Scoping Report for the New Anglia LEP

Climate Change Adaptation and Carbon Reduction Action Plan

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Executive Summary

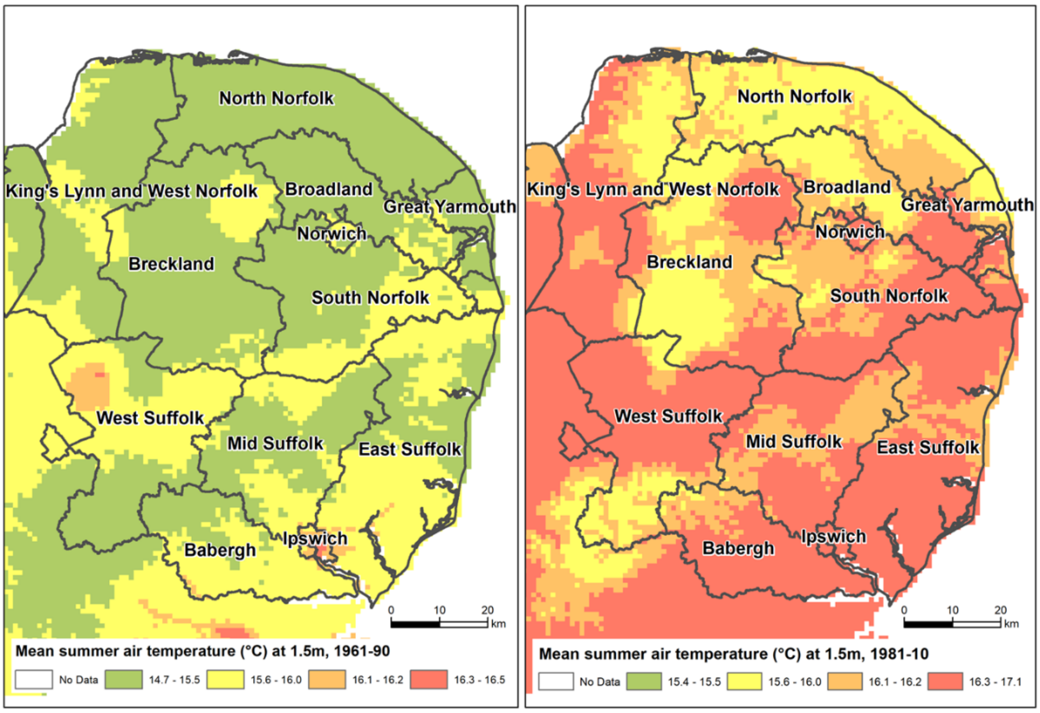
Climate change is increasingly recognised as a major and urgent global challenge, with existing and projected impacts on many dimensions of sustainable development. This is reflected in the recent decision of the UK government to adopt a target of net zero greenhouse gas (GHG) emissions by 2050 and declarations of a 'Climate Emergency' by many local government bodies.

The purpose of this scoping study is to help develop an action plan to incorporate climate change adaptation and carbon reduction ambition into the objectives of the New Anglia LEP for Norfolk and Suffolk. It is in three main sections and reviews:

- Existing knowledge on observed and projected climate changes
- Trends and geographical distribution of greenhouse gas emissions
- Local priorities for climate change mitigation and adaptation

Observed and Projected Climate Change

Details from the Met Office HadUK-Grid dataset have been analysed for two 30-year baseline time periods (1961-90 and 1981-2010) to examine recent changes in temperature and precipitation. The trends are stronger for temperature than precipitation and generally show an increase in indicators of higher summer temperatures, a reduction in those for colder winter temperatures and greater rainfall intensity. The maps below, for example, show an increase in mean summer temperatures of at least 0.5°C between the two baseline periods.



The UK Climate Projections 18 (UKCP18) outputs from the Met Office present estimates of future climate for four pathways representing different amounts of global surface temperature increase by 2100. Mapped results at a 25 km cell resolution show little geographical variability across the region and there is considerable uncertainty in the individual pathway projections. Nevertheless, taking the mid-point (50th percentile) in projections for the East of England through to around 2040 indicates the following changes compared to a 1981-2000 baseline.

- An increase in mean summer temperature of 1.2°C to 1.6°C
- An increase in mean winter temperature of 1.0°C to 1.3°C
- A decrease in mean summer precipitation of 1% to 13%
- An increase in mean winter precipitation of 5% to 8%

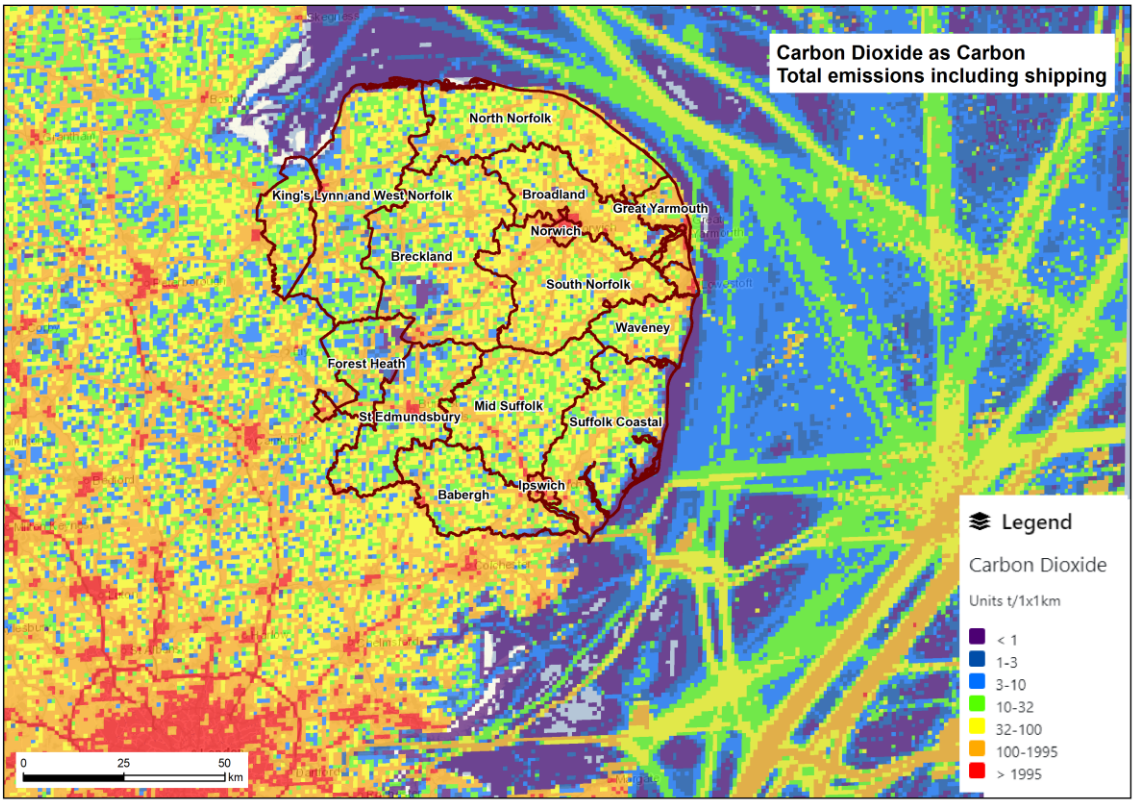
UKCP18 also includes projections for future sea level rise and storm surges. It is expected that the rise in mean sea level will be greater in the south of the UK than the north and projections for Great Yarmouth under the most extreme of the four pathways indicate a 0.2 – 0.4m mean sea level rise by the middle of the century and potentially 0.6 to over 1 metre by 2100. There is considerable uncertainty in these projections, but they provide an indication of the extent of change that should be anticipated in long-term planning.

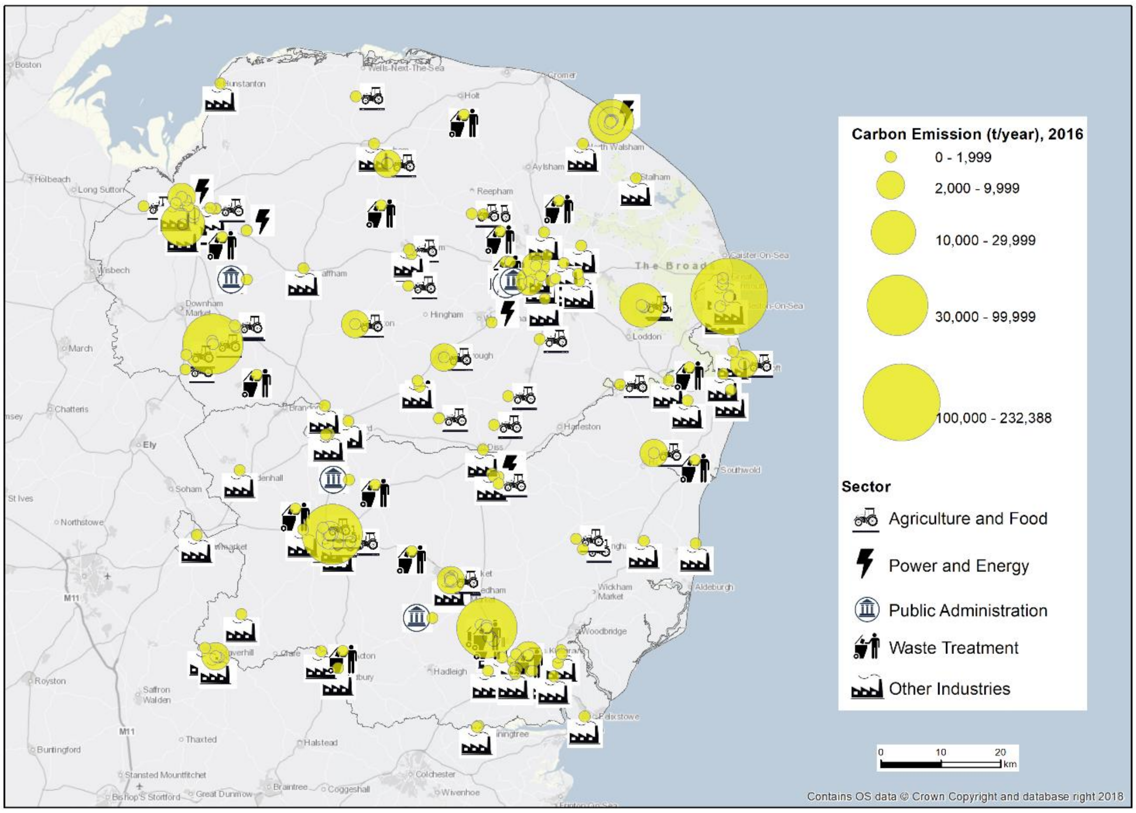
Trends in Greenhouse Gas Emissions

Data on UK greenhouse gas emissions are published by the Department for Business, Energy & Industrial Strategy (BEIS) and include carbon dioxide (CO_2) emissions estimates for local authorities (2005-16) with a breakdown by 14 economic sectors. UK CO_2 emissions declined from 522,857 kt CO_2 in 2005 to 357,470 kt CO_2 in 2016. However, the decline for transport was much smaller than that for many other sectors so its relative contribution increased from 26% in 2005 to 36% in 2016.

Per capita CO_2 emissions estimates for the UK declined from 8.7 to 5.4 tonnes/person between 2005 and 2016. Norfolk and Suffolk went from having below UK average per capita CO_2 emissions in 2005 to above average in 2016 (5.7 and 5.6 tonnes/person respectively). This was associated with an increase in the relative importance of road transport sources in the two counties. These totals will need to reduce to no greater than 1.7 tonnes CO_2e/year per capita by 2050 to meet the objective of the Paris Agreement to limit a global temperature rise this century to 1.5 °C.

A more geographically detailed perspective on emissions can be obtained from the National Atmospheric Emissions Inventory (NAEI) which contains both 1 km grid cell emissions estimates and details of individual 'point sources' (i.e. large factories and power stations). The first map on the next page shows gridded estimates for carbon dioxide and highlights that many parts of Norfolk and Suffolk have relatively low CO_2 emissions compared to the region around London, as well as illustrating the extent of carbon emissions associated with road transport and shipping routes. A second map shows major point source emitters such as power stations and food processing plants. Overall, the 37 point sources accounted for 22.6% of total CO_2 emissions in Norfolk and Suffolk during 2016.


Carbon Dioxide as Carbon
Total emissions including shipping
North Norfolk
King's Lynn and West Norfolk
Broadland
Great Yarmouth
Norwich
Breckland
South Norfolk
Waveney
Forest Heath
Mid Suffolk
St Edmundsbury
Suffolk Coastal
Babergh
Ipswich
Legend
Carbon Dioxide
Units t/1x1km
< 1
1-3
3-10
10-32
32-100
100-1995
> 1995
0
25
50
km


Carbon Emission (t/year), 2016
0 - 1,999
2,000 - 9,999
10,000 - 29,999
30,000 - 99,999
100,000 - 232,388
Sector
Agriculture and Food
Power and Energy
Public Administration
Waste Treatment
Other Industries
0
10
20
km
Contains OS data © Crown Copyright and database right 2018

Local Priorities for Climate Change Mitigation and Adaptation

Based on the data regarding climate and greenhouse gas trends the following are suggested as issues that need particular attention in an action plan for Norfolk and Suffolk.

Domestic Sector – The existing building stock will need to be adapted to provide suitable conditions for people to live and work in a warmer climate. This will be important for business productivity and also represents an opportunity for local construction businesses. An additional consideration in rural areas that are not connected to the national gas grid will be to develop alternative means of heating provision, both to meet decarbonisation targets and reduce reliance on oil.

Transport Sector – Increased use of public transport and electric vehicles will need to be a central element of decarbonising transport in the next 30 years. Provision of public electric charging points is currently limited in many parts of Norfolk and Suffolk and requires investment.

Agricultural Sector – Improved water management needs to be a priority for coming decades, both in terms of increased storage capacity and greater use efficiency. Opportunities will exist for land owners and managers to contribute to carbon sequestration and to develop enterprises based on new crops or to meet demand for local renewable generation of heat and power.

Food Processing Sector – Several processing plants make a substantial contribution to regional greenhouse gas emissions and options to reduce their carbon footprints should be investigated.

Energy Sector – The region is already a leading generator of renewable energy and the coming decades will see a growing demand for electricity, particularly from domestic and transport sectors. At present, there are constraints on the capacity of the electricity transmission and distribution network in many parts of Norfolk and Suffolk and developing an investment strategy to rectify this situation is fundamental to both meeting decarbonisation objectives as well as supporting future economic growth. Extension of the existing high-voltage transmission network to a coastal destination would also be beneficial to the marine renewables industry.

Many of these priorities interact with each other so it is important that an action plan should involve coordination between sectors as well as initiatives within them. Overall, the challenges of climate change mitigation and adaptation are considerable, but they will be less formidable if action is taken sooner than later, and this could also provide important opportunities and benefits for businesses and residents in Norfolk and Suffolk.

Introduction

Climate change is increasingly recognised as a major and urgent global challenge, with existing and projected impacts on many dimensions of sustainable development (Intergovernmental Panel on Climate Change (IPCC), 2018; Committee on Climate Change (CCC), 2019a). This is reflected in the recent decision of the UK government to adopt a target of net zero greenhouse gas (GHG) emissions by 2050 (HM Government, 2019) and declarations of a 'Climate Emergency' by many local government bodies (see https://climateemergency.uk/). Addressing the mitigation (limiting emissions of GHGs) and adaptation (altering how we live) challenges of climate change will require action by many different organisations, from global to local scales and in both the public and private sectors.

Aims

The purpose of this scoping study and report is to help develop an action plan to incorporate climate change adaptation and carbon reduction ambition into the objectives of the New Anglia LEP for Norfolk and Suffolk. It details current knowledge that could underpin development of a full action plan covering three interconnected priorities:

- How can businesses in Norfolk and Suffolk increase their resilience to climate change while maximising their growth opportunities?
- How can Norfolk and Suffolk contribute to the national carbon reduction goals while meeting its own objectives for growth and employment; where are the new opportunities arising?
- How can national and international responses to climate change support wider objectives of reducing poverty in Norfolk and Suffolk and create new opportunities for clean growth?

This scoping report examines historic and projected climate data and trends, highlights key government research related to business risks and adaptation needs, and indicates initial steps towards the development of a full adaptation and mitigation action plan for Norfolk and Suffolk.

Part I. Climate Data and Projections

This section reviews the existing knowledge on historic climate and projected changes in Norfolk and Suffolk.

1.1 Indications of changes in local climate from the recent historic record

Land surface weather observations for the UK dating back to 1862 have been compiled into a 1 km by 1 km gridded dataset (*HadUK-Grid*) which is available from the Met Office website[1]. It contains daily, monthly, seasonal and annual values for a range of variables that enables the analysis of changes in extremes and also the long term averages (over 30 year timespans) that provide a set of climatological reference periods for the UK.

The examination of changes in climate between 30 year reference periods[2] is a standard way of examining how the climate is changing over time.

For this study data from *HadUK-Grid* have been downloaded for Norfolk and Suffolk and imported into a Geographical Information System (GIS) to enable further analysis and mapping. To illustrate recent changes in the climate of Norfolk and Suffolk, two reference periods have been selected. The 1961-90 baseline coincides with many early reports from the IPCC and therefore enables these results to be compared against those documents. The 1981–2010 baseline is the basis for the new UKCP18 climate change scenarios (https://www.metoffice.gov.uk/research/collaboration/ukcp). Many of the maps published from UKCP18 data present potential future changes in climate from this baseline. Hence, using these two periods enables results in this study to be interpreted against a wide body of literature and existing research.

Temperature and precipitation are the weather variables of greatest familiarity and so, for illustration, Figure 1 shows mean annual summer (June, July, August) temperatures for both baseline periods and Figure 2 does the same for mean winter (December, January, February) temperatures. Figures 3 and 4 map mean summer and winter precipitation respectively, again for both baseline periods. Summer temperatures tend to be higher in the south of the region and in many places are at least 0.5°C higher in the second baseline period. Mean winter temperatures show a similar change between the two time periods, though with lower values inland and higher average temperatures around the coast.

For precipitation, the differences between the two baseline periods are less pronounced, though there is a tendency for summer precipitation to increase in the east of the region and winter averages are higher in the north and east compared to further inland.

[1] https://www.metoffice.gov.uk/climate/uk/data/haduk-grid/haduk-grid

[2] Climate is the weather of a place averaged over a period of time, conventionally 30 years

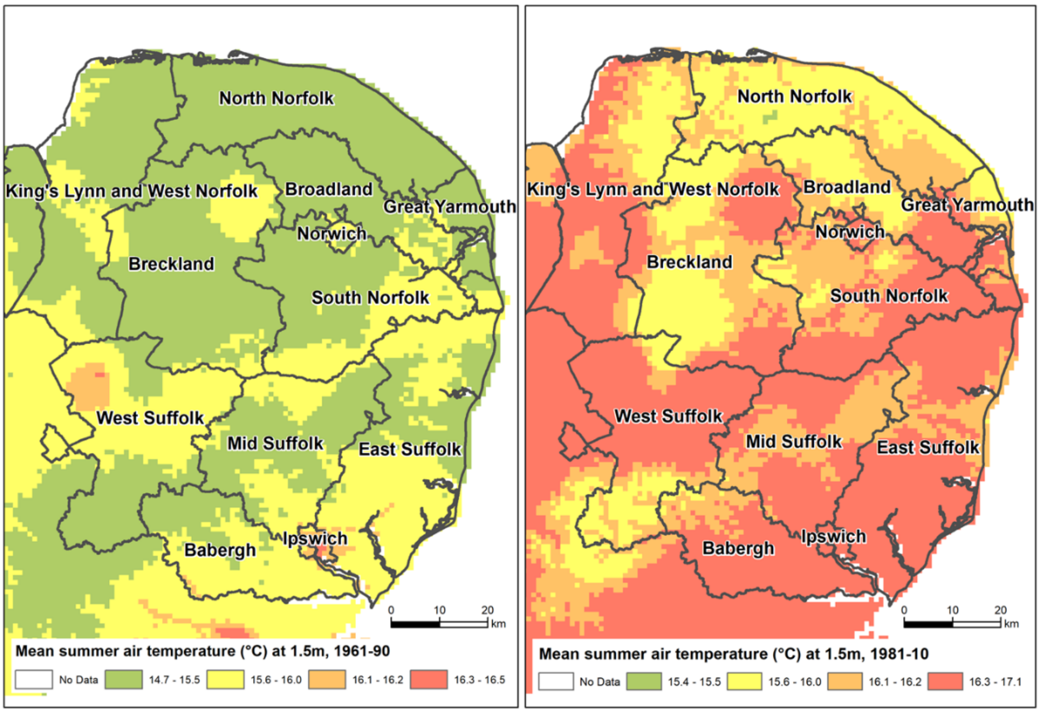


Figure 1: Observed changes in mean summer temperature in East Anglia between 1961-90 and 1981-2010

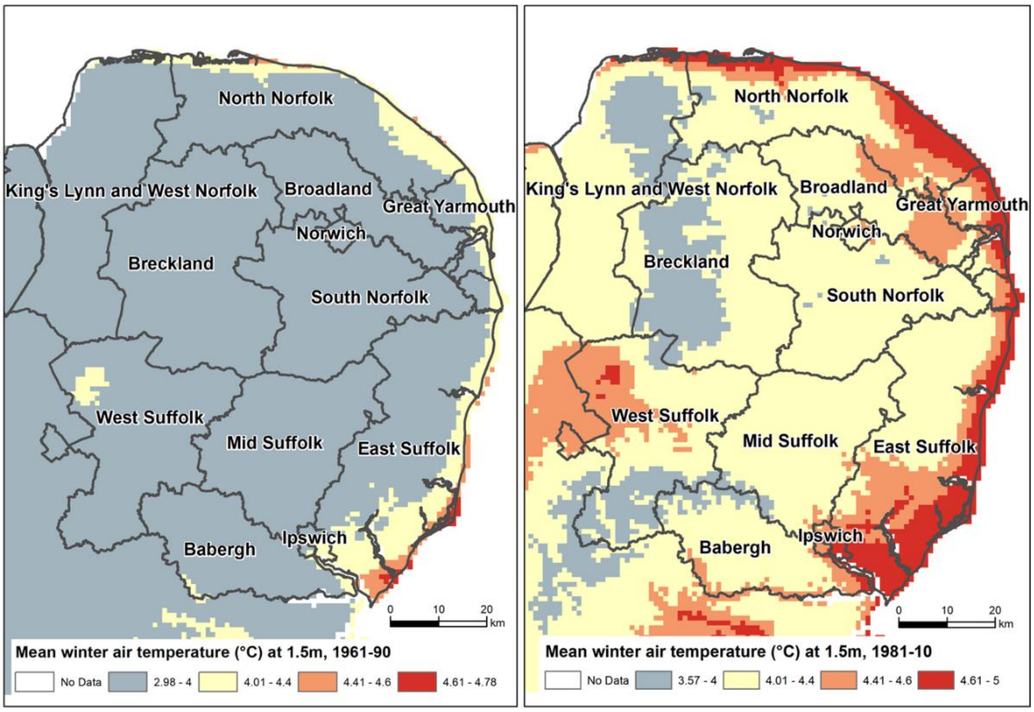


Figure 2: Observed changes in mean winter temperature in East Anglia between 1961-90 and 1981-2010

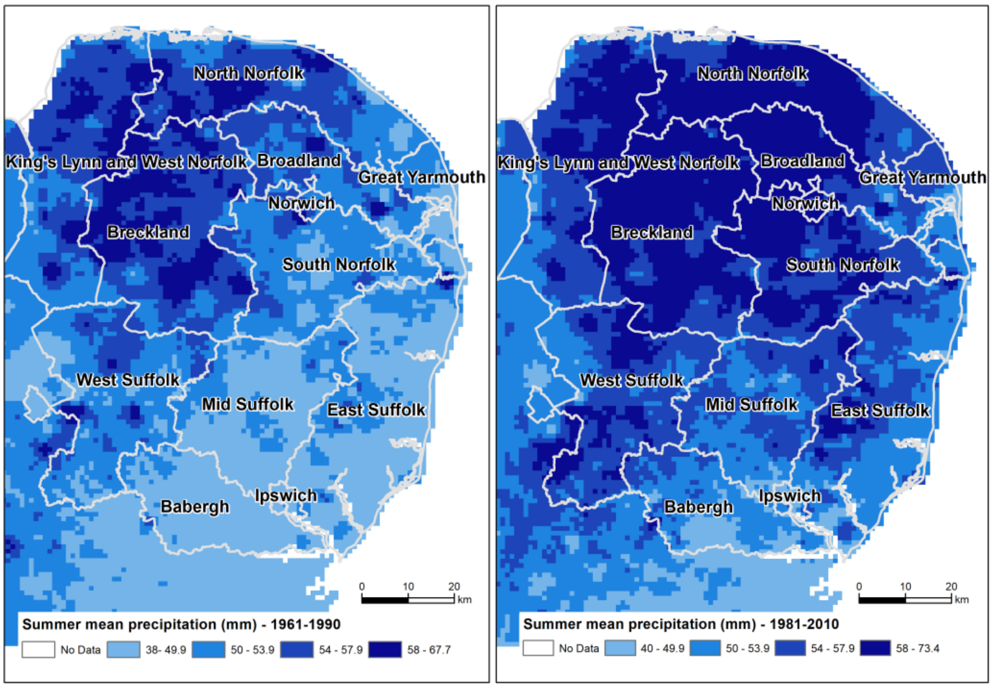


Figure 3: Observed changes in mean summer precipitation in East Anglia between 1961-90 and 1981-2010

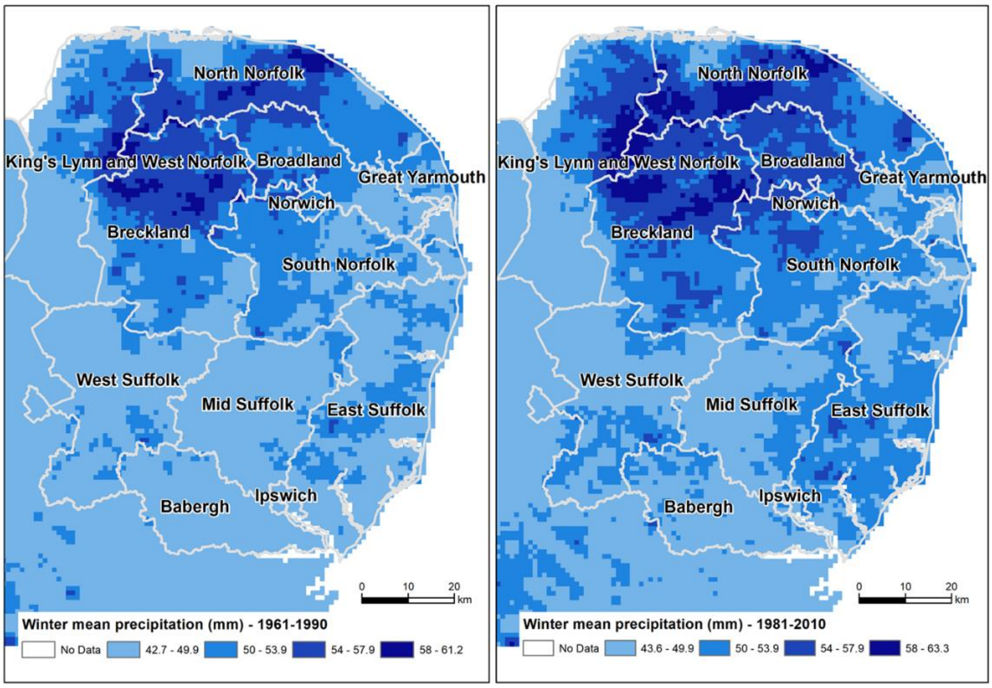


Figure 4: Observed changes in mean winter precipitation in East Anglia between 1961-90 and 1981-2010

An additional perspective on observed changes is provided by Met Office indices on climate extremes (Met Office, 2018a). These are published on a regional basis and are summarised for the Met Office East Anglian region (defined as the East of England NUTS 1 region but excluding Peterborough) in Table 1.

Table 1: Observed changes in temperature and precipitation extremes in the Met Office East Anglian region

Variable	1961-1990 Reference Period	1981-2010 Reference Period	Most Recent Decade (2008-2017)
High Temperature Indices			
Highest daily maximum temperature (°C)	28.5	29.9	30.3
Summer days (number of days with maximum temperature above 25°C)	10.8	16.4	15.7
Low Temperature Indices			
Icing days (number of days with maximum temperature below 0°C)	2.9	2.0	1.0
Lowest daily minimum temperature (°C)	-8.1	-7.1	-6.9
Cold spell duration index (days where temperature is below the 90th percentile of 1961-90 baseline)	3.7	2.8	1.0
Precipitation indices			
Maximum 5-day precipitation (mm of rainfall accumulated over 5 days)	50.6	53.1	51.8
Rainfall from extremely wet days (total rainfall days in excess of 1961-90 baseline)	50.1	56.8	53.2

Source: https://www.metoffice.gov.uk/binaries/content/assets/mohippo/pdf/uk-climate/state-of-the-uk-climate/soc_supplement-002.pdf

The indices in Table 1 show the following trends between the two 30-year baseline periods:

- An increase in indicators of higher temperatures
- A reduction in indicators of colder temperatures
- An increase in indicators of rainfall intensity

Several of these trends continue in the data from the 2008-2017 decade (e.g. those for colder temperatures), but this is not always the case. For instance, the indicators of rainfall intensity are lower for 2008-2017 than 1981-2100, though higher than in 1961-1990. This highlights the variability of weather and consequently the importance of evaluating changes in climate over longer periods of time.

Overall, the maps and indices suggest that the climate of Norfolk and Suffolk has become warmer in recent decades, with cold spells getting shorter and less cold. This has direct relevance to agricultural and horticultural production, and potential adaptive consequences for the food and drink sector, but will also affect businesses and industrial premises and other NALEP priority sectors e.g. through changes to heating and cooling requirements.

There is more ambiguity with regard to long-term precipitation trends, although it does appear that rainfall intensity is increasing and extremely wet days are becoming more frequent. Again, this can have direct consequences for farming and agricultural production, but wider implications for other business sectors and society in general e.g. with regard to flooding risks.

With regard to the potential for changes in frequency or intensity of other climate indicators (e.g. wind storms or droughts) the State of the UK Climate 2017 report (Kendon et al., 2018) examines the observed data for possible shifting trends, but reports that the evidence for change in extreme weather events appears to be weak at present.

1.2 Projected future changes in local climate

A new set of climate change projections for the UK have recently been published by the Met Office Hadley Centre Climate Programme. UKCP18 (UK Climate Projections 2018) is based on the latest climate science and examines how the climate may change over the 21st century including, for the first time, the influence of mitigation measures.

The UKCP18 climate change scenarios are based on four Representative Concentration Pathways (RCPs) that estimate GHG emissions and climate change for future radiative forcing targets in 2100 of 2.6, 4.5, 6.0 and 8.5 Wm^2 (watts per meter squared). Radiative forcing is the difference between insolation (sunlight) absorbed by the Earth and energy radiated back to space and is influenced by atmospheric concentrations of greenhouse gases. Table 2 shows the projected increase in global mean surface temperature under each pathway.

Table 2: UKCP18 climate change scenarios

RCP	Increase in global mean surface temperature (°C) by 2081-2100	Comment
RCP2.6	1.6 (0.9 – 2.3)	Closest to Paris Agreement
RCP4.5	2.4 (1.7 - 3.2)	'most likely'
RCP6.0	2.8 (2.0 – 3.7)	Intermediate stabilisation
RCP8.5	4.3 (3.2 – 5.4)	No mitigation

Source: https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Overview-report.pdf

RCP2.6 keeps climate change to below 2.0°C and is closest to meeting the Paris Agreement target of limiting the increase in global average temperature to 1.5 °C above pre-industrial levels. RCP4.5 is considered the 'most likely' pathway given current trends in GHG emissions. Emissions stabilise at 2030s with no further increases after that. RCP6.0 assumes some continuing increase in emissions increase after 2030s and RCP8.5 assumes no mitigation, and therefore represents an extreme position (Met Office, 2019).

Data are available at 25 km grid cell resolution for all scenarios. A web-based user Interface[3] enables maps and data to be downloaded for further analysis. An example of the kind of map that can be generated via the user Interface is shown in Figure 5.

The top row of maps in Figure 5 show the projected change in maximum summer temperatures for the period 2030-2059, compared to the 1981-2010 baseline under the RCP4.5 pathway. All the projections have an uncertainty range, represented by the three maps – the 10th and 90th percentiles indicating values towards the lower and upper extremes of likelihood respectively, while the 50th percentile represents the mid-point of likelihood for that particular pathway. The values mapped are temperature anomalies so illustrate differences from the 1981-2010 baseline. In the 50th percentile map all of the region is in the category for a 1-2°C projected increase, while the 10th and 90th percentile maps show a rise of 0-1°C and 2-3°C respectively.

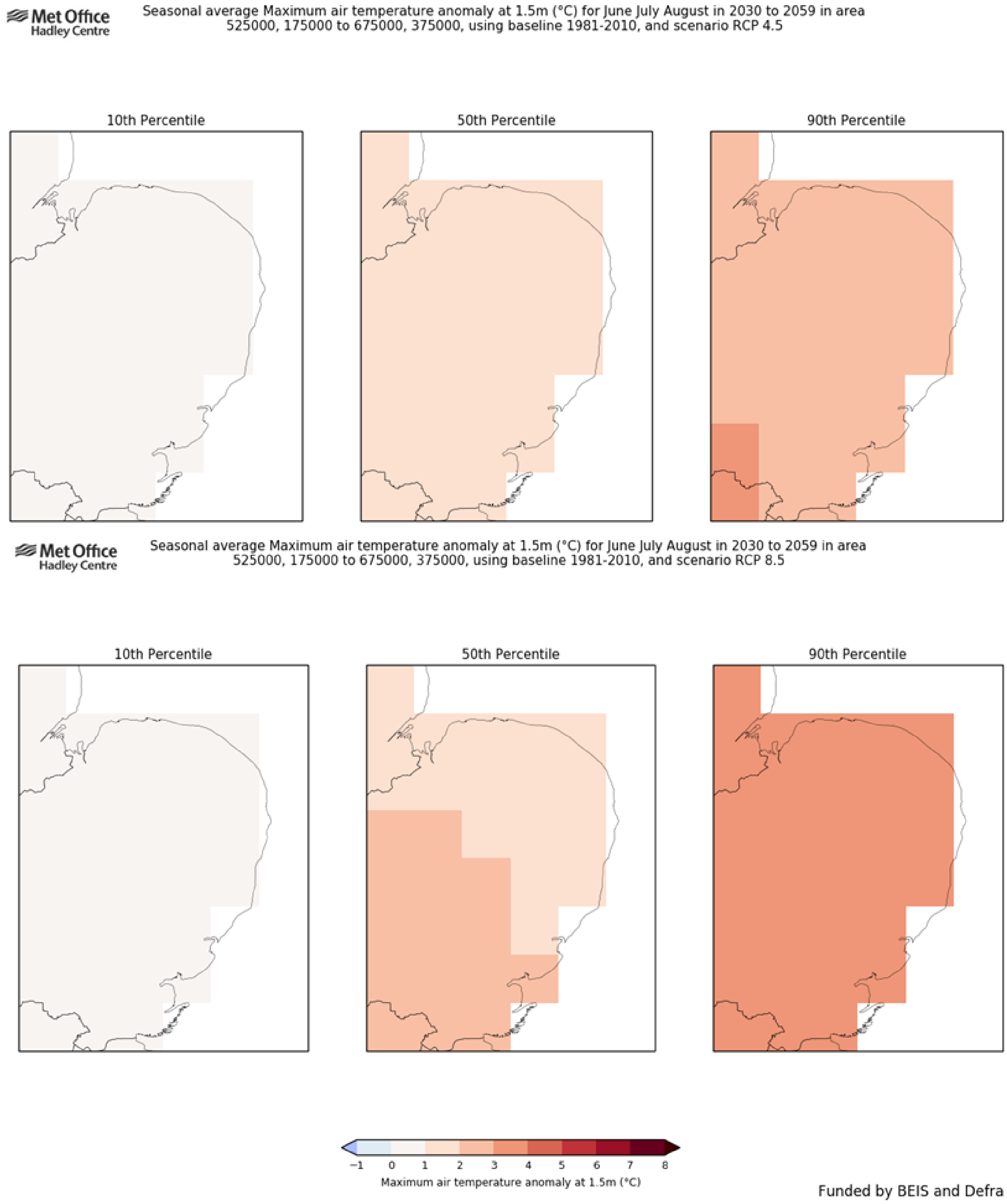
The bottom row of maps shows the same variable under the extreme RCP8.5 pathway. Comparing pathways provides a means of evaluating the sensitivity of outcomes to input assumptions and in this case the 50th percentile map indicates that parts of the region could experience a 2-3°C increase in maximum summer temperatures with an upper estimate (90th percentile) of 3-4°C.

All of the maps show little variability across Norfolk and Suffolk, but there are plans to produce downscaled versions of the projections at a 2.2 km resolution (Fang, 2019) which would enable a more detailed assessment of geographical variations in potential impacts.

Additional details can be extracted via the user interface to examine projections at a regional scale. Table 3 shows results for the East of England region in terms of changes in temperature and precipitation from 1981-2000 to around 2040 (represented by 2030-49 period). The values cover all four scenarios and five points on the range of uncertainty. One feature of these results is the range of uncertainty (e.g. as represented by the range between the 5th and 95th percentile values), but the 50th percentile results (i.e. mid point of likelihood) suggest:

- An increase in mean summer temperature of 1.2°C to 1.6°C
- An increase in mean winter temperature of 1.0°C to 1.3°C
- A decrease in mean summer precipitation of 1% to 13%
- An increase in mean winter precipitation of 5% to 8%

[3] https://ukclimateprojections-ui.metoffice.gov.uk/



Source for data download: https://catalogue.ceda.ac.uk/

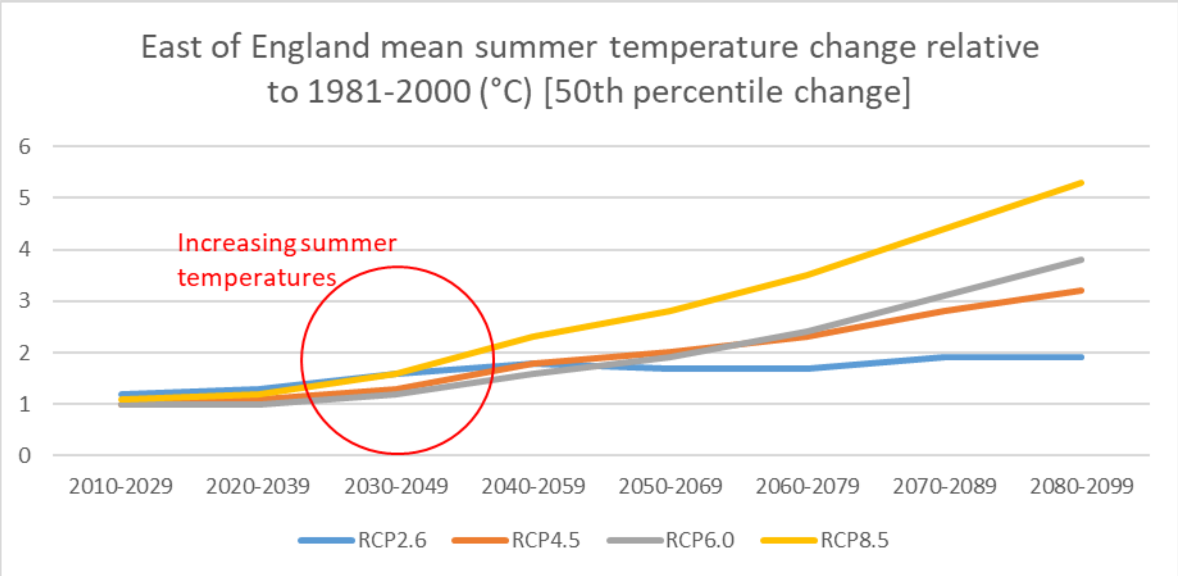
Figure 5: Example of map data that can be generated from the UKCP18 user interface

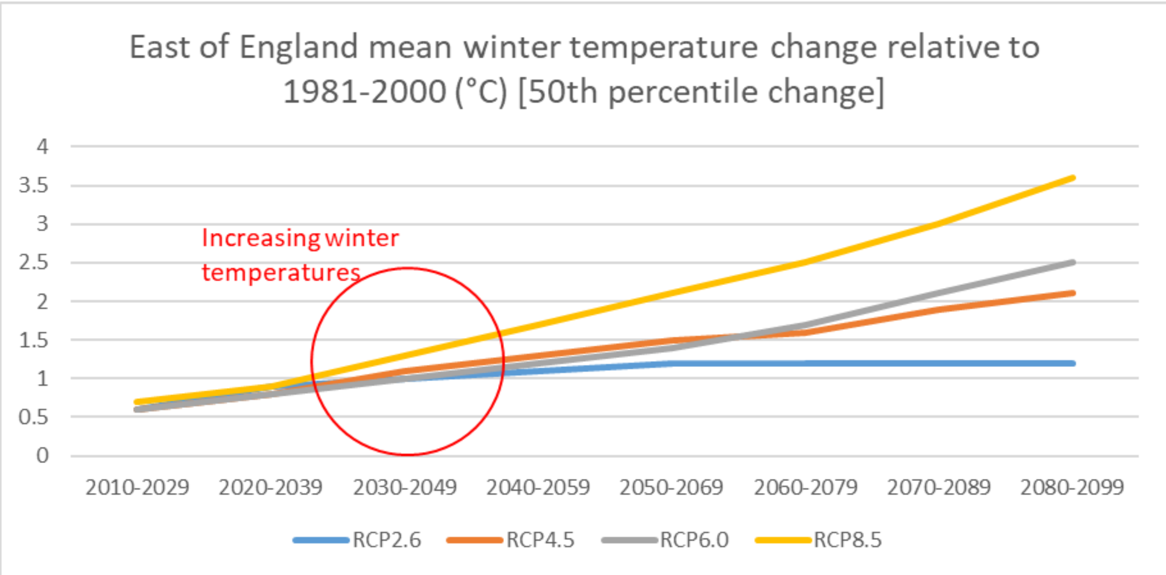
Table 3: Projected changes in temperature and precipitation for the East of England from 1981-2000 to around 2040 (2030-2049)

Variable	Emissions Scenario	5th percentile change	10th percentile change	50th percentile change	90th percentile change	95th percentile change
mean summer temperature (°C) 2030-2049	RCP2.6	0.3	0.5	1.6	2.6	2.9
	RCP4.5	0	0.3	1.3	2.3	2.6
	RCP6.0	0	0.2	1.2	2.3	2.6
	RCP8.5	0.2	0.6	1.6	2.8	3.1
mean winter temperature (°C) 2030-2049	RCP2.6	-0.2	0.1	1	2	2.3
	RCP4.5	-0.1	0.2	1.1	1.9	2.2
	RCP6.0	-0.1	0.2	1	1.9	2.1
	RCP8.5	0.1	0.3	1.3	2.3	2.6
mean summer precipitation (%) 2030-2049	RCP2.6	-37	-31	-11	10	16
	RCP4.5	-38	-32	-10	12	19
	RCP6.0	-37	-31	-10	13	20
	RCP8.5	-43	-36	-13	12	19
mean winter precipitation (%) 2030-2049	RCP2.6	-8	-5	6	18	22
	RCP4.5	-8	-5	6	17	21
	RCP6.0	-8	-5	5	17	20
	RCP8.5	-7	-4	8	21	25

Source: UKCP18-Key-results.xlsx - The UKCP18 datasets are all available under Open Government Licence (http://www.nationalarchives.gov.uk/doc/open-government-licence).

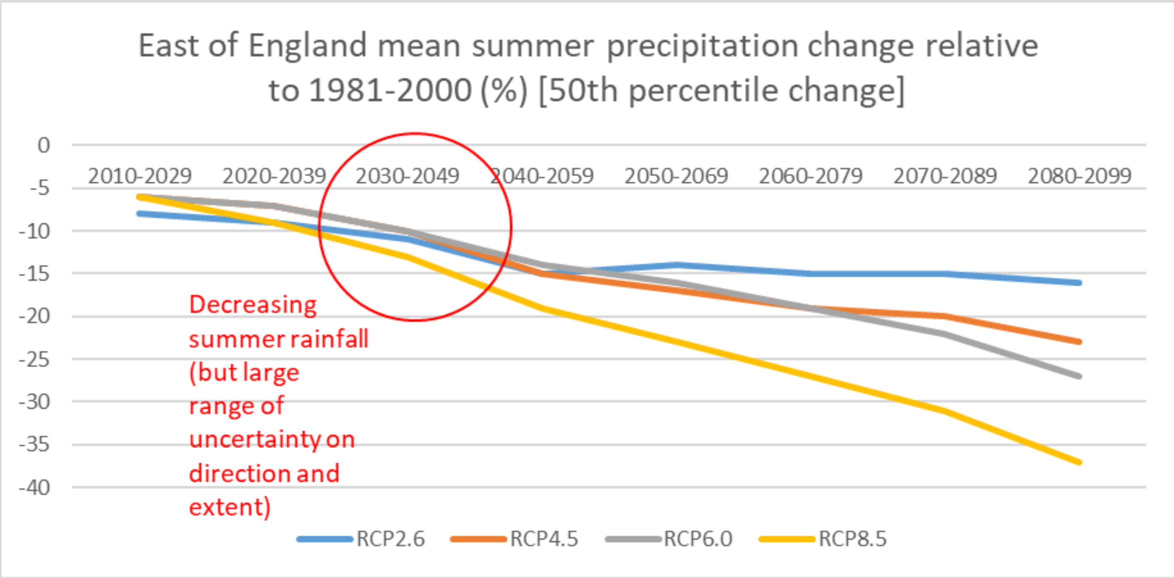
Another feature of Table 3 is that pathways with higher radiative forcing targets for 2100 are not always associated with larger projected changes in temperature and precipitation for 2040. One example of this is in the 50th percentile results for mean summer temperature where the projected changes for RCP2.6 and RCP8.5 are identical and greater than those for RCP4.5 and RCP6.0. This particular effect is because of a faster decline in aerosols (which have a cooling effect) in RCP2.6 and a consequent accentuation of warming trends in the next few decades (Chalmers et al., 2012; Westervelt et al., 2015). However, in the latter half of the 21st Century the influence of increased $C0_2$ concentrations dominates, leading to a clearer association between higher radiative forcing and greater projected changes in temperature or precipitation. This situation is illustrated for temperature in Figure 6 and precipitation for Figure 7 using the central (50th percentile) values for each pathway through to the end of the 21st Century. These graphs provide another perspective on the projected temperature increases and changes in precipitation for the East of England over this timescale.

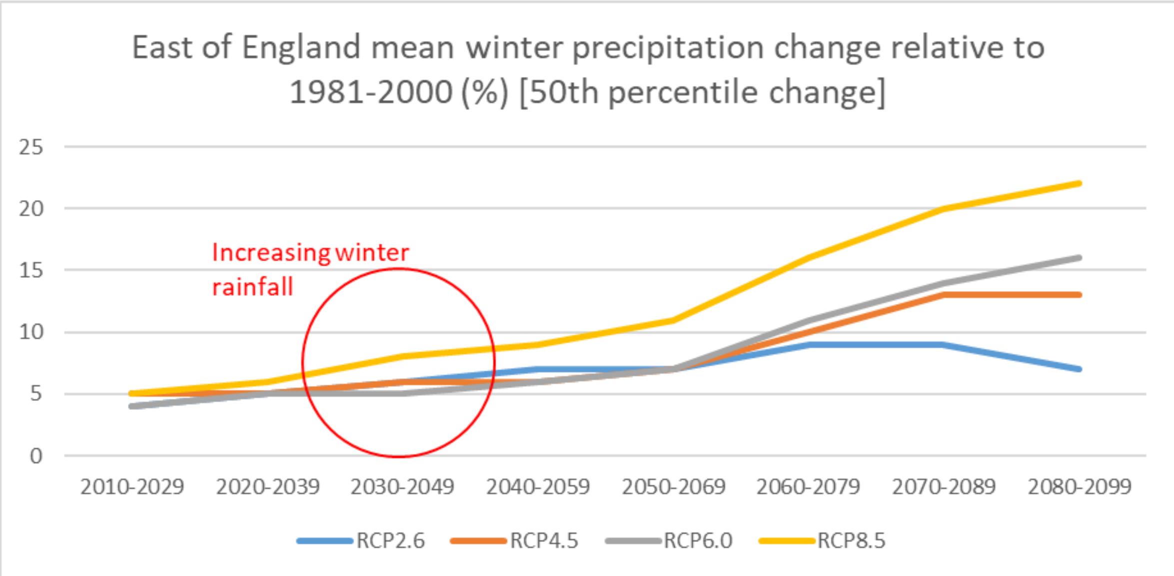




Source: UKCP18-Key-results.xlsx - The UKCP18 datasets are all available under Open Government Licence (http://www.nationalarchives.gov.uk/doc/open-government-licence).

Figure 6: Projected seasonal temperature changes for the East of England relative to 1981-2010





Source: UKCP18-Key-results.xlsx - The UKCP18 datasets are all available under Open Government Licence (http://www.nationalarchives.gov.uk/doc/open-government-licence).

Figure 7: Projected seasonal precipitation changes for the East of England relative to 1981-2010

1.3 Sea level

It is widely reported that global sea level is rising and will continue to rise over the coming centuries. Within the UK it is expected that sea level rise will be slightly greater in the south of the country than the north (Met Office 2018b). Observed sea level trend data is available for Cromer and Felixstowe from the National Tidal and Sea level facility https://www.ntslf.org/products/sea-level-trend-charts.

UKCP18 includes projections for future sea level rise and storm surges. The study found that extreme sea levels will increase due to the rise in mean sea level, but found no evidence for significant changes in future storm surges (Met Office 2018c). However, due to the considerable year-to-year variability in coastal water levels, one of its key recommendations is that coastal decision makers should account for this in risk assessments, particularly for shorter-term planning horizons (Met Office 2018c). As with the weather data, sea level rise projections can be downloaded via the Met Office user interface. Figure 8 shows sea level rise projections from 2007 – 2100 relative to a 1981-2000 baseline, under the RCP8.5 scenario, for a grid-reference approximating to Great Yarmouth. Noting that RCP8.5 is the most extreme scenario, the plotted data show a 0.2 – 0.4m mean sea level rise by the middle of the century and potentially 0.6 to over 1 metre by the end of the century.

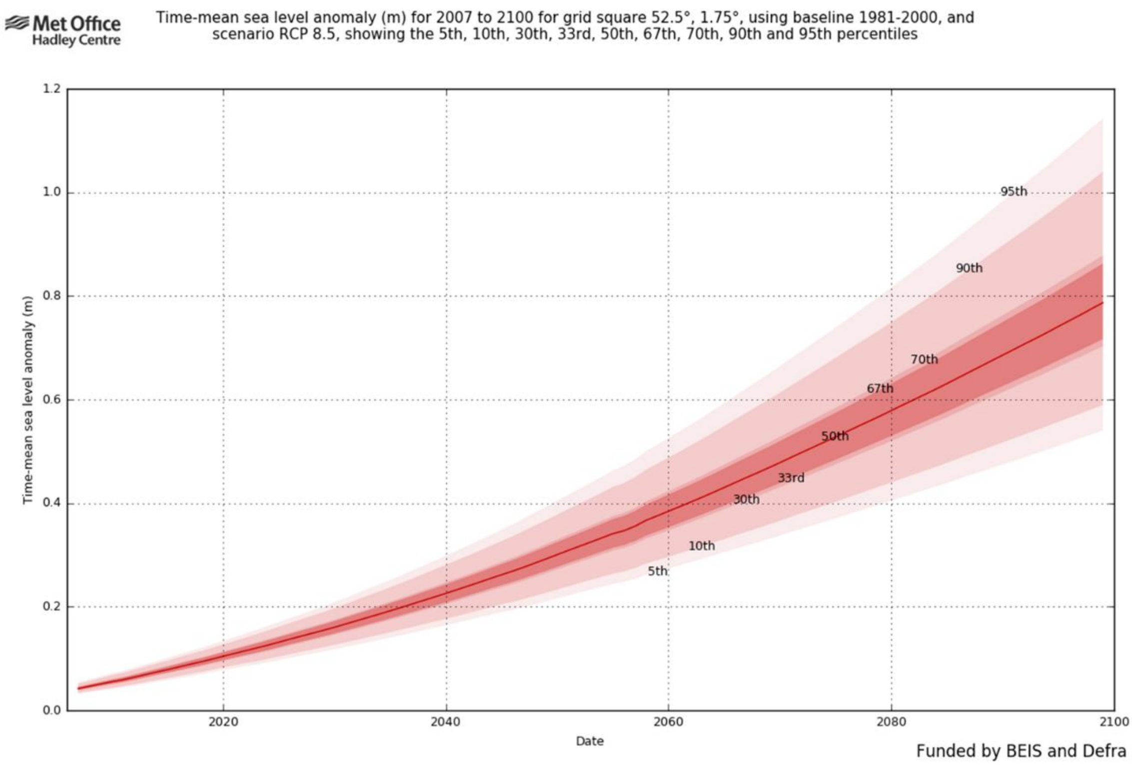


Figure 8: Local sea level rise projections 2007 – 2100 relative to 1981-2000 baseline under the RCP8.5 scenario for a grid-reference approximate to Great Yarmouth

Zsamboky et al. (2011) identify the following combined risks from sea level rise and climate changes for the East Anglian coastline:

- Weakening and collapse of cliffs due to desiccation as a result of higher summer temperatures and lower precipitation; also cliff destabilisation as a result of decreasing vegetation cover.
- Weakening and collapse of cliffs due to increased precipitation in winter, which causes more water to penetrate into desiccated cracks.
- Higher rates of coastal erosion from higher sea levels, more frequent storm surges and weakened cliffs.
- High erosion contributing to enhanced rates of longshore drift which may pose threats to the major ports of Great Yarmouth, Felixstowe and Harwich.

Overall, the precautionary principle would suggest that coastal businesses and land-owners should make an evaluation of impacts from sea level rise a consideration in long-term planning and monitor future research updates on storm surges.

Part II. Emissions Data and Projections

Data on UK greenhouse gas emissions are published by the Department for Business, Energy & Industrial Strategy (BEIS) and are available at https://www.gov.uk/government/collections/uk-greenhouse-gas-emissions-statistics. These include carbon dioxide (CO_2) emissions estimates for local authorities (2005-16) with a breakdown by 14 sectors which can be summarised into the following key groups – industry/commercial, agriculture, domestic, road transport, diesel railways, other transport and, 'land use, land use change and forestry' (LULUCF) which due to CO_2 offset through carbon sequestration, can be represented in the data by negative emissions values. The dataset also provides population and per capita CO_2 estimates for each local authority area.

Over 2005-2016 the data show that the general trend in UK CO_2 emissions was downwards, totalling 522,857 kt CO_2 in 2005 and reducing to around 357,470 kt CO_2 in 2016. However, while there was a reduction of approximately 100,000 kt CO_2 from industry/commercial sectors and just over 50,000 kt CO_2 from domestic sources in that time period, the decline for transport was less than 10,000 kt CO_2. This meant that the relative contribution from transport sources increased from 26% in 2005 to 36% in 2016.

Table 4 shows changes in per capita CO_2 estimates for the UK, Norfolk, Suffolk and their constituent local authorities between 2005-16. Norfolk and Suffolk went from having below UK average per capita CO_2 emissions in 2005 to above average in 2016. This was associated with an increase in the relative importance of road transport sources in the two counties. Contrasts between urban and rural areas are also evident in the statistics for individual authorities, with declines of around 45% between 2005 and 2016 in Ipswich and Norwich, compared to a national average of 37% and 32% for Norfolk and Suffolk as a whole.

Table 4: Changes in per capita CO_2 emissions (t/person) in 2005-16

Area	2005	2010	2016	% Decline 2005-16
UK Total	8.7	7.4	5.4	37.1
Norfolk Total	8.4	8.0	5.7	32.2
Suffolk Total	8.2	7.6	5.6	32.1
Breckland	7.7	6.7	5.1	33.0
Broadland	7.9	8.2	6.0	25.0
Great Yarmouth	5.9	5.3	3.8	35.4
King's Lynn and West Norfolk	11.4	12.8	8.0	30.3
North Norfolk	8.7	7.9	6.0	31.3
Norwich	6.9	5.8	3.8	44.3
South Norfolk	9.1	8.1	6.3	29.9
Babergh	8.1	7.4	5.6	29.9
Forest Heath	9.9	8.8	6.8	31.4
Ipswich	5.8	4.8	3.1	46.2
Mid Suffolk	9.4	8.1	6.4	32.1
St Edmundsbury	12.6	13.6	9.3	26.1
Suffolk Coastal	6.8	5.9	4.6	32.5
Waveney	6.7	6.2	4.5	32.0

The per capita values for Norfolk and Suffolk in 2016 are slightly higher than that for Lincolnshire (5.4 t/person), but lower than the average for Cambridgeshire (7.2 t/person). The latter reflects higher emissions from road transport and a positive contribution from land use change. However, it is sobering to note that all will need to reduce these figures to no greater than 1.7 tonnes CO_2e/year per capita by 2050 to meet the requirements of the Paris Agreement to keep a global temperature rise this century well below 2°C above pre-industrial levels and pursue limiting it to 1.5 °C (CCC, 2019a, Table 1).

Further insight into the differences between districts can be obtained from Figures 8 and 9 which show the composition of CO_2 emissions by sector groupings for local authorities in Norfolk and Suffolk. It is apparent that contributions from transport (overwhelmingly road transport) are higher in more rural districts and that a few authorities (e.g. Kings Lynn and West Norfolk, St Edmundsbury) have relatively large emissions from industrial or commercial sectors. In many districts the contributions from land use (LULUCF) are negative, reflecting processes such as carbon sequestration by forests and woodland.

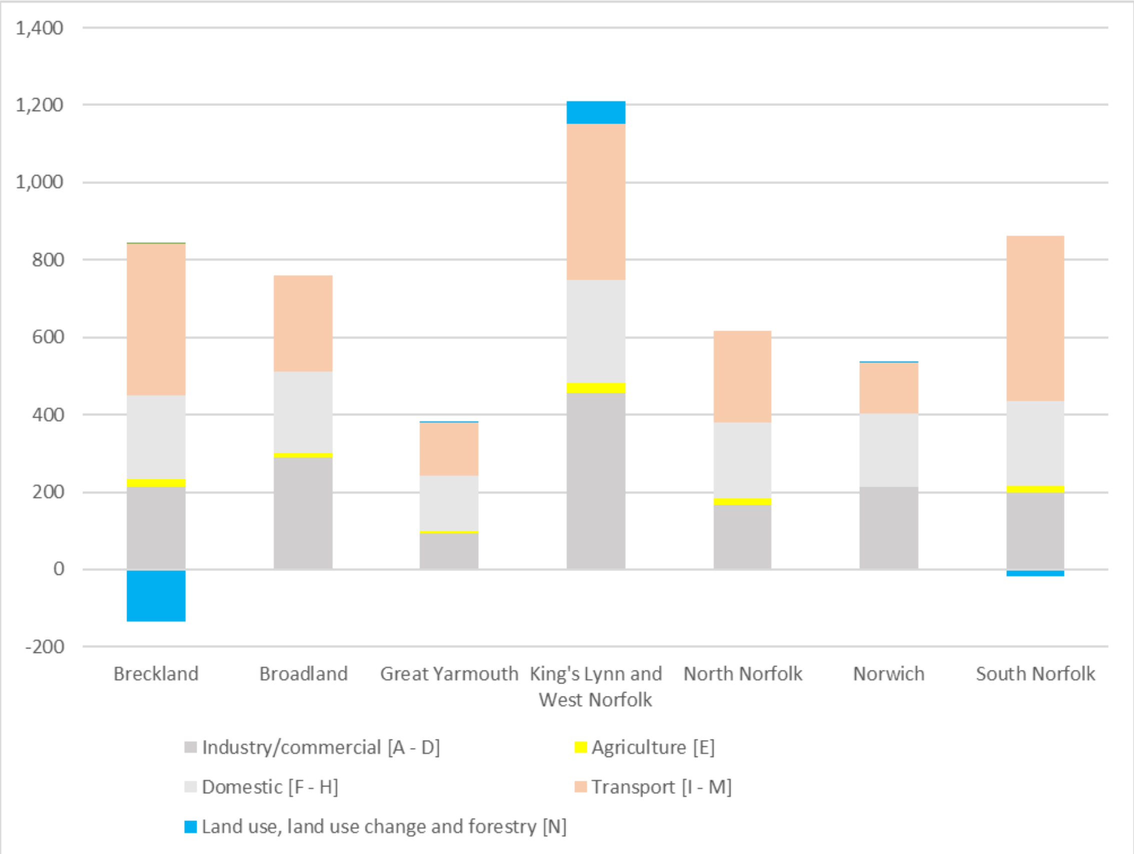


Figure 8: Emissions estimates (kt CO_2) by sector for Norfolk districts, 2016

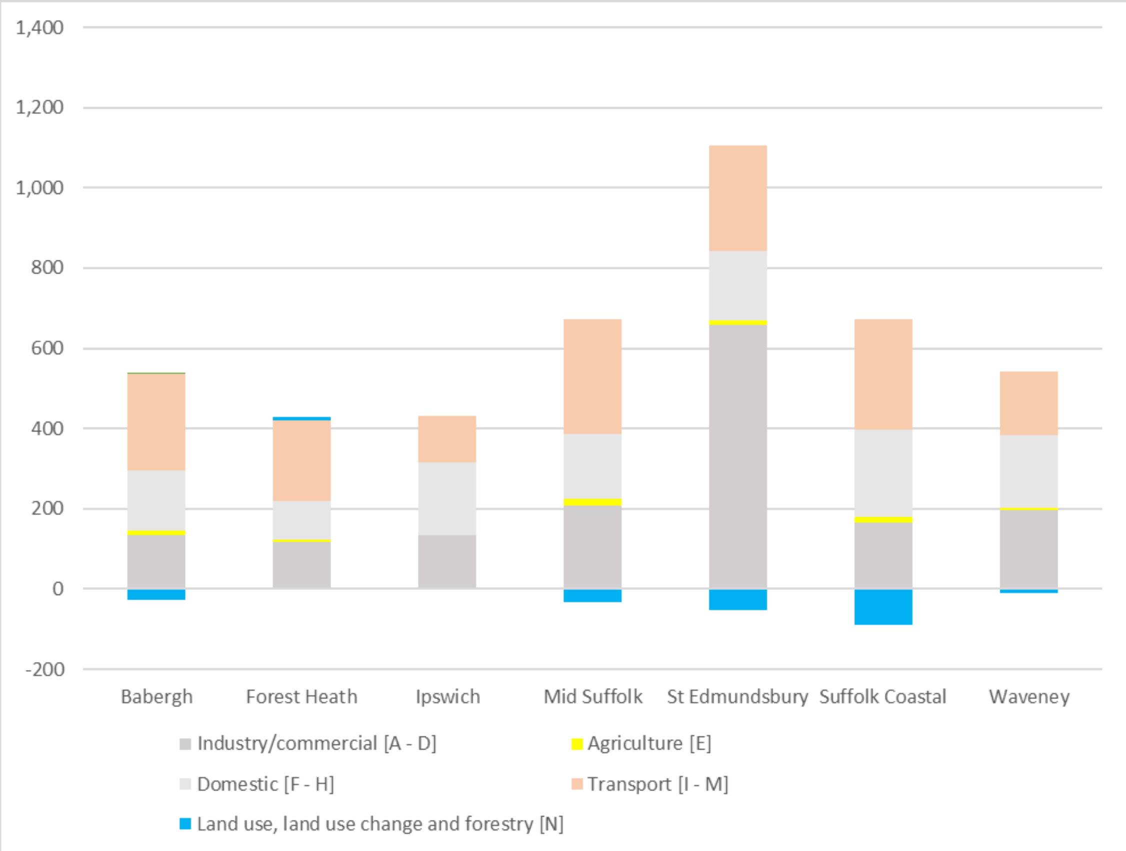


Figure 9: Emissions estimates (kt CO_2) by sector for Suffolk districts, 2016

A more geographically detailed perspective on GHG emissions can be obtained from the National Atmospheric Emissions Inventory (NAEI) (http://naei.beis.gov.uk/data/) which contains both 1 km grid cell emissions estimates and details of individual 'point sources' (i.e. large factories and power stations). Figures 10 to 12 present 1 km resolution maps for $C0_2$, methane (CH_4) and nitrous oxide (N_2O) which are the three most important greenhouse gases. The map for CO_2 (Figure 10) highlights urban areas and main roads, whereas for methane and nitrous oxide it is various agricultural and combustion sources that are more important.

A view of CO_2 emissions across a larger geographical region is provided by Figure 13 which includes shipping sources (excluded from Figure 10) and also extends down to London. The map highlights that many parts of Norfolk and Suffolk have relatively low CO_2 emissions compared to the region around London, as well as illustrating the extent of carbon emissions associated with shipping routes and ports such as Felixstowe and Great Yarmouth.

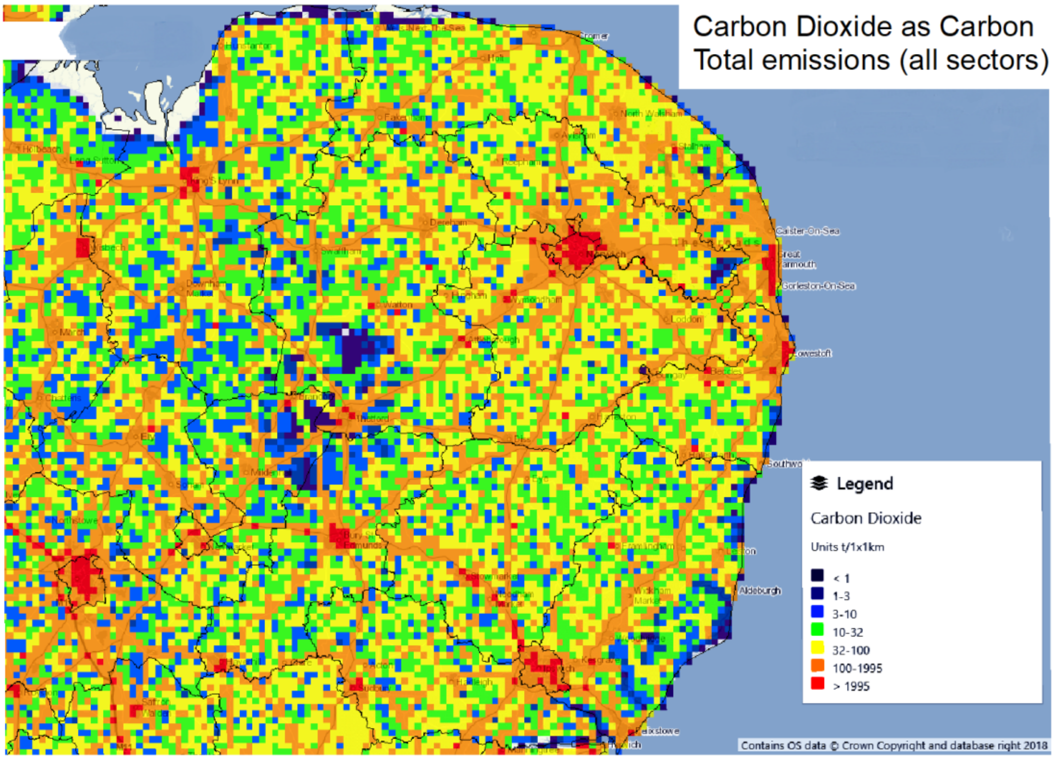


Figure 10: Gridded emissions estimates for carbon dioxide (as carbon) in 2016

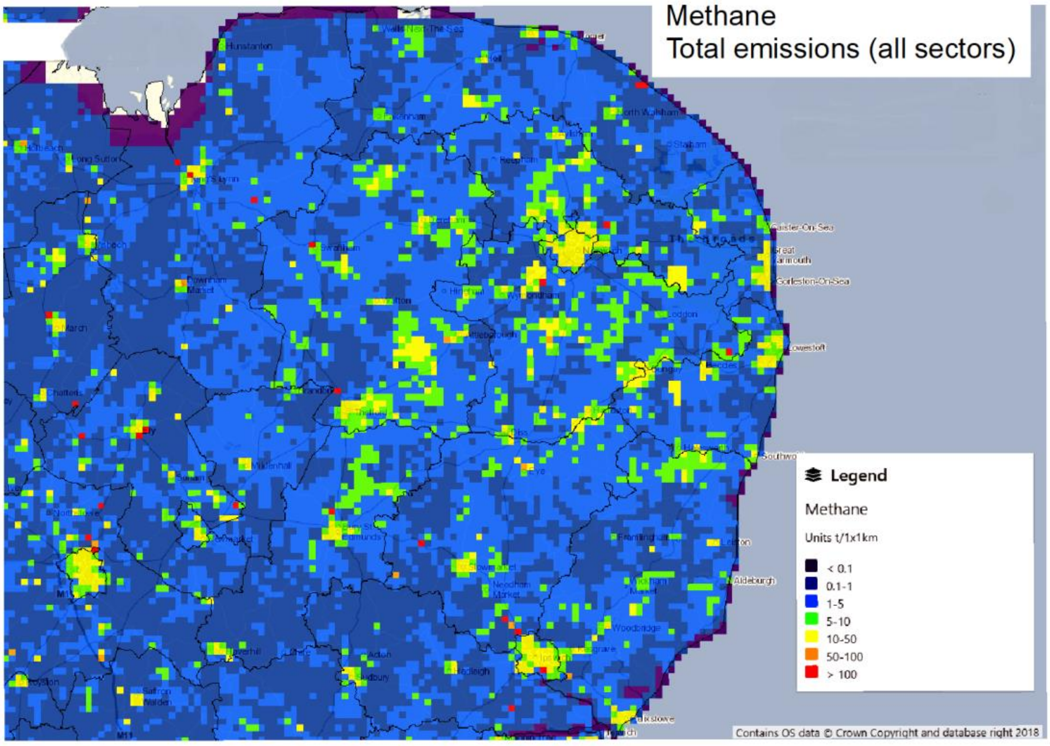


Figure 11: Gridded emissions estimates for methane in 2016

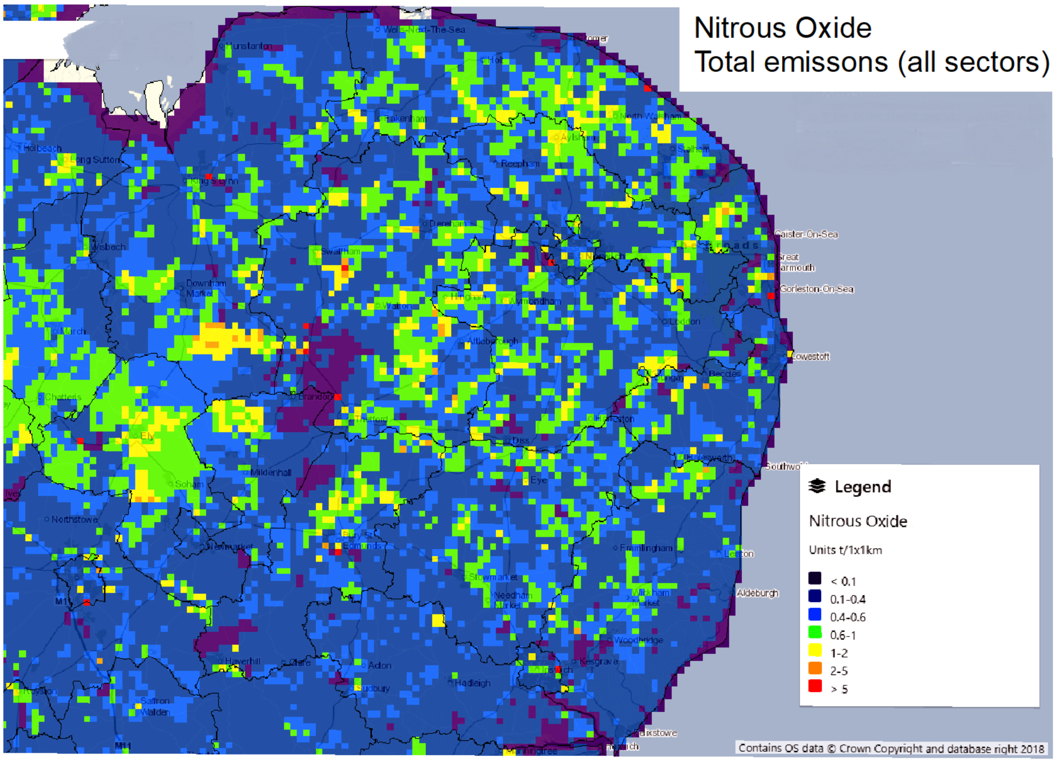


Figure 12: Gridded emissions estimates for nitrous oxide in 2016

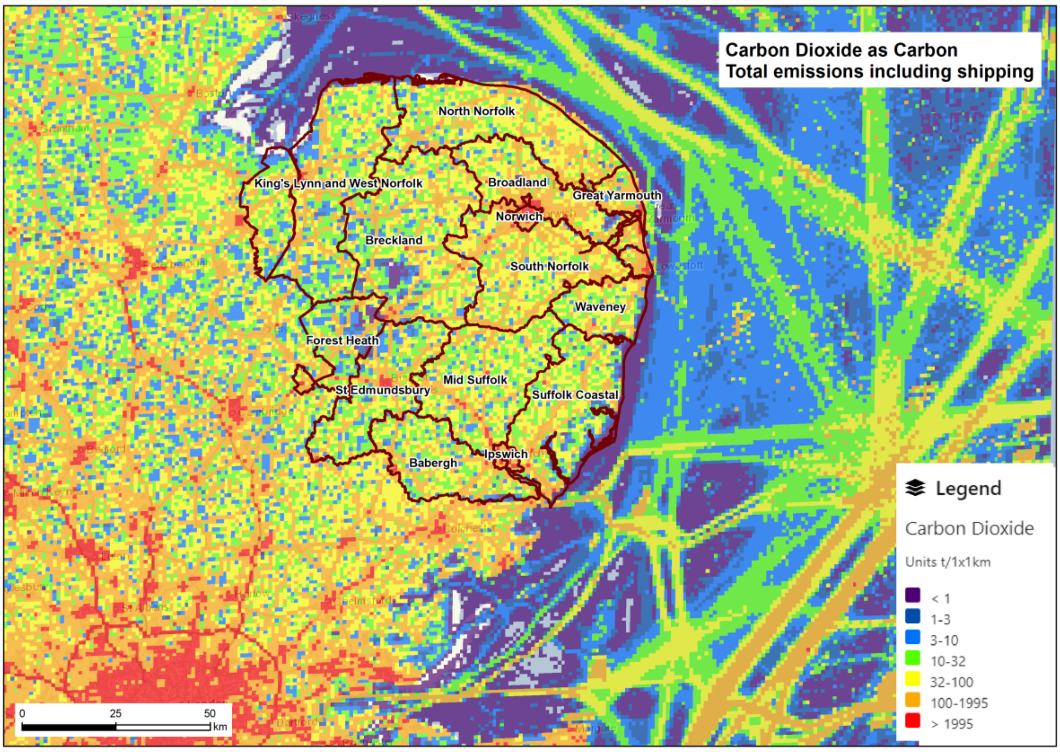
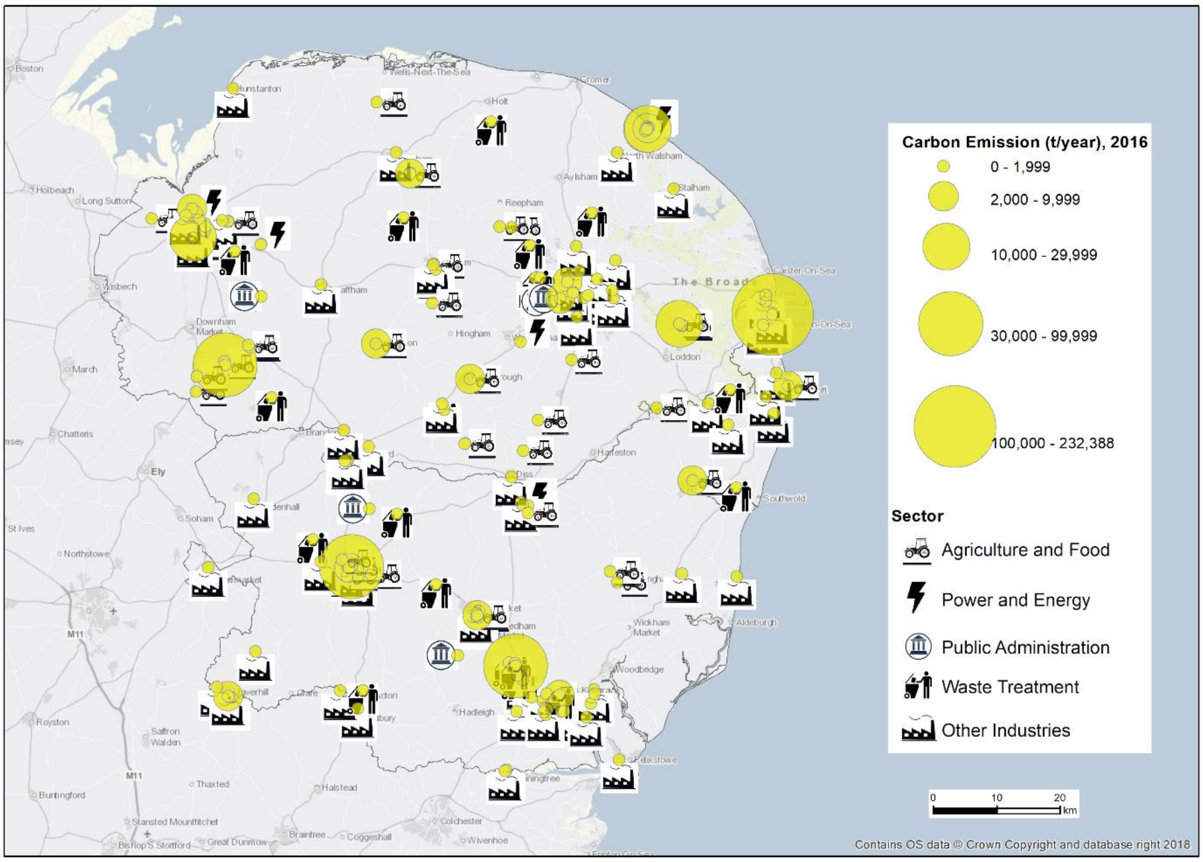


Figure 13: Gridded emissions estimates for carbon dioxide as carbon (Including shipping) in 2016

Information on point source emissions of $C0_2$ from the National Atmospheric Emissions Inventory is mapped in Figure 14. Each point is mapped with a circle to represent the amount of emissions and a symbol to show the sector involved. There are 37 sources in total. The emissions data are reported as tonnes of carbon rather than CO_2 and for the 37 point sources total 568,019 tonnes in 2016. One tonne of carbon is equal to 3.67 tonnes of $C0_2$ (conversion based on atomic weights) so 568,019 tonnes of carbon is equivalent to 2,088,303 tonnes of CO_2. The BEIS emission estimates summarised in Figures 8 and 9 total 9,232,700 tonnes of CO_2 for Norfolk and Suffolk in 2016 so the 37 point sources account for 22.6% of total CO_2 emissions.



Source: National Atmospheric Emissions Inventory http://naei.beis.gov.uk/data/map-large-source

Figure 14: Major point source emitters of Carbon Dioxide in Norfolk and Suffolk during 2016

Table 5 summarises the point source emissions of CO_2, methane and nitrous oxide by key economic sectors. Their total emissions (given in tonnes in the original NAEI data) have been converted to CO_2 equivalents (CO_2e) to aid interpretation.

Table 5: Point source greenhouse gas emissions in Norfolk and Suffolk in 2016

Sector	Carbon Emissions (tonnes)	CO_2 Emissions	%	Methane Emissions (tonnes)	CH_4 as CO_2e Emissions	%	Nitrous Oxide Emissions (tonnes)	N_20 as CO_2e Emissions	%
Agriculture	3,309	12,144	1%	0.2	5.3	0%	0.0	6.4	0%
Food processing	201,853	740,800	36%	24.2	605.8	1%	3.2	946.5	7%
Energy	303,248	1,112,919	53%	2,348.1	58,702.5	99%	41.5	12,371.8	92%
Others	59,610	218,768	10%	6.2	155.0	0%	0.4	126.7	1%
Total	568,019	2,084,632		2,379	59,469		45	13,451	

Conversion factors: https://climatechangeconnection.org/emissions/co2-equivalents/
Source: National Atmospheric Emissions Inventory http://naei.beis.gov.uk/data/map-large-source

These results indicate that power/energy producers (gas and biomass) are the largest point source emitters of all three greenhouse gases. However, there is a significant contribution from food and drink producers so businesses in these and other food producing industries would be an appropriate focus for initiatives to reduce their carbon footprints.

Part III. Developing a Climate Change Adaptation and Carbon Reduction Action Plan

Assisting businesses with identifying potential climate change impacts that might affect their operation or profitability, helping them examine their own contribution to climate change and how they can mitigate this, and supporting them to plan for and adapt to climate change is an important part of the overall response that society needs to make to meet the challenges ahead. Although there is now widespread agreement that action on climate change is urgent and necessary, there may also be a task in convincing some organisations of the need for self-reflection and change in the face of more short-term pressures.

There is an extensive literature on such issues. At the national level, the Committee on Climate Change's UK Climate Change Risk Assessments (CCRA), undertaken 5-yearly, provide a useful overview of potential risks to businesses from climate change[4]. Table 6 reproduces findings from the latest report (Adaptation Sub-Committee (ASC), 2016) summarising the risks/opportunities to businesses in England along with an urgency score for action needed by government to support the business sector.

Table 6: Actions need to support business identified in the 2nd UK Climate Change Risk Assessment

Risk/Opportunity	Urgency Score	Rationale for Scoring
Bu1: Risks to business sites from flooding	More action needed	More effort needed in England to address flood risks and inform businesses of their current and future exposure and what steps they might take to limit impacts.
Bu2: Risks to business from loss of coastal locations and infrastructure	Research priority	More research needed on costs and benefits of adaptation options for different coastal areas.
Bu3: Risks to business operations from water scarcity.	Sustain current action	Sustain current actions to create more flexible regimes and promote water efficiency among businesses
Bu4: Risks to business from reduced access to capital	Watching brief	Monitor and research action by regulators, banks and insurance firms, and information disclosures by UK companies
Bu5: Risks to business from reduced employee productivity, due to infrastructure disruption and higher temperatures in working environments	Research priority	More research needed on disruption to ICT, power and transport infrastructure which prevents workers accessing premises or working remotely, and on impacts of higher temperatures on employee safety and productivity
Bu6: Risks to business from disruption to supply chains and distribution networks. (Also international risks)	Sustain current action	Sustain and monitor the uptake of existing guidance which helps businesses improve the resilience of supply chains and distribution networks, particularly at the international level
Bu7: Risks and opportunities for business from changes in demand for goods and services	Watching brief	Monitor sales of adaptation goods and services within the UK and by UK companies

Source: Adapted from ASC (2016) Table SR.A.4: Urgency of additional actions to support business

[4] An excellent review of both the CCRA work and overall status of the knowledge base relating to climate change risk to businesses is provided by Surminski et al. (2018)

The UK National Adaptation Programme is informed by the priorities identified by the CCRA. Figure 15 provides a graphical overview of the current state of the UK National Adaptation Programme as presented in a recent update report (CCC, 2017) and in the 2nd UK National Adaptation Programme report (DEFRA, 2018). It also incorporates the actions identified in Table 6.

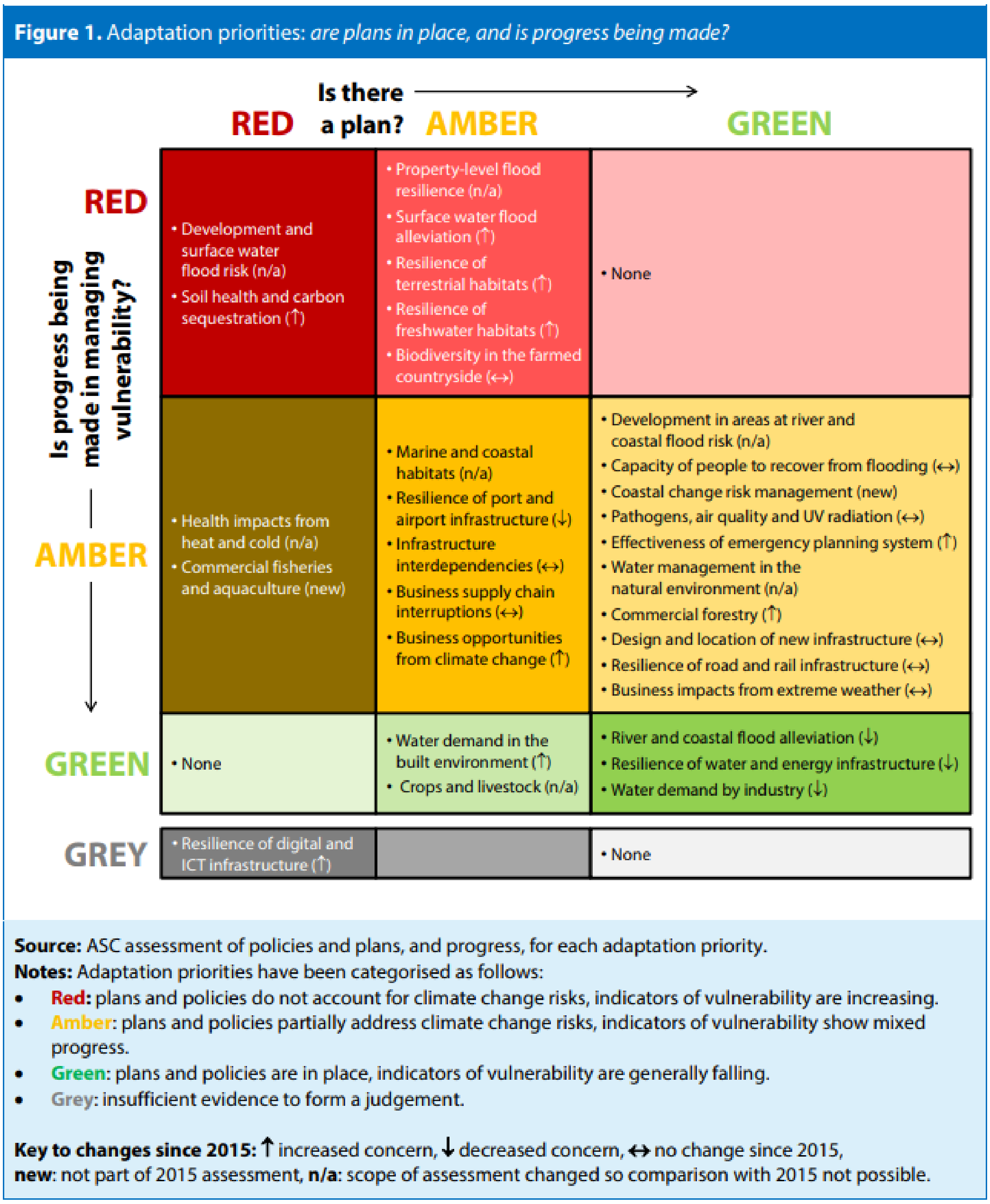


Figure 15: Status of the UK National Adaptation Programme (CCC, 2017)

The matrix in Figure 15 classifies different adaptation priorities according to whether plans or policies are in place and whether progress is being made in managing vulnerability. Issues classified as green on both dimensions are those where there is generally reduced concern (e.g. resilience of water and energy infrastructure) while those rated as red (e.g. soil health and carbon sequestration) are particular priorities.

A summary of climate change risks for the East of England was published by Sustainability East (2012) in response to the first CCRA. This reflected the national findings, stating that the

"... main climate challenges to businesses include flooding and coastal erosion, increased competition for water, and disruption of transport and communication links... The degree to which individual organisations are affected depends upon their level of vulnerability and adaptive capacity... There are potentially significant advantages to be gained for those businesses taking on the challenge." (p.8).

3.1 Downscaling to Norfolk and Suffolk and individual businesses

Whilst governments need to understand the risks and opportunities from climate change at a broad-scale across business and industry sectors, individual businesses may need to evaluate these at a site-specific scale or across their entire value chain of activity (i.e. impacts on suppliers through to operational factors and changes in customer behaviour, both domestic and international).

As a consequence, the impacts of climate change can be both indirect (as above) or direct (e.g. if a business has to close or relocate due to flooding). Some sectors (e.g. ICT) may adapt by shifting location, others will need to adapt in-situ (i.e. agriculture). The latest CCRA also highlights certain sectors where the effect of climate variability is likely to be more pronounced in terms of risks and opportunities e.g. tourism, insurance and finance, agriculture, food, utilities, engineering and consultancy (as reported in Surminski et al., 2018).

For large companies there may be legal requirements or voluntary decisions to undertake risk assessments and reporting (e.g. through corporate social responsibility reports or participations in initiatives such as the Carbon Disclosure Project or Task Force on Climate-related Financial Disclosures, Surminski et al., 2018). However, it is unclear how many smaller businesses have considered climate change in their forward planning and, even if they have, much of this information will not be in the public domain.

An initial scoping of potential considerations in relation to three key sectors of the economy in Norfolk and Suffolk (energy; digital/ICT; agriculture, food and drink) is presented in Table 7. In relation to agriculture, a recent PostNote on climate change and agriculture (Houses of Parliament, 2019) identified this sector as both one of the most vulnerable to climate change (with implications for food security) as well as being the fourth highest GHG emitting sector globally.

For agriculture, in particular, there is a considerable body of literature relating to adaptation and decarbonisation that is too large to summarise here (the PostNote mentioned in the previous paragraph alone cites 126 research articles). The IPCC has published widely on the subject and most recently has called for 'rapid and far-reaching' transitions in both agriculture and dietary change to achieve the 1.5°C target of the Paris Agreement (IPCC, 2018). This is likely to lead to new initiatives and opportunities for farming businesses as part of the planned reform of agricultural policies. However, many of the potential risks (e.g. flooding, restrictions in water availability, loss of productivity through overheating, increased energy demand for cooling, sea level rise etc.) are cross-sectoral and simply scoping out or summarising the literature will add little to understanding local business vulnerability and needs.

Table 7: Potential adaptation and decarbonisation considerations for key economic sectors

Sector and Climate Change Pressures	Adaptation Considerations	Decarbonisation Considerations
Energy		
How 'resilient' are these industries to climate change? e.g. nuclear and offshore wind to sea level rise?	Opportunities for increased renewable energy generation as fossil fuels are displaced.	Infrastructure constraints? (e.g. limiting ability to connect new renewables to the grid) Policy changes (e.g. 'renationalising' the national grid – would this speed up or slow down decarbonisation?) Carbon capture and storage? How soon will this be feasible?
Digital Creative and ICT		
Less 'location' sensitive than some other sectors		Growth in digital devices = increasing proportion of domestic/business energy use (up to 20% of electricity demand by 2050 cited by some studies). Life-cycle analysis needed for 'smart technologies'.
Agriculture, Food and Drink		
High location dependence – need for adaptation. Vulnerable to reduced water availability (e.g. for irrigation)	How closely tied are food processing businesses to local agricultural producers? Will this relationship adapt or decouple? Potential for shift in crop types bringing opportunities and challenges (capital costs and risks in changing farming practices)	Will societal changes (e.g. in dietary preferences) affect these businesses? Opportunities for increased carbon sequestration through changes in crop cultivation practices, more afforestation or bioenergy.

Instead, at the individual business level there may be a need for simplified tools or guides that businesses can use to work through issues relevant to their activities and identify appropriate actions and responses for themselves. As an example, a 'business function' risk assessment tool, developed by UKCIP (2013), evaluates business risk in the following six areas:

- Products and services
- Employee and labour productivity
- Site location
- Distribution (output)
- Supply chain (input)
- Access to capital

This online assessment tool is available at https://ukcip.ouce.ox.ac.uk/wizard/future-climate-vulnerability/bacliat/.

3.2 Elements of an Action Plan for Norfolk and Suffolk

Based on the material discussed in previous sections the following are identified as key issues in particular sectors that need attention in a climate change adaptation and carbon reduction action plan for Norfolk and Suffolk.

1) **The Domestic Sector** – There will be a need to adapt the existing building stock to provide suitable conditions for people to live and work in a warmer climate. This will be important for business productivity and also represents an opportunity for local construction businesses.

   There is an additional consideration in rural parts of Norfolk and Suffolk that many households are not connected to the national gas grid. Across England, 13% of households were not connected to the gas grid in 2016, but the proportion for Norfolk and Suffolk was 30% and there were five local authorities (Breckland, King's Lynn and West Norfolk, North Norfolk, South Norfolk and Mid Suffolk) where the share was above 40% (BEIS, 2018). This is important because it increases current reliance on oil for heating and means that the future option of supplying hydrogen through the gas grid is not available. There is consequently a need for initiatives to test and evaluate alternative means of heating provision, both to meet decarbonisation targets and reduce reliance on oil.

2) **The Transport Sector** – Decarbonising transport will need to be a major feature of climate change mitigation policies in the next 30 years. Increased use of public transport and electric vehicles will be a central element of such initiatives and will require greater investment in charging infrastructure. At present, many parts of Norfolk and Suffolk have little provision of public charging points (see Local Energy East, 2018, Figure 9) and addressing such gaps will be important in maintaining economic activities alongside transport decarbonisation.

3) **The Agricultural Sector** – Agriculture faces both risks and opportunities from climate change. The threats include more variable weather conditions that impact crop and livestock production and pressures on water resources. Improved water management needs to be a priority for coming decades, both in terms of increased storage capacity and greater use efficiency (e.g. through investment in reservoirs and transfer schemes).

Opportunities for agriculture include the potential to contribute to carbon sequestration through changes in cultivation practices and improved soil management. These could be supported as 'public goods' in future agri-environmental schemes. A warmer climate may also offer scope to grow new crops or introduce other enterprises. For instance, Norfolk and Suffolk have been identified as counties with considerable potential for vineyards (Nesbitt et al., 2018) and there is likely to be increased demand for local renewable generation of heat and power (e.g. through anaerobic digestion or other forms of bioenergy).

4) **The Food Processing Sector** – There are a number of processing plants that make a substantial contribution to regional GHG emissions. It would be an important step towards meeting decarbonisation objectives if these businesses could be supported to lower the carbon footprints of their production processes.

5) **The Energy Sector** – The East of England is already one of the leading regions of England in terms of the generation of renewable energy (Local Energy East, 2018) and this will need to further increase in coming decades to meet a growing demand for electricity, particularly from domestic and transport sectors. At present, however, there are constraints on the capacity of the electricity transmission and distribution network in many parts of Norfolk and Suffolk (see Local Energy East, 2018, Figure 6) and developing an investment strategy to rectify this situation is fundamental to both meeting decarbonisation objectives and well as supporting future economic growth. It is also worth noting that the existing high-voltage (400 kV) transmission network does not extend into northern and eastern Norfolk, as well as north-east Suffolk (see Local Energy East, 2018, Figure 2). If investment was made into extend the network to the coast in this region (e.g. to Great Yarmouth or Bacton) it would have appreciable benefits for the marine renewable industry, as well as supporting associated onshore activities.

The above discussion of priorities has been structured around individual sectors, but it is important to recognise that there are many interactions between them. It is, for instance, increasingly common to refer to a food-energy-water nexus (e.g. Simpson and Jewitt, 2019) and meeting future decarbonisation objectives is likely to be as much a matter of achieving coordination between sectors as initiatives within them. Other requirements for any action plan, such as raising awareness, disseminating information and promoting the resilience of critical infrastructure are also cross-sectoral and emphasise that addressing the challenges of climate change will require action across society and by many different organisations in Norfolk and Suffolk.

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