (EGS).

- **Warm mine waters** can, in some cases, be extracted and used for heating. Oil-geothermal co-production utilises the hot water extracted at the same time as oil as a heat source.

Varying estimates have been provided for the use of geothermal energy for power generation. The differences are in part due to the different scopes and assumptions used, but nevertheless highlight the challenge of estimating geothermal energy potential. For example, based on experiences in Germany, it is suggested that in the long term 1 to 1.5 GWe might be a reasonable estimate for the UK. This would represent approximately 4% of the current annual average UK electricity requirements and is significantly lower than other estimates. Other sources however state that geothermal energy could provide 9.5 GW of baseload renewable electricity and 100 GW of heat, which equates to approximate 20% of UK annual average electricity generation capacity requirement and the equivalent of the total annual heat consumption in the UK[144].

139 Cebr (2014). The Economic case for a tidal lagoon industry in the UK, [online]. Available at: http://www.tidallagoonpower.com/storage/documents/The-Economic-Case-for-a-Tidal-Lagoon-Industry-in-the-UK_final.pdf | 140 British Geological Survey (2016). Geothermal energy – what is it? [online]. Available at: http://www.bgs.ac.uk/research/energy/geothermal/ | 141 UKERC (2012) UKERC Energy Research Landscape: Geothermal Energy. Available at http://ukerc.rl.ac.uk/Landscapes/Geothermal.pdf - Shallow geothermal energy opportunities arising from solar radiation heating the ground, which then acts as a heat store are also often considered within the scope of geothermal energy. Typically, this is in the upper 10-15 m of the ground, below which solar radiation has limited influence . These sources are exploited through ground source heat pumps, however as the energy comes from solar radiation rather than geothermal sources these have not been considered further in this section

4.10.1 OPPORTUNITIES IN THE UK

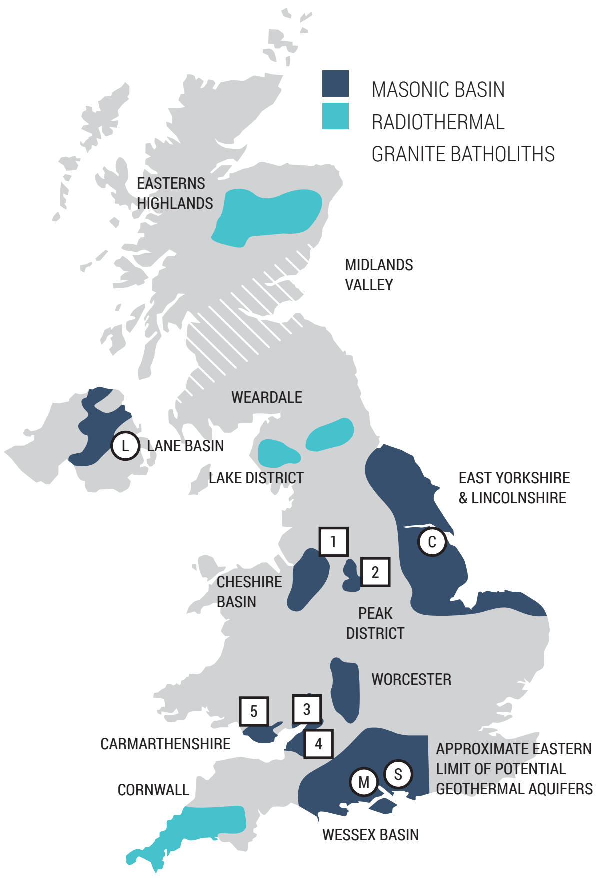
On average, the UK geothermal gradient is 26°C km^{-1}, but can exceed 35°C km^{-1} [144]. This increased temperature gradient creates the main potential opportunities in the UK for using geothermal energy from aquifer and hot rock geothermal sources. Figure 4.10 shows the heat flow map for the UK and Figure 4.11 shows the location of the main aquifers and hot rock geothermal sources. It is important to note that currently identified opportunities contain significant uncertainties. For example, methodologies for estimating temperatures at depth based on heat gradients and the heat gradients themselves have limitations.

Figure 4.10: Heat flow map of the UK[139]

mWm^{-2}

120 >	70 TO 80
110 TO 120	60 TO 70
100 TO 110	50 TO 60
90 TO 100	40 TO 50
80 TO 90	30 TO 40

Figure 4.11: Location of sedimentary basins and major radio thermal granites[145]



SPRING SITES

1 BUXTON
2 MATLOCK
3 BRISTOL
4 BATH
5 TAFF'S WELL

WELL SITES

M MARCHWOOD
S SOUTHAMPTON
L LANE
C CLEETHORPES

[142] Atkins (2013). Deep Geothermal Review Study, Final Report, [online]. Available at: https://www.gov.uk/government/publications/deep-geothermal-review-study | [143] SKM (2012). Geothermal Energy Potential Great Britain and Northern Ireland, [online]. Available at: http://www.r-e-a.net/upload/skm_report_on_the_potential_for_geothermal_energy_in_gb__ni_may_2012.pdf | [144] Busby. J (2010) Geothermal Prospects in the United Kingdom, Proceedings World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010 – Available at: http://nora.nerc.ac.uk/15965/1/GeothermalProspectsUK.pdf | [145] ATKINS (2013). Deep Geothermal Review Study Final Report, [online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/251943/Deep_Geothermal_Review_Study_Final_Report_Final.pdf

In terms of hot rock geothermal sources, areas with higher geothermal gradients result in higher temperatures. In particular, the granite rocks located in South West and Northern England could be as high as 260°C and 240°C respectively, compared to 140°C elsewhere[146]. Hot rock sources have the potential to be used for power generation, in particular those identified in the South West England, Weardale and Lake District granites, where potential scenarios have been developed[147]. Other hot rock sources may only be useable for heat. The accessible resource base for EGS in the UK has been estimated as 3.58 x 10^{10} TJ[146] (9.9 x 10^{6} TWh). Aquifer geothermal sources are generally limited to the Permo-Triassic sandstones due to their sufficient depths and hydrogeological properties. Locations include the sedimentary basins in Cheshire, East England, Worcester, Wessex and Northern Ireland[145]. Other potential sources include the Lower Carboniferous and Upper Devonian rocks of the Midland Valley of Scotland and Northern England[147]. Aquifer sources are predominately considered in terms of heat only due to limited depths and local heat gradients, however the Cheshire and Wessex basins may offer some potential for small scale power generation, based on estimated temperatures in their deepest areas[148]. Table 4.12 summarises the amount of stored heat in the main sedimentary aquifers.

Warm mine water sources are generally used to support district heating schemes close to disused collieries. The heat from water extracted at the same time as oil in oil-geothermal co-production needs to be utilised on site, due to the distance from the grid and populated areas.

Basin	**Aquifer**	**km^2**	**Geothermal resource** (TWh)	**Identified resource** (TWh)
East England	SSG Triassic	4,827	33,889	6,944
Wessex	SSG Triassic	4,188	7,500	1,944
Worcester	SSG Triassic BS Permian	500	2,222	278
Cheshire	SSG Triassic CS Permian	1,173	16,667	3,333
Northern Ireland	SSG Triassic	677	10,000	2,222

Notes: For resources above 40°C. The identified resource represents the part of the geothermal resource that may be available for development. SSG = Sherwood Sandstone Group, BS = Bridgnorth Sandstone, Collyhurst Sandstone

Table 4.12: Stored heat in UK sedimentary aquifers

[146] British Geological Survey (2011). UK data for geothermal resource assessments, [online]. Available at: http://egec.info/wp-content/uploads/2011/09/UK-deep-geothermal-resources_JBusby.pdf | [147] UKERC (2012) UKERC Energy Research Landscape: Geothermal Energy, [online]. Available at http://ukerc.rl.ac.uk/Landscapes/Geothermal.pdf | [148] Atkins (2013) Deep Geothermal Review Study, Final Report. Available at: https://www.gov.uk/government/publications/deep-geothermal-review-study | [149] British Geological Survey. Deep Geothermal energy and groundwater in the UK, [online]. Available at: http://www.groundwateruk.org/downloads/4%20Busby.pdf

4.10.2 OPPORTUNITIES IN THE SOUTH WEST

The main opportunity to utilise geothermal energy in the South West is through hot rock granite sources. It is reported that the unconstrained resource that may be available in South West England could be as high as 139,000 TWh[150]. An area of high heat flow exists in the Greater Exeter region, but development inside Dartmoor National Park is highly unlikely (Figure 4.12). It is thought that a heat flow resource potential may extend into Teignbridge, however a detailed analysis of this area has not been undertaken.

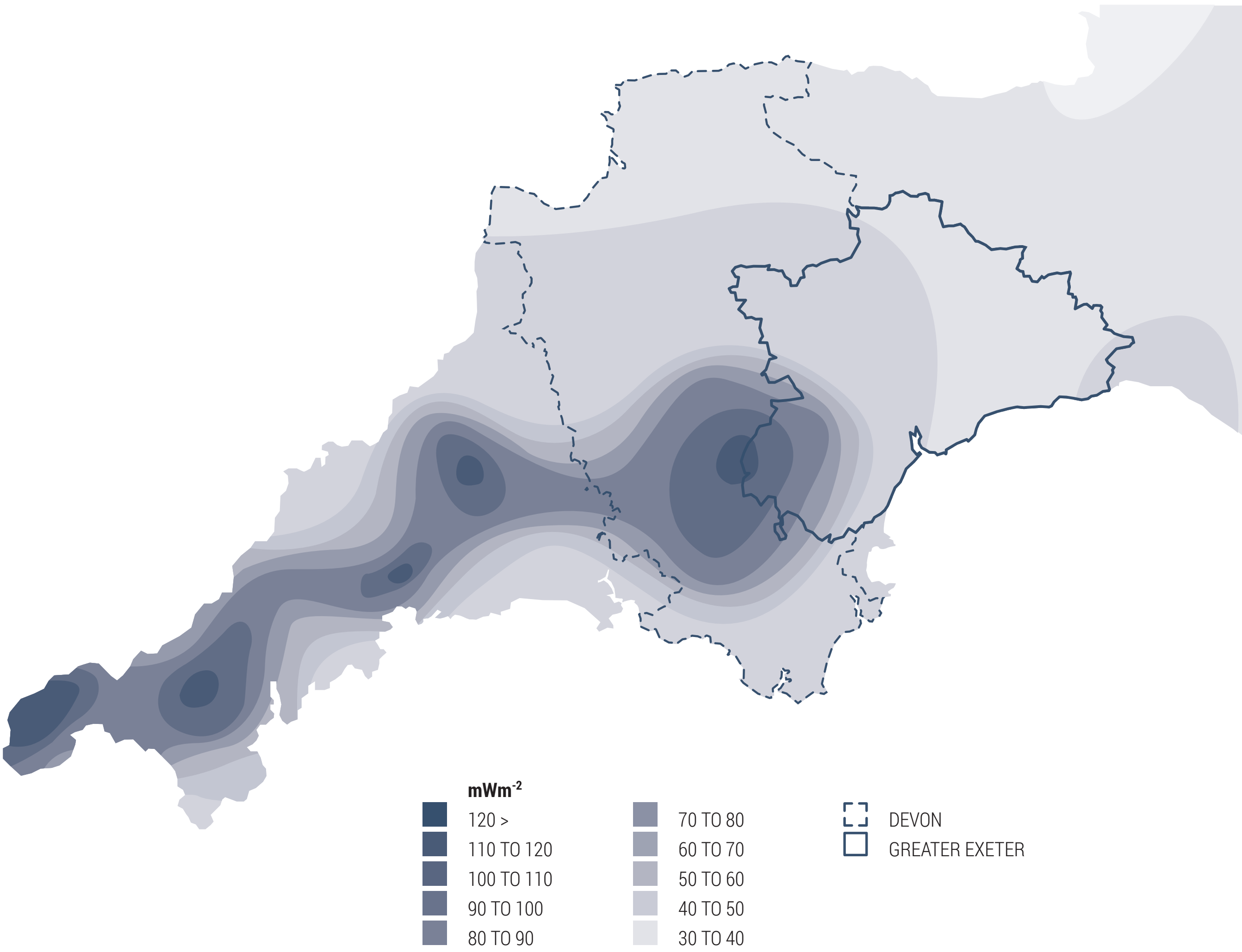


Figure 4.12 : Overlay of Greater Exeter (solid line) and Devon (dashed line) regions on the UK heat flow map

Notes

- Contains OS data © Crown copyright and database right (2017)

150 Baria et al (2010) Engineered Geothermal Program in the UK, Proceeding World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010

For each 100MWe of geothermal potential that could be harnessed, it is estimated that approximately 744 GWh[151] of energy could be produced. There would also be the potential to utilise heat alongside power generation. However, projects to date have been hindered by technical and financial uncertainty.

By way of example, in recent years planning permission has been granted for two geothermal projects in Cornwall, the first at the Eden Project and the second at United Downs, Redruth. Both projects were identified as important for confirming the viability of engineered geothermal systems for power generation in the UK. They have both experienced difficulties which means that neither have yet been developed.

4.10.3 BARRIERS

There are several distinct types of barrier to the exploitation of geothermal resources in the UK, including the South West. These include geological, technical, environmental and political factors[152]. Power generation from geothermal sources will rely on heat sales to make projects economically viable, which means that location in relation to heat demand becomes an important consideration.

A key geological barrier to the use of geothermal sources for power generation is confirming whether viable resources are available and exploitable, which requires the drilling of deep boreholes. To date, no deep boreholes have been drilled in South West England below 2.6 km. Therefore no geological data (e.g. temperature and permeability/flow rate) at the target depth of 4.5 km is available. The main technical barrier relates to the development of exploitable reservoirs for EGS. Techniques used for the hydraulic stimulation of reservoirs are developing, although mixed results observed elsewhere in the world indicate this as an ongoing barrier.

Environmental issues cover a range of factors, the most significant being induced seismicity. As highlighted above, power generation may require hydraulic stimulation of geothermal reservoir rock to improve transmissivity to exploit resources. This can result in micro-seismicity or micro-earthquakes which, as has been seen with shale gas extraction, can be a significant environmental and political issue. Public perception and consultation to address this would be an important consideration. Other environmental impacts would include, for example, water use, waste and resource management, noise and land use. These would need to be fully considered despite not being highlighted as significant barriers in the literature.

Political barriers relate to the provision of government support as well as regulatory regimes. The uncertainty regarding reserves together with the significant upfront costs of exploration boreholes means there are financial risks that need to be overcome. Supportive government policy and funding has been identified as the key requirement to help tackle some of the challenges identified. Other suggestions from stakeholders include further research studies, the drilling of test boreholes to provide confidence in reserve levels, clarification on permitting and thermal rights, and adjustments to subsidies to promote investment.

151 Based on a capacity factor of 85%. Geothermal Overview, The Carbon Neutral Company. Available at http://www.carbonneutral.com/interface/files/projects/Geothermal_energy_overview.pdf | 152 Arup (2012). Cornwall Geothermal Options Report – Options Study, [online]. Available at: http://www.erdfconvergence.org.uk/_userfiles/files/GrowthProgramme/ARUP_Cornwall_Geothermal_Options_Report_ISSUE_2_ALL.pdf, | 153 SKM (2012). Geothermal Energy Potential Great Britain and Northern Ireland, [online]. Available at: http://www.r-e-a.net/upload/skm_report_on_the_potential_for_geothermal_energy_in_gb__ni_may_2012.pdf

4.11 | NUCLEAR

15 nuclear fission reactors generate approximately 19%[154] (DECC, 2014) of the UK's annual electricity demand – a significant contribution to baseload energy requirement. The UK has been producing nuclear power commercially since the 1950s[155] with a distinguished safety record for operations and maintenance, and has developed full fuel cycle facilities including major reprocessing plants[158]. Until 2006 the industry was focussed on operating and extending the life of existing reactors and their gradual run-down towards closure[156]. Approximately half (4.2 GW) of currently operational nuclear capacity will be retired by 2025 if commercial or safety considerations prevent further extensions to operating life. The combination of nuclear and coal capacity retirement and increased demand is expected to result in a UK energy gap of approximately 40-55% by 2025[157] which will need to be met with new capacity.

The English and Welsh governments have developed a suite of policy measures which were mandated through the Energy Act 2013. This has created an economic environment more conducive to investment in low carbon generation, such as nuclear, rather than conventional, fossil-based plant and supported the industry's return to a state of long-term growth[158]. It has also supported the ambitious goal of deploying 20 GW of new nuclear capacity by 2030. In addition, the EU Industrial Emissions Directive (2010/75/EU) has put pressure on antiquated fossil plant to either reduce both greenhouse gas and particulate emissions or to cease operation, making the case for future nuclear plant investment more favourable. Following the EU referendum vote in June 2016, the new department of Business, Energy and Industrial Strategy (BEIS) has reaffirmed its support for nuclear projects[159].

Several large utility companies have plans to develop new nuclear power plants (Table 4.13), with Hinkley Point C scheduled to start construction in Somerset in 2019 following a new agreement in principle between EDF Energy and the UK Government[159]. However the first new nuclear plant is not scheduled to begin commercial operation until the late 2020s.

> *The retirement of nuclear capacity, alongside the retirement of coal capacity and increased demand, is expected to result in an energy gap of approximately 40-55% by 2025.*

[154] DECC (2015). DUKES, [online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/450302/DUKES_2015.pdf DUKES (2015), DECC available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/450302/DUKES_2015.pdf | [155] ONR (2015). A guide to Nuclear Regulation in the UK, [online]. Available at: http://www.onr.org.uk/documents/a-guide-to-nuclear-regulation-in-the-uk.pdf [accessed: 17/11/2016] http://www.onr.org.uk/documents/a-guide-to-nuclear-regulation-in-the-uk.pdf | [156] HM Government (2013). Nuclear Industrial Vision Statement, [online].[Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/168044/bis-13-629-nuclear-industrial-vision-statement.pdf https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/168044/bis-13-629-nuclear-industrial-vision-statement.pdf | [157] IMechE (2016). Engineering the UK electricity gap, [online]. Available at: https://www.imeche.org/docs/default-source/position-statements-energy/imeche-ps-electricity-gap.pdf?sfvrsn=0 | [158] World Nuclear (2016). Nuclear power in the United Kingdom, [online]. Available at: http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/united-kingdom.aspx | [159] BEIS (2016). Government confirms Hinkley Point C project following new agreement in principle with EDF, [online]. Available at: https://www.gov.uk/government/news/government-confirms-hinkley-point-c-project-following-new-agreement-in-principle-with-edf

Proponent	Site	Locality	Type	Capacity (MWe)	Construction start	Commercial operation date
EDF Energy	Hinkley Point C-1	Somerset	EPR	1670	2019	2026
EDF Energy	Hinkley Point C-2	Somerset	EPR	1670	2020	2027
EDF Energy	Sizewell C-1	Suffolk	EPR	1670	-	-
EDF Energy	Sizewell C-2	Suffolk	EPR	1670	-	-
Horizon	Wylfa Newydd 1	Wales	ABWR	1380	2019	2025
Horizon	Wylfa Newydd 2	Wales	ABWR	1380	2019	2025
Horizon	Oldbury B-1	Gloucestershire	ABWR	1380	-	Late 2020s
Horizon	Oldbury B-2	Gloucestershire	ABWR	1380	-	Late 2020s
NuGeneration	Moorside 1	Cumbria	AP1000	1135	-	-
NuGeneration	Moorside 2	Cumbria	AP1000	1135	-	-
NuGeneration	Moorside 3	Cumbria	AP1000	1135	-	-
EDF Energy & China General Nuclear	Bradwell B-1	Essex	Hualong One	1150	-	-
EDF Energy & China General Nuclear	Bradwell B-2	Essex	Hualong One	1150	-	-

Table 4.13: Planned new nuclear power stations in the UK

The significance of nuclear power in providing the large-scale delivery of safe and secure energy supply, as well as its potential for generating a construction-led boost to the regional and national economy, explains its inclusion in the UK's long-term energy strategy. In theory, given the prospective impact of Hinkley Point C, nuclear power could be considered to play an important role in the context of achieving an energy independent Greater Exeter by 2025. However, this study takes the view that Hinkley Point C is a national project related to baseload replacement and its eventual commissioning will fall outside the timescale of the Exeter City Futures goal.

[160] KPMG (2016). A UK SMR-SCRAM or 'going critical'?, [online]. Available at: https://assets.kpmg.com/content/dam/kpmg/pdf/2016/05/uk-smr-scram-going-critical.pdf | [161] DECC (2016). Small Modular Reactors: Competition Phase 1, [online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/508616/SMR_Competition_Phase_1_Guidance.pdf | [162] World Nuclear (2016). Small Nuclear Power Reactors, [online]. Available at: http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx

While not included in this analysis, it is possible that under a Maximum Technology scenario other nuclear technologies, such as fusion reactors and Small Modular Reactors (SMR), might play a part in the long-term energy strategy of Greater Exeter, albeit with a low probability of occurring within the project time horizon.

4.11.1 SMALL MODULAR NUCLEAR

A growing interest in SMR of 300 MW or less is being driven by the need to reduce project capital costs and deployment schedules and to provide power away from large centralised generation[160]. Smaller reactors could also be more easily integrated into existing grid infrastructure around Greater Exeter with waste heat additionally used for district heating processes, as discussed in Section 5.4.1. However, UK-innovated SMR technology is in its infancy. It is estimated that it will require further research, financial and technical due diligence, risk analysis, strategic analysis and market engagement at a potential cost of £1Bn before the first commercially-operating project is realised[160]. The government's announcement of at least £250M funding over the next five years for research and development of SMR-enabling advanced nuclear manufacturing is a positive step in this regard. A few existing SMR prototypes are thought to be commercially viable inside a 10 year time frame, following further detailed technical and safety analyses of specific designs[161]. Other countries have advanced SMR designs through to construction[162], demonstrating the opportunities available in this sector and the possibility that foreign technology may make SMR a viable option for Exeter during the study period. For this to happen, a different approach to planning policy for nuclear power would be required in order to accommodate the novel nature of SMR compared to utility-scale projects.

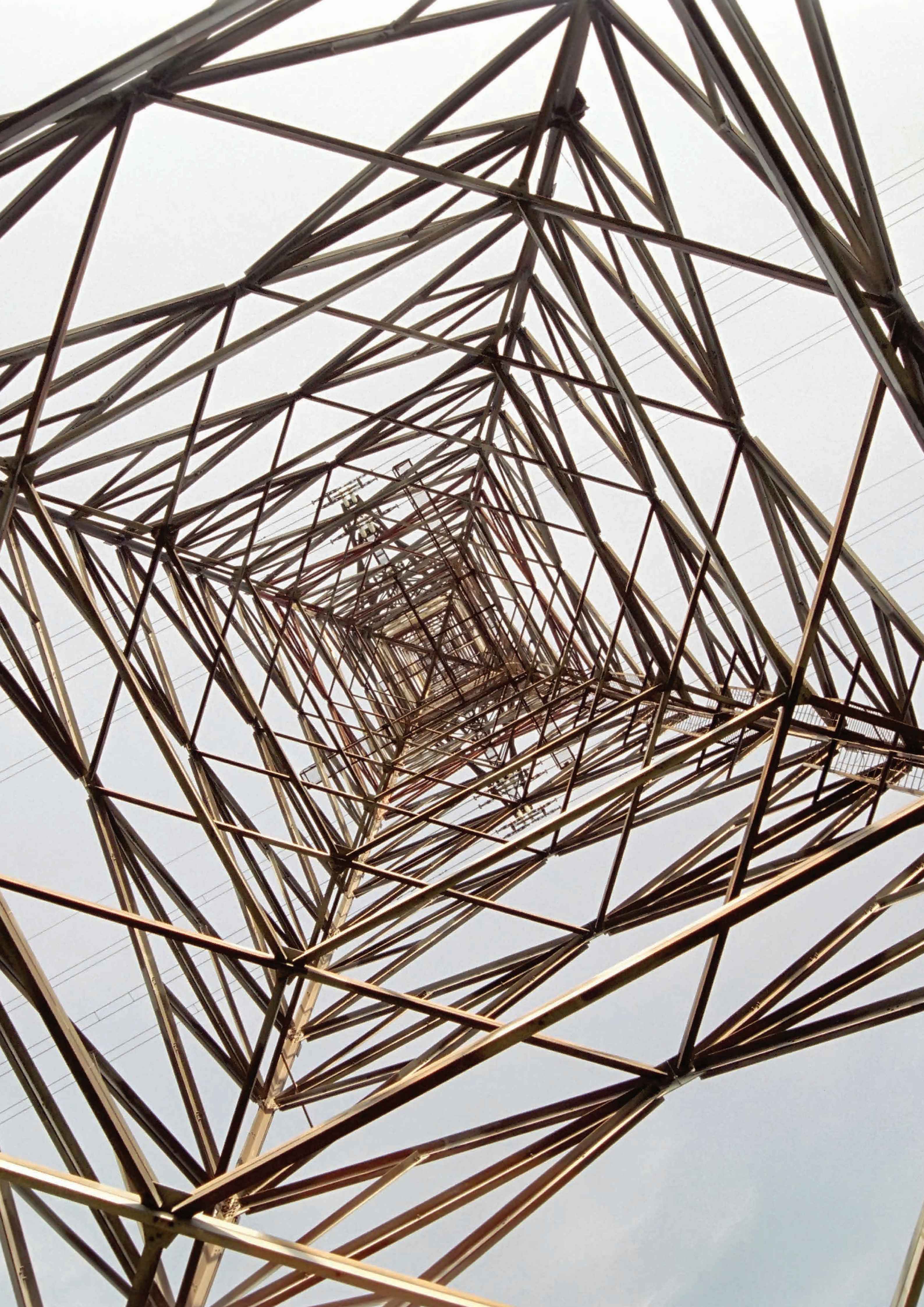
4.11.2 FUSION

Fusion reactors offer an alternative to the fission reactors commercially available today. However, the technology is still undergoing intensive research and development, which is focussed on building up and maintaining the conditions required for the reaction to be self-sustaining and energy positive. Some research bodies and companies suggest that the first fusion reactor could be operational inside a decade[163,164] although very little data is presented to substantiate these claims.

4.11.3 BARRIERS

Financing remains one of the biggest potential barriers to the deployment of new nuclear capacity, alongside the acquisition of skilled labour, the magnitude of construction projects and the timely supply of major components from foreign markets. Public perception of nuclear on a local and national level may also prove difficult to address due to concerns about risks associated with waste storage, accidents, terrorism and the effect of natural disasters[165]. A study conducted as part of the Hinkley Point C development in Somerset indicates that approximately two thirds (65%) of people in the South West recognise the need for nuclear energy, with only 14% disagreeing[166]. This may facilitate further development in the region should an opportunity arise and public perception remain unchanged.

163 Science Alert (2015). Researchers have designed a simple fusion reactor that could be running in 10 years, [online]. Available at: http://www.sciencealert.com/mit-researchers-have-designed-a-simple-fusion-reactor-that-could-be-running-in-10-years | 164 Lockheed Martin (2014). Lockheed Martin pursing compact nuclear fusion reactor concept, [online]. Available at: http://www.lockheedmartin.com/us/news/press-releases/2014/october/141015ae_lockheed-martin-pursuing-compact-nuclear-fusion.html | 165 UKERC (2013). Public attitudes to nuclear power and climate change in Britain two years after the Fukushima accident: summary findings of a survey conducted in march 2013 – Working paper, [online]. Available at: http://www.ukerc.ac.uk/publications/public-attitudes-to-nuclear-power-and-climate-change-in-britain-two-years-after-the-fukushima-accident-summary-findings-of-a-survey-conducted-in-march-2013-working-paper.html 166 Express and Echo (2012). Most in region support nuclear, [online]. Available at: nhttp://www.exeterexpressandecho.co.uk/region-support-nuclear/story-16510194-detail/story.html



5 SUPPLEMENTARY OR ENABLING TECHNOLOGIES

Smart grid technology is considered a fundamental prerequisite to the deeper decarbonisation of the electricity supply. By making better use of existing infrastructure, enabling the emergence of new markets and innovative business models, the development and deployment of smart grid technology is a central challenge of the low carbon transition.

5.1 | SMART GRIDS

Grid constraints are a major barrier for the further deployment of renewable energy capacity in the South West. In March 2015, Western Power Distribution, the regional Distribution Network Operator (DNO), was forced to restrict new connection agreements on the 132 kV network because the available capacity had been allocated. In addition, there was a large pipeline of new requests for connection.

The distribution grid is a passive system. Electricity is generated and flows through it to consumers with only limited operational control. The remit of the DNO is to operate and maintain their grid infrastructure, provide new connections and ensure security of supply. This passive approach results in an inflexible method for allocating new grid capacity connections and managing grid constraints.

Smart grid technology offers the DNOs the potential to actively manage power flows and voltage levels on individual components of grid infrastructure. The integration of communications infrastructure into the power system gives the ability to respond in real time. This can deliver improved network efficiency, a reduced need for new capital investment and, crucially for the South West, enable more distributed generation to be connected to the network at lower cost. It could enable local generators to supply local demand, potentially reducing the cost of renewable energy projects.

Smart grid technology is considered a fundamental pre-requisite to the deeper decarbonisation of the electricity supply. By making better use of existing infrastructure, enabling the emergence of new markets and new innovative business models, the development and deployment of smart grid technology is a central challenge of the low carbon transition.

Smart grid technology itself is a combination of sensors, electronics, communications systems and analytical processes that are integrated with the existing network infrastructure (substations and transformers etc.) as well as upstream generators and downstream electricity consumers. Smart grid software collects and organises the huge amount of information collected to enable both automated responses and control by the DNO and system operators.

Furthermore, it is enabling technology that provides the basis for the emergence of a new ecosystem of services and markets which can be built using the smart infrastructure. These include software-as-a-service providers, new technologies and new services that have the power to transform the electricity market. The South West has a lot to gain from being at the forefront of grid technology in the form of a more efficient network, increased renewable capacity and the high tech, high value companies that would be attracted by it.

At this early stage, a handful of these technologies are being developed or trialled but are not widely deployed. Those of most interest include:

5.1.1 ACTIVE NETWORK MANAGEMENT

Active Network Management (ANM) is the monitoring and active control of a constrained element of the grid, usually a substation which is at risk of exceeding its thermal and voltage parameters.

ANM is increasingly being used to allow more variable generators to connect to the grid through ‘non-firm’ grid connection agreements which allow the DNO to automatically curtail output if required to maintain network limits. This contrasts with firm connection agreements (the norm) where generators are guaranteed network access up to the defined capacity limit. ANM in effect allows several variable generators to operate with a combined grid connection capacity limit, increasing the number of connections possible and overall output. ANM can also include demand sites, encouraging energy consumers to increase consumption when excess energy is being generated locally. ANM technology was pioneered through a network trial on Orkney which cost £500k and avoided approximately £30m in network reinforcement costs.

> *The South West has a lot to gain from being at the forefront of grid technology in the form of a more efficient network, increased renewable capacity and the high tech, high value companies that would be attracted by it.*

5.1.2 GRID BALANCING SERVICES

The markets for grid balancing services like demand-side response, back-up capacity and frequency response (also known as ancilliary services) are growing quickly as smart grid technology allows small and distributed generators to compete in these markets.

Demand-side response means balancing the network by adjusting power demand to meet the available supply, rather than the other way around. In demand-side response electricity consumers are paid to reduce their consumption at peak times. Varying demand in this way is enabled by smart grid technology and provides clean and relatively cheap flexibility to the system.

Aggregator companies manage many small generators as well as demand-side capacity on behalf of their customers. They provide new opportunities for consumers to generate revenue by offering incentives for demand curtailment when required. Through ancilliary markets, they provide this aggregated response in a timely fashion which reduces the cost of managing the grid.

5.1.3 DEMAND TURN-UP SERVICES

Occasionally on windy days the amount of power supplied by wind turbines can exceed the demands in the nearby distribution grid. Rather than curtail generation, smart grid technology has enabled a demand turn-up service to be trialled. The demand turn-up service encourages businesses to increase their electricity consumption (provided it is used productively), or to reduce output from on-site embedded generators. This helps stabilise the grid and avoids the need for curtailment payments to the wind farm operators.

Demand turn-up is a new market which has been undergoing trials in 2016, with 309 MW of demand capacity engaged. While the market is currently small compared to the wider ancillary services market, it is expected to grow rapidly.

5.1.4 VIRTUAL PRIVATE WIRE

Physical private wire connections are direct connections between a generator and the consumer and are described in Section 5.3. The benefits of physical private wire are limited by the cost of the new connection and the difficulties in finding funding for projects with such arrangements.

Smart grid technology can enable virtual private wire connections which link generators and either one, or a small number of, demand loads across the DNO-owned network.

While it is subject to a different set of limitations, and a requirement to pay use of system charges to the DNO, the use of existing network infrastructure can dramatically reduce the cost of the private wire connection. Smart meter technology enables the more complex metering arrangements which are required to measure multiple sites in real time.

5.2 | ENERGY STORAGE

Grid-scale energy storage has a vital role to play in transforming our power supply. Storage working in tandem with smart grid technology and demand response can make the national grid more dynamic and resilient, both of which are vital to deep decarbonisation. Energy storage does this by flexibly offering to fulfil a range of different functions, including:

- Storing energy from renewables to smooth variable supply
- Helping energy consumers to manage their energy demand
- Stabilising voltage and frequency on power networks
- Managing grid infrastructure constraints

Storage permits higher levels of intermittent generation in the energy mix and allows more renewable capacity to connect to constrained distribution infrastructure, as in the Greater Exeter region. Battery solutions may also permit a greater penetration of dual-use wind and solar sites, as discussed in Section 4.3.1, by storing energy during times of high generation rather than curtailing the output. This can increase the utilisation of existing and new grid connections.

A government-backed report by the Carbon Trust[167] and Imperial College London presents detailed modelling of the potential value of energy storage as part of a smart grid in 2030. The cost of the UK's energy system could be reduced by up to £7 billion each year where energy storage is combined with smart grids and demand flexibility. National Grid's 2016 Future Energy Scenarios[168] now include energy storage and recognise the potential for storage to be 'a significant contributor to meeting system flexibility needs' with several gigawatts of new energy storage capacity potentially installed by 2025.

Scaled-up static lithium-ion batteries are beginning to be used to provide grid services because they can hold multiple megawatt hours of power and can discharge it quickly. These systems are commercially available from several suppliers in a price competitive market. Growing demand has created a virtuous combination of increasing investment in technology and production at ever-larger scales. As a result, the cost of large grid-scale batteries is falling dramatically, experiencing the same transformational learning effects witnessed with both solar panels and LED lighting. The number of instances where energy storage can provide services cost-effectively is increasing rapidly.

There are, of course, a range of other energy storage technologies, including lead acid and nickel batteries as well as pumped hydro and flywheels. R&D investment from electric vehicle manufacturers is also stimulating technology development. While it is lithium-ion that is being deployed at scale to support the grid today, there are other promising, but less mature, chemical storage technologies in development including sodium-ion, vanadium redox flow and organic flow batteries.

5.2.1 POTENTIAL ROLES AND BENEFITS

Battery energy storage is flexible, can deliver a wide range of grid support services and can potentially deliver several of these at the same time, known as 'value stacking'. The key installation contexts and functions are:

- **Behind the meter:** Industrial and other large consumers of electricity can use storage to reduce peak demand, in support of on-site generators and to increase supply resilience.

- **Alongside renewables:** Wind and solar farm operators can add storage to manage intermittent output and deliver grid services like frequency response.

- **Network support:** Distribution network operators can benefit from storage to manage grid constraints and defer larger investments in new infrastructure. This could be combined with voltage control, frequency control and enhanced frequency response services.

[167] Carbon Trust (2016). Can storage help reduce the cost of a future UK electricity system? [online]. Available at: https://www.carbontrust.com/media/672486/energy-storage-report.pdf | [168] National Grid (2016) Future Energy Scenarios, [online]. Available at: http://fes.nationalgrid.com

5.2.2 ENHANCED FREQUENCY RESPONSE

Frequency response services help maintain grid stability by holding the system frequency within a narrow band either side of 50Hz. As the penetration of renewable energy into the grid increases and the capacity of large thermal generation decreases, the overall 'inertia' of the generators connected to the system falls, making it more susceptible to sudden changes in load and therefore changes in frequency.

National Grid is increasingly in need of frequency services that can respond rapidly. Enhanced Frequency Response (EFR) is a new market which is designed to activate in one second or less. Lithium-ion batteries are one of the few technologies which can deliver this fast and sustained response.

This is a new market and the results of the first auction were published in August 2016. In total 200 MW of capacity was procured, most of which was large multi-MW batteries, many of which will be installed alongside wind and solar farms. There was a lot of interest in the auction and this is considered a strong indicator of the future potential of energy storage. National Grid has stated their intention to hold regular auctions 'over the next 10 to 20 years'.

The EFR market is seen as a significant milestone as it marks the emergence of UK expertise and as an indicator of how far the price of grid-scale storage has already fallen.

5.2.3 THE CHALLENGES TO DELIVERY

The storage opportunity has been anticipated for some time and many investors are searching for opportunities to benefit from the sector's growth. It is anticipated that costs will continue to fall as further investment into manufacturing efficiency feeds through into prices. Today, however, only a small number of battery applications are financially viable. Regulation also needs to be tailored to specifically support the unique role that batteries play within the energy system. It is anticipated that the recent call for evidence for a smart, flexible energy system (Nov 2016) will move some way towards achieving this.

5.2.4 SUMMARY

Energy storage is an enabling technology which can help create a smarter more flexible power system; a critical part of a decarbonised electricity supply. Furthermore, it can help Greater Exeter to overcome the barriers to adding new renewable capacity. It is a new technology with its full potential still to be realised. By taking a proactive approach to energy storage, working with the DNO, renewables developers and businesses, Exeter could build a local green economic advantage: a national hub for dedicated expertise and research.

> *By taking a proactive approach to energy storage, working with the DNO, renewables developers and businesses, Exeter could build a local green economic advantage: a national hub for dedicated expertise and research.*

5.3 | PHYSICAL PRIVATE WIRE

Private wire arrangements may enable greater integration of renewable generation and intelligently optimised flows in distributed clusters of energy use such as business parks, estates or large developments. A private wire arrangement is a direct connection between a generator and the consumer. Generators usually connect to the distribution grid and sell their electricity via wholesale suppliers. However, because private wire arrangements don't rely on shared grid infrastructure, they do not pay 'use of system' charges and are not affected by distribution grid connection capacity constraints. The generator can also charge more while still offering the consumer prices that beat retail rates.

While there are advantages to physical private wire connections, particularly in grid constrained areas like Greater Exeter, the arrangement remains rare in the UK. This is mainly because building new physical connections is expensive and can quickly outweigh the benefits unless the distance to the customer is short. Overhead lines also increase planning risk and the complexity of the development process.

A private wire connection is governed by a Power Purchase Agreement (PPA), a contract for the sale of electricity produced by a generator which prescribes the rules of the relationship, duties and rates. While the PPA for physical private wire can offer attractive terms to both parties, banks are often unwilling to finance new capacity on this basis because of the risk that the buyer's energy demand falls or they go out of business. Only the strongest corporate counterparties (with AAA- credit ratings) are likely to be considered acceptable where the electricity generated cannot also be exported to the grid. In practice this means that physical private wire connections are unlikely to proliferate widely without increased evidence regarding the operational reality of these risks.

5.4 | HEAT

5.4.1 DISTRICT HEATING

District heating schemes are based on a network of insulated pipes used to deliver heat, in the form of hot water or steam, from centralised points of generation to locally-distributed end users. District heating schemes can be deployed at varying scales, from a few hundred metres between homes and flats to several kilometres serving entire communities and industrial areas. A district heating network facilitates the distribution of heat from a diverse supply of sources including waste heat captured from industrial processes and power generating units such as gas-fired CHP, as well as low carbon options such as heat pumps (air and water) and geothermal sources. District heating networks are able to balance supply and demand spatially and temporally, allowing for shifts in aggregated heat demand (e.g. from residential to non-residential applications, back to residential over a typical working day) to be served by a single system, thereby improving plant utilisation.

This, alongside deployment at scale, allows price economies to be realised, making district heating more competitive than individual heating systems. They offer energy, and thus carbon, savings of up to 25% compared with regular gas boilers and up to 50% compared to electric heating[169]. The ability to integrate multiple heat sources also allows for improved service reliability and opportunities for long term price stability. In a retrofit scenario, district heating systems are more costly to set up compared to individual systems, typically requiring an additional £3,500 per electrically heated dwelling or up to £3,000 for an existing gas dwelling. New-build projects typically enable the capital costs of district heating to be kept to a minimum and avoid the disruption associated with retrofitting if not undertaken at trigger points such as property sales. £320M of funding is available until 2020 under the government's 'central heating for cities' scheme to develop low carbon heat network projects.

[169] Carbon Trust (2004). Community heating for planners and developers, [online]. Available at: http://www.communityplanning.net/pub-film/pdf/CommunityHeating.pdf

CHP units can be used to enhance the economic viability of district heating schemes since, in addition to heat distribution, electricity can be sold through power purchase agreements (ideally via private wire) to consumers at a rate greater than its value if sold to a licenced supplier at wholesale price.

Low carbon heat networks require a certain level of heat demand density to be economically viable. The government's national heat map tool and the national comprehensive assessment of the potential for combined heat and power and district heating and cooling in the UK[170] show that the main heat load densities in the Greater Exeter area lie in and close to Exeter itself. Feasibility studies for district heating schemes in Exeter have identified various opportunities for deployment with attractive returns on investment[171,172]. To date, a district heating scheme with its energy centre at the Skypark development and serving the community of Cranbrook has been taken forward. A scheme servicing anchor loads in the city centre is also currently in planning and development.

A key issue with existing district heating projects is the focus on anchor heat loads which are required to make projects financially viable. To ensure long-term PPAs, there is, whether it is acted on or not, an incentive for heating scheme developers to maintain heat demand of anchor contracts into the future. This may conflict with the opportunities presented to reduce heat demand – for example, it is rare that Passivhaus standards of energy efficiency are achieved before district heating schemes are proposed. A further issue is that while anchor loads provide significant heat demand from a single contractual point of contact, the bulk of city heat demand is often distributed widely across many buildings and users. Projects demonstrating how district heat networks might achieve wider reach in city retrofit will be essential to moving beyond the current approach. Exeter City Council has been awarded funding under the government's Heat Network Delivery Unit to explore in detail these very issues.

5.4.2 COMBINED HEAT AND POWER (CHP)

CHP units generate electricity while also capturing the usable waste heat that is produced in this process. The recovery of heat in CHP contrasts with conventional ways of generating electricity where the heat produced is simply rejected to the environment, with a typical improvement in operating efficiency of approximately 30%[173]. The wider deployment of distributed CHP plant can therefore provide significant energy efficiency and financial and carbon emission benefits compared with the separate generation of electricity and heat. However, this is conditional on being able to put a sufficient proportion of the heat to good use. Consequently, CHP is normally suited to facilities where there is a coincident demand for electricity and heat for a significant proportion of the year.

Examples of common uses include leisure centres, hospitals, universities, multi-residential complexes and industrial facilities in the food and drink, chemicals, paper and engineering sectors. With the addition of absorption chilling (chilling generated from heat), the applicability of CHP can be extended to commercial buildings, data centres, high-tech manufacturing and other facilities with significant cooling requirements.

CHP technology is available in a wide range of sizes, from domestic to large scale, and can be fuelled in several configurations. CHP units are conventionally fuelled in the UK by natural gas however renewable fuels, such as biogas and solid biomass, are increasingly being used in the abatement of emissions. Conversion of the gas grid in part to low carbon hydrogen, as discussed in Section 5.5.2, would assist in the decarbonisation of both existing and new natural gas-fuelled CHP plant.

Biomass-fuelled CHP maximises renewable resource use. However this often proves contentious where biomass resource is limited and its production competes with other land uses, particularly food production. Energy from waste plant is also increasingly being employed in CHP mode, with the heat produced serving local demands via district heating systems.

170 DECC (2016). The national comprehensive assessment of the potential for combined heat and power and district heating and cooling in the UK, [online]. Available at: https://www.gov.uk/government/publications/the-national-comprehensive-assessment-of-the-potential-for-combined-heat-and-power-and-district-heating-and-cooling-in-the-uk | 171 Element Energy (2008). East of Exeter New Growth Point Energy Strategy, [online]. Available at: http://www.exeterandeastdevon.gov.uk/element-energy-study/ | 172 http://www.exeterandeastdevon.gov.uk/developing-heat-networks-for-the-exeter-growth-area/ | 173 BRE (2016). Community Energy Systems and the UK's National Energy System – the Role of CHPV, [online]. Available at: http://www.bre.co.uk/filelibrary/pdf/presentations/CHPV-Workshop-All-200116.pdf

Large scale co-generation is a well-developed, mature technology, however widespread gas CHP deployment is currently hindered by several barriers. Sourcing finance for projects is difficult due to the lack of standard commercial and contractual arrangements for construction and operation. Financial returns are unclear due to uncertain operating variables such as the availability and longevity of heat loads, prices obtainable for electricity and heat sales, and the ongoing cost of fuel supply. The government has previously engaged with stakeholders to identify non-fiscal barriers currently preventing deployment; BEIS is considering responses to inform future policy measures. Non-fiscal barriers to deployment are widely known and documented[174] as lack of senior champions, lack of local authority and Small and Medium Enterprise (SME) technical resource and expertise to unlock CHP opportunities, a lack of understanding of CHP and the availability of benefits, and preconceptions about the cost-effectiveness of the technology.

Domestic CHP installations of less than 2kW are currently supported by a Feed in Tariff (FiT). However, only 49 new deployments have occurred in the last year[175] (Aug 2015 – Aug 2016), demonstrating the requirement for further measures to stimulate uptake on a domestic scale.

5.5 | HYDROGEN

Hydrogen is an energy vector rather than an energy source like wind, solar and other renewable power technologies. Hydrogen can be created, stored, transported, and consumed in a number of common end uses including power generation and transport. The flexibility of hydrogen, being both a fuel and a storage medium, makes it a key enabler for the wider use of renewable energy sources linking intermittent supply with demand.

5.5.1 HYDROGEN PRODUCTION

Hydrogen can be produced by Steam Methane Reforming (SMR) natural gas or through the electrolysis of water using electricity. SMR can be undertaken at a large or small scale but will produce CO_2 as an undesirable by-product. Electrolysis uses electricity to separate water into hydrogen and oxygen. The choice of electrical source for electrolysis is important when considering round trip efficiency of useful energy (Figure 5.1), which is considerably greater when renewable power sources are employed to drive it[176]. Very high levels of carbon emissions arise when electricity derived from traditional generation plant is used to produce hydrogen, whereas the use of renewable electricity delivers hydrogen with minimal emissions. Coupling renewable power sources with hydrogen production could circumvent grid infrastructure barriers (Section 5.1) that currently prevent the wider deployment of renewable power projects in Greater Exeter.

[174] DECC (2015). Tackling Non-Financial Barriers to Gas CHP, [online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/446505/Gas_CHP_Call_for_Evidence_-_Draft_Summary_of_Responses_for_Publication_docx.pdf | [175] https://www.gov.uk/government/statistics/monthly-small-scale-renewable-deployment | [176] University of Strathclyde (2016). Round trip efficiency, [online]. Available at: http://www.esru.strath.ac.uk/EandE/Web_sites/02-03/hydrogen_economy/Round%20Trip%20Efficiency.htm

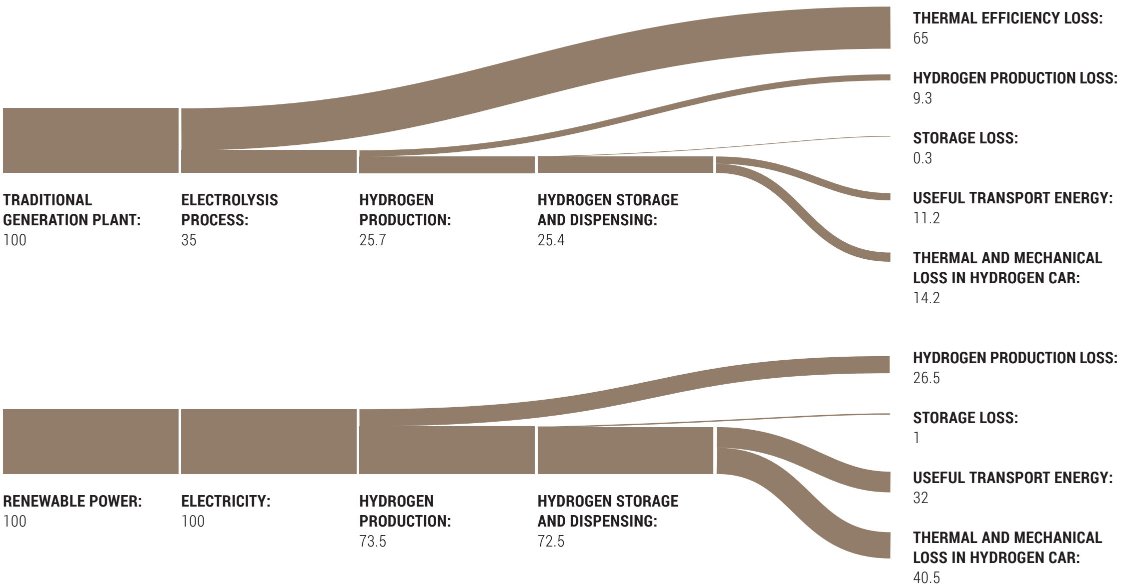


Figure 5.1: Round trip efficiencies for hydrogen used in a fuel cell car using different electrical sources for electrolysis

As natural gas is not produced in Devon for SMR, electrolysis is the more logical choice for hydrogen production. Renewable energy-coupled hydrogen plants are already successfully operating throughout Europe[177], demonstrating the opportunity for wider deployment locally. A planning application has been granted for a hydrogen generation and storage system in Fullabrook near Braunton in North Devon – however, details are sparse[178].

5.5.2 HYDROGEN AND EXISTING INFRASTRUCTURE

Hydrogen can be distributed by two means; pressurised vessels or via pipeline. Pressurised vessels can range from small industrial gas cylinders to larger trailer tubes mounted on HGVs. At both scales the vessels are moved by road, which has an associated carbon footprint. Hydrogen can be blended with natural gas and distributed using existing infrastructure (e.g. modern polyethylene gas pipes), or through dedicated hydrogen pipelines.

The Gas Safety (Management) Regulations 1995 (GS(M)R) currently prevent the injection of hydrogen into the gas distribution grid[180]. However, the Health and Safety Executive (HSE) has recently issued a research note which concludes that injecting small concentrations of hydrogen by volume up to 20% would be unlikely to increase safety risks in end-use devices[181]. No regulatory changes have been announced to date, however, progress in this area allows us to conclude that a framework permitting hydrogen injection may be inaugurated in the near future. However, this would also give rise to further challenges such as reduced line pack storage and meter replacements[182].

Using existing infrastructure for hydrogen could be advantageous in comparison to district heating schemes which have major distribution and infrastructure costs. Hydrogen blends are already being used in Germany and a proposal for a city scale hydrogen gas network has been developed for Leeds[179]. A similar option could be explored for Greater Exeter, and if combined with CHP would facilitate even greater carbon savings.

177 Energiepark Mainz, Germany | 178 Braunton Parish Council (2016). Available at: http://www.brauntonparishcouncil.gov.uk/Braunton-PC/UserFiles/Files/AP%2027June%20X.pdf | 179 Northern Gas Networks (2016). H21 Leeds City Gate, [online]. Available at: http://www.northerngasnetworks.co.uk/document/h21-leeds-city-gate | 180 National Grid (2016). Gas Quality, [online]. Available at: http://www2.nationalgrid.com/uk/industry-information/gas-transmission-system-operations/gas-quality | 181 HSE (2015). Injecting hydrogen into the gas network – a literature search, [online]. Available at: http://www.hse.gov.uk/research/rrpdf/rr1047.pdf | 182 P. Dodds and S. Demoullin (2013). 'Conversion of the UK gas system to transport hydrogen', International Journal of Hydrogen Energy. Available at: https://www.bartlett.ucl.ac.uk/energy/research/themes/energy-systems/hydrogen/dodds-demoullin-2013-gas-network-conversion

5.5.3 OPPORTUNITIES FOR HYDROGEN USE

The variety of ways in which hydrogen can be used means that there are a wide range of applications in Greater Exeter and Devon. These range from production of hydrogen in renewable energy projects in rural areas of Devon, to use for heat, power or transportation in Exeter or smaller communities:

- **Vehicle fuel:** Hydrogen fuel cells can be used to produce electricity and drive an electric drivetrain in a vehicle. An increasing range of vehicle types are becoming available:
  - **Passenger cars –** Some manufacturers, including Toyota and Hyundai, are aggressively developing fuel cell cars ahead of battery alternatives. The widespread use of hydrogen cars requires a network of refuelling systems, which could be fulfilled using pressure vessel distribution as previously discussed. Appropriate refuelling infrastructure is a prerequisite to hydrogen vehicle deployment in Greater Exeter or Devon.
  - **Buses –** Hydrogen bus fleets have been piloted in London and Aberdeen. Predefined routes allow for strategic refuelling point positioning.
  - **Industrial vehicles –** Hydrogen is a competitive alternative to battery power or compressed gas and offers low emissions and quick refuelling, which is important for large distribution centres with high rates of consumption.
- **Grid solutions:** Converting renewable energy to hydrogen has been used as a route to avoid grid constraints for wind, solar and other renewable energy schemes. Using electrolysis, the hydrogen produced can be used locally (e.g. on a farm), converted to fertiliser and distributed to other users. This could be very relevant to renewable electricity projects in rural Devon and presents a good option for the focus of a pilot system demonstrating new ways to overcome grid constraints for onshore wind and solar PV projects.
- **Fertiliser production:** In an extension of the grid solution, the local production of hydrogen could be extended to use nitrogen for conversion into ammonia. Ammonia could then be applied in anhydrous form as a fertiliser. Systems for this are being developed in the US, Canada and the Netherlands.
- **CHP:** CHP units make use of waste heat ejected during the process used to generate electricity. Hydrogen fuel cells have a very high electrical efficiency – up to 60% compared to approximately 30% for conventional combustion. Hydrogen fuel cell CHP units are significantly more efficient than conventional CHP units and can be deployed both at domestic and commercial scale (e.g. the Palestra building in London).

5.5.4 BARRIERS TO COMMERCIAL MATURITY

Hydrogen systems, both production and consumption technologies, are generally at an early stage of commercial development, hence costs are high compared to alternatives. A key difference between hydrogen systems and most forms of renewable electricity and heat is that there are limited incentives to overcome the significant cost, presenting a financial barrier to wider deployment. Hydrogen technologies are currently incentivised via two routes, but these are not strong enough to stimulate mass uptake:

1. Feed in Tariff - one of the accredited FiT micro CHP systems is a fuel cell system. Uptake of microCHP has been very low to date.
2. Grants – several grant schemes have helped initial projects. For example, the Office for Low Emission Vehicles (OLEV) offers grants for hydrogen refuelling stations and for public sector hydrogen vehicle fleets.

5.6 | CARBON CAPTURE AND STORAGE (CCS)

While energy independence is the objective for Exeter City Futures, at national level CCS is a potentially important decarbonisation technology that will have a wider impact on policy support and the costs of alternative sources of low carbon fuel. UK CCS trials are likely to be a source of innovation and the development of new business models, both around existing power-producing regions and industrial sites. The technology itself may not be applicable in Greater Exeter, but a brief overview of the current state of deployment and policy is provided here for completeness.

CCS has a key role to play in achieving deep cuts in global CO_2 emissions. The Intergovernmental Panel on Climate Change (IPCC) concluded that to limit global warming to 2°C would cost 138% more without CCS[183], and the International Energy Agency (IEA) has noted that excluding CCS as an option for mitigating emissions in the power sector alone could increase mitigation costs by $2 trillion by 2050[184]. In the UK, the Committee on Climate Change (CCC) concluded that CCS could halve the cost of meeting the UK's 2050 CO_2 emission reduction targets[185]. Modelling by the Energy Technology Institute (ETI) showed that, without CCS, the cost of reaching climate change targets in the UK could add 2 p/kWh to the overall energy bill in 2050[186].

CCS has the advantage that it can be applied to large stationary sources including power plants and industrial processes such as steel and cement refineries and chemical plants. Power plants with CCS can operate at high load and can provide flexible power by producing and storing hydrogen, which can subsequently be combusted in turbines. Alternatively, biomass with CCS has the potential to deliver negative emissions.

Carbon capture (via amines, potassium carbonate or using adsorbents or highly-selective membranes) is a proven technology with many plants already existing worldwide. For many years, injection of CO_2 for enhanced oil recovery has been used in the oil and gas industry. More recently, the transportation of CO_2 has been demonstrated with thousands of miles of CO_2 transport pipeline across the United States. If emission reductions are to be achieved across a wider range of energy infrastructure, CCS must be demonstrated and deployed on power plants as well as a wider range of industrial sites.

The deployment of CO_2 capture, transport and storage in the power generation sector is still in its early stages with a few demonstration plants worldwide. Outside the EU, there are currently 20 large-scale CCS projects either in operation or in construction. There is currently no demonstration of the full CCS chain in the UK.

5.6.1 STATUS IN THE UK

It has been estimated that if CCS is exploited effectively in the UK, around 3-4 GT could be stored by 2050[187]. This would require the development of several shoreline hubs and at least 20 storage sites at an offshore cost of £5 Bn. The most advanced CCS project in the UK is currently the White Rose project. White Rose is intended to capture around two million tonnes of CO_2 annually from a proposed new oxy-fuel power plant in North Yorkshire. The proposed Yorkshire and Humber CCS Cross Country Pipeline would transport the captured CO_2 to the coast linking to an offshore deep saline storage facility. The White Rose and Peterhead projects were the preferred bidders eligible for the UK CCS Commercialisation Programme and have been awarded funding from the European Commission under its NER300 Programme. Neither project has yet proceeded to construction.

183 IPCC (2014) | 184 IEA, 2012 | 185 UK CCC, 2015 | 186 http://www.eti.co.uk/wp-content/uploads/2014/03/ETI_CCS_Insights_Report.pdf
187 International Energy Agency (2012). CCS in a Global Climate Change Context, [online]. Available at: https://www.iea.org/media/workshops/2012/ccsmexico/1DennisBest.pdf

5.6.2 STATUS IN EUROPE

The European Commission's position on CCS is that it should be deployed from 2030 for the EU to achieve its emission reduction targets. The CCS Directive, which came into force in 2009, intended to encourage the deployment of CCS and to lead to its commercialisation by 2020. The CCS Directive provides the legislative framework for addressing environmental, health and safety concerns about the storage of CO_2. It harmonises administrative procedures for the whole cycle of carbon capture, transport and storage across member states and so creates the necessary legal certainty for investors to construct large-scale installations for CO_2 capture and transport pipelines and to develop CO_2 storage sites.

Despite the presence of the CCS Directive and the fact that most member states submitted their implementation plans, the rate of progress with large-scale CCS in Europe has been much slower than was previously anticipated in 2009. Currently, there are no examples of full CCS chain deployment on power plants in the EU. There are only four projects at the planning stage. Once operational, these projects would complement the experience of two Norwegian commercial projects, linked to natural gas production – Sleipner and Snøhvit[188].

5.6.3 POTENTIAL FOR CCS IN THE EXETER REGION

There are no coal power stations and only a single 900 MW combined cycle gas power station with no heavy industry in the South West region. The most suitable CO_2 storage sites in the UK are mainly located in the North Sea with a few adequate and well-characterised storage sites in the Irish Sea (Figure 5.2). Emissions captured from the Greater Exeter region would likely need to be transported to storage sites in the Irish Sea or the English Channel near the Isle of Wight. Storage in the Irish Sea may not be an economically feasible option unless a hub (similar to proposals for Grangemouth and Yorkshire and Humberside) is formed in South Wales, where several large stationary sources exist.

There is a lot of heavy industry in South Wales which may lead to creating a CCS hub in that region. However, the feasibility of this has not been studied. The large transport distances is one of many key challenges which need to be evaluated. Also, CCS infrastructure development in Ireland will affect the feasibility of such a CCS network.

5.6.4 BARRIERS

It should be emphasised that the challenges facing CCS deployment in the UK are not technical as the different elements of the CCS chain are well demonstrated. However, the fact that the full CCS chain has not been demonstrated on power plants remains a problem.

The cost and energy penalty associated with the capture process and the cost of transport and injection infrastructure are key challenges. There is a disconnect between the anticipated future importance of CCS and the current financial mechanisms and deployment levels.

188 The Sleipner project in Norway, which captures around 1 Mt of CO_2 from the Sleipner gas field, has been in operation since 1996. To date, more than 20 Mt of CO_2 have been safely stored in a saline aquifer in the North Sea.

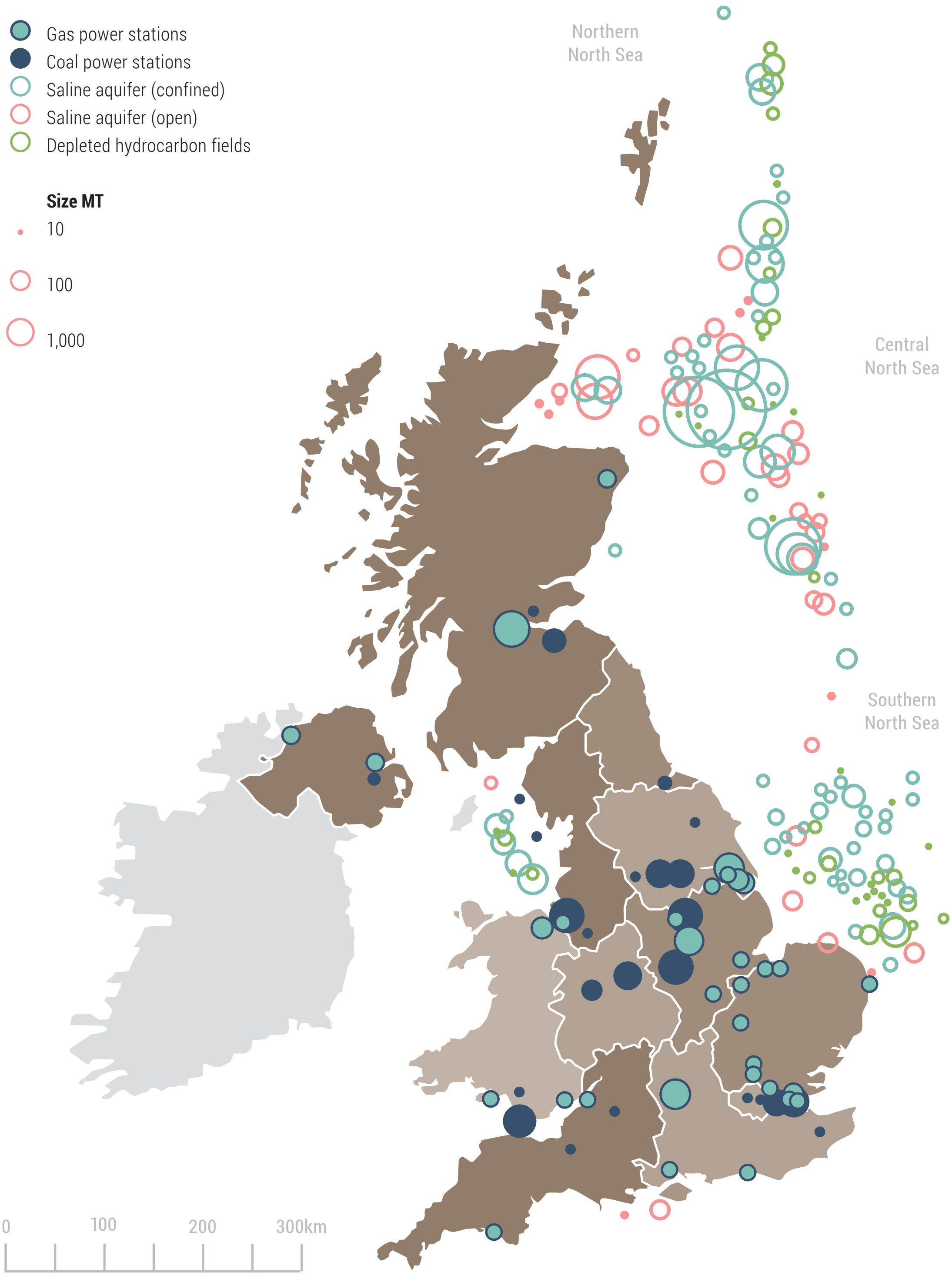


Figure 5.2: CO_2 storage sites in the UK

ROADMAPS TO ENERGY INDEPENDENCE

6

Greater Exeter has tremendous opportunities to reduce energy demand, increase energy generation from low carbon sources and adopt a proactive approach to the development of enabling energy technologies.

6.1 | FUTURE CONSUMPTION & ENERGY INDEPENDENCE OPPORTUNITY

This report demonstrates that Greater Exeter has tremendous opportunities to reduce energy demand, increase energy generation from low carbon sources and adopt a proactive approach to the development of enabling energy technologies.

When taken together, the maximum technical potential from the individual sections results in the Maximum Technology scenario for Greater Exeter – this is the hypothetical contribution from demand reduction and new generation initiatives prior to the imposition of cumulative impacts. Overall, the Maximum Technology scenario concludes that a contribution of up to 18.6 TWh of energy could theoretically be harnessed in the Greater Exeter area. This comprises 2.6 TWh of demand reduction and 16 TWh of new onshore generation. Under a Business As Usual projection, the energy consumption of Greater Exeter is forecast to rise from 10.0 TWh currently to 11.3 TWh in 2025. A comparison of future demand against the Maximum Technology scenario suggests that the goal of energy independence is eminently achievable (Table 6.1). However, certain barriers, in particular those related to the deployment of onshore wind, are deemed insurmountable to the extent that a further scenario is presented. This Maximum Deployment scenario applies a planning constraint based on cumulative visual impact that limits the amount of onshore wind that can be deployed. In practice, this is likely to reflect a more realistic scenario, but the impact is significant, removing 12.1 TWh from the assessed contribution. The resulting Maximum Deployment scenario retains ambitious demand reduction initiatives totalling 2.6 TWh, but offers a much-reduced generation contribution of only 3.9 TWh (6.5 TWh in total).

Table 6.2 demonstrates how these scenarios are derived from the unconstrained resources identified in each technology sub-section.

GWh		Unconstrained potential	Potential after designated areas removed	Maximum technical potential (hypothetical)	Deployable potential after cumulative impact/radar constraints applied	% of forecast 2025 consumption
Demand reduction	Domestic	-	-	1,952	1,952	17.3%
	Commerical	-	-	368	368	3.3%
	Industrial	-	-	250	250	2.2%
Solar	Rooftop - current domestic	-	-	99	99	0.9%
	Rooftop - new domestic	-	-	27	27	0.2%
	Rooftop - current commercial	-	-	341	341	3.0%
	Rooftop - new commercial	-	-	88	88	0.8%
	Ground mounted	111,118	51,563	1,934	1,934	17.1%
	Solar car bays	-	-	44	44	0.4%
Wind	Onshore	41,643	26,171	13,086	1,242	11.0%
	Offshore	-	-	0	0	0.0%
Hydro	Run of river	42	42	42	21	0.2%
Biomass	Forestry residues	-	-	90	45	0.4%
	Arboricultural arisings	-	-	5	3	0.0%
	Clean waste wood	-	-	12	6	0.1%
	Energy crops	224	137	27	14	0.1%
	Animal slurries	-	-	26	13	0.1%
	Food wastes	-	-	6	3	0.0%
	Sewage sludge	-	-	12	6	0.1%
	Waste wood	-	-	26	13	0.1%
	Residual waste	-	-	19	10	0.1%
Marine	Tidal stream	-	-	0	0	0.0%
	Wave	-	-	0	0	0.0%
	Tidal range	-	-	83	0	0.0%
	Total			18,322	6,477	57.0%

Table 6.1: Resource potential matrix by sector and constraint

GWh		Deployable	% of 2025 demand	Notes
Demand reduction	Domestic	1,952	17.3%	Assumes all space heating initiatives completed and 20% reduction in appliance energy use.
	Commerical	368	3.3%	Assumes retrofit saving achieved and demand growth saving achieved.
	Industrial	250	2.2%	Assumes 15% demand reduction achieved.
Solar	Rooftop - current domestic	99	0.9%	Assumes solar PV deployed on all available existing rooftops.
	Rooftop - new domestic	27	0.2%	Assumes solar PV deployed on all new-build rooftops.
	Rooftop - current commercial	341	3.0%	Assumes solar PV deployed on all available existing rooftops.
	Rooftop - new commercial	88	0.8%	Assumes solar PV deployed on all new-build rooftops.
	Ground mounted	1,934	17.2%	Excludes unsuitable land - designated areas, agricultural land grades 1-3, unsuitable slope/aspect. Assumes deployment on 20% of remaining land area.
	Solar car bays	44	0.4%	
Wind	Onshore	1,242	13.1%	Excludes unsuitable land - designated areas, low wind speeds. Includes all radar zones. Assumes deployment on 20% of remaining land area.
	Offshore	0	0.0%	1 GW potential at outer Lyme Bay, but half of this is allocated to Devon rather than Greater Exeter so excluded.
Hydro	Run of river	21	0.2%	Assumes 50% deployment is achieved.
Biomass	Forestry residues	45	0.4%	
	Arboricultural arisings	3	0.0%	
	Clean waste wood	6	0.1%	
	Energy crops	14	0.1%	Excludes landscape designated areas and permanent grassland. Assumes 20% available for energy crops, 50% of this achieved.
	Animal slurries	13	0.1%	Assumes 50% deployment is achieved.
	Food wastes	3	0.0%	
	Sewage sludge	6	0.1%	
	Waste wood	13	0.1%	
	Residual waste	10	0.1%	
Marine	Tidal stream	0	0.0%	Does not includes potential resource in Alderney which could connect to Greater Exeter via the proposed FabLink interconnector at Budleigh Salterton.
	Wave	0	0.0%	
	Tidal range	0	0.0%	River Exe barrage not likely to be deployed.
	Total	6,477	57.0%	

Table 6.2: Deployable resource potential by type and methodology summary

6.2 | RESIDUAL ENERGY REQUIREMENT

Under the Maximum Technology scenario, Greater Exeter could go from a net energy requirement of 11.3 TWh in 2025 to generating a surplus of 7.3 TWh. As discussed however, the Maximum Technology contribution is unlikely to be fully exploitable as major barriers stand in the way of its delivery. It is estimated that the major political barrier of cumulative impact would restrain this figure by 12.1 TWh. This reduction results in a net residual energy requirement for Greater Exeter in 2025 of 4.8 TWh (Figure 6.2). While this scenario is much lower than the Maximum Technology option, it retains an ambitious retrofit effort required to deliver 2.6 TWh of demand reductions.

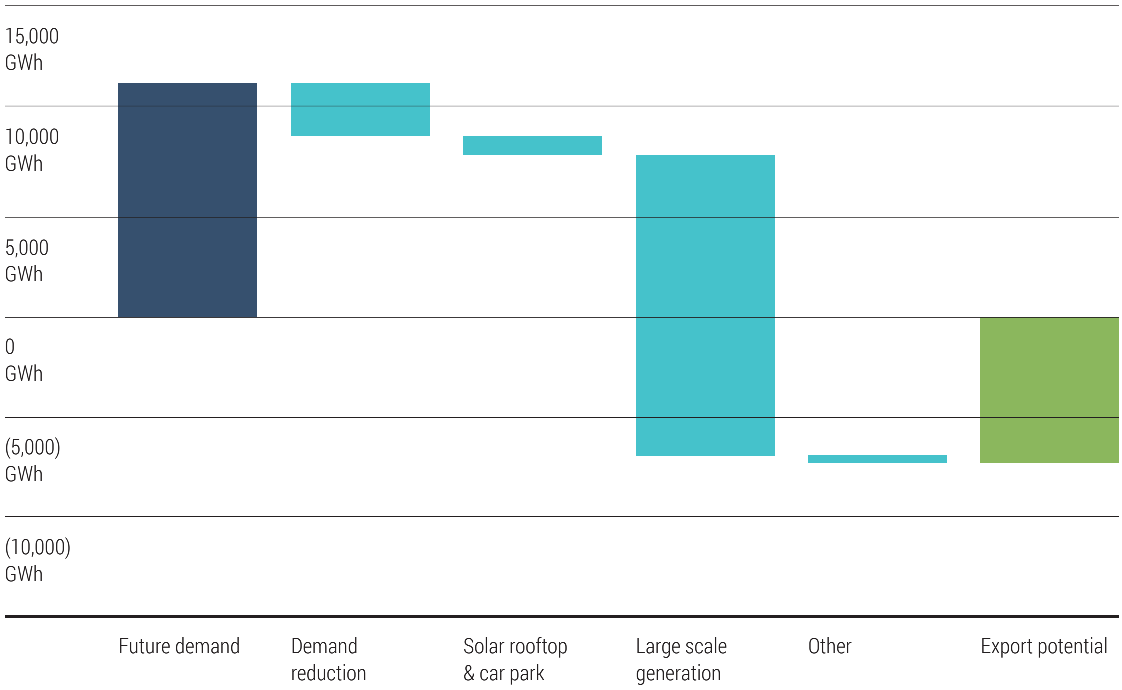


Figure 6.1: Energy gap analysis for Greater Exeter under the Maximum Technology scenario

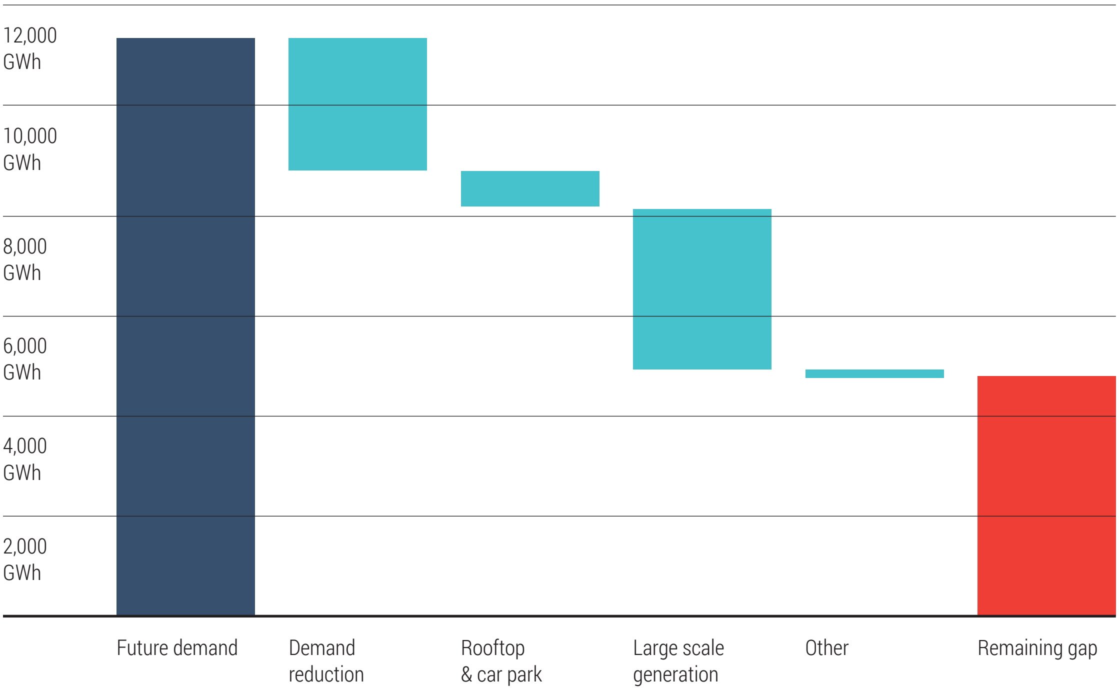


Figure 6.2: Energy gap analysis for Greater Exeter under the Maximum Deployment scenario

It is important to note the following points regarding the emergence of the residual requirement since a number of factors could still enable energy independence to be achieved:

6.2.1 UNDERLYING TECHNOLOGY ASSUMPTIONS

The Maximum Technology scenario assessed is effectively an analysis of the potential contribution from technologies as they are known today. This analysis is inherently subject to the assumptions that we hold based on our existing understanding of technology. For example, most regional resource assessments were undertaken in 2010/2011 and excluded ground mount solar since they were developed before the policy support led to ground mount becoming an established technology in the UK. A range of developments, such as generation efficiency improvements, could further enhance the performance and estimate associated with a given technology and achieve further progress. It is therefore important to both stimulate development and horizon-scan for breakthrough innovations.

6.2.2 GROWING INTEGRATION OF TECHNOLOGY

If acceptance of technologies can be increased sufficiently to allow them to occupy the region more densely, the deployable potential could increase some way towards the Maximum Technology limit. Potential future solutions, such as the integration of solar into a wider range of infrastructure, may not be restricted by current planning considerations or barriers related to social acceptability. Certain examples of technology integration are already occurring in the solar industry e.g. roof tiles and roadways. These products could enable much higher levels of deployment than assumed without the associated barriers.

6.2.3 IMPACT OF TRANSPORT EFFICIENCY

The analysis in this report does not currently include any savings from the transportation sector and in fact assumes an increase in the number of vehicles in line with household formation. Based on this, by 2025 transport will represent 4.4 TWh of Greater Exeter's energy consumption. Regional transportation will be the subject of a detailed companion study with the aim of identifying, quantifying and addressing existing inefficiencies. Transportation is a sector whose importance is often overlooked from the perspective of energy efficiency at a strategic local level. The tools and suggestions developed as part of the transportation study aim to provide a clear roadmap to delivering further efficiencies.

6.2.4 GEOGRAPHIC CONSIDERATIONS

A final factor that has been considered is whether Greater Exeter could import energy from surrounding regions. This report considers energy independence strictly in the context of the geographic area covered by Exeter City Council and East Devon, Teignbridge and Mid Devon district councils. As discussed, there are significant resources in the surrounding region, including notable offshore and geothermal opportunities. Specific sites have also been identified that could connect directly to Greater Exeter, for example, a potential 6 TWh tidal stream resource at Alderney, where an international interconnector is proposed to land in East Devon. The difficulty in counting other region's resources, however, is knowing whether a resource is, or will be, included in another region's energy strategy or whether it will contribute towards decarbonisation of the national electricity supply. Therefore, a strict geographic area has been maintained to avoid double counting. That said, Greater Exeter could potentially, through consultation with BEIS on policy for distributed resource and co-ordination with other regions on their resource plans, carve out options to use regional resource as part of an energy independent mix. This presents a real opportunity for the city to achieve low carbon supply for its remaining energy requirement, while stimulating wider regional benefit.

6.3 | CARBON SAVINGS

Implementation of the Maximum Deployment scenario could abate up to 1,218 kt CO_2 per year if the full deployment potential is realised (45% reduction at 2025 levels) and 2025 national grid decarbonisation targets are achieved (Figure 6.3). This carbon savings figure includes an adjustment to account for Greater Exeter's anticipated contribution of low carbon power to the national grid decarbonisation targets to avoid double counting. This compares favourably to the United Kingdom's national obligation to reduce carbon emissions by 50% by 2025 based on 1990 levels[189] suggesting that, in its efforts to become energy independent, Greater Exeter could deliver above and beyond its share of this target.

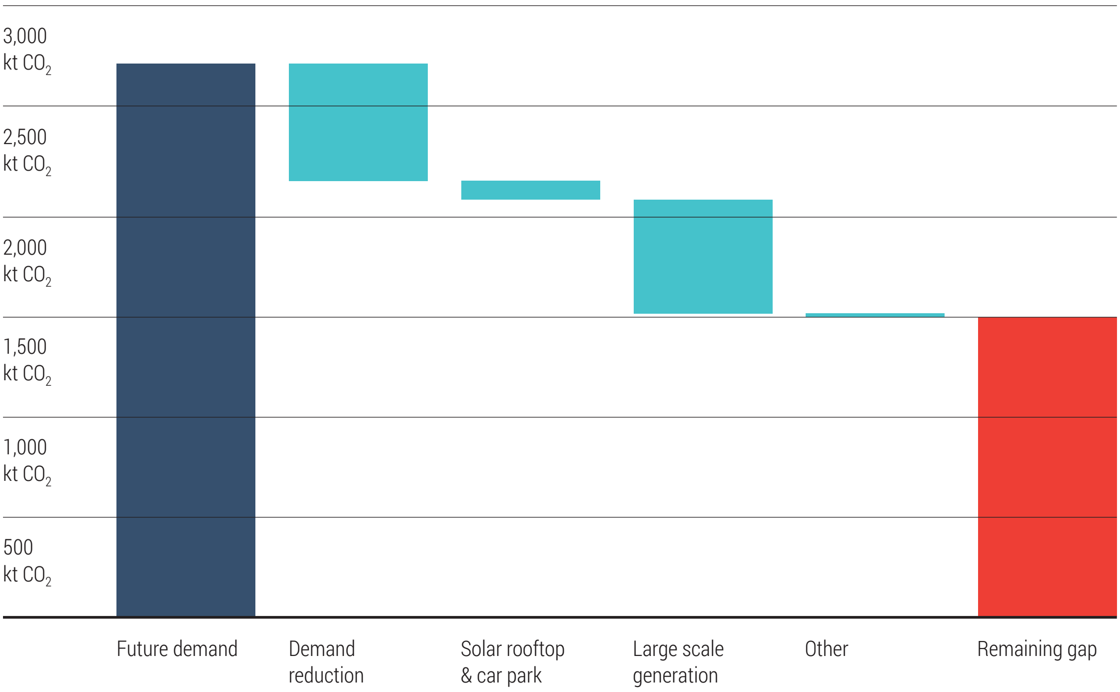


Figure 6.3: Carbon emissions savings based on 2025 emission levels (including future demand)

[189] Committee on Climate Change (2016). Carbon budgets and targets, [online]. Available at: https://www.theccc.org.uk/tackling-climate-change/reducing-carbon-emissions/carbon-budgets-and-targets/

6.4 | BARRIERS

Given the set of choices available to achieve the energy independence goal, it is recommended that the main technology solutions likely to contribute directly inside the region are given priority attention. Additional effort to explore the potential contribution from local geothermal and other regional resource should also be considered.

Quantification of the impact of adoption barriers, based on consultation with experts across technologies, reveals that the major barriers are political, financial and technical and occur across a range of potential paths. The major barriers, ranked by importance, are discussed below. Early consultation on these points should be embarked upon with a view to reducing constraints as much as possible.

6.4.1 CUMULATIVE IMPACT OF ONSHORE TECHNOLOGIES

As discussed, cumulative impact of onshore wind could reduce the overall potential by at least 12.1 TWh. If costs of solar and wind do fall, as assumed by this study, it is likely that increased numbers of planning applications will be forthcoming. However, cumulative impact policies materially affect the available resource from wind power which could range from 157 GWh, where cumulative impact is assumed to be based on a 15 km offset between each 10 MW wind farm, to 1.5 TWh where 5 km is assumed. Even achieving the 1.2 TWh from wind power taken forward in the Maximum Deployment scenario is likely to be difficult and will require significant changes in acceptance levels and policy. It is also likely that cumulative impact would feature in applications for new development of onshore solar generation, although this is expected to be to a lesser extent. Despite this, there are precedents to suggest that a change would be possible – certainly energy infrastructure of many types, such as pylons and sub-stations, is readily accepted. In the maximum case assumed here, onshore wind and ground mounted solar PV power would occupy up to 3% and 1.7% respectively of the Greater Exeter unconstrained land area.

6.4.2 TECHNICAL GRID CONSTRAINTS

The grid infrastructure in the South West is a major barrier to the further development of generation. While this has been known since the announcement by Western Power Distribution in 2015, no major action has been put forward to mitigate it. This issue could be seen by government as a costly barrier, or as an industrial innovation challenge that could enable the UK to take a leadership role. The smart grid section of this report discusses the technologies that could play a role in overcoming this critical local issue in a positive, innovative way. Greater Exeter, with the assistance of national programmes, could embrace new technologies and models to unlock the grid but this will require leadership and investment. Alternatively, political solutions such as other sources of funding for upgrade costs and capacity amnesties could be investigated.

6.4.2 OTHER TECHNICAL BARRIERS

Remaining major technical barriers relate to the radar interference of onshore wind generation and the furtherance of research into how energy efficiency measures can be integrated across the domestic, commercial and industrial sectors. Radar constraints should not be a wholesale impediment to change, but a co-ordinated approach, linking both strategic land use and consultation with air traffic users is essential to achieving a framework in which generation can be accelerated while maintaining safety. Progressing the integration of leading technologies in commercial, industrial and domestic sectors will be critical to both achieving the savings proposed, while also addressing the residual energy requirement identified above.

6.4.4 COMPONENT COST

Across less mature energy generation and demand reduction options, the cost of components makes many business models currently unviable. While ambitious savings have been proposed in the domestic sector, the scale of the challenge that is being faced to deliver these savings is not to be underestimated. Passivhaus systems exist for new build developments but they are still more costly (certainly where the developer is not seeing the lifetime benefits) than compliance with building regulations. Retrofits to Passivhaus standard can be costlier still. These costs are often related to the components and the additional skills required to undertake these types of projects. Supply chains are not mature enough to deliver components or installations at low enough prices to enable cost-effective roll-out of the levels of retrofit required to move beyond entry level efficiency improvements e.g. loft insulation. To make inroads into energy demand reduction, significant co-ordinated responses are required to stimulate a market where retrofit products and skills are fully developed.

In other areas, while it is assumed that component costs of solar and wind will continue to fall, it is by no means assured. Continued support for deployment and research into mature technologies will mitigate the risk that these price falls do not occur.

6.4.5 FINANCE AND INVESTMENT BARRIERS

Other areas where financial barriers are acute are in technologies still in their infancy in the UK, particularly those where considerable resources exist in the region, namely tidal range and geothermal. The financial issues here are complex and link closely to both the high levels of technology and deployment risk, the continued fall in the price of substitutes (wind and solar) and long-term energy policy at a national level. It is clear that in order to reach commercialisation, significant public and private funds will need to be invested in these technologies, but without a clear national priority to support these sectors it is difficult to envisage a material change occurring.

Considering the barriers above, a series of recommendations follow which propose specific measures that could contribute towards the residual energy requirement over the time horizon.

6.5 | RECOMMENDATIONS

6.5.1 RECOMMENDATION 1:

FACILITATE THE DEVELOPMENT OF NET ENERGY POSITIVE BUILDINGS

The development of a supply chain and policy environment that ensures the delivery of net positive energy buildings is an urgent priority. New developments that positively contribute to city energy use will mean that less onshore generation development and retrofitting of older building stock will be required. Greater Exeter already benefits from progressive local authorities which actively pursue building energy efficiency objectives, in particular in their own properties. The next steps are to further encourage innovative solutions, combine insights and analysis to support tighter planning policy and develop mechanisms to significantly expand the project base.

6.5.2 RECOMMENDATION 2:

DEVELOP CREDIBLE ROADMAPS TO LARGE-SCALE DOMESTIC RETROFIT

A key assumption in the Maximum Technology scenario is that viable business models which deliver large-scale retrofit will be developed over the time horizon. The development of credible roadmaps that deliver comprehensive intervention in this area is essential. This is a challenging undertaking which requires significant investment in skills, new solutions and the development of businesses that can integrate, finance and deploy the roll-out of multiple technologies at scale.

6.5.3 RECOMMENDATION 3:

ENCOURAGE AND DEMONSTRATE INNOVATIVE SOLUTIONS TO REDUCE DOMESTIC APPLIANCE ENERGY USE

While space and water heating consume the largest proportion of domestic energy, appliance use represents 0.5 TWh of Greater Exeter demand. The benefits of upgrading to the highest efficiency appliances should be promoted and systems developed which enable and manage behavioural change to both optimise use and reduce overall cost. Identified technologies should be trialled and best practice fostered.

6.5.4 RECOMMENDATION 4:

DEVELOP COMMERCIAL AND INDUSTRIAL CASE STUDIES

This study identifies 359 GWh of potential savings from commercial buildings and 250 GWh of potential savings from industrial processes, based on current understanding of technical opportunities. More specific demonstrator projects are required to advance and promote greater understanding of what is achievable across a varied range of end users. A diverse group of local commercial and industrial partners should be brought together to develop leading-edge strategies to encourage potential energy savings.

6.5.5 RECOMMENDATION 5:

DEVELOP CREDIBLE ROADMAPS TO CUT TRANSPORT CONSUMPTION

Transportation is expected to represent 4.4 TWh of annual energy consumption by 2025. Developing roadmaps to significantly address this consumption is an essential priority, and is the focus of a forthcoming report. In this context, wider participation in the development of various options should be encouraged, in particular through Exeter City Futures' innovation programme.

6.5.6 RECOMMENDATION 6:

CO-ORDINATE SOLUTIONS TO ADDRESS GRID CONSTRAINTS

The grid is a critical technical constraint that impedes the viability of projects across the region. Moving past this barrier is essential if the regional energy industry is to thrive. Several options exist including capacity amnesties, the socialisation of upgrade costs and technology-led options such as smart grid infrastructure. All would need considerable co-ordination with the local grid operator to progress, but should be seen as a pivotal issue for the South West economy and Exeter City Futures' goals. If this barrier can be overcome, Greater Exeter could play a key role in stimulating a regional approach to energy independence, drawing on the skills, expertise and innovation of local research and industry. Close collaboration with the Department for Business, Energy and Industrial Strategy (BEIS) and other national stakeholders is required to develop policy and technology mechanisms to realise the potential local benefits of regional generation.

6.5.7 RECOMMENDATION 7: STIMULATE ONSHORE GENERATION

In the face of considerable planning barriers, improved stakeholder understanding of the impact of onshore generation options - principally wind and solar - is required. Co-ordinated Greater Exeter multi-authority strategic planning is needed to optimally locate new generation and work openly and collaboratively with the public to identify solutions that would be acceptable in the context of the energy choices available. Furthermore, the exploration of generation technologies that achieve higher levels of aesthetic acceptability should be encouraged. This is already happening within the solar industry, with the introduction of technology integrated into rooftops and roads. Further integration into other standard infrastructure could achieve both new generation and cost reduction without facing political barriers.

6.5.8 RECOMMENDATION 8: PROVIDE AN ECONOMIC EVIDENCE BASE

Evidence for the economic benefits of the proposed approach to energy independence and the opportunities afforded by being at the forefront of integrated smart energy infrastructure development should be provided, and is the focus of a forthcoming report. Demonstrating significant potential for increased local productivity, jobs and growth will enable the development of a wider network of support for this approach.

6.5.9 RECOMMENDATION 9: ENCOURAGE AND SUPPORT RESEARCH INTO ENHANCED GENERATION EFFICIENCY

Estimates of generation made here are potentially conservative. While they are based on widely accepted methodologies, the efficiency of many technologies can be expected to improve with time. Extrapolating the historical trends in technology efficiency would increase the estimates of generation made in this report. Research into areas with the potential to improve natural energy resource conversion efficiency, for example solar cell technology, should be prioritised.

6.5.10 RECOMMENDATION 10: ENCOURAGE INVESTMENT IN MARINE AND GEOTHERMAL TECHNOLOGIES

In the wider South West region, geothermal and marine technologies offer sizeable generation potential in the Maximum Technology scenario. These capital-intensive sectors require significant levels of investment to reach commercial viability. High technology and deployment risk, alongside falling substitute technology prices, mean public sector support is likely to be required to achieve long-term market development. Private investment and innovation in these sectors should be supported and promoted, alongside strategic engagement with policy-makers at national level.

Overall, Greater Exeter benefits from considerable energy resources, relevant technical skills and strong leadership that position it to tackle Exeter City Futures' ambitious 2025 goal. While the challenge of delivering energy independence is considerable, much can be gained from progressing the technology opportunities explored in this report. Significant barriers limit the extent to which the Maximum Technology scenario can be exploited, however, the recommendations provide a clear roadmap to progress towards Exeter City Futures' stated vision. Cities are the primary driver globally of how much energy is used, how it is used, and to a growing extent, what sources it comes from. The technologies and barriers in this report will apply to many cities with similar sustainability ambitions. While the recommendations are broad, it is only through a concerted effort across multiple technologies and sectors that cities like Exeter, and by extension the whole of the UK, will be able to reduce cost, energy and meet long-term decarbonisation targets.

7. | APPENDIX A – BARRIER TABLES

TABLE 7.1: Key barriers and constraints for domestic sector retrofit

MEASURE	Saving GWh/yr	Barrier(s)	Significance	Difficulty to overcome	Potential action to address barriers
Cavity wall insulation	49.8	**Risk:** Numerous reported instances of damp increase post installation. Now being removed. **Cost:** Medium **Payback:** Medium (without subsidy).	Medium	49.8	**Risk:** Independent survey of external skin prior to decision on installation. **Cost:** Education campaign required to identify remaining cavity walled buildings with zero insulation, and show benefits. Subsidy to improve payback period.
Solid wall insulation	62.8	**Risk:** Technical risks – trapped moisture etc. Air quality risks. Numerous failures now being reported. Heritage risks in pre-1919 traditional construction, particularly to streetscapes in terraced streets. **Disruption:** Major for IWI and substantial for EWI. **Information:** People often don't know what SWI is. **Cost:** High **Payback:** Long.	High	High	**Risk:** Independent survey of property prior to decision on installation. Correct detailing wherever installed. Whole house approach. Ventilation must be improved where necessary and MVHR considered. **Cost:** Would need significant subsidy in owner-occupied sector. Focus on non-traditional dwellings (e.g. system build and no-fines) in social housing sector. **Information:** Educational campaign based on responsible retrofit and whole house approach.
Loft insulation (from zero)	3.8	**Disruption:** Loss of storage space, access thru property. **Cost:** Low-medium cost. **Payback:** Short.	Medium	Medium	**Disruption:** Option to build storage shelf above insulation. Use approved contractors. **Cost:** Education campaign required to identify remaining lofts with zero insulation, and show benefits.
Loft insulation top-up	31.7	**Cost:** Very limited benefit (only 10% of benefit from zero insulation) so difficult to justify if 100mm or more. **Payback:** Long.	Low	Medium/High	**Cost:** Top-up is required as a condition of RHI and FiT, for example. **Technical:** Solid floors: provision of high quality thermal underlays for carpets. **Suspended floors:** Robotic installation is used but there are risks relating to spray foam insulation where there is inadequate sub floor ventilation and large energy/carbon costs of repair when failure occurs.
Floor insulation	9.4	**Technical:** Solid floors cannot normally be insulated above for practical reasons and it is uneconomic to dig out concrete and re-lay with insulation. Suspended floors often have very small voids below. **Structural:** Risks to floor members if natural ventilation is reduced in any way. **Fabric:** For insulation fitted from above, butt-jointed boards are now fragile, T&G boards tend to break when lifted.	High	High	**Structural:** Education campaign to manage risks of installation and ensure sub floor ventilation maintained or reinstated. **Fabric:** If installing insulation below suspended timber floors from above, ensure that boards are lifted by a specialist carpenter.
Window upgrade	10.1	**Risk:** Loss of heritage value (rolled glass and timber frames) in traditional buildings. **Information:** People are not aware of the benefits of secondary glazing, nor of the existence of slim profile double glazing, nor of the potential to replace elements while retaining frames. **Cost:** Limited benefit for high cost. **Payback:** Long (note that much can be achieved through draft proofing windows).	Medium	Medium	**Risk/Information:** Educational campaign to demonstrate the benefits from secondary glazing and thick curtains. **Cost:** Greatly reduced cost of secondary glazing as opposed to window replacement. Also, consider promoting the use of slim profile double glazing (using existing frames).

Draft proofing	20.9	**Risk:** Inadequate natural ventilation leading to poor indoor air quality and increased condensation risk. As this is a DIY measure the risk increases. **Payback:** Short (but note high comfort taking).	Medium	Low	**Risk:** Subsidise air pressure testing (?), provide low cost air quality monitoring kits (?).
Hot water tank insulation	9.1	**Information:** Lack of awareness of modern standards of insulation of tanks being so much better. **Acceptance:** Some people like small heat leakage to heat an airing cupboard.	Low	Low	**Information:** Educate and inform public of the savings to be achieved through improvements to tank insulation, and the rate of standing losses.
Hot water distribution pipe insulation	0.7	**Access:** Most distribution pipework is inaccessible.	High	Medium	**Access:** educate plumbers and electricians so that whenever boards are lifted for access to services, insulation is retrofitted wherever practicable. Perhaps provide free pipe insulation to encourage this.
Improved heating controls	4.1	**Information:** Lack of understanding of how heating controls operate. **Payback:** Short.	Medium	Low	**Information:** Education campaign to identify dwellings without system timers, thermostats or TRVs.
Gas boiler upgrade	59.7	**Cost:** For newer boilers, the payback is longer than the life of the boiler. Only worse than D rated should be targeted. **Payback:** Long.	High	Medium	**Cost:** Boiler scrappage scheme for boilers worse than D rating.
Heat pumps	1166.7	**Information:** Lack of awareness of new technologies (heat pumps and pellet boilers) / Perceived risk. Not all properties suitable due e.g. to space restrictions. **Cost:** High cost of heat pumps and wood pellet boilers. More cost-effective for off gas grid properties **Disruption:** Medium – depending on system installed and what is being replaced. **Payback:** Medium	Very high	Low	**Information:** Educational campaign targeted at off-grid housing on coal, oil or electrical resistance heating. **Cost:** promotion of the RHI to cover pellet boilers and heat pumps. **Disruption:** Education campaign to demonstrate the ease of operation of replacement systems.
Smart metering	47.5	**Acceptance:** Data protection concerns and intrusion. **Cost:** Not a barrier as paid for by energy companies.	Medium (as all stock)	Low	**Acceptance:** These will be rolled out in any case by 2020 and an education campaign is required. The same campaign can be used as for measures listed above.
Lighting	52.4	**Technical:** Poor colour temperatures of some LEDs and CFLs. **Cost:** LEDs still much higher cost. **Payback:** Short/Medium.	Medium	Low	**Technical:** Await technical improvements. **Cost:** Subsidise or promote through educational campaign. Highlight the saving through much better length of life of LEDs.

TABLE 7.2: Key barriers and constraints for commercial sector

Type	Barrier(s)	Significance	Difficulty to overcome	Potential action to address barriers
ENERGY MANAGEMENT				
Financial	A nominated individual will need to allocate time specifically to energy efficiency activities. Other activities may encroach on time required for energy management.	Medium	Low	Management should provide leadership by nominating an individual to lead energy management activities and ensure time is ring-fenced for the activities to be carried out. In many cases the potential savings will lead to short paybacks on the cost resulting from the time spent on energy management activities.
Technical	Installation of BEMs: system may not be set up and/or operated properly. There have been cases where the staff with knowledge have left and no one knows how to change the settings.	Medium	Medium	Nominated staff to be trained in setting up and running the BEMs. This knowledge (and any guidance documents) should be shared with a deputy.

TABLE 7.2: Key barriers and constraints for commercial sector

Type	Barrier(s)	Significance	Difficulty to overcome	Potential action to address barriers
HVAC				
Behavioural	Optimisation of heating and cooling hours and set points: there may be significant objections by staff to heating/cooling hours being changed, heating set points being lowered or cooling set points being raised.	Medium	Medium	Objections should be considered fairly. The advantages of changes should be explained clearly.
Behavioural	Replacement fossil fuel boiler (where boiler is over 15 years old): possible significant disruption to building and staff.	Medium	Medium	Plan to carry out replacement during building refurbishment or during non-heating season.
Financial	Replacement fossil fuel boiler (where boiler is over 15 years old).	Medium	Medium	High capital cost, but this is offset by likely high efficiency improvements leading to a medium-term payback.
Legal/Financial	Many properties are leased and the occupants have no control over improvements to the building fabric.	High	High	Incentives for landlords to improve energy efficiency of property such as EPCs.
Financial	Replacement fossil fuel boiler (where boiler is over 15 years old) with heat pump. Substantial capital costs and cost differential compared to standard boiler replacement.	High	Medium	Current action is to offer incentives: RHI.
Technical	Replacement fossil fuel boiler (where boiler is over 15 years old) with heat pump. Not all heating systems are suitable for use of heat pumps.	High	High	Detailed assessment of each opportunity required to determine applicability.
LIGHTING				
Financial	Capital cost of replacing existing lighting with LEDS is high with medium term payback.	Medium	Medium	Provide incentives for organisations to take up energy-efficient equipment with medium paybacks.
Behavioural	There may be resistance from staff to use of occupancy and daylight sensors in new lighting schemes.	Low	Low	Provide information on potential savings. Make sure lighting scheme has been installed correctly.
BUILDING FABRIC				
Financial	The cost and payback of some measures such as solid wall insulation and to a lesser extent replacement windows is high.	High	Medium	Provide incentives for organisations to take a longer-term view on payback. Provide direct financial support for measures in some cases.
Behavioural/Social	Installation of installation and other changes to building fabric can cause significant disruption within a commercial building to staff.	Medium	Medium	Aim to carry out measures during building refurbishment. Otherwise plan carefully to minimise any disruption.
Legal/Financial	Many properties are leased and the occupants have no control over improvements to the building fabric.	High	High	Incentives for landlords to improve energy efficiency of property such as EPCs.

TABLE 7.3: Key barriers and constrains for the implementation of industrial energy efficiency measures

ENERGY MANAGEMENT				
Financial	A nominated individual will need to allocate time specifically to energy efficiency activities. Other activities may encroach on time required for energy management. Company priorities are usually production.	Medium	Low	Management should provide leadership by nominating an individual to lead energy management activities and ensure time is ring-fenced for the activities to be carried out. In many cases the potential savings will lead to short paybacks on the cost resulting from the time spent on energy management activities.

Technical	Installation of BEMs: System may not be set up and/or operated properly. There have been cases where the staff with knowledge have left and no one knows how to change the settings.	Medium	Medium	Nominated staff to be trained in setting up and running the BEMs. This knowledge (and any guidance documents) should be shared with a deputy.
STEAM AND HOT WATER GENERATION AND DISTRIBUTION				
Financial	Some of the measures outlined will lead to boiler downtime with implications for the continued running of the process. In addition, some of the measures will be large capital expenditure items.	High	Medium	Changes to heating system to be carried out during process downtime and planned maintenance/ refurbishment periods. Incentives for energy savings (such as the CCA scheme) are required to encourage adoption of energy savings measures with longer pay backs.
VARIABLE SPEED DRIVES AND ENERGY-EFFICIENT MOTORS				
Technical	Difficult to identify the viability of addition of a VSD without detailed data on pump use.	Medium	Medium	A systematic approach should be taken to identifying which pump and fan motors would be suitable for VSDs and calculations carried out to determine savings potential.
WASTE HEAT RECOVERY				
Technical	Waste heat recovery is usually process specific and there needs to be a viable nearby use for the waste heat.	Medium/High	Medium/High	A systematic approach should be carried out to determine sources of waste heat and their viability for further use in terms of the grade of waste heat required and the nearness of the source to the point of use.
IMPROVED LIGHTING				
Financial	Capital cost of replacing existing lighting with LEDS is high with medium term payback.	Medium	Medium	Provide incentives for organisations to take up energy-efficient equipment with medium paybacks.
Behavioural	There may be resistance from staff to use of occupancy and daylight sensors in new lighting schemes.	Low	Low	Provide information on potential savings. Make sure lighting scheme has been installed correctly.
Technical	Specific types and intensities of lighting may be needed for some industrial applications (such as inspection areas).	Medium	Medium	Care should be taken when specifying lighting schemes to allow for specific local requirements.
REFRIGERATION				
Financial	Capital cost of replacing existing refrigeration units with new or alternative equipment is high.	Medium/High	Medium	Provide incentives for organisations to take up energy-efficient equipment with medium to longer term paybacks.
COMPRESSED AIR				
Behavioural	Resistance from staff to change operating practices to reduce compressed air wastage.	Low	Low	Carry out energy awareness training and tool box talks.
Financial	Additional cost required for compressed air leakage detection and repair campaigns.	Medium	Medium	Calculate the cost of compressed air leakage compared to the cost of repair showing the relatively short payback of this action.
Financial	Capital cost of replacing of upgrading existing compressed air units with new equipment is high.	Medium	Medium	Provide incentives for organisations to take up energy-efficient equipment with medium to longer term paybacks.
LONGER TERM SAVINGS				
Technical	Process intensification and changes to process flowsheets represent step changes to current practice requiring detailed investigation.	High	High	Carry out initial high level survey and identify the most promising areas of application for more detailed studies.

TABLE 7.4: Key barriers and constraints to deployment of roof mounted PV system

Type	Barrier(s)	Significance	Difficulty to overcome	Potential action to address barriers
Technical	**Lease contract (Commercial):** The occupier of the building might not be the owner and not have permission to install a PV system. Most of the commercial buildings are in lease	High	Medium/Low	Contact the building owner and investigate the possibilities.
Planning	**Planning permissions (Commercial and Domestic):** Under most circumstances for domestic dwellings, the PV array can be installed under the amendments made in the General Permitted Development Order (GPDO). However, this may not be the case in areas of AONB, national parks conservation areas etc., both for domestic and commercial.	Minor	Medium	Contact the local planning authority as early as possible in development of a project to determine any specific requirements that may be needed to obtain planning permission.
Technical	**Roof weight limit (Commercial and Domestic):** It might be determined that structural work is required to alter or strengthen a roof prior to the installation of the PV system – such works will always require a building notice to be submitted.	Significate for commercial	Medium	Contact a structure engineer to assess the roof and submit a building notice if required.
Financial	**Financial (Commercial and Domestic):** dwelling owners or companies might not have the required capital needed to install a PV system. Operational costs for PV roof mounted system are minimal.	Medium	Medium	Competition among installers is high. Contact several installers and evaluate different options in terms of total kW size, PV modules and inverters.

TABLE 7.5: Key barriers and constraints to deployment of ground mounted PV systems

Technical	Grid connection: the capacity of a PV farm or the financial viability of the project can be limited by the lack of grid capacity or cost of connection.	High	High	It is advisable to contact the relevant Distribution Network Operator (DNO) as early as possible in the project process to determine indicative grid connection costs and any grid constraints that may impact on a project.
Technical	Road access: access to suitable area could be an issue, thus areas adjacent to major roads in rural area are attractive both for the perspective of vehicle access and because these correspond to lower grad agricultural land. Where road access is limited the construction of a new rural road might be required.	Medium	Low	Site should be carefully planned and ease to access evaluated. If a new road is needed works should be taken into considerations in the business plans for a project.
Environmental/Social	Visual impacts and landscape considerations: PV system could have a large visual impact if installed on a visible slope or near to motorways and large roads. This can be an issue with local communities of where landscape designations recognise special qualities of a landscape (such as value, distinctiveness of character, level of modification or a sense of tranquillity and remoteness).	High	Medium	Sites should be carefully planned. Landscape designations that recognise special qualities of a landscape should be avoided. Visual impact assessment will also help to determine visual impact on local communities or where there are multiple PV ground mounted systems in a vicinity.
Planning	Planning permission: It is important to determine where planning permission is required for a project and any specific pre-planning requirements or planning conditions to be addressed.	High	Medium	Contact the local planning authority as early as possible in development of a project to determine any specific requirements that may be needed to obtain planning permission. Maintain a dialogue throughout project development.
Financial	Financing a project: Financing elements of a project need to be well planned through, considering elements such as capital and operational costs, financing method(s), etc.	High	Medium	Develop an initial business case as early as possible in a project to determine the financial viability. Continuously update this as further information becomes available.
Environmental	Ecological considerations: The impact of construction and operation of a project on species may be a concern. Specific consideration will need to be given to areas such as Special Area of Conservation (SAC), Special Protection Area (SPA), Important Bird Areas (IBAs), Sites of Special Scientific Interest (SSSI), National Nature Reserve (NNR) and Local Nature Reserve (LNR).	Medium	Medium	Early consultation with Local Planning Authorities and environmental agencies will be important to determine the viability of a scheme, any requirements for environmental impact assessments and to determine the likelihood for the development of site mitigation plans. The cost of additional works should be taken into considerations in the business plans for a project.

TABLE 7.6: Key barriers and constraints for wind power

Technical	Grid connection: The capacity of a wind energy project or the financial viability of the project can be limited by the lack of grid capacity or cost of connection.	High	High	It is advisable to contact the relevant Distribution Network Operator (DNO) as early as possible in the project process to determine indicative grid connection costs and any grid constraints that may impact on a project.
Environmental/Social	Visual impacts and landscape considerations: Due to their vertical scale, wind turbines are often highly visible in the landscape. This can be an issue with local communities of where landscape designations recognise special qualities of a landscape (such as value, distinctiveness of character, level of modification or a sense of tranquillity and remoteness).	High	Medium	Sites should be carefully planned. Landscape designations that recognise special qualities of a landscape should be avoided. Sites outside of this area should still consider the visual impact of the wind energy development on views from any designation. Visual impact assessment will also help to determine visual impact on local communities or where there are multiple wind farms in a vicinity.
Planning	Planning permission: It is important to determine where planning permission is required for a project and any specific pre-planning requirements or planning conditions to be addressed.	High	Medium	Contact the local planning authority as early as possible in development of a project to determine any specific requirements that may be needed to obtain planning permission. Maintain a dialogue throughout project development.
Financial	Financing a project: Financing elements of a project need to be well planned through, considering elements such as capital and operational costs, financing method(s), etc.	High	Medium	Develop an initial business case as early as possible in a project to determine the financial viability. Continuously update this as further information becomes available.
Environmental	Ecological considerations: The impact of construction and operation of a project on species may be a concern. Specific consideration will need to be given to areas such as Ramsar sites, Special Area of Conservation (SAC), Special Protection Area (SPA), Important Bird Areas (IBAs), Sites of Special Scientific Interest (SSSI), National Nature Reserve (NNR) and Local Nature Reserve (LNR). This is of particular importance if sites are designated for species of bats and birds.	Medium	Medium	Local Planning Authorities and environmental agencies usually take a precautionary approach in decisions regarding wind energy schemes. Early consultation with these agencies will be important to determine the viability of a scheme, any requirements for environmental impact assessments and to determine the likelihood for the development of site mitigation plans. The cost of additional works should be taken into considerations in the business plans for a project.

TABLE 7.7: Key barriers and constraints for forestry and clean wood wastes

FORESTRY THINNINGS AND RESIDUES				
Financial	Insufficient value in wood fuel to bring woodlands into management.	High	High	Requires a 'whole forest' approach to identify markets for all wood products to ensure overall woodland management is profitable.
Technical	Variability of the chemical composition and physical presentation of the wood fuel product. Of relevance to alternative wood fuel sources such as arboricultural arisings and hedgerow coppice.	High	High	Work to agreed specification for the physical presentation of the biomass. Ensure suppliers/ customers understand the applications suitable for each type of biomass produced.
Education	Lack of awareness in heat market of wood fuel option. Wood fuel option perceived difficult or expensive.	High	Medium	Raise public awareness of and confidence in wood fuel options for heating, especially in target markets of off-grid heating and district heating. Actions could include case studies, advice centres and demonstrations.
Financial/Social	High level of unmanaged woodland due to Inaccessibility/ small size of woodlands, which means management not cost-effective.	High	Medium	Devon has already pioneered a 'Ward Forester' approach to group several small woodlands under the care of a forester. This approach could be extended.
Political	Uncertain long term renewable energy market	Medium	Medium	Include biomass as an action in Devon strategic renewable energy plan. Lobby Government for long term stability for bioenergy support.
Environmental	Carbon storage/ savings	Medium	Medium	Raise awareness of forestry practice guidelines. Ensure engage qualified forester.
Environmental	Soil compaction	Low	Medium	
Environmental	Biodiversity	Low	Low	
Supply chain	Immature supply chains	Low	Low	Devon has already developed several local wood fuel supply chains. Dissemination of information would encourage further developments.

TABLE 7.7: Key barriers and constraints for forestry and clean wood wastes

Type	Barrier(s)	Significance	Difficulty to overcome	Potential action to address barriers
ARBORICULTURAL ARISINGS				
Technical	Variability of the chemical composition and physical presentation of the wood fuel product. Of particular relevance to alternative wood fuel sources such as arboricultural arisings and hedgerow coppice.	High	High	Work to agreed specification for the physical presentation of the biomass. Ensure suppliers/ customers understand the applications suitable for each type of biomass produced.
Technical	Development and piloting of hedgerow coppicing process.	High	Medium	Start demonstration of proposed scheme.
Social	Resistance to wood waste separation options from the public.	Medium	High	Public education. Expand wood waste recycling schemes.
Technical	Hedgerow Biodiversity compromised by coppicing management option.	Low	Low	Ensure sensitive management plan adopted. Move to trial of proposed hedgerow coppicing option.
Political	Uncertain market for renewable energy.	Low	Low	Include biomass as an action in Devon strategic renewable energy plan. Lobby Government for long term stability for bioenergy support.
Education	Lack of awareness in heat market of wood fuel option. Wood fuel option perceived difficult or expensive.	Low	Low	Further awareness raising in the relevant industries.
CLEAN WASTE WOOD				
Technical	Potential contamination with treated wood.	Medium	Low	Ensure wood is rigorously separated into treated and untreated.
Technical	Matching waste wood availability to heat requirements.	Medium	Low	Undertake assessment of heat and feedstock profiles prior to installation of boiler. Ensure adequate storage facilities and/ or external supply contracts.
Educational	Resistance to wood waste separation options from companies/ staff.	Medium	High	Education. Separate collection facilities supplied. Incentives.

TABLE 7.8: Key barriers and constraints for energy crops

Technical	Variability of the chemical composition and physical presentation of the energy crop product.	High	High	Work to agree specification for the physical presentation of the biomass. Ensure suppliers/ customers understand the applications suitable for each type of biomass produced.
Political	Uncertain market.	High	High	Long term policy of energy crops development. Inclusion of energy crops in local development plans. Development of diverse market.
Technical	Pest/ disease issues associated with SRC.	High	Medium	Follow guidelines on cultivars for planting and agronomy techniques. Impartial advice for best cultivars/ cultivation techniques for the local area.
Supply chain	Immature supply chains.	High	Medium	Include energy crops as another product to be sold via existing wood fuel supply infrastructure. Instigate regional producer groups to share specialised equipment and disseminate information on production techniques for SRC.
Environmental	Concerns over Visual impact, soil compaction, high water use, impact biodiversity.	High	Low	Implement guidelines to ensure energy crops appropriately sited Local advice centres/ crops schemes to ensure advice given and acted on.
Financial	Cash flow problems relating to high upfront costs of establishment and delay to crop productivity.	Medium	Low	Implement support mechanism. Long term supply agreements.
Financial	Not economically competitive with other crops.	Low	Low	Advice on planting energy crops in the most appropriate location.

TABLE 7.9: Key barriers and constraints for anaerobic digestion

AD OF FOOD WASTES				
Market	Competing cost-related feedstock uses (particularly where waste contracts in place already) Gate fee dropping due to competition for food waste by existing plant.	Medium	High	Need to explore all sources of food waste. Ensure appropriate levels of support are in place.
Technical	Integration into energy supply markets: current use of biogas restricted by access to heat demands and energy markets.	Medium	High	Se of heat could be facilitated by more district heating type schemes
Financial	Returns insufficient (needs generous gate fee, energy return not sufficient).	Medium	Low	Ensure appropriate levels of support are in place and that these reflect changing nature of feedstock market
Social	Planning issues: perceived as waste facility so can be subject to public objections (NIMBYism).	Medium	Medium	Public education and increased guidance for planners.
Financial	Perception of market complexity (markets perceived as complex by financiers, particularly issues related to grid connection). This can lead to difficulty in obtaining project finance (high return expected due to lack of experience with AD).	Medium	Low	Education of financial community. Will partly ease as market is developing and more plants are coming to maturity.
Education	Food waste can be highly contaminated with other materials and so require pre-treatment before digestion which increases costs and has an energy penalty.	Medium	Low	Need to encourage high rates of separation by households and businesses, and educate as to what can be put into food bins.
Political	Lack of source separated feedstock. Need to facilitate separate collection of food waste.	Low	Medium	LA's to instigate source separate food collections. Public education to increase separation rates.
AD OF ANIMAL WASTES				
Technical	Dispersed nature of feedstocks, - waste may be spread around several small farms and due to high liquid content of waste, it is not usually desirable to transport the waste far.	High	High	Can be codigested with other wastes or energy crops so plant does not need to be solely supplied by slurries.
Technical	For remote farms: integration into energy supply markets – may be difficult to get grid connection. May be a lack of heat load.	High	High	
Financial	Requirement for substantial upfront investment, and difficulty in obtaining project finance (low returns).	Medium	Low	Ensure adequate financial support. Awareness raising in finance community about technology and mitigation of risks.
Education	Lack of knowledge and skills in farming community to develop AD project. Perception of risks and uncertainty.	Medium	Medium	Guidance and support for farmers looking to develop projects
Technical/Education	Biogas yield from slurry low; best combined with other materials such as energy crops or food wastes. This increases complexity of project development.	Medium	Medium	Guidance and support for farmers looking to develop projects. Potential role for project developers.
Environmental	Use of energy crops in AD plant can have poor greenhouse gas balance.	Medium	Medium	More efficient production of crops, use of low carbon N fertilisers and use of digestate as fertiliser can help to reduce GHG emissions.
Supply chain	Lack of transport infrastructure. Road access needs to be sufficient, particularly if taking in wastes from other farms or from other sources. Tankers must not transmit pathogens.	Medium	Medium	Choice of suitable site can alleviate transport issues; although need to balance road access with several other factors, such as access to energy system and location of feedstocks as need to keep transport distance for waste feedstocks low.
AD OF ANIMAL WASTES				
Financial	Requirement for substantial upfront investment, and difficulty in obtaining project finance (low returns).	Medium	Low	Ensure adequate financial support. Awareness raising in finance community about technology and mitigation of risks.
Technical	Smaller sewage sludge treatment plant may be in more remote areas and lack access to infrastructure to export power or biomethane.	High	Medium	

TABLE 7.10: Key barriers and constraints for waste bioenergy

Type	Barrier(s)	Significance	Difficulty to overcome	Potential action to address barriers
Market	As Error! Reference source not found. demonstrates, there are many competing technologies in Devon already at various stages of development. Furthermore, the UK waste industry is perceived by many to be near capacity for thermal treatment. The presence of incinerators at Exeter, Devonport and in Cornwall suggests that any new facility will struggle to secure the necessary waste.	High	High	A detailed availability study would be required to determine whether there would be sufficient waste to merit a new bioenergy plant. Alternatively, the plant could be co-fired, to diminish its dependence on waste feedstocks.
Technical	Residual waste is extremely hard to gasify successfully, as demonstrated by the very public collapse of the Air Products development on Teesside, and the descent of New Earth Solutions into receivership.	High	Medium	Potential developers are encouraged to either adopt a convention combustion solution, or discount residual waste as a potential feedstock, and to focus on source-separated streams – wood or food.
Environmental	Waste should be treated respecting the waste hierarchy, under which bioenergy is less preferred to minimisation and reuse, and combustion is inferior to composting, too.	Medium	High	The hierarchy can be overturned when LCA demonstrated an overall environmental benefit. Moreover, our analysis already excludes existing fates.
Market	Waste is relatively expensive to transport. Devon is large and rural, so waste will need to move some distance to achieve critical mass for a new facility.	Low	Low	Most of Devon's population is focussed in a few regions. By choosing a site near one of these, issues of transport cost can be reduced.

TABLE 7.11: Key barriers and constraints for tidal stream and wave development

Barrier	Comment
Grid access	Initial arrays are likely to connect to the distribution network at 33kV, but the larger arrays developed in future would need to connect to the transmission network. There are limited grid connection points available. A 2016 study by WPD estimated that a maximum of 23 MW could connected to the distribution network by 2025. Site-by-site assessment of local grid capacity is required and with the constrained grid in the south west, will dictate where the first arrays can be deployed. There are sections of the Devon coastline along the Hartland Peninsula and Exmoor National Park and around the tip of Cornwall that are further than 10 km from a 33kV grid connection point. 10 km is approximately the maximum distance power can be transmitted along a 33kV cable.
Interactions with fisheries	Tidal turbines and wave energy convertor areas will be excluded to fisheries which may potentially increase the stock. Certain fisheries may be excluded from tidal development.
Interactions with other marine users	These include leisure craft users and surfing areas and would all need consultation on a site by site basis.
Interactions with the natural environment	There is limited data on the impacts of potential commercial arrays of wave and tidal stream technologies on the physical environment and habitats. Similarly, there is little information on the interaction of birds, marine mammals and fish with wave and tidal devices . Future research is required to address these gaps (locations of seabird foraging areas, migration routes, distributions and electromagnetic force interactions).
Selected areas used by the Ministry of Defence (MoD).	MoD Practice and Exercise Areas (PEXAs) cover wide tracts of the South West maritime area. Many of the offshore PEXAs cover large areas and are used for a wide range of MoD activities. However, their presence does not necessarily preclude other activities. Developers would need to consult with the MoD on a case by case basis.

[190] WPD and Regen South West (2016). Distributed generation and demand study – Technology Growth Scenarios to 2030, [online]. Available at: https://www.regensw.co.uk/distributed-generation-and-demand-study-technology-growth-scenarios-to-2030 | [191] The Offshore Energy Strategic Environment Assessments (OESEA) are produced by DECC and include an assessment of the impact of marine energy on the environment. The most recent was produced in March 2016 and evaluated the potential environmental impacts of marine energy over the next 5 years. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/504874/OESEA3_Non-technical_summary.pdf

TABLE 7.12: Key barriers and constraints to wider deployment of energy storage

Type	Barrier(s)	Significance	Difficulty to overcome	Potential action to address barriers
Legal/Political	Energy storage is a new technology and is not addressed in current regulations and remains a 'grey area'. This uncertainty creates legal and contractual risk. For example, regulated DNOs are not able to invest in storage, beyond pilots like the Enhanced Frequency Control Capability (EFCC) project.	High	Low	BEIS and Ofgem are developing energy storage policy, building on DECC's position paper Towards a Smart Energy System published in 2015. New regulation is expected towards the end of 2016. These changes will be key to the successful large-scale deployment of new storage technologies.
Financial	Energy storage can provide several services and the price for some of these is not signalled strongly in the current UK market. There are missing markets for some battery services and other prices are supressed.	Medium	Medium	Transmission and distribution usage charges need to be updated to better reflect the benefits of storage and to align incentives. Ofgem and National Grid will need to undertake a review in consultation with market participants.
Financial	It is difficult to reflect the full value of the flexibility and resilience energy storage provides because of the number of different beneficiaries. Activity in multiple markets would make it difficult to meet all contractual requirements at the same time. Will be complex to overcome even with fully unbundled and price-reflective markets.	Medium	High	Co-ordinated design of ancillary service markets, payments between parties (i.e. DNO/TSO/Renewable project developer etc.) and aligned contractual requirements through procurement.
Research	Grid-scale batteries are a relatively new use of lithium-ion and technology research and development is needed. Other competing technologies demand further development in order to be commercialised.	Medium	Medium	Additional research at all stages of the value chain and deployment by industry.
Supply chain	Energy storage is a new technology and the UK supply chain, expertise and ecosystem of related activities needs to be fully developed.	Medium	Medium	Public support for energy storage from public and private organisations in Greater Exeter could help encourage energy storage related business to locate in the region, providing a boost to the local green economy.
Political	Energy storage is a new technology and is not addressed in planning policy. This increases development risk for storage developers.	Low	Low	While energy storage installations are likely to have low landscape and visual impact, a proactive policy would encourage the deployment of systems in Greater Exeter.

TABLE 7.13: Key barriers and constraints for CHP and District Heating

DISTRICT HEATING				
Financial	Significant capital costs and extended payback periods.	High		ESCO financing Acceptance that DH is a long-term infrastructure investment. Financial appraisal should be done on a life-time NPV or IRR basis.
Political	Commitment of and co-ordination and agreement between various parties.	High		Selling of the benefits, significant stakeholder engagement activities.
Education	Scepticism amongst potential heat customers regarding heat charges and reliability.	High		Early and ongoing engagement with potential heat customers, building confidence in the advantages of DH over individual systems.
Social	District heating is a natural monopoly so consumer protection issues are relevant and can add to consumer scepticism.	Medium		Adoption of the voluntary 'Heat Trust' Consumer Protection scheme.
Technical	Uncertainty regarding the longevity and reliability of heat demand.	High		Building a diverse portfolio of heat loads (customers) to mitigate the impact of the loss of particular loads, adding further loads over time. Long-term agreements where possible with critical customers.

[192] http://www2.nationalgrid.com/Mediacentral/UK-Press-releases/2014/%C2%A312-6million-boost-for-two-innovtive-National-Grid-projects/

Type	Barrier(s)	Significance	Difficulty to overcome	Potential action to address barriers
Technical	Unsuitable existing heating systems in potential buildings for connection.	Medium	Medium	Difficult to address unless building owners are prepared to consider change of system. Most likely to be possible at the time of major refurbishments.
Political/Education	For local authority led schemes, shortage of internal resource and knowledge	Medium	Low	Engagement of consultancy support Use of HNDU financial support
Supply chain	Identification and selection of suitably qualified consultants	Medium	Low	Use of consultants, designers and/or ESCOs experienced with DH and have clear track record of delivering successful schemes. Ensure conformity with CIBSE/ADE CP1: Heat Networks: Code of Practice for the UK
CHP				
Technical	Situations where there is insufficient heat load duration over the year.	High	High	Incorporate additional heat loads via district heating. If there are cooling requirements, use absorption chillers driven by CHP heat.
Financial	Relatively high capital costs	Medium	Low	Use of ESCO financing arrangements if the host organisation is unable or unwilling to invest itself, and/or wishes to transfer risk.
Financial	Risk from variations in the difference between the cost of fuel and the value of electricity generated (known as the spark spread).	High	Medium	Undertake sensitivity tests on lifetime cost projections to quantify risk. Share or transfer risk under an ESCO arrangement.
Technical	Plant maintenance requirements	Medium	Low	Ensure realistic maintenance costs are incorporated into lifetime costing. Transfer maintenance responsibilities to ESCO or other third party with suitable performance guarantees.
Technical	Complexities of integrating heat and power outputs with existing infrastructure	Medium	Low	Use of consultants, designers and/or ESCOs experienced with CHP.