UK Health Security Agency

NIHR | Health Protection Research Unit in Environmental Change and Health at London School of Hygiene and Tropical Medicine

# Climate change and public health indicators: scoping review

# Contents

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## Editors

- Sari Kovats and Giovanni Leonardi

## Contributors

- Sari Kovats – Department of Public Health, Environments and Society, London School of Hygiene and Tropical Medicine (LSHTM)
- Giovanni Leonardi – Environmental Epidemiology, UK Health Security Agency
- Grace Turner – Department of Public Health, Environment and Society, LSHTM
- Jennifer Israelsson – Climate Change and Health, UKHSA
- Penny Murage – Department of Public Health, Environment and Society, LSHTM
- Shakoor Hajat – Department of Public Health, Environment and Society, LSHTM
- Angela Hands – Housing, Planning and Environments for Health, Office for Health Improvement and Disparities
- Jolyon Medlock – Medical Entomology and Zoonoses Ecology, UKHSA
- Emma L. Gillingham – Climate Change and Health, UKHSA
- Helen L. Macintyre – Climate Change and Health, UKHSA
- Giorgos Petrou – Institute for Environmental Design and Engineering, University College London
- Paul Wilkinson – LSHTM
- Louise O'Connor – Department of Public Health, Environment and Society, LSHTM
- Neelam Iqbal – Environmental Epidemiology, UK Health Security Agency
- Priyanjali Ratwatte – Behavioural Science and Insights Unit and Climate Change and Health, UKHSA
- Revati Phalkey – Climate Change and Health, UKHSA
- Raquel Duarte Davison – Chemicals and Environmental Effects, UKHSA
- Gordon Nichols – University of East Anglia; University of Exeter; University of Surrey

# Acronyms and abbreviations

| Abbreviation | Meaning |
|---|---|
| 25YEP | 25 Year Environmental Plan |
| ALAS | Active Lives Adult Survey |
| AWHP | Adverse Weather and Health Plan |
| BEIS | Department for Business, Energy and Industry Strategy |
| CCC | Climate Change Committee |
| CCRA3 | UK's Third Climate Change Risk Assessment |
| CIBSE | Chartered Institution of Building Services Engineers |
| COMEAP | Committee on the Medical Effects of Air Pollution |
| DAQI | Daily Air Quality Index |
| Defra | Department for Environment, Food and Rural Affairs |
| DESNZ | Department for Energy Security and Net Zero |
| DfT | Department for Transport |
| DWP | Department for Work and Pensions |
| EA | Environment Agency |
| ECDC | European Centre for Disease Prevention and Control |
| EFUS | Energy Follow-Up Survey |
| EHS | English Housing Survey |
| EPHI | Environmental Public Health Indicators |
| EU | European Union |
| EWD | Excess Winter Deaths |
| EWP | England and Wales precipitation series |
| FAO | Food and Agriculture Organisation of the UN |
| FCERM | Flood and Coastal Erosion Risk Management |
| FDRS | Fire Danger Rating System |
| FFD | food, feed and drink |
| FRS | Family Resource Survey |
| FSA | Food Standards Agency |
| FSI | Fire Severity Index |
| FWD | Floodline Warnings Direct |
| FY | financial year |
| GHG | greenhouse gases |

| Abbreviation | Meaning |
| --- | --- |
| GI | green infrastructure |
| GPOOH | GP out of hours |
| HSE | Health Survey for England |
| ICB | integrated care board |
| ICS | integrated care system |
| IPCC | Intergovernmental Panel on Climate Change |
| LRF | local resilience forum |
| NDNS | National Diet and Nutrition Survey |
| NCERM | National Coastal Erosion Risk Mapping |
| NE | Natural England |
| NEUB | non-essential use ban |
| NFS | National Food Strategy |
| NHS | National Health Services |
| OHID | Office for Health Improvement and Disparities |
| ONS | Office for National Statistics |
| PHE | Public Health England |
| PHOF | Public Health Outcomes Framework |
| PLR | property level resilience |
| PM | particulate matter |
| PTSD | post-traumatic stress disorder |
| PWS | private water supply |
| RMAs | risk management authorities |
| SDG | Sustainable Development Goal |
| SIT | standardised indoor temperature |
| SMP | Shoreline Management Plan |
| TUB | temporary use ban |
| UKFSR | UK Food Security Assessment |
| UKHSA | UK Health Security Agency |
| UKRI | UK Research and Innovation |
| UN | United Nations |
| UV | ultraviolet |
| WHO | World Health Organization |
| WRAP | Waste and Resource Action Programme |

# Introduction and context

A climate resilient UK requires a comprehensive intersectoral programme to protect and improve population health. This includes robust information systems to provide a strong indication of progress in adaptation (actions to reduce current and anticipated impacts of climate change). A climate resilient health system should include (i) health governance and policies tackling climate risks; (ii) health information, integrated surveillance, and weather-based early warning systems; and (iii) evidence based preventive and curative services (water and sanitation, pest and vector control, food safety, disaster risk management). This report reviews current and potential indicators and metrics to support these goals.

The UK government is required by the Climate Change Act 2008 to monitor progress on adaptation. This report reviews the current sets of environmental and public health indicators that can be used to monitor progress in climate change adaptation and mitigation in the United Kingdom (UK), with a focus on England and priorities for the UK Health Security Agency (UKHSA).

We reviewed 59 indicators with relevance to population health. The indicators are mapped to the climate risks to health identified in the UK's 'Third Climate Change Risk Assessment (CCRA3)': heat, cold, flooding, coastal change, vector-borne diseases, food security, food safety, water quality and availability, health and social care services (1). We also discuss indicators related to mitigation where there are synergies with adaptation policy (for example, particulate pollution, indoor air quality, and active travel).

The primary focus of this report is adaptation. Table 1 summarises the indicators in category types of exposure, vulnerability, outcome, and action, and whether they are relevant locally as well as nationally. Each indicator is described in more detail below.

## Objectives

1. Review current indicators that relate to health implications of climate risks or climate action.
2. Agree criteria for indicators to inform public health actions to address climate change.
3. Identify new indicators that could be implemented.

**Table 1. List of indicators in this report**

## Key for letter colouring

The availability and suitability (A/S) of each indicator is indicated in column 2 with a coloured letter:

A green letter **A** indicates 'Yes, data available that could be used, or the indicator is currently in use'.
A blue letter **P** indicates 'Needs new processing of existing data'.
Red letters **NF** indicate 'No feasible data available'.
Grey letters **NR** indicate 'Indicator not recommended'.

**Table 1a. Heatwaves and heat risk to health**

| Name of indicator | A/S | Available at local authority level | Type of indicator |
|---|---|---|---|
| H1. Exposure to solar ultraviolet (UV) radiation | A | Yes | Exposure |
| H2. Proportion of housing stock with overheating risk | P | Yes | Vulnerability |
| H3. Annual heat-related mortality | P | Yes | Outcome |
| H4. Annual heat illness | A | Yes | Outcome |
| H5. Use of outdoor space for physical activity | A | Yes | Outcome |
| H6. Health impacts of wildfires | NF | Yes | Outcome |
| H7. Spatial planning measures for urban cooling | P | Yes | Action |
| H8. Local heatwave plan | P | Yes | Action |
| H9. Extreme heat in the local risk register | P | Yes | Action |

**Table 1b. Cold and cold risks to health**

| Name of indicator | A/S | Available at local authority level | Type of indicator |
|---|---|---|---|
| C1. Proportion of housing stock with low indoor temperature | P | Yes | Vulnerability |
| C2. Fuel poverty | A | Yes | Vulnerability |
| C3. Annual cold-related mortality and morbidity | P | Yes | Outcome |
| C4. Proportion of homes with (retrofit) energy efficiency upgrades by type | P | Yes | Action |

**Table 1c. Flooding and flood risks to health**

| Name of indicator | A/S | Available at local authority level | Type of indicator |
|---|---|---|---|
| F1. Number of floods or populations flooded | P | Yes | Exposure |

| Name of indicator | A/S | Available at local authority level | Type of indicator |
|---|---|---|---|
| F2. Flood warnings by populations affected | NR | Yes | Exposure |
| F3. Populations with estimated frequency of flooding of more than a 1% chance in any year | P | Yes | Vulnerability |
| F4. New properties built on land with an estimated frequency of flooding of more than a 1.3% chance in any year | P | Yes | Vulnerability |
| F5. Proportion of households without flood insurance | P | Yes | Vulnerability |
| F6. Death or injury from flood events | P | Yes | Outcome |
| F7. Estimated number of people suffering flood-related adverse mental health impacts | NF | Yes | Outcome |
| F8. Number of people displaced from home for more than 30 days because of flood damage | NF | Yes | Outcome |
| F9. Local Authority planning policy and guidance to minimise new dwellings and assets in flood risk areas | P | Yes | Action |
| F10. Proportion of dwellings with property-level flood resilience | P | Yes | Action |
| F11. Monitoring of the Flood and Coastal Erosion Risk Management Strategy implementation | P | Yes | Action |

**Table 1d. Coastal change risks to health**

| Name of indicator | A/S | Available at local authority level | Type of indicator |
|---|---|---|---|
| E1. Rate of coastline loss due to coastal erosion | A | Yes | Exposure |
| E2. Population at risk of inhabitability within 20 years because of coastal erosion | P | Yes | Vulnerability |
| E3. Population at risk of coastal flooding or erosion without insurance or compensation scheme | NF | Yes | Vulnerability |
| E4. Number of camping and caravan sites with evacuation flood or erosion plans in place | P | Yes | Vulnerability |
| E5. Coastal risk management plans | P | Yes (coastal regions) | Action |

**Table 1e. Vector-borne disease**

| Name of indicator | A/S | Available at local authority level | Type of indicator |
|---|---|---|---|
| V1. Seasonal temperature profile compatible with survival of disease vectors | P | National | Exposure |
| V2. Weekly tick activity | NF | National | Exposure |
| V3. Fortnightly mosquito activity | NF | National | Exposure |
| V4. Invasive species | NF | National | Exposure |
| V5. Tick bite species at veterinary practices | NF | National | Exposure |
| V6. Number (rate) of Lyme disease cases | P | National | Outcome |
| V7. Autochthonous cases of vector-borne disease | P | National | Outcome |
| V8. Implementation of monitoring and reporting system for vectors | P | Yes | Action |

**Table 1f. Food systems and health impacts**

| Name of indicator | A/S | Available at local authority level | Type of indicator |
|---|---|---|---|
| FS1. Pollinator abundance | P | National | Exposure |
| FS2. Yields per hectare and livestock or productivity by crop and livestock group | P | National | Vulnerability |
| FS3. Foodborne outbreaks and or reported concerns and alerts | P | National | Vulnerability |
| FS4. Proportion of food waste along the value chain | P | National | Vulnerability |
| FS5. UK food imports and exports by food group | P | National | Vulnerability |
| FS6. Frequency and length of disruptions in supply by food group | NF | National | Vulnerability |
| FS7. Proportion of households that are food insecure | A | Yes | Vulnerability |
| FS8. Healthy (sustainable) diets and dietary diversity score | P | Yes | Vulnerability |
| FS9. Rate and frequency of foodbank use | P | Yes | Vulnerability |
| FS10. Food price change by food group | P | National | Vulnerability |
| FS11. Incidence of foodborne diseases | P | Yes | Outcome |
| FS12. Development and implementation of national and or local food strategy | P | Yes | Action |
| FS13. Development of dietary guidelines that embed climate change adaptation | NF | Yes | Action |

**Table 1g. Water quality and quantity and their health impacts**

| Name of indicator | A/S | Available at local authority level | Type of indicator |
|---|---|---|---|
| W1. Population affected by supply disruption | NF | Yes | Vulnerability |
| W2. Population supplied by private wells | P | Yes | Exposure |
| W3. Drinking water quality | P | Yes | Outcome |
| W4. Bathing water quality | P | Yes | Outcome |

**Table 1h. Health services**

| Name of indicator | A/S | Available at local authority level | Type of indicator |
|---|---|---|---|
| HS1. Hospitals overheating incidents | A | ICS | Exposure |
| HS2. Health services flooded | P | ICS | Outcome |
| HS3. Trust Green Plans that consider adaptation | P | ICS | Action |
| HS4. Health care facilities adapted to be climate-proof | NF | ICS | Action |

**Table 1i. Social care services**

| Name of indicator | A/S | Available at local authority level | Type of indicator |
|---|---|---|---|
| SC1. Care home overheating incidents | NF | ICS | Exposure |
| SC2. Care homes flooded | P | ICS | Outcome |

**Table 1j. Health impacts from mitigation action**

| Name of indicator | A/S | Available at local authority level | Type of indicator |
|---|---|---|---|
| M1. Mortality attributable to $PM_{2.5}$ by sector | NF | Yes | Outcome |
| M2. Indoor air quality | NF | Yes | Exposure |
| M3. Active travel | A | Yes | Action |

# Types of indicators

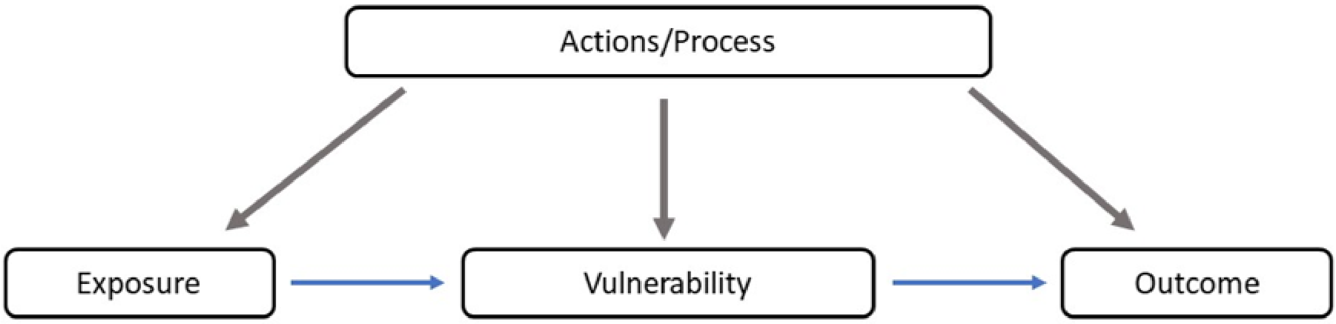
Indicators and metrics can track the progress of climate adaptation and mitigation. A useful indicator would include observed changes over time across key components of adaptation, as well as indicators of risk and 'climate impact' (2). As this report is focussed on health effects, we are following established frameworks in environmental public health for the development of indicators (2). Table 2 lists the categories that we are using in this report and how they map to other categories being used, such as the Environmental Public Health Indicators (EPHI), the

Climate Change Committee (CCC), and the Centers for Disease Control and Prevention Indicators (CDC).

**Table 2. Definitions of indicator type**

| Category | Definition | EPHI and CDC indicators | CCC categories |
|---|---|---|---|
| **Exposure or hazard** | Situations or activities that identify the potential for exposure to a hazardous condition or climate hazard.<br>Includes both weather or climate exposure, climate hazards and climate-sensitive environmental hazards (for example, air pollutants, UV). | Hazard indicators: Situations or activities that identify the potential for exposure to a contaminant or hazardous condition.<br>Exposure indicators: for example, biomarkers in tissues or fluids that identify the presence of a substance or combination of substances that could harm an individual. | |
| **Outcome** | Experienced effects on human systems that can be attributed to environmental or climate hazards. | Health effect indicators: Diseases or conditions that identify an adverse effect from exposure to a known or suspected environmental hazard. | Realised impact |
| **Vulnerability** | Factors that strongly affect risks and health outcome. | | |
| **Process** | Measures taken to reduce exposure, vulnerability, or to increase adaptive capacity. | Intervention indicator: Programmes or official policies that minimise or prevent an environmental hazard, exposure, or health effect. | Action |

**Figure 1. Diagram showing the interaction between exposure, vulnerability, outcome and action or process indicators**




We developed the following criteria for indicators to include in this report:

- frequency: annual
- data available at local level
- data available or feasible to use in England
- sensitive to health impact
- health relevant:
    - relates to a health impact of climate change
    - relates to an action that will reduce the impact of climate change on health (adaptation)
    - relates to a mitigation (low carbon) action that benefits health
- relevant to UKHSA
- relevant for local authority decision-making

Adaptation actions are within the remits of a wide range of departments within local government and other agencies that operate at the local level (spatial planning, water resources, flood management, agriculture, energy, transport, environment, and public health). This report assesses whether indicators are useful for monitoring national or local progress towards adaptation. It is important to note that despite no mandatory policy for public health and related agencies to develop mitigation and adaptation policies (except in Scotland where public bodies are required to report on adaptation), a variety of national initiatives are encouraging climate action in the public health sector.

This report is divided into health topics according to health-related climate risks identified in the CCRA3 evidence report (1). These include risks from heat, flooding, food safety, food security, and risks to the delivery of health and social care services. Risks to health from heat, flooding, and vector-borne diseases were assessed as a priority for urgent action. Within each section, several indicators have been identified. Each indicator is described in relation to its sensitivity of the climate risk to human health, and data and methods available to measure the indicator. Comments on the feasibility and robustness of the indicator are also included.

Several important indicator data sets have been reviewed. Many of the indicators presented in this report are already established and in use in England. Table 3 highlights some key documents referenced in this report.

**Table 3. Indicator sets that are referenced in this report**

| Organisation or report |
|---|
| 'Committee on Climate Change (2017 report)' |
| 'Committee on Climate Change (2019) report)' |
| 'Committee on Climate Change (2022 indicator report)' |
| 'PHE Public Health Outcome Framework' (now OHID) |
| '25 Year Environment Plan' – Defra |
| 'Agriculture in the UK 2020' |
| 'UK Food Security Report 2021' |

# Heatwaves and heat risks to health

Exposure

H1 Exposure to solar ultraviolet (UV) radiation – **A**

Vulnerability

H2 Proportion of housing stock with estimated overheating risk – **P**

Outcome

H3 Annual heat-related mortality – **P**
H4 Heat illness – **A**
H5 Use of outdoor space for physical activity – **A**
H6 Wildfires – **NF**

Actions

H7 Spatial planning measures for urban cooling – **P**
H8 Local heatwave plan – **P**
H9 Extreme heat in the local risk register – **P**

There is very good evidence that acute mortality and other heat risks are related to daily temperatures. Rising temperatures are also indirectly linked to other environmental risks discussed elsewhere in this report, including increases in foodborne and vector-borne diseases, worsening air quality, changes in crop yield and livestock productivity, and longer pollen seasons. Heat also has important impacts on morbidity and is associated with acute increases in hospital admissions. Heatwaves further disrupt public services including education and health services (see health and social care system indicators).

Characterising harmful heat varies by region within the UK. Regional or local threshold values of heatwaves or 'hot days' have been developed. UKHSA launched the impact-based Heat-Health Alerting system in England in 2023 in partnership with the Met Office. This new approach to alerting underpins the new Adverse Weather and Health Plan (AWHP) which replaces the Heatwave and Cold Weather Plans for England. The new alerting approach uses epidemiological temperature thresholds to define temperatures at which a dynamic risk assessment is undertaken in relation to issuing an alert. Heat alerts are one of a range of response measures for addressing the impact of heat. Policies in the built environment (housing and urban planning) are also important to reduce heat exposures.

## H1. Exposure to solar ultraviolet (UV) radiation

### Sensitivity

Acute high or chronic exposure to sunlight increases risk of skin cancers, sunburn (erythema), cataracts, premature skin aging and a weakened immune system (4). Sunlight also has benefits through increasing vitamin D (5 to 7). The links between UV exposure and adverse health effects is well understood. The World Health Organization (WHO) and the World Meteorological Organization (WMO) have developed a UV index which indicates the risk of sunburn between 0 to 20 and provides advice on when to take more protective actions. Ambient temperature is not directly correlated with the environmental level of UV, although temperature may influence behaviours such as the time spent outdoors (8) and the type of clothing worn, which in turn affects the exposure to UV. The health implications of sun exposure are dependent on behaviour and vary by socio-demographic variables such as skin colour and age. In England, UV level peaks around June, while the peak temperature is normally at least a month later. Moderate temperatures in the spring are wrongly perceived to carry a low UV risk even though the risk may be higher than in peak summer when heatwave alerts and general sun awareness is higher (9).

### Data and methods

UKHSA has been undertaking ground-based measurements of erythema effective UV, UV-A irradiances, and illuminance for over 30 years. Erythema effective UV (10) is used to determine the risk of causing sunburn which is simplified for the public in the form of the UV index. UKHSA monitors UV radiation from 10 ground-based sites and displays near real-time UV Index to the public. Forecasts of UV index are based on Earth observation satellite data which includes the effects of cloud cover and ozone.

### Comments

This indicator is already established. However, climate change means that UV warnings may need to start earlier in the year, as the harmful UV season is likely to extend with climate change.

## H2. Proportion of housing stock with estimated overheating risk

### Sensitivity

Indoor overheating is qualitatively defined as the state at which occupants experience thermal discomfort due to the indoor environment. Vulnerability to overheating in dwellings (houses, flats and so on) varies by location, type of dwelling, and individual dwelling characteristics. People spend a lot of time indoors, especially individuals more vulnerable to heat-related mortality (such as older people and people with chronic diseases). Thus, housing characteristics are an important determinant of heat-related health effects (11 to 13). Overheating has also been linked with reduced productivity, cognitive performance, sleep quality, and overall dissatisfaction with the indoor environment (14, 15).

The CCC assessment of UK climate risks considers health risks posed from indoor heat exposure as one of the areas requiring highest priority for adaptation (16). This indicator can be used to monitor prevalence of indoor overheating risk, changes over time due to climate change and policy-driven adaptation or mitigation measures. It has been suggested for this purpose by the CCC and the Department for Business, Energy and Industrial Strategy (BEIS) (now Department for Energy Security and Net Zero (DESNZ)). Although building regulations are in place to ensure comfortable indoor thermal temperatures, these standards only apply to the construction of new buildings (17). With the expected uptake in energy efficiency measures in the 'fabric first' (upgrade the building fabric (for example walls) before installing other measures (such as new heating systems)) approach outlined by the Heat and Buildings Strategy (17), and the potential link between energy efficiency and indoor overheating risk (18), it is important to track the proportion of housing stock that overheats.

## Data and methods

It is possible to derive this indicator through empirical or modelling methods. Thermal comfort surveys of a representative sample of households can be used to estimate the proportion of the housing stock that overheats. Alternatively, or in addition, indoor temperature measurements can be used to estimate an overheating risk using temperature-based metrics. Data collection can take place at a local authority scale, or national scale, assuming an effective sampling strategy. The Energy Follow-Up Survey (EFUS) is the largest data collection campaign in England that gathered data relevant to indoor overheating risk during the summers of 2011 and 2018. During the 2018 summer, 19% of dwellings overheated according to the adaptive criterion in the Chartered Institution of Building Services Engineers (CIBSE) Technical Memorandum 59 (TM59) (19), while only 2.5% overheated during the relatively cool summer of 2011 according to the same metric (20).

It might be possible to quantify indoor overheating risk based on the use of satellite data which could overcome the data availability limitations described above. However, no work could be identified that has explored the feasibility of this idea. Any insights generated would only relate to the rooms directly below the roof, and any estimates would be associated with large uncertainties.

Alternatively, modelling (machine learning or building physics-based) may be carried out to estimate this indicator, but this would still need to be validated against observations. The empirical approach is likely to result in a more accurate estimation of this indicator since it would not be influenced by uncertainties common to modelling procedures. However, such systematic data collection may be costly. Modelled estimates are more feasible, since the data required as model inputs are already being collected to an extent. Beyond modelling uncertainties, challenges with implementing this approach include the need for expert skills and specialist software.

## Comments

This indicator is not yet possible due to the lack of regular and frequent monitoring of summer indoor temperatures or large-scale thermal comfort surveys in a representative sample of UK homes. In addition, when derived from monitored indoor temperatures, the level of indoor overheating risk will depend on the metrics used. There is currently work ongoing to refine Criterion 2 of CIBSE TM59 that will help identify a standard.

# H3. Annual heat-related mortality

## Sensitivity

High temperature increases the risk of acute mortality, as shown by epidemiological studies and peaks in mortality associated with heatwaves. Health outcomes such as mortality and morbidity increase above given temperature thresholds. The relationship between these outcomes and temperature are reported either as risk of outcome (relative risk) or odds of outcome ratios (odd ratio). In the UK, the heat mortality effect increases at around the 93rd percentile on the temperature continuum of annual daily mean temperatures. Population heat thresholds can vary by age group and other risk factors for heat-related mortality and also vary over time (21). In England, heat risk varies by region, with London experiencing the greatest risk (22).

UKHSA and partner agencies provide information on excess mortality that occurs during recognised heatwaves. The excess mortality is broken down by age group, region in England, and heatwave event, and published in mortality surveillance reports (23). The heatwave mortality is only a proportion of the total heat-related mortality, and it can be considered as a separate indicator.

## Data and methods

Previous work in the UK has reported effect sizes at a national and regional level (22), and across cities (24). A commonly applied metric for estimating heat risk is the relationship between mortality and changes in ambient temperature. A more meaningful metric for local users is the 'heat attributable fraction' which uses heat risk to estimate the population burden or total attributable number of deaths caused by high temperatures (24). Processing requires expert use of statistical software and some knowledge of epidemiology. However, attributing mortality to heat exposures at a local authority level is likely to lead to imprecision because of the small numbers observed in some areas.

## Comments

This indicator is technical feasible but may be prone to imprecisions due to low numbers of heat-related mortality in some local authority areas.

# H4. Heat illness

## Sensitivity

Hot weather has a range of effects on morbidity, characterised by acute increases in general practitioner in hours (GPIH), general practitioner out of hours (GPOOH), hospital admissions and ambulance dispatches. Generally, mortality outcomes show stronger impacts than morbidity, which may reflect the fact that many cases bypass medical presentation because heat effects can become acute very quickly if left untreated, and in some cases heat risks are not recognised. Some conditions are more likely to be exacerbated by heat exposures, including renal disease, diabetes, and some mental health conditions.

UKHSA collects information related to illness (morbidity outcomes) on a real-time basis through syndromic surveillance systems that includes calls to NHS 111, GP consultations and emergency department attendances (23). The use of syndromic surveillance also offers opportunities to address the knowledge gap on the impact of heatwaves on morbidity.

## Data and methods

Syndromic surveillance is an important surveillance tool for monitoring public health in real-time and is used to monitor the health impact of heatwaves. Heat illness remains the best indicator for monitoring the impact of a heatwave, however, these cases are very low when disaggregated by local authority populations (25). Syndromes that may map to symptoms of heatstroke or heat exhaustion, such as difficulty breathing or fever, may be used as indicators; although these may not be sensitive to show any trend during periods of mild heatwaves (25).

Some knowledge of what could be driving differential timing of presentations by demographic groups is needed. For example, a previous study found higher GPOOH and heat illness in children of school age (25), suggesting that parents are more likely to present their children earlier to healthcare services, while the elderly are more likely to delay presentation to avoid burdening services.

## Comments

This indicator is feasible and is already used within the public health system. However, numbers are very low, and it may not be a good indicator of overall population impact. UKHSA is reviewing this indicator.

# H5. Use of outdoor space for physical activity

## Sensitivity

There is strong evidence to suggest that greenspaces have a beneficial impact on physical and mental wellbeing and cognitive function through both physical access and usage. The indicator is in line with Commitment 55 of the ‘Natural Environment White Paper: The Natural Choice –

Securing the Value of Nature'. Use of outdoor space may increase with the increase in warmer weather due to climate change and is therefore an opportunity for health improvement associated with climate change.

## Data and methods

### Indicators

- Public Health Outcomes Framework (PHOF) – indicator on accessing greenspace
- PHOF – Access to woodland
- PHOF_B16 – Utilisation of outdoor space for exercise or health reasons

Some indicators on the prevalence of the use of greenspace are in use with data regularly collected. Visits to the natural environment are defined as time spent 'out of doors' for example, in open spaces in and around towns and cities, including parks, canals and nature areas; the coast and beaches; and the countryside including farmland, woodland, hills and rivers. This could be anything from a few minutes to all day. It may include time spent close to home or workplace, further afield, or while on holiday in England. However, this does not include routine shopping trips or time spent in own garden.

The UK government also supports the People and Nature Survey for England, which has replaced the Monitor of Engagement with the Natural Environment (MENE) survey (26). This new survey includes the following relevant indicators: % adults spending time outside in the last 12 months by frequency, % children spending time outside in last 12 months by frequency, % adults visiting outside in last 14 days, % adults visiting outside in last 7 days, % adults visiting outside by place type (for example, parks) in last month.

## Comments

Several related indicators are already in use. Further research is needed to understand which indicator is likely to reflect benefits of local strategies to increase use of greenspace for physical activity.

# H6. Wildfires

## Sensitivity

Climate change intensifies wildfire activity through increased availability of fuel (that is, dry vegetation available to burn) and longer fire seasons (that is, days when meteorological conditions are conductive to fire) (27). Wildfires pose a risk to life, which is enhanced by the UK's relatively high population density. In addition, wildfire smoke can have negative impacts on population health. Wildfire smoke includes both gases and particulate matter (PM) which can cause the onset of acute lower respiratory disease, and the exacerbation of chronic conditions such as chronic obstructive pulmonary disease (COPD), cerebrovascular disease, ischaemic heart disease, and lung cancer (27).

## Data and methods

Air quality is currently monitored for the UK by Department for Environment, Food and Rural Affairs (Defra) which is able to detect significant increases in local PM levels associated with large wildfires. Wildfires themselves can also be monitored as part of the Copernicus system using remote sensing data. There is currently no systematic or central monitoring of the number of households affected by wildfires, including evacuations, or the number of deaths or injuries due to wildfires in the UK.

A potential indicator could be a Fire Danger Rating System (FDRS). FDRSs are used globally to successfully predict fire danger (28). By incorporating UK fuel types, it could be used to guide the timing of management burning (29). The Met Office's Fire Severity Index (FSI) is an assessment of how severe a fire could become if one were to start. It is not an assessment of the risk of wildfires occurring. FSI maps are provided for the whole of England and Wales. Historical daily FSI maps are available, plus the latest and forecast daily FSI maps up to 5 days ahead.

## Comments

Further work needs to be done to define the most useful indicator for wildfires and their health impacts, and the development of an appropriate spatial model that is relevant for the UK population.

# H7. Spatial planning measures for urban cooling

## Sensitivity

Urban environments with higher vegetation cover are markedly cooler and may experience lower heat-health burdens (30). Green Infrastructure (GI) such as parks, gardens, trees, greenspaces, wetlands, and green roofs and walls offer sustainable, low-cost cooling solutions.

Vegetation cover may also reduce some air pollution such as PM via mechanisms such as deposition, dispersion and modification (31). However, some tree species also release pollen and emit ozone precursors which may impact on air pollution levels during heatwaves. Therefore, careful consideration needs to be given to the design of urban greenspace to maximise health benefits and minimise negative impacts.

Increase in vegetation cover is one of the actions that cities such as Bristol, England, are currently employing to mitigate against high outdoor temperatures. Cooling increases with the size and volume of vegetation cover, and multiple layers (tall trees, shrubs, and ground cover species) offer the highest cooling effect, whereas single layered trees of identical species offer least cooling (32). To support the 25 Year Environment Plan (25YEP), Natural England (NE) and Defra have developed a GI Mapping Database for England which holds multiple data sets on woodland, country parks, greenspace, rivers, lakes, local and national nature reserves, forests, and public rights of way.

### Data and methods

Satellite imagery of Normalised Difference Vegetation Index (NDVI) can give detailed high-resolution information on the level of urban greenery by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). The GI Mapping Database can provide a consistent approach to assessing local GI provision against GI standards that are under development. A standard for GI that measure 'cooling potential' has not yet been developed, but this would be very relevant for public health. There are currently no established indicators for cooling effects of GI components or characteristics, but an indicator could be derived regarding the increase in cooling-friendly greenspace. Area or extent, the shape, and the type of greenspaces affects the potential for cooling. NE has published its Green Infrastructure Framework in 2023 that identifies several principles for the consideration of urban cooling in planning green infrastructure (33).

### Comments

Some work needs to be done to define the most useful indicator with respect to urban development and cooling.

## H8. Local heatwave plan

### Sensitivity

The AWHP for England triggers actions in the NHS (National Health Services), public health, social care, and other community and voluntary organisations to support people who are vulnerable to heat, to reduce summer deaths and illness (34). Actions are triggered when temperatures reach defined thresholds which vary by region and the UKHSA provide sector specific guidance and action cards to help in the planning and preparation for the adverse weather. Increased awareness of heat risks would likely increase uptake of adaptation measures and interventions, especially in populations particularly vulnerable to the health effects of hot weather, such as adults over the age of 65 or those with pre-existing health conditions such as respiratory and cardiovascular diseases. Several key parts of the plan are implemented locally and therefore a local strategy for addressing hot weather would have benefits to health.

### Data and methods

Several key parts of the plan are implemented locally although details on local area implementation is not centrally collected, and local information will vary. An evaluation of the Heatwave Plan for England conducted in-depth interviews with key informants from 5 local authorities and found that heatwaves were given lower priority on emergency preparation agenda because they were viewed as likely to be infrequent and short-lived (35). Other natural hazards such as flooding and cold weather were given higher priority (35).

There is currently no data available to produce this indicator. Developing this indicator will require national coordination by public health agencies such as UKHSA in the UK to gather information on whether local authorities have implemented various aspects of the plan (yes or no) and more detailed information on the nature of implementation.

## Comments

This indicator is feasible. However, a more useful additional indicator would be a measure of implementation of the local heatwave plan.

# H9. Extreme heat in the local risk register

## Sensitivity

The local resilience forums (LRFs) aim to plan and prepare for localised incidents and catastrophic emergencies. They work to identify potential risks and produce emergency plans to either prevent or mitigate the impact of any incident on their local communities. LRFs are multi-agency partnerships made up of representatives from local public services, including the emergency services, local authorities, the NHS, the Environment Agency (EA), and others (Category 1 responders, defined by the Civil Contingencies Act). The LRF is also support by organisations, such as public utility companies, which have a responsibility to co-operate with Category 1 responders and share relevant information with the LRF. Each LRF has a risk register to recognise and plan for the most important risks. Floods are usually registered as a key local risk; however, heatwaves are often not yet included. Thus, the inclusion of heatwaves and at what risk level is a useful indicator of preparedness for extreme heat.

## Data and methods

This indicator could consider whether heatwaves are considered in the risk register (yes versus no) and the level of risk assigned (low, medium, high). This information provides an indication of the level of prioritisation (including resource allocation) when managing heatwaves. The risk assessment process is defined in the guidelines on emergency preparedness which to some extent avoids the subjectivity in assigning risk status. A total of 42 LRFs have been established and serve communities defined by the boundaries of police areas across England and Wales.

Category 1 responders have a duty to publish the risk register in order to increase awareness to communities and businesses. This indicator is feasible as all registers are publicly available but would require resources to systematically access the information and generate the indicator.

## Comments

This indicator is feasible.

# Cold and cold risks to health

Vulnerability

C1 Proportion of housing stock with low indoor temperature – **P**

C2 Fuel poverty – **A**

Outcome

C3 Annual cold-related mortality and morbidity – **P**

Actions

C4 Proportion of homes with (retrofit) energy efficiency upgrades by type – **P**

## C1. Proportion of housing stock with low indoor temperature

### Sensitivity

Health impact assessments show that climate change is likely to reduce the burden of cold-related mortality due to milder winters, however, the overall burden of cold will remain high in the UK, even to the end of the century. Population aging is likely to offset some of the benefit from warmer winters for cold-related mortality (22). Low standardised indoor temperature (SIT) is considered as temperatures below 18°C in the liveable rooms. With increasing uptake of home thermal efficiency measures, it is expected that the proportion of the housing stock with low SIT will decrease, however monitoring this is crucial. Other factors, such as household energy costs may also affect this indicator.

### Data and methods

Monitoring indoor temperatures of a representative sample of the housing stock is the most reliable method for quantifying the proportion of homes with low SIT. A study analysed the SIT of the homes monitored during the 2011 EFUS, the largest data collection campaign in the UK available at that time (36). Upon publication of the 2018 EFUS results, an analysis of the data would allow for comparison of the proportion of homes with low SIT.

### Comments

This indicator is not yet feasible with currently available data.

## C2. Fuel poverty

### Sensitivity

Fuel poverty is a measure of the proportion a household spends on energy compared to their income. In 2017, 10% of households in England were in fuel poverty (approximately 2.53 million households) (37). Climate change will result in warmer winters, which may then reduce heating demand. This has potential benefits in reducing fuel poverty. Lower income households allocate a higher percentage of their total expenditure to energy relative to the wealthiest households (38), with the cost of living survey reporting 9.6% of total expenditure for the former (the lowest income decile) compared to 3.6% for the latter (the highest). Policies to address energy efficiency as part of the net zero strategy should also reduce fuel poverty. A large proportion of the fuel poor in England use electricity as their main source of energy (including prepayment for electricity which can be more expensive). Households that use electricity for heating are projected to see the largest benefits from the reduction in winter heating demand as a result of climate change.

Climate change may increase the proportion of households using air conditioning systems. In 2008, 0.5% of households in the UK had air conditioning. By 2050, it is projected that 5% to 32% of English households will have air conditioning (39). The use of air conditioning can increase household energy spending by 35% to 42%, and therefore may become an additional cause of energy poverty in low-income households (40).

## Data and methods

### Indicators

- PHOF_B17 – Fuel poverty (low income, high-cost methodology)
- PHOF_B17 – Fuel poverty (low income, low energy efficiency methodology)

Under these indicators, a household is considered to be fuel poor if they are living in a property with a fuel poverty energy efficiency rating of band D or below (41), and when they spend the required amount to heat their home, they are left with a residual income below the official poverty line. Household income, household energy requirements, and fuel prices are important elements in determining whether a household is fuel poor.

Fuel poverty statistics are derived from the English Housing Survey (EHS) (42). Fuel poverty levels in local authorities are estimated using a logistic regression model.

## Comments

This indicator is already in use. However, it should be noted that fuel poverty measures can be driven by energy prices and changes in demand. Although warmer winters resulting from climate change may reduce home heating needs, the rising cost of energy continues to push many households into fuel poverty. It is unlikely that summer fuel poverty will be realised until beyond 2050 and only in South East England and London.

# C3. Annual cold-related mortality and morbidity

## Sensitivity

Explicit assessment of cold-related mortality is a better indicator than Excess Winter Deaths (EWD) which is an annual metric produced by the Office for National Statistics (ONS) to reflect wintertime mortality burdens. The EWD index simply compares average deaths during the 4 coldest months (December to March) to other times of the year, and as such is a very simple indicator to calculate and convey to policymakers. However, it is biased in fundamental ways which renders it an inappropriate indicator of cold-related health. Although cold-related deaths do contribute to a high EWD value, this may also be caused by a wintertime flu epidemic or other seasonal factors unrelated to weather. Furthermore, cold-related deaths also occur on days with moderate temperatures falling outside of the December to March period, and these deaths bias the EWD measure since, by definition, they contribute to the comparison months in the calculation. Owing to the greater frequency of moderate temperature days, the number of cold-related deaths associated with these days is far from small. For example, in London over 70% of all cold-related deaths occur on days warmer than 5°C, based on models adjusted for seasonal factors. The calculation of EWDs is also sensitive to unusual mortality patterns occurring at other times of the year, including heatwaves and extreme hot summers (21) and in recent years high mortality levels due to COVID-19. Excess winter morbidity based on data from hospital episode statistics which can be calculated in the same way as EWD, also suffers from the same biases.

## Data and methods

### Indicators

- PHOF_E14 – Excess Winter Death Index
- PHOF_E14 – Excess Winter Death (over 85s) Index

The most useful measure for attributing acute effects of cold to health outcomes is the relationship between daily mortality and changes in ambient temperature after controlling for underlying seasonal patterns in the mortality series unrelated to temperature. These studies use time-series regression methods or case crossover designs and show that, in the UK, mortality risk increases in a gradual fashion as temperatures fall (43, 44). Similar patterns have been observed with morbidity outcomes such as emergency inpatient hospital admissions (45) and GP consultations (46). Estimating the effect at a local authority level may lead to imprecision because of the small numbers observed in some areas. However, there is more precision than for heat-related risk due to the higher number of cold-related mortality and morbidity impacts. In England, spatial variation in cold-related mortality risk has evidently increased since the introduction of the Cold Weather Plan in 2011, which may reflect local differences in implementation of the plan (47).

## Comments

Estimating cold-attributable mortality is feasible, and a better indicator than EWD of cold-related impacts.

# C4. Proportion of homes with (retrofit) energy efficiency upgrades by type

## Sensitivity

Energy efficiency upgrades are a key component to the decarbonisation of the housing stock. Certain energy efficiency upgrades, such as the installation of wall insulation or double glazing, are thought to result in warmer and more comfortable homes during the winter. However, research has suggested that more insulated and airtight homes may have a greater potential to overheat in summer.

## Data and methods

The EHS is a continuous national survey which collects information on households, their occupants, and dwelling physical and energy efficiency state (48). By looking at the data collected over the years, trends in the proportion of energy efficiency upgrades by type can be identified. Another detailed resource is the Homes Energy Efficiency Database (HEED) that contains records of energy efficiency measures for roughly half of the housing stock (49).

## Comments

This indicator is not yet feasible without further investment.

# Flooding and flood risks to health

### Exposure

F1 Number of floods or populations flooded – **P**
F2 Flood warnings by populations affected – **NR**

### Vulnerability

F3 Populations with estimated frequency of flooding of more than a 1% chance in any year – **P**
F4 New properties built on land with an estimated frequency of flooding of more than a 1.3% chance in any year 1 in 75 years – **P**
F5 Proportion of households without flood insurance – **P**

### Outcome

F6 Death or injury from flood events – **P**
F7 Estimated number of people suffering flood-related adverse mental health impacts – **NF**
F8 Number of people displaced from home for more than 30 days because of flood damage – **NF**

### Actions

F9 Local authority planning policy and guidance to minimise new dwellings and assets in flood risk areas – **P**
F10 Proportion of dwellings with property-level flood resilience – **P**
F11 Monitoring of the Flood and Coastal Erosion Risk Management Strategy implementation – **P**

# F1. Number of floods or populations flooded

## Sensitivity

Flooding is a regularly occurring event in the UK. Recent significant events include floods in August 2017, May 2018, June 2019, November 2019, February 2020 (Storm Ciara and Storm Dennis), December 2020 (Storm Bella) and January 2021 (Storm Christoph) causing more than 10,000 flooded properties and a significant number of people displaced from their homes. Flood events are associated with a range of social, health, and economic impacts to households and communities.

## Data and methods

The CCC proposes an indicator which monitors the number of emergency services stations, hospitals, GP surgeries, care homes, and schools which are flooded. However, there is currently a lack of annualised data that could be used for this indicator (50). The Defra 25YEP includes an indicator which monitors the disruption or unwanted impacts from flooding. This is a proposed indicator which requires significant development before being operational. However, post-hoc cost analyses of selected flood events are available.

Rainfall is monitored by the Met Office using the England and Wales precipitation series (EWP) which provides a homogeneity-adjusted series of real-averaged precipitation (51). EWP totals are based on daily weighted totals from a network of stations within each of 5 England and Wales regions. Additionally, the Met Office use registered rain gauges to provide daily rainfall data. The spatial distribution of the network has changed with time, but nevertheless the high network density ensures that all but the most localised convective events are captured at a daily timescale. These indicators allow for central government, UKHSA, and local authorities to initiate and implement the necessary actions where a flood is likely, as well as monitor the changes in flood frequency across England and the UK over time.

SurgeWatch is a database of coastal flood events in the UK which documents and assesses the consequences of coastal flood events around the UK (52). Data is based on sea level observations supplemented with 'soft' data such as journal papers, newspapers, weather reports, and social media for past and future events. Each flood event is ranked using a multi-level categorisation based on levels of inundation, transport disruption, costs, and fatalities from 1 (nuisance) to 6 (disaster). From 1915 to 2016, there were 329 events (a period of high sea levels and or waves arising from a distinct storm which were associated with coastal flooding) identified.

### Comments

Although this indicator is not yet available, it could be achieved through updating current monitoring systems to report the number of flood events (for different types of flooding) and the population flooded. Rainfall data is consistently monitored, and a database of coastal flood events exists; however, to achieve this indicator, the current monitoring databases and monitoring of floods would need to be updated to include more details such as number of households impacted by flood type and outcome for example mental health, loss of property, injury. and .

## F2. Flood warnings by populations affected

### Sensitivity

The Multi Agency Flood Plan Review (53) confirmed that existing emergency planning processes and arrangements are effective in responding to small and medium sized flood events, but the response to major events affecting multiple local authorities and thousands of people, needed improvement. Enhancements in forecasting and warning systems for local populations are increasingly important to raise awareness and reduce health burdens. Mental health outcomes have been shown to be worse in displaced populations after flooding that received no warning (54). Flood warnings for England are broken down into core warning types:

- severe flood warning (severe flooding – danger to life)
- flood warning (flooding is expected – immediate action required)
- flood alert (flooding is possible – be prepared)

Note also that this relates to the ‘G’ set of indicators established by the United Nations (UN) for better disaster reporting (G3: Number of people per 100 000 that are covered by early warning information through local governments or through national dissemination mechanisms) (55).

## Data and methods

### Proposed indicator

- CCC2019 – number and coverage of flood warnings issued by type

Flood warnings (fluvial and coastal) in England (and Wales), are provided through the joint Met Office and EA Flood Forecasting Centre through Floodline Warnings Direct (FWD). The Cabinet Office Resilience Direct platform also provides street-level surface water flood forecasts. The FWD data set is held by the EA and provides a listing of all severe flood warnings, flood warnings and flood alerts issued since the FWD service went live in January 2006. The data sets include flood warnings (including flood alert, flood warnings and severe flood warnings) issued for flooding from rivers and the sea and, for a limited number of locations, groundwater flooding.

## Comments

This indicator can provide an indication of the number of warnings issued on FWD. However, the data is not robust enough to interpret trends over the long-term due to changes in the flood warning areas. From 2006 to 2016, the number of flood warning areas has increased due to the expansion of FWD services and because Flood Warnings are increasingly more targeted (that is, flood warning areas have got smaller and more precise). Additionally, warnings may not be triggered by exactly same threshold.

# F3. Populations with estimated frequency of flooding of more than a 1% chance in any year

## Sensitivity

The risk to people and communities from increased flood risk due to climate change is significant. It was ranked as a high risk that required further action in the CCRA3 (56). Just under 1.9 million people across all areas of the UK live in areas at risk of flooding from fluvial, coastal, or surface water flooding (57). Current risk is most prevalent for surface water flooding. However, health impacts from flooding are more significant for fluvial and coastal flood events. The flood risk is present in most local areas but there are significant regional differences. 10 local authorities account for 50% of the socially vulnerable people living in flood risk areas, these are: Hull, Boston, Belfast, Birmingham, East Lindsay, Glasgow, Leicester, North East Lincolnshire, Swale District, and Tower Hamlets.

The Defra 25YEP includes a proposed indicator focused on communities resilient to flooding and coastal erosion (resilience to natural hazards). This indicator will show changes in the resilience of communities that are at risk of flooding and coastal erosion. This indicator, which requires development, will be sensitive to future climate change and show the need for adaptation. The scope of this indicator, particularly for coastal erosion, is contingent on data being available to track broader community resilience beyond that of property. Scope and details of this indicator are subject to decisions on long-term Flood and Coastal Erosion Risk Management (FCERM) policy. However, there is currently no available data for reporting on this indicator.

## Data and methods

The EA has strategic management responsibilities for flood risk and works in partnership with the Met Office to provide flood forecasts and warnings. Long-term flood risk is mapped by the EA for England to a high spatial resolution (postcode level data). This map shows the potential extent of flooding to properties from rivers, surface water, or reservoirs across the UK, as well as details of the long-term risk of flooding for a property.

## Comments

An annual ‘population at risk of flooding’ indicator is technically feasible and could be achieved through processing of current mapping data held by the EA, but the data have to be updated regularly to reflect changes to flood defence systems. Indicators of resilience that are more sensitive to action on adaptation are yet to be developed.

# F4. New properties built on land with an estimated frequency of flooding of more than a 1.3% chance in any year

## Sensitivity

Housing developments in areas prone to frequent coastal and surface water flooding (1 in 75 years (1.3% annual exceedance probability (AEP)) or more frequent) across the UK have disproportionally taken place in the most vulnerable neighbourhoods. By the 2080s, while all these developments are expected to experience a significant increase in exposure to flooding across all sources, the increase is greatest in the developments built in the most vulnerable neighbourhoods (58).

The National Planning Policy Framework (NPPF) states that local plans should take a proactive approach to mitigating and adapting to climate change, considering the long-term implications for flood risk, coastal change, water supply, biodiversity, and landscapes. Planning Practice Guidance (PPG) provides detailed guidance for developers and planners regarding flood risk assessment to avoid development in areas of flood risk. The EA is a statutory consultee to all applications for development that could be at current risk of flooding from rivers and the sea, or are in a critical drainage areas (59).

## Data and methods

The CCC have proposed the indicator 'Rate of development of properties in areas at risk of flooding', that assesses the types of development that are being carried out at the different risk levels to understand changes and trends in exposure and vulnerability of properties to flooding. The indicator uses HR Wallingford data sets which identify areas of high (each year, there is a chance of flooding of greater than 1 in 30), medium (each year, there is a chance of flooding of between 1 in 30 and 1 in 100) and low (each year, there is a chance of flooding of between 1 in 100 and 1 in 1,000) flood risk and overlays property data through spatial analysis (2).

New development in areas at highest river and coastal flood risk (Flood Zone 3b – the functional flood plain) in England increased from 7% of all new developments in 2013 to 2014, to 9% in 2016 to 2017 (19,550 properties). In 2019 to 2020, 96% of planning applications were determined to be in line with the EA's flood risk advice and 98% of new homes included in planning applications were determined to be in line with the Agency's advice. There is no information regarding the degree to which new buildings are actually built with flood protection measures in the areas at greatest flood risk (Flood Zone 3).

## Comments

The development indicator is technically feasible and could be achieved through processing the current mapping data held by the EA and others. The EA currently report on properties built in areas prone to flooding on an annual basis. Developments may be targeted to disadvantaged areas as part of a local regeneration strategy, so some care needs to be taken when interpreting this indicator. Housing developments can be resilient to flooding if they are built with sufficient flood protection measures. Planning applications for development in areas at risk of flooding need to be supported by independent evidence that flood risk from all sources, including surface water, has been assessed, mitigated against, and takes into account the implications of climate change.

# F5. Proportion of households without flood insurance

## Sensitivity

Public Health England's (PHE) National Study of Flooding and Health has shown that individuals without insurance have worse mental health outcomes from being flooded than those with insurance (60). In 2039, the Flood Re scheme will end and there will be a free market for flood risk insurance. Flood Re re-insurance is a non-profit, joint initiative between the UK government and the insurance industry to provide affordable insurance for households in high flood risk areas, for whom premiums might otherwise be unaffordable. In the financial year (FY) 2019 to 2020, Flood Re provided cover for over 196,000 household policies. Approximately 88% of households in high flood risk areas have a policy which covers both buildings and contents insurance, whilst 6% have separate policies for contents and buildings insurance (61).

### Data and methods

Due to Flood Re being delivered through private insurers, the tracking and monitoring of homes or individuals in flood risk areas with or without flood insurance is challenging. Data availability and sharing issues prevent an indicator currently being developed.

### Comments

Despite the importance of insurance in managing risk, this indicator is not yet feasible.

## F6. Death or injury from flood events

### Sensitivity

Flood events have a range of impacts on health. Deaths may occur from drowning and physical injury (such as being struck by debris). Mortality associated with flooding can also include car accidents, falling into fast flowing water, and injuries or deaths associated with cleaning up (including carbon monoxide poisoning). Therefore, standardised definitions of flood deaths need to be developed. WHO provides technical guidance on the reporting of the health impacts of a disaster (55). There has been significant investment to improve disaster reporting as part of the Sendai Framework and ensure better understanding of risks across different countries and over time.

The total annual impact of flooding on mortality is uncertain as data on UK deaths resulting from flooding are not routinely reported in health or vital registration data systems. Deaths reported from drowning do not indicate the cause of drowning or if flooding was involved. Deaths are reported within post-flood event reporting at the local level. This data is also collected by the EA together with the numbers of properties flooded.

### Data and methods

Defra include an indicator monitoring the disruption or unwanted impacts from flooding or coastal erosion (resilience to natural hazards) in the 25YEP which includes impacts to health from flooding. However, no data is currently available for the EA to create this indicator.

### Comments

This indicator is not yet technically feasible without improved health surveillance systems.

# F7. Estimated number of people suffering flood-related adverse mental health impacts

## Sensitivity

The greatest burden of ill health from flooding is likely to be due to the long-term impacts on mental health. Flooding increased the risk of mental disorders (anxiety and depression) and PTSD (post-traumatic stress disorder) in people whose homes have been flooded and who experienced disruption as a result of flooding (62). There is also evidence that children's mental health is severely affected by flooding (63). The English National Study of Flooding and Health found evidence of the persistent impact of flooding on mental health (64). The prevalence of probable depression amongst those whose homes were flooded was 20.1%, anxiety 28.3%, and PTSD 36.2%. This compares with the general prevalence of depression amongst adults in Great Britain of 10% in 2019 to 2020 (pre-COVID-19 pandemic) (65). The prevalence of negative mental health outcomes in affected people is reduced 3 years after flooding, but is still significant (60). Evacuation and displacement, particularly without warning, increases the risk of anxiety and PTSD (54). Many people experience persistent flood-related damage to their homes and this is associated with worse mental health outcomes (60).

The CCC also raises the importance of work or school days lost due to flooding. Currently, school closures and days lost due to flooding is not captured centrally. Instead across local authorities, it ranges in whether schools inform and log disruption due to flood events. Where data was provided, most councils were unable to allocate a specific weather type as the reason for the closure. This information was provided by 4 councils; however, the date ranges provided did not allow for a robust comparison. Other issues included some schools closing for half, or part of a day, meaning considerable manipulation of the data would be required to fully analyse the number of school days lost. It is also important to note that the data is not always accurate or checked, so some of the data may be prone to inaccuracies within the numbers provided by councils.

## Data and methods

### Proposed indicator

- CCC 2017 – Number of people suffering mental health impacts following a flood or severe weather event

The CCC has proposed an indicator monitoring the number of people suffering mental health impacts following a flood. The prevalence of mental health conditions (anxiety, depression, or PTSD) can be derived from routine health data (including primary care data). However, the attribution of such conditions in individuals to flood exposures is technically difficult.

### Comments

This indicator is not yet technically feasible without improved health surveillance systems. Although mortality and morbidity data is available through routine sources, there would need to be some epidemiological assessment or new reporting mechanisms to attribute deaths or illness to flood events.

## F8. Number of people displaced from home for more than 30 days because of flood damage

### Sensitivity

The wider social impacts of flooding are increasingly being quantified for flood events, including disruption to services, loss of school and workdays, travel disruptions and displacement from homes (66). Flooding can make homes unsafe to be occupied, either because of structural risks, or health concerns due to mould or contaminated flood water. This often means that people are displaced from their homes whilst flood repairs take place. Flood repairs can vary in length, from weeks, to months, to years. The length of time during which people are displaced from their homes can cause substantial financial and emotional stresses. Evacuation and displacement increases the risk of anxiety and PTSD in individuals that have been flooded (54).

### Data and methods

The CCC proposes monitoring the average length of time between flood events and people returning to their homes. The Association of British Insurers may be able to provide some information to inform this indicator.

### Comments

This indicator is not yet technically feasible without improvement to reporting systems.

## F9. Local authority planning policy and guidance to minimise new dwellings and assets in flood risk areas

### Sensitivity

Community resilience involves working with local people and businesses to assess, plan for emergencies, and act to manage flooding. In England and Wales, LRFs develop emergency plans and provide information on what to do before, during, and after a flood at the local level, which should support recovery from flood events. Other bodies also provide advice on how to prepare for and recover from flooding events.

## Data and methods

It is not clear what available data exists for this indicator.

## Comments

Many local authorities have set up local flood risk management partnerships which bring together risk management authorities and others in their area to help with the development, maintenance, application, and monitoring of their local flood risk management strategies. Continually increasing awareness of flooding amongst public and private sector stakeholder organisations as well as the public and businesses is essential to ensure that responsibility for flood risk management is shared beyond risk management authorities (RMAs), and that individuals and businesses know what actions to take to minimise their own risk and manage the impacts should events occur.

# F10. Proportion of dwellings with property-level flood resilience

## Sensitivity

Property level resilience (PLR) measures can help reduce the risk of water getting into homes and businesses, and reduce the impact of the flood water if it does get in. Defra's Property Flood Resilience Action Plan (2016) (67) aims to achieve an 'environment where it is standard practice for properties at high flood risk to be made resilient', and within 2 years to have made 'significant progress towards developing the systems and practices within the insurance, building, and finance sectors that normalise the uptake of property level resilience within existing activity' (67). The plan does not quantify the number of properties or locations to target (68).

## Data and methods

### Proposed indicator

- CCC2019 – Number of households in flood risk areas retrofitting property-level flood protection measures

The CCC includes an indicator which monitors the number of households in flood risk areas retrofitting property-level flood protection measures. Publicly available data on the number of homes with PLR is sparse, with no known data sets that provide annual time series on the number of properties that have PLR. The limited, publicly available data provides an indication of the number of properties that implemented PLR through the relevant schemes. However, this data does not include cases where households have installed PLR after a flooding event or have implemented PLR at their own cost.

## Comments

This indicator is technically feasible but will require some updates to the current reporting systems.

# F11. Monitoring of the Flood and Coastal Erosion Risk Management Strategy implementation

## Sensitivity

Under section 18 of the Floods and Water Management Act 2010, the EA must produce FCERM Reports every year. These reports must include information about the application of the national flood and coastal erosion risk management strategy. The updated National FCERM strategy (2020) has a vision of ‘a nation ready for, and resilient to, flooding and coastal change – today, tomorrow and to the year 2100’ (69).

## Data and methods

The strategy strongly promotes a shift from protection to resilience through a basket of measures and describes what needs to be done by all RMAs involved in FCERM for the benefit of people and places. It also promotes the use of adaptive pathways that enable local places to better plan for future flooding and coastal change and adapt to the future climate. All FCERM activities conducted by RMAs, including plans and strategies, must be in alignment with the FCERM Strategy. Long-term delivery objectives are set out that should be implemented over the next 10 to 30 years. It also includes shorter term practical measures RMAs should take working with partners and communities. The strategy has a greater focus on addressing climate change than the previous version with its 3 objectives being: climate resilient places, today’s growth and infrastructure resilient in tomorrow’s climate, and a nation ready to respond and adapt to flooding and coastal change.

## Comments

The proposed indicator is feasible as the EA currently has a comprehensive reporting system established which tracks progress towards actions required by 2026 to ensure the country achieves the strategy vision by 2100.

# Coastal change risks to health

### Exposure

E1 Rate of coastline loss due to coastal erosion – **A**

### Vulnerability

E2 Population at risk of inhabitability within 20 years because of coastal erosion – **P**
E3 Population at risk of coastal flooding or erosion without insurance or compensation scheme – **NF**
E4 Number of camping and caravan sites with evacuation flood or erosion plans in place – **P**

### Actions

E5 Coastal risk management plan – **P**

# E1. Rate of coastline loss due to coastal erosion

## Sensitivity

The coastal zone is one of the most vulnerable areas to climate change, whilst also being one of the most valuable to people for economic, social, cultural, and health reasons. Sea level rise will increase local coastal flood and erosion risks and increase exposure (particularly infrastructure) in coastal zones. Coastal processes such as sediment movement and erosion exacerbate the risk threatening long-term sustainability of coastal communities. The EA estimates that about 1,800km of England's coastline (total coastline is 4,500km in length) is at risk of erosion (70).

## Data and methods

This data is currently provided by the National Coastal Erosion Risk Mapping (NCERM).

## Comments

This indicator is technically feasible.

# E2. Population at risk of inhabitability within 20 years because of coastal erosion

## Sensitivity

In England, 8,900 properties are currently at risk from erosion if coastal defences are not considered (1). Better understanding of local risks is needed to ensure a fair approach to managing this risk. There is a need for guidance on and support with monitoring coastal erosion, monitoring property and infrastructure at risk, and when this is lost to coastal erosion (including temporary infrastructure for example, caravans). A UK or national assessment identifying which locations are likely to be unsustainable in the long term is required, enabling planning to commence regarding any potential relocation of communities.

## Data and methods

### Proposed indicator

- 25YEP_F1 – Disruption or unwanted impacts from flooding or coastal erosion (resilience to natural hazards)

Defra conducted a mapping exercise of properties at risk of coastal erosion over the next 20 years using existing national data sets and assuming the interventions set out in Shore Management Plans (SMPs) are fully implemented across all time frames (see E5 for more details). The mapping does not include caravans which are numerous on all stretches of the coast in close proximity to the cliff edge, and which are likely to be at considerable risk (71). Consistent data is not collected across the UK on the number of properties lost to, or at risk of coastal erosion.

## Comments

This indicator is feasible using the mapping data from Defra. Further advances in modelling and mapping are required regarding coastal erosion and populations at risk to enhance understanding and enable a more consistent assessment across the UK.

# E3. Population at risk of coastal flooding or erosion without insurance or compensation scheme

## Sensitivity

Insurance or compensation is not currently available to mitigate against the risk of losing properties to coastal erosion.

## Data and methods

### Proposed indicator

- 25YEP_F2 – Communities resilient to flooding and coastal erosion (resilience to natural hazards)

Defra proposed an indicator which monitors community resilience to flooding and coastal erosion, and insurance or compensation schemes could form part of this. This indicator is currently being developed.

## Comments

This indicator is not yet feasible. Further advances in modelling and mapping are required.

# E4. Number of camping and caravan sites with evacuation, flood or erosion plans in place

## Sensitivity

Defra has highlighted that since 1996, around 50 permanent properties and 30 temporary properties have been lost as a result of coastal erosion, as well as approximately 100 beach huts (71). Caravans would also have been lost had they not been moved back from the cliff edge. Defra conducted a mapping exercise of properties at risk of coastal erosion over the next 20 years using existing national data sets and assuming the interventions set out in SMPs are fully implemented. The mapping does not include caravans which are numerous on all stretches of the coast in close proximity to the cliff edge, and which are likely to be at considerable risk (71).

## Data and methods

### Proposed indicator

- CCC2017 – Number of camping and caravan sites with evacuation or flood plans in place

The CCC has an indicator which identifies numbers of camping or caravan sites with evacuation or flood plains in place using the OS AddressBasePlus data set for sites that fall into 'Commercial Leisure Holiday or Campsite' (CL02); Camping sites (CL02CG); and Caravanning sites (CL02CV). This is then overlaid with EA data sets: Flood Map for Planning (Rivers and Sea) Areas benefiting from defences and Flood Map for Planning (Rivers and Sea) Flood Zone 3.

## Comments

This indicator is feasible.

# E5. Coastal risk management plans

## Sensitivity

Coastal flood management is driven by integrated engineering, planning, insurance, and preparedness activities, but there has been an increasing emphasis on community or individual led activities to increase resilience. The FCERM Strategy (69) has a strategic objective 1.3 'to help coastal communities transition and adapt to climate change'. SMPs identify the most sustainable approach to managing the flood and erosion risks in the short-term (0 to 20 years), medium-term (20 to 50 years) and long-term (50 to 100 years). SMPs are non-statutory documents that provide a broad assessment of the long-term risks, providing guidance on strategic and sustainable coastal defence policy options in order to reduce these risks for the local population, as well as protecting the natural environment (and other local objectives). Plans can promote nature-based solutions, building and enhancing the resilience of communities, and adaptive pathways. Monitoring is needed to understand how the strategies are being delivered, to understand the actions being taken and the impact they are having on managing risk.

## Data and methods

An SMP Refresh was initiated in 2019 focusing on changes since the second round of SMPs were published, such as new legislation, planning guidance, and climate projections, and advising how these should be considered in SMPs. However, it does not involve developing a new set of SMPs (72). Defra is committed to a review of national policy for SMPs to ensure local plans are transparent, continuously review outcomes, and enable local authorities to make robust decisions for their areas.

## Comments

This indicator is technically feasible but will require some criteria for the evaluation of individual local plans. Best practice developed across the UK regarding community engagement and messaging needs to be widely shared, facilitating knowledge transfer and improving planning for the relocation of communities. This should enable high levels of awareness and understanding of the implications for individuals as well as the wider community.

# Vector-borne disease

### Exposure

V1 Seasonal temperature profile compatible with survival of disease vectors – **P**
V2 Weekly tick activity – **NF**
V3 Fortnightly mosquito activity – **NF**
V4 Invasive species – **NF**
V5 Tick bite submissions at veterinary practices – **NF**

### Outcome

V6 Number (rate) of Lyme disease cases – **P**
V7 Autochthonous cases of vector-borne disease – **P**

### Actions

V8 Implementation of monitoring and reporting system for vectors – **P**

Arthropods are very responsive to changes in temperature (impacting activity and development) and rainfall (affecting activity and aquatic habitats). Transmission cycles can involve wild and domestic animals, transmission is therefore also dependent upon abiotic factors such as animal host population dynamics and land-use. The risk of vector-borne diseases was highlighted as urgent action needed in the CCRA3, particularly for the south of England. Although there are numerous vector-borne pathogens that have the potential to cause human disease, only 2 tick-borne diseases have been reported to do so in the UK so far. However, it is anticipated that climate change will lead to new pathogens or vectors becoming established in the UK.

## V1. Seasonal temperature profile compatible with survival of disease vectors

### Sensitivity

Transmission of vector-borne diseases is related to temperature but modelling of these associations is complex. Patterns of climate variability have been shown to increase the risk of infections, but it can be difficult to directly link climate factors and transmission cycles. Seasonal temperatures are strongly linked to climate patterns and may provide a suitable indicator of vector activity. There are some limitations with vector observations, particularly vector abundance, as data is often collected over short periods of time which limits long-term data analysis with meteorological data.

### Data and methods

Meteorological data is available and would require some processing to report on the specific indicators (which could be regionally specific).

## Comments

This indicator is technically feasible but would require some research to identify the most appropriate climate-based index. Additional vector monitoring may be required.

# V2. Weekly tick activity

## Sensitivity

Ticks respond directly to changes in temperature, humidity, and rainfall. Weather and climate may impact on survival in the environment through climatic extremes, such as increased mortality at particularly high or low temperature thresholds (for example, heatwaves can cause desiccation of ticks). Field sampling of ticks can be hugely time-consuming and expensive, and often is only sustained for one or 2 years. This is a challenge for all work on vectors, where much of the data is snap-shot surveys. However, such data exists for other invertebrate species such as moths, butterflies, and these species are now being used as indicators of climate change. So, given the desire and funding, there is little reason why arthropod vectors could not also be monitored in some way, assuming we can find a sufficiently interested stakeholder group to collect such data. There are some data sets on human-biting by insects (73), and whilst these can be very spatially specific, they are often not species specific, only detailing that biting has occurred, and not confirming the type of arthropod. Data sets on seasonal activity of vectors are available but very limited. The data collection requires a network of volunteers.

## Data and methods

Regular monitoring of tick activity using blanket dragging of vegetation has been shown to provide useful long-term data on tick densities, seasonality and potential tick exposure (74, 75).

Regular weekly surveys are used for a range of invertebrates for biological monitoring (for example, UK Butterfly Monitoring scheme), and given sufficient numbers of locations and surveyors, a network of datapoints can enable data to be gathered to inform models and climate change indicators. The main caveat though, in contrast to other invertebrates is the potential exposure of surveyors to pathogens.

## Comments

This indicator is technically feasible but would require some further investment to undertake regular surveys.

# V3. Fortnightly mosquito activity

## Sensitivity

Mosquito activity surveys are less time consuming than tick surveys (see above discussion). Studies over 10 years have generated such data, but stakeholder engagement and resources for sampler processing are key considerations.

### Data and methods

Regular weekly surveys can be achieved given sufficient numbers of locations and surveyors to generate a network of datapoints. Mosquito surveys are relatively less time consuming because mosquito traps can be run over fixed numbers of nights to assess changes in abundance. This data can then be correlated with temperature, rainfall, and extreme events, such as flooding or drought (UKHSA unpublished data). The main caveat though, in contrast to other invertebrates is the potential exposure of surveyors to pathogens. Studies over 10 years have generated data on mosquito activity, but stakeholder engagement and resources for sampler processing are key considerations.

### Comments

Data on mosquito seasonality and abundance can be collected easily using traps, although there is a financial cost and technical expertise required for identification. Often the density of mosquitoes can relate to water management, rather than just precipitation and temperature, and this would need to be taken into account to avoid misinterpretation of trends.

## V4. Invasive species

### Sensitivity

Detection of non-native vectors (for example, *Hyalomma* ticks) on animals (including sentinel animals) can provide an insight into emerging risks from climate change. However, for this to generate robust data as an indicator, surveys must be active and extensive, rather than ad-hoc and passive. So far there is too little data to enable such vulnerability indicators.

### Data and methods

Numbers of positive ovitraps capturing eggs, or numbers of localities with invasive mosquitoes, or numbers of reports of imported ticks on livestock or migratory birds.

### Comments

Climate change will facilitate establishment of non-native species associated with warmer climates. So far, the incidence of detections remains too low to make this indicator feasible.

## V5. Tick bite species at veterinary practices

### Sensitivity

Tick abundance is a good indicator for the transmission of tick-borne diseases. Tick-related indicators would include data on the:

- seasonal abundance of ticks as shown by tick bites in animals (for example, tick-bite records) (73, 76)
- changes in the distributions of ticks (tick bites) overtime (76 to 78)
- changes in distribution and numbers of detections of non-native (invasive) tick species (79 to 81)

## Data and methods

There is some data on human exposure to arthropod biting, which is collected through use of pharmacies, GP visits, NHS Direct, Accident and Emergency (A and E) submissions and RCGP (Royal College of General Practitioners), however linking this to specific vector species or groups is problematic. Similar data is available through SAVSNET (Small Animal Veterinary Surveillance Network) for inquiries at veterinary practices for tick bites on companion animals (82). This data set is sufficiently robust, both spatially and temporally, to be useful. However, there are some caveats over location and timing of exposure. This data is already passively collected, and exceedance thresholds can be generated for local alerting.

## Comments

There is good data on the temporal and spatial collection of tick submissions at veterinary practices. However, the data is very limited on the specific tick species being reported, and therefore assumptions need to be made regarding which species are present. The regular reporting of ticks would provide data on seasonality which could be a good indicator of climate impacts, providing there is no seasonal bias in reporting.

# V6. Number (rate) of Lyme disease cases

## Sensitivity

Although there are numerous tick-borne pathogens that have the potential to cause human disease, only 2 have been reported to do so in the UK so far. There are approximately 1500 confirmed cases of Lyme disease in England and Wales each year (83), and many more that are clinically diagnosed but not reported in official statistics. To date, there have been 2 probable cases of tick-borne encephalitis virus since the virus was first detected in the UK in 2019 (84 to 86). They are classed as probable on account of only serological evidence of exposure which cannot be separated from possible louping ill virus exposure. Other potential tick-borne pathogens, such as *Anaplasma, Babesia, Rickettsia* are not routinely reported. There are no current human cases of locally acquired mosquito-borne diseases, despite several arboviruses occurring in continental Europe. Whilst Lyme disease is a notifiable disease, only a low number of confirmed infections are reported and there is a lack of information about the onset of infection in time and space. However, reported rates of Lyme disease may give an indication of whether rates are increasing. Case data would need to be investigated before any attribution to climate factors or observed climate change could be made.

### Data and methods

Data is collected on Lyme disease, either as laboratory-confirmed cases, or assessments of incidence rates (87). Their use as an indicator is contingent on the spatial and temporal resolution of the data collected.

### Comments

This indicator is feasible but association with climate drivers need to be interpreted with experts.

## V7. Autochthonous cases of vector-borne disease

### Sensitivity

Measuring the occurrence, incidence, and prevalence of a vector-borne disease in an animal population would provide information useful for managing climate risks to human health. This may include sampling the animal population directly for evidence of exposure (through serological surveys) or evidence of infection (through PCR-based tests). This has been used in the detection of vector-borne viral pathogens, such as exposure to tick-borne encephalitis in wild deer (88), or exposure to Usutu or West Nile viruses in wild birds (89), or even exposure in domestic animals, such as horses (Defra unpublished data). Whilst these studies give an idea of spatial risk, there are economic constraints on generating sufficient spatial data to compile temporal data sets that allow comparisons with climatic data sets.

### Data and methods

Reported through current surveillance systems or short-term research projects.

### Comments

This indicator is feasible but association with climate drivers need to be interpreted with experts.

## V8. Implementation of monitoring and reporting system for vectors

### Sensitivity

There are no current interventions to manage and control tick activity in the field. Some local authorities undertake mosquito management, for example, specific biocidal control in salt marshes and flooded river systems, but these activities are ad hoc, rather than routine.

Data on the acquisition of bite relief creams may be useful as an indicator of household level responses to vectors. Similarly, there may be data on uptake of tick control products used for companion animals, but they are unlikely to show specific spatial and temporal granularity for use as indicators of response measures.

## Data and methods

No current data sets are available. However, an indicator could be developed based on criteria for an effect monitoring and reporting system that could be implemented by a local authority.

## Comments

This indicator is feasible but requires changes to local reporting systems.

# Food systems and health impacts

## Exposure

FS1 Pollinator abundance – **P**

## Vulnerability

FS2 Yields per hectare and livestock, or productivity by crop and livestock group – **P**
FS3 Foodborne outbreaks and/or reported concerns and alerts – **P**
FS4 Proportion of food waste along the value chain – **P**
FS5 UK food imports and exports by food group – **P**
FS6 Frequency and length of disruptions in supply by food group – **NF**
FS7 Proportion of households that are food insecure – **A**
FS8 Healthy (sustainable) diets and dietary diversity score – **P**
FS9 Rate and frequency of foodbank use – **P**

## Outcome

FS10 Food price changes by food group – **P**
FS11 Incidence of foodborne diseases – **P**

## Actions

FS12 Development and implementation of national and/or local food strategy – **P**
FS13 Development of dietary guidelines that embed climate change adaptation – **NF**

Agriculture and supply chains may be increasingly vulnerable to climate change impacts, which in turn has implications for food security. Climate change will increasingly impact global food systems which has potential consequences for food security and diet quality. Non-resilient and vulnerable food systems can be challenged by climate change through direct impacts on crop yields affecting food production, nutrient composition, and bioavailability, as well as influencing access to and affordability of food. Climate impacts to global and domestic agricultural and livestock yields are expected in future years. In the UK, climate change is projected to result in warmer, wetter winters and hotter, drier summers which may positively or negatively affect domestic agriculture in the future. Furthermore, the UK has a highly complex food system with long supply chains and is dependent on imports often from highly climate-vulnerable countries as well as experiencing its own environmental challenges.

Impacts of climate change on agriculture across the globe will have direct implications for UK food security, as the UK imports approximately 40% of the food it consumes (90). This is higher for some specific food groups, for example 65% of fruit and vegetables are imported, a third of these being from climate-vulnerable countries. It is unexpected that the global food sources the UK access will become insecure in the coming years. However, global food production is unevenly distributed across regions and some specific food types may become vulnerable. It is critical that climate change impacts and policy responses are monitored and evaluated to identify potential vulnerabilities and subsequent consequences for food and nutrition security.

# FS1. Pollinator abundance

## Sensitivity

A variety of insects (social and solitary bees, flies, wasps, beetles, butterflies and moths) provide an ecosystem service to humans through crop pollination (91). Multiple threats impact pollinators so any dependence on individual species for agricultural crop pollination is challenging. Regional losses of pollinators which alter delivery of crop pollination services may decrease the availability of some food products or increase economic costs of production. If demand for insect-pollinated crops rise and pollinator densities or diversity falls, then shortages of insect-pollinated crops or price increases might follow without agronomic, technological, or economic responses. The extent of the impact pollinator losses may have on human nutrition is uncertain in the UK but may have implications for dietary quality or more reliance on synthetic micronutrients. Climate change has the potential to impact the abundancy of pollinators required for maintaining crop yields.

## Data and methods

Currently there is no single indicator for climate-related pollinator abundance relevant to crop yields. Monitoring the most important supply of pollination services to UK crops (mostly bees and flies) is reliant on inference from studies of specific environmental impacts on particular pollinator communities or on changes in species occurrence. These are recorded by voluntary organisations (for example, Bees Wasps and Ants Recording Society, Hoverfly Recording Scheme) and held at the Biological Records Centre (hosted by the Centre for Ecology and Hydrology) where they are accessible via the National Biodiversity Network.

Long-term standardised monitoring data is available for butterflies and moths (Lepidoptera). These wild insects are less important to crop pollination compared with bees and flies, but probably contribute to the pollination of various wild plant species and as part of wider food webs. This data is collected following regular standardised protocols to produce time series data on both abundance and distributions of insects.

## Comments

Long-term databases of confirmed bee and fly species records have been collected at different times by different recorders and so provide a limited source of information. This indicator is feasible with additional investment (see also indicators V1 and V2).

# FS2. Yields per hectare and livestock, or productivity by crop and livestock group

## Sensitivity

Many factors contribute to global food production and availability, and therefore national and local food security, including climate change, conflict, bio-fuel production, water resources, demographic, and demand change as well as suitable land availability. Domestically, higher temperatures may accelerate crop growth and alter development stages, leading to reduced yields. High temperatures are known to increase mortality in some livestock species and reduced productivity. UK crop production is dependent on temperatures and water resource availability. In 2018, the heatwave and drought in the UK led to shortages of some cereals, carrots, potatoes, and livestock fodder (90). With warming temperatures, insect winter survival is prolonged which increases crop damage and pesticide use. Additionally, temperature changes may lead to invasive species of pests and disease into the UK where resistance in plants or animals is lacking, for example, bluetongue in sheep. Climate-related pest and disease outbreaks may impact agricultural yields resulting in protective national import and export bans, for example, African Swine Fever.

## Data and methods

The CCC and Defra are the primary leads for tracking agricultural and livestock impacts from climate change. The CCC monitors current distribution and productivity of crops by change in agricultural area for key crops that are projected to become climatically unsuitable in future within different Agricultural Land Classification (ALC) grades (2). This indicator is measured using the Crop Map of England (Crome) database which is updated annually for a large number of main crop types, grassland, and other land covers (water, woodland, fallow land and so on). The analysis does not consider some specific adaptation measures to improve productivity (for example, use of irrigation to improve the quality of land).

AUK – 'Agriculture in the UK' report

### Domestic production indicators

- CCC2019 – Change in agricultural area for key crops that are projected to become climatically unsuitable in future
- CCC2019 – Agricultural losses from drought, soil erosion, pests and pathogens
- 25YEP – Area of productive agricultural land
- 25YEP – Volume of agricultural production
- Defra AUK – UK food production to supply ratio
- Defra AUK – Domestic UK grain, meat, raw milk, egg, fresh vegetables and fruit, and other crops production

Defra proposes several indicators to monitor agricultural production and yields. Agriculture provides around 75% of the Indigenous food we eat and accounts for around 70% of land use. This indicator shows annual changes in land used for agriculture in 3 categories: grassland (including sole rough grazing); crops (including horticulture and perennial crops); and uncropped arable (land left fallow or under environmental management). Data for area of productive agricultural land is currently reported annually. Currently, an interim indicator to monitor volume of agricultural production as a metric is being developed.

#### International production indicators

- Indicator FAO; 'UNEP Food waste Index Report 2021'; Fefac; Alltech – Calories and world agricultural production per person; global food loss and waste
- Indicator FAO – Cereals yields and yield growth rates
- Indicator FAO – Meat production by region; global dairy production
- Indicator UN SDG Goal 14 (2020) – Share of marine fish stocks under or moderately exploited

The Food and Agriculture Organization (FAO) in collaboration with other organisations is responsible for monitoring global food availability and food security. Food production per capita data from FAO is useful to determine the availability; however, it does include seed and feed not intended for human consumption which biases the availability of food for human consumption. The FAO predict that global agricultural production will increase by 1.4% per annum for the next 10 years (if all COVID-19 restrictions are lifted by end of 2021) (92). Concerns have been raised over the projections for global cereal yields in the future due to climate variability and change having a possible negative impact on yield growth rates. Therefore, both global and domestic indicators of agricultural yields and livestock are essential to track the progress of food security to understand the potential consequences of future climate change on production.

### Comments

An indicator on UK food production is feasible but requires revisions to some reporting systems. Furthermore, multiple components are required to understand the status of food production globally and domestically across food groups.

## FS3. Foodborne outbreaks and or reported concerns and alerts

### Sensitivity

Agricultural response to climate impacts may involve increased use of pesticides, antibiotics, fertilisers, and chemicals to maximise yields; however, this can lead to rising chemical contamination of crops and livestock.

Several epidemiological studies have shown that the incidence of diseases from bacterial contamination is sensitive to temperature. There are many gastrointestinal pathogens and microbial contaminants that have a food safety impact. However, 4 major bacterial pathogens are considered priority pathogens for national surveillance due to the substantial implications for food safety in the UK: Campylobacter, non-typhoidal Salmonella, STEC O157, and *Listeria Monocytogenes*. There is a need to track risks across Europe and therefore some value in adopting indicators that can be used across multiple countries (93), however, individual countries may have special interests that need a more focused response (94). For zoonotic pathogens, the regular monitoring of infection rates in slaughtered animals has been effective in focusing interventions. Routine monitoring of food products at various stages of food production is part of modern Hazard Analysis and Critical Control Point (HACCP) procedures.

The COVID-19 pandemic has highlighted the risks from foreign travel and the poor controls over cross-border transit. Many of the gastrointestinal infections are acquired abroad and there is a need to improve the surveillance of travel related infections. This needs to support cross-border interventions to reduce disease transmission and to monitor longer term trends associated with climate and other changes.

## Data and methods

Public health surveillance data currently exists for a range of infectious diseases that relate to food safety. The outputs from these are published by UKHSA, Public Health Wales, Public Health Scotland and Public Health Agency Northern Ireland and the data contributes to local and national understandings, and to European (ECDC) and international (WHO) data sets.

UKHSA routinely publishes surveillance data on foodborne disease outbreaks including the following:

- general outbreaks of foodborne illness (including causative organism and number of people ill)
- laboratory reports of cases of common enteric infections (Campylobacter, STEC O157, Salmonella, *Shigella sonnei, Shigella flexneri*, rotavirus, norovirus, *Cryptosporidium* and *Giardia*), with weekly and cumulative totals, reported to UKHSA's Second Generation Surveillance System (SGSS), including stratification by serovar or species where appropriate, for Salmonella spp. and Shigella spp.
- laboratory reports on other enteric diseases, with cumulative totals (quarterly) following up cases with questionnaires that provide more information on exposure to various risk factors and clinical details which includes numbers of cases, hospitalisations, and deaths by pathogen

SGSS – UKHSA Second Generation Surveillance System: Database of reported cases of infectious disease and antimicrobial resistance

ECOSS – Electronic Communication of Surveillance in Scotland: Holds all positive microbiology laboratory specimen results and a subset of antimicrobial susceptibility and resistance data in Scotland.

eFOSS – Foodborne and non-foodborne gastrointestinal outbreaks surveillance: Outbreaks reported to PHE's electronic foodborne and non-foodborne gastrointestinal outbreak surveillance system (eFOSS).

ObSurv – surveillance system established in 1996 for all general outbreaks of Infectious Intestinal Disease (IID) in Scotland.

### Indicators

- Indicator SGSS, ECOSS – Reported infections of Campylobacter, non-typhoidal Salmonella species STEC O157 and Listeria monocytogenes in the UK, 2015 to 2020
- Indicator eFOSS, ObSurv – Number of foodborne outbreaks investigated and reported in the UK and associated number of human cases and hospitalisations 2015 to 2020
- Indicator eFOSS, ObSurv – Foodborne disease causative agents and food vehicles implicated in the foodborne outbreaks investigated and reported from 2015 to 2020 and outbreak settings

## Comments

There is a need to be able to mark surveillance records with flags indicating that the patient's record occurred at a time when there was an increased occurrence of the pathogen nationally, regionally, or locally. As with other climate-sensitive diseases, there is a need to establish the role of climate and weather factors in any change in incidence. This needs to be done with expert advice.

# FS4. Proportion of food waste along the value chain

## Sensitivity

Food waste in agriculture and in the supply chain is an economic and environmental loss, as well as being a factor in understanding overall domestic production and efficiency, and therefore food security. It represents unnecessary land and resource use, millions of tonnes of carbon emissions, and billions of pounds of wasted value. Approximately 30% of food purchased in the UK is wasted (estimated 5% to 10% of UK total greenhouse gas (GHG) emissions), and it is determined that 20% of this is avoidable and a further 60% is preventable with appropriate food management (95). Of the 30% wasted, the majority is meat and salad vegetables. Total annual food waste reached 9.5 million tonnes in 2018, with 70% arising in the home. Spoilage during transportation, disease outbreaks, and consumer stockpiling all contribute to food waste.

Reducing food waste is an objective of mitigation. However, climate change may also increase the risk of spoilage of some foods. Degradation and spoilage occur during storage and transportation of produce from microbial decay and changes in populations of stored product pests due to changing humidity and temperature (96). Produce is more likely to spoil as it may ripen more quickly and therefore rot quicker due to increased temperatures. An important consideration is the increased probability of climate-related food shortages may influence how food is stored, leading to bulk purchasing of some foods which risks further spoilage or wastage.

## Data and methods

The Waste and Resources Action Programme (WRAP) 'Love Food Hate Waste - Household Food and Drink Waste Resource Listing' includes estimates of UK food waste annually. The UK is required to report progress against Courtauld 2025 targets and UN Sustainable Development Goal (SDG) 12.3 United Nations Environment Programme – Food Waste Index which measures food waste at retail and consumer level (households and food service). The Food Waste Index also allows countries to measure and report on food loss generated in manufacturing processes. Hospitality and Food Services data is a modelled result, based on changes in the number and types of hospitality and food service sites, and the assumption that food waste per site has remained constant since 2011. Currently there are no data sources to enable a UK-level estimate for food waste from this sector.

### Indicators

- WRAP – Food waste in primary production in the UK
- WRAP – Food surplus and waste in the UK
- SDG 12.3 – Food Waste Index

## Comments

Whilst the UK evidence base on food waste is recognised as robust, significant uncertainties are associated with the data as the quality ranges between sectors, for example, primary production is weak and partly modelled using non-UK data (95). For the supply chain, developing estimates of national food waste levels from existing data sources, such as those from the EA, is not sufficiently robust for all manufacturing sub-sectors, nor possible for the hospitality and food service sector.

# FS5. UK food imports and exports by food group

## Sensitivity

Agricultural trade has increased over the past 20 years which increases the resilience to supply shocks and the potential impacts on specific geographic areas. However, the reliance on trade increases the vulnerability to events disrupting the food system. In 2020, 46% of food consumed was imported to the UK, with no more than 11% of those imports being from one country (92).

However, divergent productivity growth, climate change impacts on production, the outdoor workforce, food safety, as well as transport being affected by extreme weather events such as storm surges, heat and flooding, and developments in crop and animal diseases may all pose a risk to UK food supply in the future.

The proportion of fruit and vegetables supplied to the UK from climate-vulnerable countries increased by 60% from 1987 to 2013 and is likely higher today (97). Emerging evidence from the 2022 summer heatwave reports of crop failures and an approximate average 4% yield reduction across many European countries including many fruits and vegetables (98). UK domestic fish supply varies by species and is dependent somewhat on imports, however warming seas, ocean acidification, and salinity changes could impact stocks, prey distribution, nutritional quality and introduce invasive species (92). Droughts, floods and cold winters in California, South America, Spain and France had direct impacts on UK fruit and vegetable supply through yield reductions and disruption in transportation (97).

## Data and methods

Internationally, food imports and exports are monitored by the FAO to track the share of global production traded between countries. This trade has been monitored since the 1960s and data has illustrated a general linear increase in maize, meat, beef and veal, oilseed, soybean, rice, and wheat since then. However, there is considerable variation and volatility in the trading of oil and palm.

Defra is responsible for monitoring the UK imports and exports of food, feed, and drink (FFD) in the UK. Data indicates that the majority of UK imports are from Netherlands, Germany, Ireland, France, Spain, and other European countries as well as the US. The UK export the most FFD to Ireland, France, and USA. Around 93% of domestic consumption of fresh vegetables was fulfilled by domestic and EU production, reflecting the importance of geographical proximity for importing fresh produce of relatively low value (92). UK production to consumption has declined slightly over the last decade, while reliance on the European Union (EU) and African supply sources has increased.

### Indicators

- FAO – Share of global production internationally traded
- Defra – UK imports of FFD by value and by country of dispatch, 2020
- Defra – UK exports of FFD by value and by country of destination, 2020
- HMRC – Origins of fresh vegetables and fruit in UK domestic consumption
- HMRC – UK fish imports and exports by weight

## Comments

This indicator is feasible and already established at the global and domestic level through FAO, Defra, and HMRC (HM Revenue and Customs). There are concerns about water availability for fruit and vegetable production in many of the countries on which the UK currently depends, for example in the Mediterranean region. Therefore, an indicator is required to monitor the water availability in countries that supply fruit and vegetables to the UK.

# FS6. Frequency and length of disruptions in supply by food group

## Sensitivity

Global markets and supply chains are likely to be affected as transport and trade routes suffer disruptions from climate change. Climate change-related extreme weather events globally will also increase the likelihood of crop failures and water shortages. It is unclear about the potential frequency and severity of disruption to the UK food supply chain due to climate change. The climate events described above have led to supply chain disruptions causing delays in the transportation of produce, impacting food stocks and business continuity at the retail level. In 2022, an international survey from the Business Continuity Institute reports that over 40% of respondents which included UK businesses, experienced supply chain disruptions due to extreme weather (99). The survey unveiled challenges in acquiring critical products, significant delays, failure of supplier operations, increased costs of wholesale goods, and supplier liquidation following extreme weather events (100).

## Data and methods

### Indicators

- Strategic Road Network – road congestion and travel time statistics
- Defra – percentage share of UK food imports by port and mode of transport
- Defra – breakdown of the Short Strait food imports from the EU

There is currently no data available to monitor supply chain disruptions. Although individual companies and organisations are increasingly undertaking a climate change risk assessment on their supply chains, this information is not publicly available.

## Comments

This indicator is not yet feasible.

# FS7. Proportion of households that are food insecure

## Sensitivity

FAO estimates that approximately 2.2 million people in the UK are severely food insecure (101). Food security has not been routinely collected by the UK government until recently (2019). Food poverty is considered to be when an individual does not have sufficient money for food or are unable to access food in their community. This entails adults and children missing meals due to a lack of food availability and more unhealthy diets, because unhealthy foods are typically cheaper. The UK Food Security Report states that 2.2 million UK households regarded themselves as food insecure in the FY 2019 to 2020 (92). Only 0.1% of the population meets all UK dietary guidelines, and micronutrient rich, high fibre foods such as fruits, vegetables, and legumes are particularly under-consumed (97, 102).

The Intergovernmental Panel on Climate Change (IPCC) reports of "irreversible damage to global food security as many natural and human systems are unable to adapt to climatic changes and further increase in global warming (between 1°C and 2°C) would contribute additional pressure to food production and access" (103). Advances in agricultural production and significant transitions in global food demand have shifted disease profiles, such that food-related non-communicable diseases rather than undernutrition are now the largest contributor to the global burden of disease (104). However, inequalities in the distribution of food supply for adequate and healthy diets remain (105). Climate impacts also disrupt supply chains which adversely impacts food availability as well as price. The risks to food availability in the retail food environment have important consequences on food price at the national and local level. Climate-dependent food prices and availability fluctuations may exacerbate existing health inequalities in food consumption by impacting dietary diversity and the nutritional quality of UK diets. Issues of affordability may lead to shifts in diets to increased consumption of HFSS (foods and drinks high in fat, salt, or sugar), high calorie, and more processed foods if 'healthier' options such as fruits and vegetables are increasingly inaccessible due to climate driven availability or cost changes.

## Data and methods

There is currently no climate change impact indicator on food prices available in the UK, however, the government does annually survey sub-sets of the population regarding food expenditure. The Family Resources Survey (FRS) is a continuous annual interview-based survey collecting information on the income and circumstances of individuals in private households over the past 30 years. This survey is led by the Department for Work and Pensions (DWP) which informs the development, monitoring and evaluation of social welfare policy. As of FY 2019 to 2020, household food security was added to the FRS with questions relating to households' experience in the 30 days immediately before the interview. From the responses to the interview questions, a household score for food security is derived.

The Living Costs and Food Survey collects information on spending patterns and the cost of living that reflect household budgets. The survey is a voluntary sample survey of private households led by the ONS, carried out on a calendar year basis from 2008. Information on household and eating out purchases for a detailed set of food and drink types is reported in the Family Food module of the Living Costs and Food Survey, which is led by Defra and surveys around 5,000 households in the UK annually.

The dietary indicators that are available for monitoring intake in the UK are primarily survey based. UK dietary intake and nutritional status is monitored through the National Diet and Nutrition Survey (NDNS) which is currently led and funded by UKHSA and the UK Food Standards Agency (FSA). This survey collects detailed, quantitative food consumption, nutritional intake, and status information from the general UK population aged 1.5 years and over living in private households. The NDNS covers a nationally representative sample of approximately 1,000 people per year and has been routinely collected since 2008. NDNS is essential for providing evidence of the diet and nutrition of the UK population allowing the Office for Health Improvement and Disparities (OHID) and others to address nutritional and dietary issues and monitor the progress towards public health nutrition objectives and wider targets.

The UK Food Security report published in 2021 proposes the below indicators to monitor food security at the household level (92). These metrics can help determine the impact shocks to the food system (for example, climate change) may have on food security of a household.

### Indicators

- ONS Family spending in UK – Food expenditure growth compared to other household spending growth
- ONS family spending, ONS consumer price inflation – Spending on good purchased for home consumption as a percentage of total spending, by all households and low-income households
- DWP, Family Resources Survey – Household food security of all households.

## Comments

This indicator is feasible and can act as a proxy for understanding the impacts climate change may have on food prices and subsequent food security at the household level.

# FS8. Healthy (sustainable) diets and dietary diversity score

## Sensitivity

Sustainable diets are defined by the FAO as ‘those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy while optimizing natural and human resources.’ (106). In the UK, sustainable diets are seen as a key part of mitigating climate change. The CCC’s Sixth Carbon Budget calls for a reduction in red meat and dairy consumption and increase in fruits, vegetables, and legumes to reach net zero by 2050 (107).

The UK government's 'Eatwell Guide' (2016) provides a dietary pattern that moves people toward a healthier and more sustainable diet than that currently eaten. Analysis of the 'Eatwell Guide' indicates that if the UK populations adhered better to the guide, a 7% reduction in mortality and a 30% reduction in GHG emissions would be observed (97, 102).

## Data and methods

The dietary indicators that are available for monitoring intake in the UK are primarily survey based, such as the NDNS (see FS6). Other surveys used in England to track elements of dietary consumption include the Health Survey for England (HSE) which has annually surveyed adults aged over 16 since 1990, children aged 2 to 15 since 1995, and from 2001 infants aged 2 and below. HSE is led by NHS Digital, and reports in most years on fruit and vegetable intakes. OHID (previously PHE) includes an indicator measuring the proportion of the population meeting the recommended '5-a-day' on a 'usual day' for adults in the Public Health Outcome Framework (PHOF) using the Active Lives survey led by Sport England. This could be adapted to monitor or develop a dietary diversity score.

Whilst there currently is no formal indicator for the sustainability of UK diets, other established indicators for sustainable healthy diets have been developed, for example, the World Index for Sustainability and Health (WISH), which evaluates diets for healthiness and sustainability based on the EAT-Lancet commission dietary recommendations.

### Indicators

- HMRC – Origins of food consumed in the UK, 2009 to 2020
- Kantar – Diversity within the food industry
- NDNS – Food consumption and nutritional intake at household level in UK

## Comments

This indicator is not yet feasible.

# FS9. Rate and frequency of foodbank use

## Sensitivity

The UK's reliance on food banks has been rising consistently year-on-year for nearly a decade. Food and You is a biennial national survey with a representative sample of adults aged 16 and over. It is sponsored by the FSA and covers England, Wales, and Northern Ireland. The survey collects information about the public's reported behaviours, attitudes and knowledge relating to food safety and food issues, which includes food bank use. It also measures food insecurity using the adult version of the Household Food Security Survey Module. The UK Household Longitudinal Study has also included questions on food bank use and food insecurity in selected editions of the survey, however, response rates were low (around 42% of the main wave responding sample).

## Data and methods

### Indicator

- Trussel Trust – number of people receiving 3 days' worth of emergency food by Trussell Trust foodbanks in the UK

The Trussell Trust publishes statistics twice a year on its website. The data is a measure of volume rather than unique users, and on average people needed around 2 food bank referrals in the last year. The 'Food and You' biennial national survey also collects data on food bank use.

## Comments

This indicator is currently not developed but is feasible due to data availability. The Trussell Trust data does not include food parcels distributed by independent food banks who are not part of the Trussell Trust network. The Trussell Trust food bank data is considered in the latest UK Food Security report published in 2021 and is recognised as a key data source for developing indicators on food insecurity by government departments.

# FS10. Food price change by food group

## Sensitivity

Economic shocks such as the financial crisis, disease outbreaks, and extreme weather events can adversely impact production and consumption costs, leading to spikes in food prices. Food price pressures do not seem to be adversely impacting household food security. In the last 10 years, food prices overall have fallen in real terms, but there are variations between food groups. The poorest 20% of households spend a higher proportion of their income on food and are thus more exposed to changes in food prices.

Due to recent (2022) political developments – conflict in Ukraine, Brexit, cost-of-living-crisis as well as COVID-19 and extreme events leading to crop failures – the UK has experienced spikes in food prices of some products, demonstrating the impact shocks can have on the UK food system and household expenditure. It is essential to track the prices of foods in the UK. Whilst the evidence base on food price impacts from climate shocks is limited, the 2008 food price crisis following shocks to staple crop yields, was partly weather-related and saw export bans from key countries to protect supply (97). There is considerable anecdotal evidence of food price spikes following extreme events in the UK media. Furthermore, the CCC approximate a 20% mean global food price rise by 2050 as a result of climate change (100).

## Data and methods

The aim of this indicator is to monitor trends in the affordability of a healthy diet to provide a measure of consumers' nutritional food security. The Consumer Prices Index including Owner Occupiers' Housing costs (CPIH) food groups that are analysed in this indicator serve as a proxy for some of the main foods recommended by government for a healthy diet, and look at vegetables (including potatoes), fruit, milk, cheese and eggs, fish, meat, and bread and cereals.

### Indicator

- ONS, CPIH – Index of real terms food prices for vegetables, fruit, fish, meat, milk, cheese, eggs, bread, and cereals

## Comments

This indicator is feasible. Food prices are determined by various factors. For fruit in particular, poor harvests, a fall in sterling exchange rates, or transport disruptions leading to fresh fruit being spoilt, can have an impact on consumer prices. The UK imports most of its fruit from the EU, South America, and Africa. Any issues arising in these regions as well as further down the supply chain may affect fruit prices in future. It is not clear whether the increase in fruit prices since 2011 has been driven by increased consumer preferences for imported out-of-season fruit.

# FS11. Incidence of foodborne diseases

## Sensitivity

Several epidemiological studies have shown that the incidence of diseases from bacterial contamination is sensitive to temperature, particularly salmonella and campylobacter.

## Data and methods

FSA are responsible for monitoring food safety in the UK through alerts of outbreaks and estimating foodborne disease cases. New estimates indicate that 2.4 million cases of foodborne diseases were reported in 2018, with approximately 222,000 GP presentations and 16,400 hospital admissions. Approximately 0.9 million of these cases were attributable to 13 known pathogens, Norovirus being the most common cause (383,000 cases in 2018). This data was acquired through the Foodborne Disease Estimation Model (FDEM) which is a Monte Carlo simulation model built using Microsoft Excel and the @Risk add-in (108). It provides estimates for the total foodborne disease cases in the UK as well as individual estimates for the 13 pathogens included in the infectious intestinal disease (IID2) study extension (109). The model is used by the FSA to produce annual estimates.

PHE (now UKHSA) provided outbreak data between 1 January 2001 and 31 December 2016. For each outbreak, the following data was provided: pathogen, number of cases, number of cases hospitalised, number of cases who died, and mode of transmission.

FSS – Food Standards Scotland

### Indicator

- FSA, FSS – Total number of incident notifications received by the FSA and FSS from 2010 to 2021, recalls and alerts issued by the FSA and FSS from 2010 to 2021

## Comments

This indicator is already used within public health authorities. However, attribution to climate factors needs to be carefully assessed as there are important non-climate factors that affect foodborne disease incidence.

# FS12. Development and implementation of national and or local food strategy

## Sensitivity

Managing the food system at the local level allows for context specific strategies which addresses the issues of that local authority. Developing local food system strategies allows local authorities to address specific issues more easily, as well as providing national government with robust food system data due to improved monitoring of the climate impacts on the food system.

## Data and methods

Part one of the National Food Strategy (NFS) for England was published at the end of 2020 in response to the COVID-19 crisis as well as Brexit. Part one of the NFS states that climate change is the biggest risk to food security, and the potential worst-case scenario could be multiple harvests failing worldwide limiting the availability of food. Part 2 of the government's NFS for England was published in 2022, which presents priorities for a 'resilient, healthier, and more sustainable food system that is affordable to all' and mentions the implications of climate change (110). The CCC described the strategy as a 'missed opportunity' for addressing climate risks and implementing climate adaptations to build a resilient food system.

The Global Food Security Programme (GFS) currently has 2 research programmes addressing the UK food system in a global context.

1. The Transforming UK Food Systems SPF Programme was launched in 2020 and is delivered by UK Research and Innovation (UKRI) in partnership with:

- the GFS
- Biotechnology and Biological Sciences Research Council (BBSRC)
- Economic and Social Research Council (ESRC)
- Medical Research Council (MRC)
- Natural Environment Research Council (NERC)
- Defra
- Department for Health and Social Care (DHSC)
- UKHSA
- Innovate UK
- FSA

The programme is supported by UKRI's Strategic Priorities Fund (SPF). The strategic framework is split into 6 focus areas: sustainable agricultural systems, crop and farmed animal health, food safety and nutrition, reducing waste, understanding and exploiting genomics and precision agriculture and smart technologies.

2. Resilience of the UK Food System in a Global Context (2016 to 2021). This interdisciplinary research programme is funded by BBSRC, ESRC, NERC, and the Scottish Government. It aims to help policymakers and practitioners improve the understanding of where the major vulnerabilities of the UK food system lie and how its resilience to environmental, biological, economic, social, and geopolitical shocks can be enhanced.

Additionally, key policy activities have been important for supplementing the NFS as they support the implementation of a range of interventions and strategies. Two key documents are: 'The Path to Sustainable Farming: An Agricultural Transition Plan 2021 to 2024', and 'Biodiversity 2020: A strategy for England's wildlife and ecosystem services', both led by Defra.

The UK Food Security Assessment (UKFSR) (Defra) which is updated every 3 years and was first published in 2021 provides a comprehensive assessment and presentation of indicators to monitor the UK food system. The UKFSR states that climate change threatens the long-term security of global food production and food security as a consequence. This assessment presents the state of food security to Parliament as part of the agriculture Act 2020. Whilst the report mentions and presents some of the risks from climate change on the UK food system, it does not specifically assess climate change impacts.

## Comments

This indicator would need to be developed in partnership.

# FS13. Development of dietary guidelines that embed climate change adaptation

## Sensitivity

Adaptation to climate change with regards to the food system considers how the UK population can access a healthy diet with available foods that are not climate vulnerable. Whilst UK policy calls for more sustainable and heathier diets which includes, increasing fruits, vegetables, legumes and other plant-based foods, the resilience of the food system is as important. A climate-resilient diet would theoretically prioritise foods that are not climate vulnerable and may not prioritise high consumption of plant-based foods that are at risk of crop failure, low yields and extreme weather events causing supply disruptions. As previously discussed, food system impacts from climate change may have consequential effects on food prices, availability and subsequently impact consumption. As reported in an analysis on UK fruit and vegetable supply in 2013 (97), over 30% of fruit and vegetables consumed in the UK were imported from climate vulnerable countries which is an increase by 60% compared to 1987. Therefore, mitigation strategies recommending the UK population to consume more fruits and vegetables may need to consider the implementation of adaptation strategies to climate change.

## Data and methods

No current dietary guidelines specifically consider climate change adaptation.

## Comments

This indicator would need to be developed in partnership with OHID and Defra.

# Water quality and quantity and their health impacts

Vulnerability

W1 Population affected by supply disruption – **NF**

W2 Population supplied by private wells – **P**

Exposure

W3 Drinking water quality – **P**

W4 Bathing water quality – **P**

## W1. Population affected by supply disruption

### Sensitivity

Climate change and reduced precipitation resulting from climate change will increase the likelihood of periods of water scarcity and droughts. Together with demand increases from economic and population growth this may lead to interruptions of household water supplies and associated health, social and economic impacts, particularly for vulnerable households. There is a need to better understand the potential vulnerability of water supply to drought. There is evidence from UKCP18 that summers will be drier in coming years, and the Yorkshire Water failure of supply in 1995 suggests there could be concerns in the future.

Parts of the UK, particularly in South East England, are already water stressed, and analysis of the impacts of climate change on future water supply identifies that deficits are likely by the middle of the century in other parts of England and parts of Wales. Private water supplies (PWS) are most vulnerable to current and future climate hazards that affect water quality (outbreaks) and quantity (interruption of supply), and are particularly important for more isolated communities (see indicator W2 below).

### Data and methods

Water supply disruptions include any restrictions on use, including hose pipe bans, and the use of standpipes. Restrictions on usage come in the form of temporary use bans (TUBs) and non-essential use bans (NEUBs). Some households are particularly at risk of adverse health impacts from water supply interruptions, for example, those with young children and people with chronic disease or disabilities. The number of applications for bans and the number of bans issued is collected by the water companies and it could be collected centrally.

### Comments

This indicator is not currently feasible but could be collected with appropriate linkage of data on TUBs or NEUBs with population distributions.

# W2. Population supplied by private wells

## Sensitivity

Previous assessments have shown that PWS are particularly at risk of contamination, as well as disruptions in supply. Recent hot summers (for example, 2018 and 2022) have highlighted that PWS are vulnerable to dry and warmer weather, and it is likely that as the climate continues to change more private supplies will dry out (111).

The populations served by PWS are potentially more vulnerable to waterborne disease because such supplies are often contaminated. These are often in rural locations. There is a need to map the distribution of these more vulnerable premises so that the real vulnerabilities can be measured. There should also be on-going reporting of the percentage of households served by a mains supply.

As of 2019, local authorities have reported a total of 37,702 and 13,880 PWS in England and Wales, respectively. In England, over 795,000 people live or work in premises that rely on a private supply (112, 113).

## Data and methods

There is currently no routine monitoring of the number or location of private wells or the population relying on PWS. There is no routine method of assessing the quality of PWS.

PHE (now UKHSA) undertook as survey of private wells in the southwest of England between 2011 to 2013 and found that 20% of household had one or more exceedance of health-based values for drinking water (114).

Currently systems are not able to capture contamination of water with chemicals from agriculture.

## Comments

The collection of data by PHE took a long time but could be replicated if information systems were put in place.

# W3. Drinking water quality

## Sensitivity

Public water supplies are at risk of contamination from biological or chemical hazards caused by extreme weather events (flooding and drought).

The relationship between water quality and outbreaks of waterborne diseases have been understood for many years and reflect the use of key microbial indicator organisms that show where faecal contamination is affecting potable and recreational waters. The relationships between water related disease and climate change have been reviewed previously (115, 116). The traditional bacterial indicators (*Escherichia coli*, coliforms, faecal streptococci, *Enterococcus*, *Clostridium perfringens*, sulphate reducing clostridia, aerobic plate count, *Pseudomonas aeruginosa*) and more specialised viral indicators, have contributed to a sound understanding of the reasons that water bodies become contaminated with human and animal waste (117).

The contamination of potable water supplies can be linked to rainfall (118, 119) and more severe weather events may contribute to infections related to contaminated drinking water (120, 121). Contamination of drinking water with *Cryptosporidium* spp. in England has been linked to faecal contamination from both human and animal sources, but the association between rainfall and *Cryptosporidium* spp. has reduced due to mitigation measures (122, 123).

## Data and methods

Current indicators of water quality – *Cryptosporidium, E. coli* and coliform indicators provide good protection of supplies when used with appropriate risk assessment through water safety plans within water utilities.

The quality of drinking water is regulated by the Drinking Water Inspectorate (DWI) and monitored by the individual water companies or by local authorities for PWS. Outbreaks in water supplies are reported. However, the cause of the contamination and the role of weather is not routinely reported.

There is a need for a better understanding of how local, regional, and national outbreaks occur. The exceedance reports produced by UKHSA provide an early warning of regional and national outbreaks, while local public health experts monitor changes in infectious diseases in their environments. Records flagged as exceedances may later become of no significance as a result of reporting delays. There is a need for an exceedance to be permanently logged in the individual records to allow this to be analysed retrospectively and by small areas with an underlying population, so that incidence can be measured. This would have the potential to gain a better understanding of risks in different water supply catchments that may be impacted by climate change related extreme weather.

## Comments

This indicator is feasible.

# W4. Bathing water quality

## Sensitivity

Surface water (fresh or coastal) is at risk of contamination from biological or chemical hazards caused by extreme weather events (flooding and drought).

The relationship between weather parameters and contamination in surface water is different for freshwater and coastal water. Infections in humans are through contact with water due to bathing or leisure activities. Indicator organisms are applied to bathing beaches to monitor risk, and the routine testing of faecal contamination in coastal waters is statutory. High temperatures also increase the risk of algal blooms in freshwater.

## Data and methods

Water quality at designated bathing water sites in England is assessed by the EA. From May to September, weekly assessments measure current water quality, and at a number of sites daily pollution risk forecasts are issued. Annual ratings classify each site as excellent, good, sufficient, or poor based on measurements taken over a period of up to 4 years. Information about bathing water quality in other countries in the UK is available.

## Comments

This indicator is feasible.

# Health services

### Exposure

HS1 Hospitals overheating incidence – **A**

### Outcome

HS2 Health services flooded – **P**

### Actions

HS3 Trust Green Plans that consider adaptation – **P**
HS4 Health care facilities adapted to be climate-proof – **NF**

## HS1. Hospitals overheating incidents

### Sensitivity

During hot summer days, many buildings can experience overheating, including hospitals and care homes. Overheating is defined as indoor temperature exceeding the threshold temperature of 28°C. For many buildings, this may be an infrequent issue on a few days a year where temperatures are well above average, whilst for other buildings, particularly those with poor design or inadequate cooling mechanisms, this may be much more common. A study investigated the impact of summer overheating in the built estates of 4 NHS England Acute Trusts from 2009 until 2013 (124). Further studies suggest that up to 90% of hospital wards are vulnerable to overheating during periods of high temperatures due to the type and design of buildings (125).

### Data and methods

#### Proposed indicator

- CCC2017_HCR13 – Proportion of hospital or care homes that experience overheating

NHS England Trusts are required to report instances of overheating as part of their estates return information collection; the threshold used is 28°C (126). However, changes in reporting mean that data on the ‘proportion of clinical areas with thermal monitoring’ are no longer collected, which makes the instances of overheating difficult to interpret.

### Comments

NHS England already collect data on this indicator. New overheating metrics are currently being developed by NHS Property Services to ascertain the extent of overheating impacts on their portfolio (127).

# HS2. Health services flooded

## Sensitivity

Flood events can cause disruptions to health services. This indicator looks to examine such closures or damages to health assets. It is also indicative of the vulnerability of the UK's national infrastructure to flood events. For instance, 2 flooded hospitals in Lancaster and Carlisle were running on emergency generators for several days due to power failure, and a flooded hospital in London had to divert all ambulances to other hospitals. All 3 hospitals were forced to cancel all routine appointments and operations. The number of GPs affected by flooding is not known.

## Data and methods

### Proposed indicator

- CCC2017_HCR43 – number of emergency services stations, hospitals, GP surgeries, or care homes flooded

NHS England Trusts are required to report major incidents, which would include where flood events have caused a significant disruption to services. However, the number of major incidents due to flooding, or flood damage that does not cause a major incident are not routinely reported (126).

## Comments

This indicator is technically feasible but reporting systems need to be updated.

# HS3. Trust Green Plans that consider adaptation

## Sensitivity

All NHS England Trusts are required to complete Green Plans that describe plans and strategies to achieve their emission reduction and other environmental targets, now mandated by the new Health and Social Care Act 2022. The act also covers measures to adapt to any current or predicted impacts of climate change identified within the 2008 Climate Change Act (and the UK National Climate Change Risk Assessments). Trusts and integrated care boards (ICBs) have submitted their first localised Green Plans, and every Trust and ICB also has a board-level 'climate' lead. Guidance on emission reductions accounting is fairly well developed by Greener NHS. It is hoped that guidance on adaptation will also be developed and that a 'standard' for climate resilience can be established to monitor progress in adaptation in health and social care services. The implementation of a heatwave plan could be one part of this indicator.

## Data and methods

### Proposed indicator

- CCC2017_HCR11 – numbers of hospitals, care homes, or surgeries implementing heatwaves plans

Although this indicator was proposed by CCC, data is not currently available.

Green Plans are a statutory responsibility of NHS England Trusts and Integrated Care Systems (ICSs). The data is collated by the Greener NHS Data Collection team. As part of the requirement of the NHS Standard Contract to develop a Green Plan, adaptation measures should be included by 2027 (128).

## Comments

This indicator will be feasible once an adaptation standard is developed as Green Plan reporting is an annual statutory requirement. Green Plans are expected to be updated around every 3 to 5 years. Greener NHS is working on developing guidance for Green Plans that will support adaptation.

# HS4. Health care facilities adapted to be climate-proof

## Sensitivity

To minimise distribution from severe weather such as overheating and flooding, most health care facilities need to undergo retrofitting. Adaption measures range from installing external shading to reduce overheating, to moving IT equipment to higher floors to reduce the risk of losing access to vital systems in case of flooding. As part of the requirement of the NHS Standard Contract to develop a Green Plan, adaptation measures should be included by 2027 (128). Trusts most vulnerable to flooding will work with the national NHS Estates and Facilities team to move data centres out of the basements.

## Data and methods

There is currently no system in place to monitor and evaluate if health care facilities are climate-proof. There is a need for the development of specific criteria for classifying a facility as climate-proof, this would include managing overheating and increased intensity of rainfall events. The implementation of the adaptation plans will be monitored by the Greener NHS, but the system for this is still under development.

## Comments

The data for this indicator is not yet available. There are currently no methods for assessing climate-proofing and criteria need to be developed.

# Social care services

EXPOSURE

SC1 Care home overheating incidents – **NF**

OUTCOME

SC2 Care homes flooded – **P**

## SC1. Care home overheating incidents

### Sensitivity

During hot summer days, many buildings can experience overheating, including care homes (see HS1). For many buildings, this may be an infrequent issue on a few days a year where temperatures are well above average, whilst for other buildings, particularly those with poor design or inadequate cooling mechanisms, this may be much more common. Care home residents are particularly vulnerable to heat-related mortality.

### Data and methods

#### Proposed indicator

- CCC2017_HCR13 – proportion of hospitals or care homes that experience overheating

This data is not collected by care homes.

### Comments

The data for this indicator is not yet available.

## SC2. Care homes flooded

### Sensitivity

Flood events can cause disruptions to health and social care services, with care homes particularly high risk due to the potential need to relocate vulnerable residents in a short time. This indicator looks to examine such closures or damages to residential care homes, which reduces their capability to deliver care. It is also indicative of the vulnerability of the UK's national infrastructure to flood events. Due to the issues of relocating care home residents during the flooding event, they may need to be evacuated when there is a flood warning.

## Data and methods

### Proposed indicator

- CCC2017_HCR43 – number of emergency services stations, hospitals, GP surgeries or care homes flooded

This indicator looks to examine the closure or loss of services in care homes. All organisations that the Care Quality Commission (CQC) regulates must report all service disruptions and a description of what caused it. It is however currently not possible to pull out specific causes from the CQC data base, and some of the descriptions are too vague to determine if a flooding is, for example, due to rain or a faulty pipe.

## Comments

This indicator is technically feasible but reporting systems need to be updated.

# Indicators of the health impact of climate mitigation actions

Most actions aimed at the low carbon transition have health effects. Their potential impact on population health is often very large, especially if changes of the range and scale required by the net zero pathway are achieved (129). The health impacts are also expected to occur with a short time lag because they are a consequence of fairly rapid changes in exposure or behaviour. Most of the ancillary health effects of net zero policies are, or can be, beneficial (such as reductions in outdoor air pollution; see Table 3)). Some policies may have negative consequences, for example, the potential adverse effects on the concentration of indoor air pollutants relating to home energy efficiency measures, or changes in road traffic injuries and deaths following the promotion of active travel (walking and cycling). However, research has shown the net benefit of these mitigation policies to health.

Some net zero policies may disrupt adaptation. Table 4 describes how net zero strategies may interfere with adaptation for specific climate risks to health if policies are not implemented properly with due consideration of potential disbenefits.

Mitigation indicators for public health therefore tend to fall into 2 groups:

1. Those relating to the realisation of beneficial reductions in harmful exposures or improvements in health-related behaviours from mitigation actions (sometimes known as the ‘co-benefits for health’), (for example, FS6, M1).
2. Those monitoring the occurrence of important adverse consequences of net zero mitigation actions (for example, H1, M2).

There have been several initiatives to monitor the implementation of emission reductions at national or city level (and for organisations and commercial entities). We have not reviewed these in detail but have reported indicators where there is a significant public health outcome (see Table 3).

**Table 3. Suggested indicators relating to mitigation actions that impact health**

Key for letter colouring

The availability and suitability of the indicator is indicated in column 2 with a coloured letter:
A green letter **A** indicates 'Yes, data available that could be used, or the indicator is currently in use'
A blue letter **P** indicates 'Needs new processing of existing data'.
Red letters **NF** indicate 'No feasible data available'.

| | | |
|---|---|---|
| Energy | Contribution: outdoor air pollution | M1: Energy sector contribution to ambient $PM_{2.5}$ – **NF** |
| | Contribution: outdoor air pollution | M1. Deaths attributable to energy sector ambient $PM_{2.5}$ – **NF** |
| Housing | Contribution: outdoor air pollution | M1 Housing contribution to ambient $PM_{2.5}$ – **NF** |
| | Contribution: outdoor air pollution | M1: Deaths attributable to housing ambient $PM_{2.5}$ – **NF** |
| | Indoor air quality | M2. Indoor radon = C8 – **NF** |
| | Indoor air quality | M2. (Change in) radon-related lung cancer mortality – **NF** |
| | Indoor air quality | M2. Indoor $PM_{2.5}$ = C9 – **NF** |
| | Cold | C4 Cold-related mortality – **P** |
| Food | Contribution: outdoor air pollution | M1: Agriculture contribution to ambient $PM_{2.5}$ – **NF** |
| | Contribution: outdoor air pollution | M1: Deaths attributable to agriculture ambient $PM_{2.5}$ – **NF** |
| | Red meat | FS6. Change in consumption of red and processed meat – **P** |
| | Fruit and vegetables | FS6. Change in consumption of fresh fruit and vegetables – **P** |
| Transport | Contribution: outdoor air pollution | M1: Transport contribution to ambient $PM_{2.5}$ – **NF** |
| | Contribution: outdoor air pollution | M1: Deaths attributable to transport ambient $PM_{2.5}$ – **NF** |
| | Active travel | M3. Change in active travel – **P** |
| | Active travel | M3. Active travel-related change in mortality – **P** |
| Waste | Contribution: outdoor air pollution | M1. Waste contribution to ambient $PM_{2.5}$ – **NF** |
| | Contribution: outdoor air pollution | M1. Deaths attributable to waste ambient $PM_{2.5}$ – **NF** |
| | Food waste | FS4. Food waste (tonnes per year) – **P** |

**Table 4. Risks where adaptation is likely to be affected by net zero objectives, policies, or interventions**

| CCRA3 risk or opportunity | net zero objective | Comments | Key current plans and policies to address net zero objectives at a national level [not an exhaustive list] |
|---|---|---|---|
| H1: Risk to health and wellbeing from high temperatures | • increase in energy efficiency in buildings<br>• increase in low-carbon heating systems | • high levels of insulation installed in new and existing homes can increase risk of overheating if appropriate adaptation measures are not implemented | • Energy Company Obligation<br>• Renewable Heat Incentive<br>• Scotland's Energy Efficient Strategy<br>• Prosperity for All: A Low Carbon Wales<br>• Northern Ireland Sustainability Energy Programme<br>• Review of Part L of Building Regulations (England and Wales) |
| H3. Risks from flooding | • not specific to flooding in the context of health | • flood defences have high embodied carbon<br>• Natural Flood Management (NFM) has the potential to sequester substantial amounts of carbon particularly if undertaken on a large scale involving woodland planting, soil carbon improvements and land use change | • Carbon Planning Tool (Environment Agency) and similar tools under development in Scotland and Wales<br>• nature-based solutions for carbon capture |
| H7: Air quality | • reduce emissions for energy production, industry and transport<br>• increase in energy efficiency in buildings | • reducing emissions will improve outdoor air quality and reduce the impact of future climate change exacerbating poor air quality<br>• high levels of energy efficiency in new and existing homes can increase the airtightness of the building. This can increase exposure to indoor air pollutants if appropriate ventilation measures are not implemented | • Clean Growth Strategy (2019)<br>• 25 Year Environment Plan<br>• as Risk H1 for indoor air quality<br>• review of Building Regulations Part F (England and Wales) |
| H9: Food safety and food security | • changes in land use and food production<br>• changes in food consumption (types of food, sources of food) | • food safety risks may change especially as animal products are more prone to contamination<br>• reductions from less meat in diet, or increased contamination by pesticides (for increased local production). UK's future trade relationship with EU, may result in increased dependence on domestic food supply<br>• health benefits from diets low in animal fat | • Agriculture Bill<br>• Environment Bill<br>• National Food Strategy<br>• Fisheries Bill<br>• 25 Year Environment Plan<br>• National Food Strategy |
| H12: Risks to health and social care delivery. | • reduce carbon emissions associated with buildings (energy efficiency)<br>• changes to travel and products (for example, pharmaceuticals). | • restrictions on air conditioning and space cooling measures<br>• same as H1 and H5 | • Health and Social Care Act 2022 NHS England Net Zero target<br>• NHS Long Term Plan<br>• NHS Green Plans<br>• Sustainable Development Strategy for NHS Scotland<br>• Carbon Neutral Public Sector 2030 target (Wales) |

Source: Adapted from (1)

# M1. Mortality attributable to $PM_{2.5}$ by sector

## Sensitivity

Air pollutants and greenhouse gases often have similar sources (for example combustion processes, such as in vehicle engines, fossil fuelled power plants, or other energy generation). The health benefits of mitigation through reduction in air pollution have been quantified for the UK (129 to 131). The main actions to reduce harm from air pollution are reducing emissions (mitigation rather than adaptation) although local air pollutant concentrations can be affected by weather factors.

## Data and methods

### Indicator

- PHOF_ D01 (previously 3.01) – Fraction of mortality attributable to particulate air pollution

This indicator is based on the anthropogenic fraction of $PM_{2.5}$ (so as to indicate what might be feasible to influence through policy actions). This is updated annually and calculated for each local authority in England. The data is freely available through the OHID (formerly hosted by PHE) fingertips tool from 2010 to 2019 for the old method and 2018 to 2020 for the new (132).

Public Health Wales has recently launched a similar tool, the Air Quality in Wales Health Impact Assessment Tool (133). This tool allows examination of daily (DAQI) and annual ($PM_{2.5}$, $NO_2$) levels of air pollution, broken down by health board, local authority, and income quintile for 2015 to 2018. It is also possible to filter results by age and deprivation for DAQI levels. Health effects by health board are also shown for long-term effects (134, 135).

Daily Air Quality Index (DAQI): This is a daily index of air pollution together with recommended actions and health advice. The index is numbered 1 to 10 and divided into 4 bands, low (1 to 3), moderate (4 to 6), high (7 to 9), and very high (10), to provide detail about air pollution levels in a straightforward way, similar to the sun (UV) index or pollen index. It is based on the highest concentration of 5 pollutants; $NO_2$, $SO_2$, $O_3$, $PM_{2.5}$ and $PM_{10}$. Historical DAQI is available regionally for the UK and by some agglomerations (urban areas), and a forecast is also provided.

The 2021 report of the Lancet Countdown included an indicator on ‘Mortality from Ambient Air Pollution by Sector’ as part of its mitigation actions and health co-benefits chapter (136). Estimates of sectoral source contributions to annual mean exposure to ambient $PM_{2.5}$ were calculated using the GAINS model, which combines bottom-up emission calculations with atmospheric chemistry and dispersion coefficients to produce estimates at the regional level. It is not clear that this model output would be valid at the national level for the UK.

## Comments

The PHOF indicator of air pollution mortality is already available. It is based on modelled estimates but would be sensitive to reductions in outdoor air pollution levels following mitigation measures, particularly for transport. It would be beneficial to further analyse mortality attributable to $PM_{2.5}$ by sector but this is not currently feasible for the UK.

There is some evidence that those living in more deprived areas are more exposed to poorer air quality, and there may be benefit in quantifying the air pollution benefits for different income groups. The Committee on the Medical Effects of Air Pollution (COMEAP) does not currently recommend different quantification of health effects for different age groups.

# M2. Indoor air quality

Changes in indoor air quality (including radon and $PM_{2.5}$) are important as people spend most of their time in indoor environments. Increases in indoor air pollution may reflect a potential disbenefit from home energy efficiency measures that are needed to reduce carbon emissions. Indoor environments are affected by mitigation measures that are part of energy efficiency retrofit (for example, insulation, draught reduction and so on) which could reduce exposure to ambient air pollution by reducing ingress but increase the accumulation of and exposure to indoor-sourced pollutants (for example, from cooking, household products, or indoor sources of allergens).

## Data and methods

Indoor air quality in dwellings is not widely or systematically monitored. As people spend a large amount of their time indoors, this is an environment people are strongly exposed to. Monitoring of indoor air quality could be very resource intensive to monitor at a scale sufficient to provide enough data to derive population-level statistics.

Personal air quality monitors (for example, low-cost sensors) have come to the market in recent years. These are adequate for providing qualitative indication of air pollution levels, but not yet sufficient for regulatory purposes. However, there is potential wide reach as sensor technology improves and costs reduce. $CO_2$ monitors (which increased in popularity in response to ventilation recommendations during the COVID-19 pandemic) are now being used more by individuals. However, $CO_2$ monitors only provide a proxy for ventilation and the data is not centrally collected and available.

Most toxic air pollutants, such as fine particles ($PM_{2.5}$) and $NO_2$, are not routinely measured. Radon is an important indoor air pollutant as it is a cause of lung cancer. The UKHSA currently undertakes radon monitoring, but this is done on an as-requested basis, where radon measurements packs can be ordered for homes or workplaces to monitor levels for 3 months (with results used to advise on whether radon levels are high enough to recommend remediation action). Although not routinely monitored, radon monitoring can provide useful evidence about changes in indoor exposures over time, especially in relation to home energy efficiency characteristics, if coupled with dwelling data. They may also provide a more general indication of changes to the levels of air exchange in dwellings and hence be relevant to other pollutants generated from indoor sources (which depended on air change for their dispersal).

## Comments

There is currently no large-scale monitoring of the changes in indoor air quality at the population level. Undertaking such monitoring would be expensive, however, this cost would be small compared to the enormous investments expected in the housing stock, and it could help avoid locking in unintended adverse health effects in millions of homes (137).

# M3. Active travel

Active travel (walking or cycling for transport) is considered the most sustainable and low carbon form of travel. Active travel policies exist in all devolved administrations in Great Britain.

- England: 'Gear change: a bold vision for cycling and walking' (2020)
- Scotland: 'Long-term vision for active travel in Scotland 2030'
- Wales: Active Travel (Wales) Act 2013; 'Active travel action plan for Wales'

## Sensitivity

Active travel is a very sensitive indicator of physical activity in the population. The evidence for the health benefits of regular physical activity is well established, reducing the risk of several health conditions, such as cancer, diabetes, obesity, hypertension, and depression. Physical inactivity costs the NHS up to £1 billion per annum, with further indirect costs of £8.2 billion – active travel can reduce that (138).

Estimating the impacts of changes in active travel to transport-related $CO_2$ emissions are complex (139). One study (140) estimated that changes in active travel have significant lifecycle carbon emission benefits, even in European urban contexts with already high walking and cycling shares. An increase in cycling or walking consistently and independently decreased mobility-related lifecycle $CO_2$ emissions, suggesting that active travel substituted for motorised travel – that is, the increase was not just additional (induced) travel over and above motorised travel. An average person cycling one trip per day more and driving one trip per day less for 200 days a year would decrease mobility-related lifecycle $CO_2$ emissions by about 0.5 tonnes of $CO_2$ ($tCO_2$) over a year, representing a sizeable chunk of annual per capita lifecycle $CO_2$ emissions from driving (which for example in the UK amount to approximately 1.4 $tCO_2$ per person per year) (140).

Regular walking or cycling rates vary significantly in different parts of the country according to analyses of Active Lives Adult Survey (ALAS) data (141). Indicators of walkability have been developed for some urban areas as a spatial indicator of the suitability of an area for active travel. There are currently no operational indicators used in the UK.

## Data and methods

### Indicators

- PHOF Indicator – % of adults who walk for travel at least 3 times per week
- PHOF Indicator – % of adults who cycle for travel at least 3 times per week

For these indicators, OHID uses data from the ALAS, an annual survey of residents in England conducted by Sport England (142).

The Department for Transport (DfT) also produce Active Travel Statistics (walking stages, trips, and miles per person per year, and cycling stages, trips, and miles per person per year), based on findings from the ALAS and the National Travel Survey.

Sustrans carry out an annual survey for 17 UK Walking and Cycling Index cities (143). The survey is representative of all adult residents, not just those who walk, wheel or cycle. The following indicators are used and are disaggregated by gender, sexuality, disability, ethnicity, age, and socio-economic group:

- proportion of residents who walk or wheel at least 5 days a week
- proportion of residents who think walking or wheeling safety in their local area is good
- proportion of residents who cycle at least once a week
- proportion of residents who think cycling safety in their local area is good

There are also London-specific active travel indicators. The London Boroughs Healthy Streets Scorecard sets out data to show the health of each borough's streets according to 9 indicators, including one indicator on rates of active travel. Data is taken from the ALAS. Furthermore, the London Travel Demand Survey is conducted annually, and the results inform the Travel in London reports. These reports summarise trends and developments in travel and transport in Greater London, including walking and cycling (disaggregated by number of trips, proportion of trips, location (Inner, Outer, or Greater London), and gender).

There are emerging opportunities to link observed transport data to personal information from apps such as STRAVA (personal monitoring of walking, running, and cycling). Other countries are exploring citizen science methods to better understand active travel patterns.

The 2021 report of the Lancet Countdown on health and climate have included mitigation indicators around sustainable and healthy transport (136). The report highlights the need for active travel infrastructure to be rolled out with consideration of sociocultural inequities.

## Comments

Overall, there are several indicators used to measure active travel at the national or local level. However, active travel is often not regionally representative. Further disaggregation would be useful with respect to both place and population groups. There are some limitations to current indicators, including:

- household surveys are limited, episodic and do not give a good picture of changing trends
- surveys could be linked to other types of environmental behaviours (for example, diet) which would be more informative
- active travel is associated with an area’s walkability – including walkability indicators would be beneficial

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