

Health Climate Change impacts report card technical paper

6. Impact of extreme weather events and climate change for health and social care systems.

Sarah Curtis¹, Alistair Fair², Jonathan Wistow¹, Dimitri Val³, Katie Oven¹.

¹Durham University;

²Cambridge University;

³Heriot-Watt University.

Email: s.e.curtis@durham.ac.uk

Key findings

- **It is challenging to produce reliable information about future risks of extreme weather events for health and social care, particularly at local scale.**
- **Most projection exercises do not include local estimates of future risks and costs, or make allowance for potential effects of adaptation.**
- **Impacts of climate change and extreme weather reflect the way that health and social care operates as a 'system of systems' including built infrastructures and also 'social and institutional infrastructures' made up of human resources and practices.**
- **Impacts of extreme weather and climate are not only of concern for the emergency services and preparedness and response planning by health and social care providers is also advisable.**
- **Potential adaptation measures vary in terms of sustainability, given requirements for carbon reduction and reduced public sector funding.**
- **A number of low-energy, and relatively low cost options are available to adapt existing buildings including hospitals and design new buildings for improved thermal comfort and operational resilience during heatwaves.**
- **Network flow models have potential to assist the local development of cost effective adaptation strategies for the wider systems of physical infrastructure, of which hospitals are a part.**
- **The literature reports recent developments in surveillance and monitoring systems to support adaptive responses to extreme weather.**
- **Understanding the impacts on health and social care systems of climate change and extreme weather requires co-production of knowledge by diverse stakeholders, and raises issues of equity and inclusivity**

Executive summary of the research findings reviewed in this report:

Impacts of heatwaves (Section 5.1)

- Heatwaves cause problems with the functionality of hospitals including medical equipment and storage of medicines.
- Heatwaves affect thermal comfort for patients and staff in hospitals.
- Structural design features can affect thermal comfort and functionality of hospitals during heatwaves;
- Hospital admissions for respiratory diseases are observed to increase during heatwaves. Also syndromic surveillance data show increased emergency department and GP activity for some conditions likely to be associated with heatwaves, and ambulance call out rates have been shown to increase during very hot weather.
- It is likely that heatwaves also have adverse consequences for patients being treated for other conditions, including cardiovascular diseases and mental illness, though these may not be reflected in additional demands for health care.

- There is relatively little evidence available on impacts of extreme heat in facilities such as care homes though some studies suggest that problems may occur, associated with poorly adapted equipment, structural design and care practices, so more research is needed on the general extent of such problems, especially since mortality risks during heatwaves are particularly high for older people in care homes.
- Impacts of extreme heat on the wider networks of built infrastructure and utilities that support health care systems are not very significant given the levels of extreme temperatures observed to date in the UK.
- Extreme weather plans for the NHS include special measures to be taken when temperatures reach thresholds which vary across the UK.

Impacts of coldwaves (section 5.2)

- Although utility systems such as power supplies are unlikely to be affected during cold conditions observed in the UK, infrastructure networks, particularly transport systems are likely to be disrupted in cold weather, creating difficulties of access for patients needing to use health facilities and for domiciliary care staff in reaching their clients in their homes. Ambulance response times also become longer during very cold weather.
- Impacts on health service activity arising from cold waves have been observed in terms of increased rates of consultation and treatment for respiratory conditions and emergency treatment for injuries resulting from falls in ice and snow, and these risks are most pronounced for older people.
- Hospital admissions due to cardiovascular diseases have not been observed to increase due to coldwaves, although mortality rates from this cause are higher during coldwaves.
- Individual physiological risk factors such as age and pre-existing health problems have been shown to relate to risk of health impacts from coldwaves, but the statistical evidence for socio-economic risk factors affecting coldwave impacts is not very robust.

Flooding impacts (Section 5.3)

- Flood events can interrupt health service delivery and accessibility for local populations and may also disrupt other essential infrastructure on which health services depend.
- 'Direct' impacts on health in the UK due to flooding may particularly relate to mental illness, but although some research is suggestive of these impacts, the statistical evidence from the UK is not very robust and it is not clear how health service activity may be affected.
- Relatively little research exists on how levels of demand for, and use of health services are impacted by flooding.

Potential future impacts of extreme weather on health services demand due to mortality and morbidity in the UK (evidence from other countries and scenario models in the UK) (Section 6)

- Research to estimate future impacts of extreme weather events on health services faces several challenges which make forecasting difficult and potentially unreliable. These include: relative imprecision in projections for extreme events; limited consideration of local factors

such as urban heat island effects; difficulties in anticipating levels of adaptation to extreme events.

- Climate change forecasts suggest that we are likely to experience more heatwaves and that intense rainfall and higher sea levels are likely to lead to more frequent flooding events. Risks of cold waves may reduce in future, although some research suggests that in the immediate future they may continue to occur under conditions of climate change.
- Projections for the UK, as well as studies from other countries suggest we might expect future increases in hospital admissions due to illness associated with high temperatures and high ozone levels.
- There is little evidence available on likely future impacts on health and health care use associated with flooding in the UK.
- We have relatively little evidence regarding the future impacts of climate change on use of primary and ambulatory care.

7. *Adaptation of infrastructure design and practice for improved preparedness and performance during extreme weather*

- It is recognized internationally that adaptation strategies for climate change are a necessary and important part of health and social care planning (not limited to emergency response agencies).
- These strategies need to be framed within a 'system-of-systems' approach to address the connections between built, social and institutional infrastructures which need to adapt.
- The NHS and Public Health England have begun to operationalise surveillance and warning systems during extreme weather events, designed to improve responses and outcomes.
- Collective adaptation will be necessary and this calls for greater collaboration and cooperation, including partners in the wider social infrastructure as well as among the formal institutional sectors of health and social care.
- Processes of adaptation in health and health care bring into question issues of social inclusion and equity in the collective response to climate change.

1. Introduction and Scope

This report was commissioned by the *Living With Environmental Change* (LWEC) programme. It provides a review of findings from research on the impacts of climate change and extreme weather conditions on physical, institutional and social infrastructures supporting health care of the United Kingdom population.

An assessment of research on health effects of climate change in the UK, produced in 2012 for the Health Protection Agency and the Environment Agency (Hames and Vardoulakis 2012, Vardoulakis and Heaviside 2012), provided a comprehensive review of much of the research published up to that time, particularly from an epidemiological standpoint. We concentrate below on more recent research, and particularly on evidence relating to impacts on health and social care infrastructures in the UK of extreme weather events under conditions of climate change.

Extreme weather events considered below include heatwaves, coldwaves and pluvial, fluvial and coastal flooding. Trends in these extreme events associated with climate change are discussed in other reports in this series. Changes to prevailing *average* climatic conditions and the implications for routine health service provision are not reviewed here in detail. However, the literature does include discussion of likely alterations to general prevalence and incidence of various health conditions arising from future climate change, reviewed in other reports in this series.

2. Conceptual framework for this report

This report conceptualizes health care infrastructure as the supporting systems which are important for provision of health care. The World Health Organisation has defined a health system as follows:

A health system is the sum total of all the organizations, institutions and resources whose primary purpose is to improve health. A health system needs staff, funds, information, supplies, transport, communications and overall guidance and direction. And it needs to provide services that are responsive and financially fair, while treating people decently. (WHO 2005)

Consistent with this definition and as proposed by other authors (Zaidi and Pelling 2013, Castelli et al. 2011, Landstroem et al. 2011) we consider physical, institutional and social infrastructures as part of a complex system which are important for the sustainability of essential functions for societies such as health care.

We have therefore assessed research on health system impacts of extreme weather on health care in terms of 3 sets of interrelated processes:

- performance during extreme weather of **built infrastructures** which are important for health care delivery (including individual buildings, but also networks of built infrastructure comprising interoperability of facilities, utilities and transport networks on which health facilities depend for their operation);
- performance under extreme weather conditions of **human and social infrastructure** essential for the provision of health care (comprised of human resources and professional and social practices);
- Impacts due to unusual **pressure and type of demand for health care** in the UK population (associated with population health effects of extreme weather events, that are moderated by varying vulnerability of different population groups).

These processes combine to produce impacts to health care in ways that make it important to take a 'whole system' perspective. The risks to health systems associated with extreme weather impacts result from interaction of the *hazards* presented by extreme weather events with the *vulnerabilities or resilience* of the system (Oven et al. 2012, Curtis and Oven 2012).

In this review we consider evidence regarding the present and projected future impacts of extreme weather on health and social care systems and research which has examined the potential of preparedness and adaptation measures that may enhance resilience.

3. Background to this review: wider evidence on climate and its relationship to health

This review should be considered in the context of other evidence which is summarised in other reports in this series. To avoid overlap with these, we do not discuss in detail the evidence regarding observed or future weather patterns in the country as a whole, or on the health effects of extreme weather events on population health in general (eg effects on mortality rates). This review focuses on evidence regarding impacts of extreme weather on health and social care systems, which is relevant for local as well as national planning for preparedness and response. Locally relevant information is especially useful for many users of this research, since planning for the health and social care system needs to be appropriate for conditions which are complex and diverse from one area to another.

In addition to climate projections for the country as a whole (reviewed in other reports) research has explored the local variability of present and estimated future projections of risks of extreme weather events. The capacity of the latest weather generator technology has been tested for assessment of extreme temperatures at subnational level in the UK (Oven *et al.* 2012) and estimates are available showing local variability of risks of flooding (Foresight 2004). More recent updates on local flood risk are also available from the Environment Agency eg (Environment_Agency 2014). Methods for assessment of climate hazards within urban areas have also been developed (Gwilliam *et al.* 2006, Mavrogianni *et al.* 2011).

Furthermore, population vulnerability and resilience to extreme weather may be locally variable. It depends on physiological vulnerability of members of the population, associated with their pre-existing medical status, but also on socio-economic characteristics and local environmental conditions (Mcgregor, Pelling M. and Wolf 2007, Zaidi and Pelling 2013, Landstroem *et al.* 2011, Lindley *et al.* 2011). Vulnerability or resilience is also associated with the capacity and readiness of local organizations to work together to support continuity of care during extreme weather (Curtis *et al.* 2014, Wistow 2013, Child and Rodrigues 2011, Cilliers 2001, Office_for_National_Statistics 2013).

It is also important to note that although they are outside the scope of this review, other changes to the wider environment in which health and social care is provided may be very important for outcomes. These include changes to the organization of health and social care services and the level and manner of funding.

4. Review method

As outlined above, the aim of the review was to provide an assessment of key messages from the literature regarding locally variable impacts of climate changes associated with exposure to extreme weather events, (including temperature extremes and flooding), on health care systems in the UK, both at present and in the future (up to 2050). The review aimed to consider literature on impacts relating to *pressure of demand, performance of built infrastructure and human resources and practices*. Given this broad ranging aim, and the diversity of different types of sources and disciplines that are represented in the literature, we have not attempted a fully systematic review, as defined in the literature on review methodology (Bambra 2011). This report has been compiled first by drawing upon literature reviews previously prepared for projects supported by the LWEC *Adaptation and Resilience to Climate Change* programme (<http://www.lwec.org.uk/activities/arcc>) and by ESRC and EUFP7 (see acknowledgements). A number of key reviews and assessments produced recently for government agencies were also considered (Defra 2012, DEFRA 2013, Department of Health 2011, Department_of_Health 2002, Foresight 2004, Hames and Vardoulakis 2012, Intergovernmental_Panel_on_Climate_Change 2011, Menne and Murray 2013, Pitt 2007, Public_Health_England 2013, Castelli et al. 2011, WHO Regional Office for Europe 2002, Vardoulakis and Heaviside 2012). These were supplemented by an automated search for relevant literature published since 2010, on the online search engines *Web of Science* and *PubMed*, using the following terms: *climate change, heat, cold, flood, health care, health services*, combined with manual selection of relevant articles identified through this search.

This overview generated findings relating to: current sensitivity of health care infrastructure to extreme weather conditions; potential future impacts of extreme weather up to 2050-80; potential for impacts to be avoided through adaptation strategies. For the sources covered in this review there are some ***difficulties in summarising the 'strength of the evidence'*** across the whole field of research. For the reasons outlined below we considered it inappropriate to offer assessments of the strength of the evidence.

Few studies follow strictly comparable methodologies, so it is difficult, for example, to determine from the literature a consistently measured indication of the scale of the impact and whether this varies systematically in relation to the severity of the extreme weather event. Some studies have examined impacts relative to temperature above or below a threshold when the impact is thought to become most significant, while others have examined the temperature/outcome relationship over the whole range of varying temperatures about the most equitable level. Also there are issues relating to the *period of time* over which it is appropriate to assess the lagged impacts of extreme weather events, and this may depend on the type of hazard. Studies of impacts of extreme temperatures are mainly observed in the period within a few days of the extreme event. In contrast, flooding impacts have been observed over a longer period of months following a flood, probably because flood damage typically has a more persistent impact on health determinants than the shorter run effects of extreme hot or cold weather.

Measuring changes in service activity across all or part of the health service system is difficult when there is no routine surveillance mechanism generating longitudinal service use data in a way that can be used to assess impacts of localised weather related events, such as flooding. Some studies also lack any rigorous method to assess exposure to an extreme weather event, making it difficult to reliably identify extreme weather impacts. The study designs are also often *limited in their ability to control for other factors*, in addition to extreme weather, that may affect the outcomes of interest.

While it is important to develop approaches to assess the cost implications of different extreme weather impacts and adaptation options, there are some **major challenges in costing** some of the essential elements. For example, the concept of a 'statistical life' used to assess mortality costs to society of extreme weather events is based on a number of important assumptions (Huang *et al.* 2013) and the CCRA report suggests that at local scale, economic cost estimates may not be reliable (Field 2012).

A significant part of the research on performance under extreme weather conditions of the built infrastructures supporting health care is concerned with design of *individual buildings*. In addition, a smaller body of research reviewed here suggests that such buildings should be considered as parts of a **'system-of-systems' model** of health care infrastructure. This involves consideration of the infrastructure *networks* such as power, water, sewage and communication systems that are essential for hospitals to function and deliver care to the populations in their catchment areas (Holden *et al.* 2013).

A number of well conducted qualitative case studies in the UK provide very valuable insights into individual or localised experience. Statistical criteria for 'strength of evidence' treat the evidence from these studies as relatively weak, since they cannot be generalised to other settings across the country. However, especially with respect to adaptation of local institutional and social infrastructure, such case studies are important for helping to communicate examples for scenario planning (Carlsen, Dreborg and Wikman-Svahn 2013, Ebi 2014) and development of good practice, and there is some scope to apply 'constant comparison' methods (Strauss and Corbin 1990) to assess how far the messages from different case studies are consistent. Thus it might be argued that knowledge from qualitative and local case study research is currently undervalued in conventional hierarchies of research evidence, especially with regard to social and institutional interventions and impacts (Child and Rodrigues 2011). **We therefore make reference below to qualitative as well as quantitative research** that has explored the impact of extreme weather on social and institutional infrastructures and on health and demand for health care in the population.

5. Findings regarding observed impacts of extreme weather on health service infrastructure

In this section we summarise evidence regarding the impacts of extreme weather on health and social care systems that have been observed and reported in the research literature. This review focuses on impacts on the functionality of health and social care infrastructures and on

health service use. For some diseases, the impacts on population health reviewed in other record cards are also reflected within the health service, as they result in changes in service use. However, this is not always the case since changes in mortality due to some causes of death are observed during extreme weather events but are not reflected in changes in service use.

5.1 impacts of heatwaves

The evidence reviewed below reports the following observations regarding heatwave impacts on health systems:

- **heatwaves cause problems with the functionality of hospitals including medical equipment and storage of medicines;**
- **heatwaves affect thermal comfort for patients and staff;**
- **Structural design features can affect thermal comfort and functionality of hospitals during heatwaves;**
- **Hospital admissions for respiratory diseases are observed to increase during heatwaves. Also syndromic surveillance data show increased emergency department and GP activity for some conditions likely to be associated with heatwaves, and ambulance call out rates have been shown to increase during very hot weather.**
- **It is likely that heatwaves also have adverse consequences for patients being treated for other conditions including cardiovascular diseases and mental illness, though these may not be reflected in additional demands for health care;**
- **There is relatively little evidence available on impacts of extreme heat in other facilities such as care homes though some studies suggest that problems may occur, associated with poorly adapted equipment, structural design and care practices, so more research is needed on the general extent of such problems, especially since mortality risks during heatwaves are particularly high for older people in care homes.**
- **Impact of extreme heat on the wider networks of built infrastructure and utilities that support health care systems are not very significant given the levels of extreme temperatures observed to date in the UK;**
- **Extreme weather plans for the NHS include special measures to be taken when temperatures reach thresholds which vary across the UK.**

Heat waves impact the **functionality of individual buildings** used to deliver health care. Recent policy attention has focused on heat related risks for built infrastructures, including those relevant to the health service (Defra 2012). A recent US review also suggested that the climate change impacts on infrastructure needed to be reviewed to ensure resilience to heat (Office_for_National_Statistics 2013). A WHO report (WHO 2009) and an overview of evidence (Carmichael *et al.* 2013) summarise a number of technical problems in the delivery of care experienced when hospitals overheated during the 2003 heatwave in the UK (based on public media reports). Problems may include failure of essential refrigeration systems, impairment of

the efficiency of drugs; disruption of IT systems and laboratory work as well as impacts on thermal comfort.

During heatwaves UK ***hospitals can be uncomfortably hot*** with effects including high night time temperatures that may make sleep difficult ((Lomas and Giridharan 2012, Lomas et al. 2012, Short et al. 2012). Overheating in parts of the building may also occur under more moderate climatic conditions due to poor heating system control strategies with one 'set point' activating the heating across a whole hospital, regardless of varied internal uses and conditions. The Chartered Institute of Building Services Engineers has published guidance in respect of ventilation, illumination and air conditioning (CIBSE 2002, CIBSE 2005, CIBSE 2012) .

Structural design intended to meet other requirements in a hospital may compromise performance in terms of thermal regulation. For example, in high rise buildings, or in psychiatric settings where hospitalization may not be voluntary, safety protocols now require that windows typically only open 100mm, or are locked shut. According to research in a UK hospital (Lomas et al. 2012) and guidance from Scotland (Lomas et al. 2012, Health_Facilities_Scotland 2006) this reduces natural ventilation and produces thermal discomfort in hot weather. For example, in a qualitative study this was reported as detracting from the therapeutic quality of a recently built psychiatric hospital (Curtis et al. 2013). Lightweight suspended ceilings mask the thermal mass of buildings, which would normally retain coolness in summer (Short et al. 2012). Internal courtyards, essential for natural ventilation and daylight, have been filled in, creating buildings that are more dependent on mechanical air conditioning and artificial light (Giridharan et al. 2013). Temporary 'modular' buildings are widely used in the NHS but are lightweight structures that overheat as temperatures rise (Lomas et al. 2012). In contrast with these thermal regulation problems in newer hospital buildings, older, more traditionally built hospitals were designed to rely on wider opening windows for natural ventilation and passive cooling (Thompson and Goldin 1976) and research conducted under the LWEC programme confirms that 'Nightingale' Hospital wards, incorporating larger, communal wards and wide opening windows are more 'passively' resilient in high temperatures (Lomas et al. 2012).

Conditions in nursing homes are relatively under-researched, and further evidence is probably needed. Nursing homes comprise another crucial part of the built infrastructure in respect of risks associated with heatwaves, especially as they provide long term accommodation for residents whose age and health status makes them particularly vulnerable to very high temperatures. Furthermore, research in England and Wales 1993- 2003 suggested that the heatwave related mortality risk (controlling for age) was greater for older people living in nursing homes than those living in the community (Hajat, Kovats and Lachowycz 2007) and this is also noted in other international reviews (Astrom, Bertil and Joacim 2011, Mason, Andrews and Upton 2010) which include reference to UK research (Abrahamson et al. 2008). A local case study using participant observation suggested that problems of restrictions on window opening, and prohibition of door wedges to hold doors open restricted ventilation in hot weather. Also protective barriers around beds made it more difficult for highly dependent residents to adjust their position in bed for thermal comfort and the management of the central

heating control system was limited (Brown and Walker 2008). Some similar conclusions are drawn from observational and qualitative interview research in residential care homes in two case study areas in London (Zaidi and Pelling 2013), which found that even in new facilities, the built design did not facilitate heatwave resilience. There was little resource for retrofitting or mitigating equipment, such as fans for cooling, and features designed to counter cold weather risk, such as window restrictors tended to exacerbate the risks of overheating. Also access to internet and communication systems broadcasting heatwave alerts was limited (Zaidi and Pelling 2013).

Impacts of heatwaves on the **performance of the wider built infrastructure network** supporting health care in the UK are rare, or relatively insignificant, under current climatic conditions. A review of relevant literature (Oven *et al.* 2012) noted that the temperatures at which infrastructure networks may be impaired are generally more extreme than those producing physiological stress on the human body, or causing uncomfortable indoor conditions within a building. For example, Electricity Grid transmission components are designed with an ambient heat tolerance of 40 °C (National Grid Electricity Transmission PLC 2010). In an international survey of electricity power failures and their impact on health care systems (Klinger, Landeg and Murray 2014) only 1 of 52 significant power outages due to extreme weather were associated with heat. Other ARCC projects summarised on <http://www.arcc-network.org.uk/project-summaries/> such as FUTURENET, SNAC, CREW have investigated the impact of heat on wider networks of built infrastructure such as domestic buildings and transport infrastructure.

Health care activity impacts of heatwaves in the UK depend on the health service response to changes in population health. Since the absolute temperature threshold considered likely to trigger a significant rise in mortality varies according to local prevailing average temperature, there is regional variation in the absolute temperatures now treated as critical for intervention under National Health Service (NHS) according to protocols for heat alerts (from 28 °C in the North East to 32 °C in London) (NHS 2010). These alerts should trigger service activity including additional checks on vulnerable patients. However, research which has directly measured the impact on service activity associated with heatwaves is less extensive than for health outcomes such as mortality (reported in other reviews in this series). A particularly relevant study in 12 European cities, including London, examined hospitalization rates for cardiovascular and respiratory causes (Michelozzi *et al.* 2009) showed that in London, between 1992 and 2000, admissions due to respiratory illness for all age groups increased 1.7% for every 1 °C above the city specific 90th centile apparent temperature and for those over 75 years admissions increased by 4.9%. The Public Health England Syndromic Surveillance System provides weekly reports on patterns of service use in different parts of the health service system including a sentinel survey of 2900 GP practices, emergency units and 'NHS Direct' telephone advisory services. It provides almost real time assessment of impacts on health service activity associated with morbidity during heat waves (<http://www.hpa.org.uk/Topics/InfectiousDiseases/InfectionsAZ/RealtimeSyndromicSurveillance/HeatwaveSurveillance/>). A national study of heatwave outcomes in summer 2011 (Green *et al.* 2012) reported (but without providing details) that a rise in service activity associated with

morbidity in the population was recorded during this heatwave by the Public Health England Syndromic Surveillance System. Change in health service activity (in emergency departments and GP practices) was also monitored during a heatwave in 2013 using the Syndromic Surveillance System and minor increases in heatstroke morbidity were detected, although emergency department attendances for cardiac illness fell during the heatwave (Elliot *et al.* 2014). It has also been reported that during the heat wave of August 2003, the number of ambulance call-outs increased by up to a third (Thornes *et al.* 2014).

Some research examines **health outcomes for those already receiving health care**, though it is less clear how this translates into additional health and social care activity. A study of patients with mental illness from a nationally representative cohort sample of general practices showed an overall increase in risk of death of 4.9% (95% CI 2.0-7.8) per 1°C increase in temperature above the 93rd percentile of the annual temperature distribution (Page *et al.* 2012). An international review of studies of preterm birth associated with extreme heat (Carolan-Olah and Frankowska 2014) included one study using time series data from a maternity unit in London for the period 1988 to 2000 (Lee *et al.* 2008). Lee and colleagues assessed cumulative exposure for up to a week prior to birth and found that atmospheric conditions including high temperatures and air pollution showed no association with the risk of preterm birth. Cardiovascular disease risk for patients already being treated for cardiovascular conditions shows a relationship to higher temperatures in the UK. A study at a London clinic treating patients with implantable cardioverter defibrillators showed some increase in serious cardiac arrhythmias associated with higher temperatures (McGuinn *et al.* 2013).

5.2 Impacts of Coldwaves

The evidence reviewed below reports that the following impacts of cold waves on health care systems have been observed:

- **Although utility systems such as power supplies are unlikely to be affected during cold conditions observed in the UK, infrastructure networks, particularly transport systems are likely to be disrupted in cold weather, creating difficulties of access for patients needing to use health facilities and for domiciliary care staff in reaching their clients in their homes. Ambulance response times also fall during very cold weather.**
- **Impacts on health service activity arising from cold waves have been observed in terms of increased rates of consultation and treatment for respiratory conditions and emergency treatment for injuries resulting from falls in ice and snow and the risks are most pronounced for older people.**
- **Hospital admissions due to cardiovascular diseases have not been observed to increase due to coldwaves, although mortality rates from this cause are higher during coldwaves.**
- **Individual physiological risk factors such as age and pre-existing health problems have been shown to relate to risk of health impacts from coldwaves, but**

the statistical evidence for socio-economic risk factors affecting coldwave impacts is not very robust.

Most of the relevant evidence relates to **impacts on wider built infrastructure and communications networks that are essential for health and social care**, National Grid electricity transmission systems are designed to withstand indoor temperatures down to -5 °C and outdoor conditions down to -25 °C (National Grid Electricity Transmission PLC 2010, Oven *et al.* 2012). Case studies show that temperatures at or below freezing can restrict road and footpath access to health and other facilities, especially for more vulnerable older people (Hughes *et al.* 2004, Oven *et al.* 2012, Skinner, Yantzi and Rosenberg 2009, Wistow 2013). Accounts of local case studies from the cold winters experienced recently in the UK (Curtis *et al.* 2014, Wistow 2013) showed that extended periods of freezing weather had significantly impacted on connectivity through the health care system, especially due to impacts on the road transport system, and reduced access to health and social care services. Evidence from local case studies also shows that disruption of transport connections during extended periods when snow is lying uncleared from the road network disrupts the operation of informal social infrastructure systems provided by family and neighbours that are very important for care of vulnerable groups such as frail older people and others with long term physical or mental illnesses (Curtis *et al.* 2012b, Dominelli 2013, Menne and Murray 2013, Oven *et al.* 2011, Oven *et al.* 2012, Skinner *et al.* 2009, Wistow 2013, BIOCICCC 2011, Curtis *et al.* 2012a). Analysis of ambulance response times during the cold weather of 2010-11 showed that for every reduction of air temperature by 1 degrees C there was a reduction of 1.3% in performance (Thornes *et al.* 2014), which may be due partly to increased demand as well as difficult road conditions.

Studies of the impacts of coldwaves on **health care activity** in the UK have observed that up to 15 days following each 1°C fall in temperature below 5°C, consultations for respiratory disease in study practices in London increased by 10.5% for respiratory consultations (Hajat and Haines 2002). Cardiovascular disease consultation rates did not show a significant change associated with temperature in this study. In an extension of this research to 16 locations across the UK (Hajat, Bird and Haines 2004) an increase in consultations for respiratory diseases was also consistently reported for other parts of the country. The largest impact was for practices in Norwich, East Anglia, for which a 19.0% increase in consultations for lower respiratory tract illnesses (95% CI 13.6, 24.7) was associated with each 1°C drop in mean temperature below 5 °C observed 0-20 days before the day of consultation. Emergency hospital admissions due to injuries from falls on snow and ice vary significantly from year to year and reached 16,604 in England in the relatively severe winter of 2009/10, costing an estimated £42m in NHS inpatient care (Beynon *et al.* 2011). Generally northern areas showed the largest increases in consultation rates with falling temperatures. Emergency Department activity in the UK during cold spells in the winter of 2010-11 was monitored using the Syndromic Surveillance System, showing that cold related health conditions increased as a proportion of total emergency department activity from 3% to 7% and that cold related fractures among older people (particularly women) showed a particularly marked increase just after a drop in winter temperatures (Hughes *et al.* 2014).

Some research which has assessed evidence **for risk factors associated with health impacts of cold weather** suggests that, at least at the ecological level, risks may depend more on age and preexisting morbidity than individual's socioeconomic status. Research in South Yorkshire (Maheswaran *et al.* 2004) found no evidence of significant variation by area socio-economic deprivation in winter excess mortality or emergency hospital admission. For mortality similar findings were reported for Croydon near London (Shah and Peacock 1999). A study of elderly people in Britain (Wilkinson *et al.* 2004) also found no evidence of variation linked to area socio-economic indicator in winter excess mortality, though for older people with respiratory conditions winter excess mortality risks were 20% higher than for others. However these studies did not use individual data on socio-economic position and the evidence for socio-economic risk factors is probably not very robust.

5.3 Flooding impacts

The evidence reviewed suggests that:

- **Flood events can interrupt health service delivery and accessibility for local populations and may also disrupt other essential infrastructure on which health services depend.**
- **'Direct' impacts on health in the UK due to flooding may particularly relate to mental illness, but although qualitative research is very suggestive of these impacts the statistical evidence from the UK is not very robust.**
- **relatively little research exists on how levels of demand for and use of health services are impacted by flooding.**

A recent review for WHO (Menne and Murray 2013) summarises evidence from Europe of **flood impacts on physical infrastructures supporting health services** including flooded health facilities (sometimes resulting in evacuation of patients), interruptions to power and water supplies, safety of and access to patient records, interruption to ambulance services, continuity of outreach and community care. For wider infrastructure systems, thresholds for assessment of flood risk are based on geographical position in relation to flood risk zones and the related return periods of floods of specific depths (Zahran *et al.* 2008), and risk assessments are made locally rather than nationally. Key infrastructure systems may currently have a degree of tolerance of local flooding. For example electricity substations should be resilient to flooding up to a depth of 300mm (National Grid Electricity Transmission PLC 2010, Oven *et al.* 2012). However, reports of local experience, show that flooding to less than this depth may interrupt road access for patients to health services and for community care professionals delivering domiciliary care (Curtis *et al.* 2012b, Menne and Murray 2013, Oven *et al.* 2011, Oven *et al.* 2012, Wistow 2013).

'Direct' health impacts of flooding may also impact on health service activity. Floods in domestic buildings may involve risk of injuries due to collapse resulting from pressure if water levels inside and outside differ by more than 1m, respiratory illness due to mould and microbes

during long term exposure to damp in flooded buildings (Menne and Murray 2013). Direct health impacts of floods in the UK are summarized in the National Flood Emergency Framework (DEFRA 2013) in terms of: risks for drowning; injury by submerged or floating debris, fire or electrocution; toxicity or infection linked to water shortages or contamination, heart attacks; psychological distress and mental illness. This policy document draws especially on evidence relating to the UK from the WHO review (Menne and Murray 2013). While mortality directly inflicted by floods in the UK is comparatively rare (e.g. 13 flood related deaths reported during severe flooding in 2007 (Menne and Murray 2013)) there is evidence for mental and physical morbidity associated with exposure to flooding. This issue has been investigated in UK research. However these are cross sectional studies, and lack of adequate controls for pre-existing mental health status of those surveyed before the flood makes it difficult to assess how much of the risk of illness reported after a flood is likely to be directly attributable to flood exposure. Following serious flooding in 2007, a retrospective study (3 - 6 months after the event) reported impacts of flooding based on a postal/telephone questionnaire supplemented with face to face interviews (Paranjothy *et al.* 2011) with response rates 38% (Yorkshire) and 14% (Worcestershire) and a total responding sample of 2266. Comparisons between those exposed/not to flooding were made using measures of self reported mental health. People who perceived negative impact on finances were more likely to report psychological distress (Odds Ratio 2.5, 1.8-3.4), probable anxiety (Odds Ratio 1.8, Confidence Interval 1.3-2.7) probable depression (OR 2.0, C.I. 1.3-2.9) and probable PTSD (OR 3.2, V.I. 2.0-5.2). These findings are echoed in a report of a government inquiry (Pitt 2007) of the flooding in 2007, which included a survey of 647 households. The survey included collection of data on health and wellbeing and concluded that self-reported symptoms of mental disorders, distress and PTSD were significantly greater for those suffering disruption to essential services. In a survey of 440 people living in 2 local areas affected by flooding, with no comparator group from outside the flood affected areas, (Mason *et al.* 2010) found that those who were forced to vacate their homes due to flooding (indicating more severe flood exposure) had significantly higher risks of reporting anxiety or depression, with odds ratio over 2.00 compared with others in the sample, after controlling for information on coping mechanisms that helped to reduce the psychological impacts.

Qualitative studies have also explored the causes of the psychological impacts of flooding. A review of the evidence linking floods to psychological impacts (Curtis 2010) drew attention to very similar findings from two qualitative studies in different parts of the UK (Carroll *et al.* 2010, Carroll *et al.* 2009, Tunstall *et al.* 2006) which illustrate the individual experience of long term distress and reported symptoms very similar to those in survey instruments designed to measure post traumatic disorder.

The WHO review of health impacts of flooding (Menne and Murray 2013) concluded that, although there are population level studies of health impacts (see other reviews in this series) ***relatively little research exists on how levels of demand for health services are impacted by flooding.*** This seems to be a gap in the UK literature. Such research is difficult to conduct because effects of flooding are restricted to relatively limited geographical areas. Most of the

evidence relates to impacts through damage to built infrastructure (reviewed here) which impacts on capacity to meet normal demands for care.

6. Potential future impacts of extreme weather on health services demand due to mortality and morbidity in the UK (evidence from other countries and scenario models in the UK)

The evidence reviewed suggests that:

- **Research to estimate future impacts of extreme weather events on health services faces several challenges which make forecasting difficult and potentially unreliable. These include: relative imprecision in projections for extreme events; limited consideration of local factors such as urban heat island effects; difficulties in anticipating levels of adaptation to extreme events.**
- **Climate change forecasts suggest that we are likely to experience more heatwaves and that intense rainfall and higher sea levels are likely to lead to more frequent flooding events. Risks of cold waves may reduce in future though some research suggests that in the immediate future they may continue to occur under conditions of climate change.**
- **Projections for the UK, as well as studies from other countries suggest we might expect future increases in hospital admissions due to illness associated with high temperatures and high ozone levels.**
- **There is little evidence available on likely future impacts on health and health care use associated with flooding in the UK.**
- **We have relatively little evidence regarding the future impacts of climate change on use of primary and ambulatory care.**

A primary challenge lies in estimating future patterns of extreme weather events. Climate change **projections for future decades are relatively imprecise with respect to extreme events** (as compared to prediction of average prevailing conditions). Also, forecasts for long range trends occurring at the more local scale within particular countries are less reliable than for national or global models (Field 2012, IPCC 2011, IPCC Forthcoming). Recent assessments of climate change suggest that **we are likely to experience more heat waves and intense rainfall and higher sea levels are likely to give rise to more frequent flooding events** (IPCC 2013). Rainfall is highly variable from month to month and year to year, making it difficult to detect or attribute the cause of long-term trends. However, for the UK, it has generally got wetter, particularly in the winter months. The magnitude and duration of river flooding during the winter in the UK has increased over the last 30 years, although a longer record is required to establish what is driving this trend. Record rainfall levels were recorded in 2000, 2012 and 2013. There is also growing concern about the impacts of pluvial flooding due to very intensive rainfall causing surface water to build up faster than it can drain away into rivers. Our knowledge of, and capacity to predict these intense rainfall events in the very short term is improving (Coulthard *et al.* 2012, Jones *et al.* 2013) but the longer term trends in pluvial flooding is less

certain. Recently published research suggests that trends in flooding events may not be well summarised in terms of simple linear trends (Pattison and Lane 2012b) and that adaptation to more intense rainfall through changes to land use management in catchments are likely to need complex strategies that are different from conventional, engineered methods and need to be designed to fit varying local conditions (Pattison and Lane 2012a). Mean sea-levels are continuing to rise, driving an increase in extreme sea-levels and projected coastal flooding risks have been published (Foresight 2004, Evans *et al.* 2008). In winter 2013 observations included some of the highest sea levels ever recorded on the East and West Coasts of England. **Risks of cold waves may reduce in the long term**, though some research suggests that in Eurasian countries they will continue to occur in the shorter term under conditions of climate change, due to sea ice influences (Mori *et al.* 2014).

Processes of adaptation are particularly difficult to take into account when modelling future conditions. Local health services may face challenges in adapting to impacts of heatwaves in areas where the rate of *change* in risk is relatively rapid, as well as in areas where risks of heatwave events are greatest. Research using the UKCIP09 weather projections generator (version 2) (Owen *et al.* 2012) mapped local variation across the UK in the forecasted risks for periods of extreme heat and cold in the 2030s. They found, for example, that the areas where the risk of heatwaves are expected to show the greatest relative *increase* up to 2030 are not necessarily in parts of the country where the annual probabilities of heatwaves will be greatest. Owen and colleagues also point out that the results from all climate projection models depend on assumptions about the future trends in factors driving climate change, and that their estimates are based on the 'medium emissions scenario'. These emissions scenarios also reflect varying interpretations of how human societies may adapt their behaviour to be more sustainable in future.

Studies of **projected mortality impacts** likely to be associated with extreme temperatures are discussed in a companion review, and a comprehensive exercise in forecasting likely trends in mortality due to extremes of temperature has generated projected levels of deaths associated with heat and cold in different regions of the UK up to the 2080s (Hajat *et al.* 2014). There is a degree of uncertainty over such projections. For example, although it has been widely assumed that we might expect a reduction of excess winter deaths as average winter temperatures become milder, this has recently been questioned in research reporting that the association between periods of extreme cold and excess winter deaths has weakened in recent decades (Staddon, Montgomery and Depledge 2014). Recent work to review climate change risk assessment for the health sector (Hames and Vardoulakis 2012) and identify gaps in the evidence (Vardoulakis and Heaviside 2012) quantified likely **future trends in hospital activity associated with extreme weather** as the climate changes, including projected increases in hospitalisation rates due to high Ozone concentrations by 2030 compared with 2003 and estimates of rising costs of hospitalisations due to high temperature, with a range of projections based on different scenarios for population growth as well as climate change. It is acknowledged that these predictions are not certain and that current estimation methods are not able to take into account local heat island effects, which are significant in major cities, and do not adjust for possible future adaptations of medical care which might result in changes in

medical care models and service use during extreme weather events. For example, in research reviewed above (section 5) extreme temperatures are at present to be associated with increased risk of mortality due to cardiovascular disease, but do not seem to result in excess hospitalisations due to cardiovascular illness. We might speculate as to whether health services might in future be more effective in mitigating excess cardiovascular mortality outside hospital among those most at risk, but this might require more hospital or care home admissions. Furthermore, we have ***relatively little information on how primary and ambulatory care services may be impacted by extreme weather events in future.***

In order to build scenarios of likely future conditions, we may be able to learn from ***research on health impacts of extreme weather occurring in other countries today***, as well as from the UK experience. In doing so we would be assuming a degree of human adaptation to climate change, although it is debatable how quickly populations and health systems can adapt to rapidly changing climatic conditions. There is a great deal of work on adaptive comfort which gives a more reliable indicator of experienced comfort and tolerance in populations than crude maxima, 28 ° C in the UK (CIBSE) or 27 ° C in the USA (ASHRAE), based on the running mean of temperatures recently experienced (BS EN 15251) (Brager and de Dear 2000) . We searched particularly for international, comparative studies which have analysed data collected in relatively systematic and directly comparable ways in the UK and in other countries. Especially relevant here is a study of the impacts on health service activity of extreme weather involving a comparison of changes in hospitalization rates associated with maximum apparent temperature in 12 European Cities including London (Michelozzi *et al.* 2009) . This used a standard definition of the causes of admission, and showed that generally admissions due to respiratory diseases increased during heatwaves, particularly for older age groups, but this was not the case for admissions due to cardiovascular disease. It is suggested that poor air quality during heatwaves contributes to the risk. Increases in admissions were more pronounced in warmer Mediterranean cities than in Central and Northern European cities, perhaps because in these regions heatwaves are likely to involve the most extreme temperature levels presenting the greatest physiological risks for health. Arguably these findings might be indicative of conditions that might in future occur in the UK if our climate becomes more similar to that now experienced in parts of Southern Europe. This said, international comparisons should not be treated as accurately predictive of what may happen in the UK in future, since they also reflect other contextual differences among countries, such as living conditions, behavioural adaptation to extreme weather and health service organization, which are important to consider when building scenarios about future population health impacts of extreme weather events.

There are also a number of international reviews of flood risks for health (Few 2007, Few *et al.* 2004 , Few and Matthies 2006, Ohi and Tapsell 2000, Stanke *et al.* 2012, WHO Regional Office for Europe 2002) and some which specifically focus on reviews of evidence relevant for European states (Menne and Murray 2013) showing that the reported scale of the impact is quite variable across studies. A recent literature review of 35 epidemiological studies internationally, including some studies from the UK (Alderman, Turner and Tong 2012) points out that we know relatively little about the longer term health impacts of floods. The

international research they review includes studies from the USA which highlighted the greater vulnerability of poor and disadvantaged social groups and older people. Also a study of flood casualties over time in Texas suggested that aspects of exposure such as level of precipitation at the time of the flood, flood duration, property damage and population density in the flooded area were significant predictors of casualties (Zahran *et al.* 2008). Alderman and colleagues also report international findings showing a significant increase in prevalence of psychiatric morbidity following flood exposure ranging from 8.6 – 53% (Alderman *et al.* 2012), in line with other literature reviews that also conclude that post-traumatic impacts of flooding are significant (Neria, Nandi and Galea 2008, Tapsell *et al.* 2002). We did not identify with respect to flood impacts any research using internationally comparative data, of the type that have been conducted on health impacts of heat and cold weather risks.

7. Adaptation of infrastructure design and practice for improved preparedness and performance during extreme weather

The evidence reviewed reports:

- **Increasing recognition internationally that adaptation strategies for climate change are a necessary and important part of health and social care planning in general (not limited to emergency response agencies).**
- **These strategies need to be framed within a ‘system-of-systems’ approach to address the connections between built, social and institutional infrastructures which need to adapt.**
- **In recent years the NHS and Public Health England have begun to operationalise surveillance and warning systems which help to prompt special measures during extreme weather events, designed to improve responses and outcomes.**
- **Collective adaptation will be necessary and this calls for greater levels of collaboration and cooperation with partners in the wider social infrastructure as well as the formal institutional sectors of health and social care.**
- **Processes of adaptation in health and health care bring into question issues of social inclusion and equity in the response to climate change.**

In addition to mitigation of climate change through more environmentally sustainable practices (Pencheon 2013, Charlesworth, Madden and Capon 2013, McGain and Naylor 2014), strategies to adapt to climate change are important. The World Health Organization Working Group on Health in Climate Change reported from a survey of European governments in 2012 that areas where implementation would benefit from further action are the development of national health adaptation plans (Wolf *et al.* 2014). The task is one for the health and social care system generally, not only a matter for emergency response services. Other international literature also draws attention to the need for health and social care services to engage more directly in planning for adaptation to climate change (Burton, Bambrick and Friel 2014, Davis and Chornesky 2014, Mayhew, Van Belle and Hammer 2014, Sheffield *et al.* 2014, Woodward *et al.* 2014, Zhong *et al.* 2014).

Adaptive strategies should address at least three important considerations: long term protection by 'climate proofing of settlements, institutions and societies', equity and difference in vulnerability and cost effectiveness, (Mason *et al.* 2010). Here we consider adaptation of built infrastructure and social and institutional infrastructures as related elements of a 'whole system' perspective.

7.1 Adaptation of built infrastructure

A number of changes to infrastructure design have been proposed for the UK. Much of this advice relates to design of individual buildings rather than whole infrastructure systems.

With respect to **adaptation to more frequent heatwaves**, a number of possible strategies have been put forward which may imply changes to official guidance for construction of hospital buildings. Technical guidance from the Government may be referenced, particularly when new hospitals are constructed (CIBSE 2002, CIBSE 2005, CIBSE 2012). The result has been the use of full mechanical cooling or air conditioning to reduce risks of overheating. However, increased use of mechanical cooling by enhanced air conditioning in response expected higher temperatures would undermine the NHS Carbon Reduction Strategy and contravene the Climate Change Act (Lomas *et al.* 2012, Short *et al.* 2012) so it may not be appropriate to continue to follow the standards precisely in future.

More sustainable 'adaptive' comfort models offer greater scope for low energy solutions (Short and Al-Maiyah 2009). Alternatives to mechanical cooling in new buildings in future may include attention to building mass and orientation may be used to positive effect. Historically buildings were designed with close reference to their site, in order to profit from the prevailing winds and to avoid solar overheating (Thompson and Goldin 1976). Buildings constructed before the 1950s demonstrate resilience to overheating because they are heavyweight (with thick walls) and often have high ceilings. Some more recent hospitals have a degree of resilience that refurbishment could amplify. They potentially form a more climate resilient resource than might be expected (Short *et al.* 2012, Lomas *et al.* 2012). In addition, solar shading options may help to reduce internal temperatures.

A low-energy new-build hospital (Short and Al-Maiyah 2009) features: clinical spaces located in a medium-rise building of 3-4 storeys, with courtyards that facilitate the ventilation strategy whilst also providing daylight and views; air entering the building after being cooled naturally in a low level chamber (easily accessed for cleaning) and ducted through the building; 'thick' walls forming the building's elevations, within which the air supplies, exhausts and other services are co-located; openings shaped and sized to reduce undesirable solar gain whilst preserving good daylighting; single patient rooms that are naturally ventilated but in a more sophisticated way than by opening windows alone.

LWEC work has examined options for the low-energy refurbishment of existing, older hospital buildings. Simply insulating and sealing a 1960s ward block, and installing an efficient ventilation system, would halve its energy use (Short *et al.* 2012). Using 'natural ventilation',

various types of external solar shading devices and removing suspended ceilings could deliver greater savings. Research including studies reviewed above suggests that more 'passive' forms of ventilation' could be suitable for many parts of hospital buildings. Advanced Natural Ventilation can be devised to move air through a building (Lomas and Yingchun 2009, Short, Lomas and Woods 2004, Short and Al-Maiyah 2009).

Options for 1970s courtyard types have also been presented (Giridharan et al. 2013) . These options include, for an industry-standard model for refurbishment of a 1960s ward block: insulating and sealing it and installing an efficient ventilation system, which would halve its energy use. Using 'natural ventilation', external solar shading devices and adjustment of suspending ceilings which lower room height could deliver even greater savings. The research summarized in section 4.1 also suggests that **refurbishment of pre-1948 buildings** should aim to take the opportunity to improve further the already high resilience of this type of structure, whilst enhancing patient privacy and dignity with design features such as individual patient rooms. These options can be executed in stages and are likely to achieve long term savings through greater energy efficiency. It is suggested that measures of these types might need to be applied differently in different parts of the country, since overheating in hospitals is likely to be especially problematic in more southerly and urban parts of the UK. In these areas the measures proposed could provide effective solutions up to the 2040s (Short et al. 2010).

When considering the **functionality of the wider infrastructure**, adaptation to increasing risks posed by flooding, as well as measures to ensure continued resilience to cold weather events, seem to be priorities. A recent review considers how the literature on flood risk management may apply to the health care service (Menne and Murray 2013). A system-of-systems approach, which takes into account interdependencies between different infrastructure systems, is also required. In order to apply this approach at the local level network flow models seem to be most suitable. These models have potential to assist the development of cost effective adaptation strategies for wider infrastructure of which hospitals are a part (Holden et al. 2013, Arboleda et al. 2009). The ARCC BIOPICCC project also pioneered the use of the NHS Strategic Health Asset Planning and Evaluation toolkit (<http://shape.dh.gov.uk/>) to map the distribution of NHS estate and facilities in relation to flood risk zones as a way to identify parts of the infrastructure for which adaptation may be most needed. Based on such system wide assessments of infrastructure systems, health services may in future be able to make more comprehensive assessments and deploy more effectively specific adaptation strategies involving modifications to equipment, such as the use of winter tyres for ambulances during cold weather (Thornes et al. 2014), installation of emergency generators at key health facilities to ensure continuity in power supplies (Holden et al. 2013), or strategic planning for future shortages of essential supplies (Grose and Richardson 2014).

7.2 Social and institutional infrastructure adaptation

Action for adaptation of social infrastructure will include measures to modify collective **social and institutional** factors as well as enhanced understanding of **individual** vulnerability and action to modify individual physiological, psychological and behavioural factors.

The importance of **individual household level adaptation** may be best illustrated by international research including the UK, showing that areas with warmer winters see more pronounced mortality during coldwaves than in countries with colder average winter weather. Comparative studies (Eurowinter_group 1997, McKee 1989) suggest that behaviours to improve resilience to cold such as clothing and central heating vary and in colder regions protective behaviour is more common. Historic changes in such behaviours over the long term in the UK may have contributed to reductions in cold weather mortality in London over the last century (Carson *et al.* 2006) Case study research for the BIOPICCC project (Curtis *et al.* 2012a) also demonstrates that some individuals take what they consider to be effective measures to protect their health during extreme weather events. However, there is relatively little research on whether such behaviour is widespread among those most at risk in the UK population. An international review of ways to reduce heatwave mortality (Bassil and Cole 2010) included only one study from the UK; a local semi-structured survey of 73 older people in Norwich, who would be considered 'vulnerable' to extreme heat, (Abrahamson *et al.* 2008) showed that many of the study participants had little awareness that they were at particular risk due to hot weather but that most made what they considered 'common sense' adaptations to hot weather when it occurred, by altering their routine (e.g. going out or doing heavy chores at cooler times of day), changing other behaviours (such as dress, diet, taking cool showers), and modifying their living environment (e.g. acquiring cars with air conditioning, altering ventilation, using electric fans, drawing on social support of family and friends).

The above mentioned review of international literature on adaptation to hot weather (Bassil and Cole 2010) also showed that most studies of public awareness of adaptive strategies to protect health during extreme weather events have failed to assess whether these are effective for the most socially isolated and marginalized groups, who may be most vulnerable. They suggest that new methods are needed for this purpose. The review found evidence that many people who are aware of public health advice do not practice the advice they receive. Basil and Cole conclude that while the high levels of publicity given to recent heatwave events such as the 2003 heatwave in Europe has made the public more aware, older individuals do not always consider themselves vulnerable, and that extreme weather warnings for different conditions such as high temperature and air pollution can be confusing when issued from different sources and appearing to offer conflicting advice. They also note that there are challenges in assessing whether public awareness and response to public health is improving over time since many programmes have only recently begun, extreme weather events tend to be rare, and the same populations are not always exposed repeatedly to the same types of events.

Institutional and collective adaptation to increase resilience to extreme weather includes changes to risk governance and professional practices in health and care services as well as action in wider society to change collective social processes (Wolf *et al.* 2014). Several authors call for *improvements to the ways that risks are evaluated and responded to*. An adaptive capacity index has been proposed, developed by the MOVE project (see acknowledgements), which considers potential for institutional adaptation in terms of **risk identification, risk reduction, disaster response and adaptive governance** and was applied as a tool to aid

reflection and discussion in a case study which interviewed managers of care homes for frail elderly people in two parts of London about their strategies for managing risks of heatwaves (Zaidi and Pelling 2013). This revealed that adaptive capacity was rather limited in most of the institutions surveyed, highlighting the point that management of heatwave related health risks for older people tends to be seen as an issue for the emergency services rather than institutions such as care homes. Since the main disaster response mechanisms were operated through health care checks of the type made routinely under normal conditions, these authors concluded that adaptive capacity mainly depended on the general quality of care, rather than on preparedness and management of extreme weather risks specifically.

Enhanced **risk identification** involves *understanding* the factors that make certain groups in the population relatively vulnerable to extreme weather events, *recording* information on those in the population who are most at risk and *acting* on the information to help target relief efforts particularly towards these groups during extreme weather events. At the aggregate scale, a useful source of local indicators of potential vulnerability to climate change was created for localities in England (Landstroem et al. 2011). The research literature is also beginning to report on findings from real time surveillance systems which in future may become important ways to assess changes in the health and social care system and issue alerts in order to respond to extreme conditions more effectively (Elliot et al. 2014, Hughes et al. 2014). Risk registers allowing community groups and professional carers to locate individual vulnerable people are important resources, but are becoming increasingly difficult to maintain effectively as service provision becomes more fragmented among different providers in the UK, raising questions about data sharing and confidentiality as well as incompatibility of data systems from different agencies (BIOPICCC 2011, Panhuis et al. 2014).

Several authors in the international literature argue for **more integrated planning and preparedness** for extreme weather, which acknowledges the complex interdependencies involved (Lanham et al. 2013). The recent Climate Change Risk Assessment (CCRA) for the UK (Field 2012) underlined the need to integrate robust, consistent scientific knowledge with local knowledge to improve resilience (section 5.5.4.4.) and this message has been broadcast in a professional magazine (Kause et al. 2012). Also the CCRA suggests (section 5.3.1) that local government policy structures may be in place but are not always effectively implemented throughout the system to the local level, and this is born out through findings in local case studies (Carroll et al. 2010, Costello et al. 2009, Oven et al. 2011, Wistow 2013, Curtis et al. 2014).

It is argued that **sustainable social care** should be based on co-production, mutualism and localism (Evans, Hills and Orme 2012, Joseph, Skinner and Yantzi 2013). For flood risk planning more generally, it is suggested that local knowledge needs to be integrated more effectively with environmental science (Lane et al. 2011, Landstroem et al. 2011). The BIOPICCC project exemplified this kind of approach for health and social care through local case studies (Dominelli 2013, Wistow 2013, LWEC 2014) and it is emphasised also in a report by the independent Stockholm Environment Institute in York (Haq 2010).

Similar emphasis on ***integrated planning*** comes from the international literature including international reports (IPCC 2011). In Canada, Critical Systems Heuristics (CSH) theory and methods have been applied address problems of public health impacts on climate change and health equity, and was shown to be helpful in engaging stakeholders, and addressing issues of power relations between collaborating partners (Buse 2013). Another Canadian study also emphasises stakeholder engagement and proposes a framework for critical social infrastructure to promote resilience which emphasises processes including connectedness, collaboration and adaptive response (O'Sullivan *et al.* 2013). In the USA examples include a model for: (a) analysing potential climate impacts at the basin scale; (b) engaging government agencies and stakeholders involved with the natural, human and built and economic dimensions of the system; (c) preparing systems to be more resilient to extreme weather through methods that enhance, and not undermine, climate preparation efforts in the other sectors (Doppelt, Hamilton and Vynne 2011). Planning will also require close collaboration with the non-health sectors (BIOPICCC 2011). In Australia an assessment of strategies for heatwave preparedness (Huang *et al.* 2013) calls for coordinated action to; reduce heat exposure; improve access to cooling; adapt the built environment; enhance surveillance and early warning systems and public awareness communications.

Reviews emphasise the need for a greater attention to ***equity and inclusivity*** in society and draw attention to the inequalities between socio-demographic groups in exposures to and impacts of extreme weather (Curtis and Oven 2012). For example the increased care burdens that women are expected to undertake during disasters involving extreme weather events are not always sustainable, especially given changing roles for women in society, and the tendency for formal agencies to pass responsibility down to the level of informal carers in the community in communities without attending to the lack of necessary support services and built infrastructures (Dominelli 2013). Collective action at local level may benefit from solidarity of shared 'place identity' but must also pay attention to inclusive representation of subgroups within communities (Fresque-Baxter and Armitage 2012).

8. Conclusions and key messages

This overview underscores conclusions regarding the forward agenda for research to inform preparedness for extreme weather events in the UK.

Extreme weather events impact the operation of health services through the effects on built, social and institutional infrastructures which support health and health care. It is challenging to accurately forecast the likely pattern of extreme weather events in future decades, especially for local areas within the UK. However, it seems likely that, particularly for heatwaves and floods, the frequency will increase and the pattern will be regionally variable. The impact of these changes on population health and health care systems will depend in part on our ability to adapt to these changes. Adaptation is not generally considered in models projecting likely future health impacts of climate change and more research is needed to allow for the implications of different scenarios for adaptation as well as climate change and their impact on population health. There are particular research gaps concerning ways to anticipate future impacts of

extreme weather at the very local scale, where adaptation and resilience measures need to be taken, in addition to action at the wider national or regional scale.

Adaptation will need to include changes to built infrastructure systems, not only by making individual buildings, such as hospitals, more resilient, but also by action to modify the whole network of infrastructure supporting the health care system. Hospitals can already be uncomfortable environments during heatwaves and, without adaptation, are likely to become more so under future climatic conditions. Strategies for effective, resilient low-energy refurbishment and new construction have been developed and modelled and these would allow these buildings to remain resilient well into the present century. Health services depend on a wider built infrastructure system, so research on the impacts of extreme weather and resilience of utilities, transport and communications systems needs to be brought to bear in adaptation of health services to climate change.

Also institutions and communities will need to adapt their practices to improve resilience of health and health care to extreme weather. Preparedness and emergency response strategies need to extend beyond the emergency response services and to include health and social care providers more generally. Much of the existing evidence driving policy relates to activity in hospitals, and more research is needed on current and future impacts of extreme weather on primary and ambulatory services in the UK. More needs to be done to encourage an integrated approach across different parts of health and social care services, and there are gaps in research about how effectively national governmental advice about evidence-based good practice is filtering through the health and social care system to affect practice on the ground. Evaluation of the various sources of guidance and 'toolkits' now available is needed. Communities have an important role to play in adaptation and resilience and research is only beginning to build on how far changing behaviour and practices by individuals and communities, as well as professional carers may modify the potential impact of extreme events under conditions of climate change.

Acknowledgements

Contributions for this report were received from researchers associated with the following research projects:

- **Built Infrastructure for Older People's Care in Conditions of Climate Change (BIOPICCC)**. Funded by EPSRC. Dr Katie Oven, Dr Jonathan Wistow, Prof Lena Dominelli

- **Design and Delivery of Robust Hospital Environments in a Changing Climate (DeDeRHECC)** Funded by EPSRC. Professor C. Alan Short and Dr Alistair Fair Cambridge University. See: www.robusthospitals.org.uk. Also, a summary of the refurbishment work can be seen in two films, which may be downloaded or streamed at

<http://sms.cam.ac.uk/media/1446036> (30 minute version)

<http://sms.cam.ac.uk/media/1559781> (10 minute version)

We also acknowledge advice from:

- Dr Zehra Zaidi and Professor Mark Pelling Kings College London in respect of the following study: Rapid climate change in the UK; towards an institutional theory of adaptation Funded by ESRC; Methods for the Improvement of vulnerability Assessment in Europe (MOVE) <http://www.move-fp7.eu/index.php?module=main> (funded by EU FP7).
- Dominic Hames, HR Wallingford.

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