Public Weather Service
Value for Money Review

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Public Weather Service Value for Money Review
Executive Summary

Through analysing existing studies and literature on the economic value of weather forecasts, and using up to date figures, this review concludes with high confidence that the benefits of the Public Weather Service (PWS) to the UK are very likely to exceed £1bn per annum, and are likely to be close to £1.5bn per annum. This is consistent with the findings of the previous value for money study prepared for the PWS Customer Group (PWSCG) by PA from 2007 which assessed the economic benefits of the PWS at £614m per annum and, given its limited scope, considered the benefits to be many times that figure.

Sectors considered in the review were the perceived value to the public (which had an estimated benefit of £480m per annum), value to aviation (£400m per annum), added value to other sectors of the economy (£400m per annum), storm damage avoidance (£80m per annum), value to land transport (£100m per annum) and flood damage avoidance (£64m per annum). Other benefits included the hosting of the European Centre for Medium-range Weather Forecasting (ECMWF) in the UK (£60m per annum) and business of over €200m for the UK space industry by being able to bid for EUMETSAT (the European Organisation for the Exploitation of Meteorological Satellites) contracts by virtue of UK membership paid for by the PWS. It is estimated that the PWS contributes to reducing deaths from high impact weather by many tens per year, and many more during individual severe events such as North Sea coastal flooding. There is limited quantitative data demonstrating the value of weather forecasts to the civil contingency sector, and this is an area which would benefit from future case studies.

Given the 2014/15 costs of the PWS are £120m, of which major components are £98m contributed from BIS and £18m from the Aviation sector, the benefits of £1.5bn per annum represent a return on investment of at least 10 to 1. This investment is primarily used to fund the National Capability (£59.4m) – which is the underpinning infrastructure of observations, science and weather forecast production upon which all weather services in the UK depends – and International Commitments (£51.2m) which includes the provision of meteorological satellites through EUMETSAT. The International Commitments are long-term costs committed by international treaty over which the UK has some influence but not control, whilst most of the other costs are medium-term (2-5 years) commitments, including staff and high performance computing (HPC).

Although the PWS can be demonstrated to already represent a good return on investment for the UK taxpayer, strategies going forward should be looking to further increase this value. Four main areas where opportunities and risks lie are:

- Improving forecast accuracy, through exploiting the enhancements in HPC capability, especially in areas where it is currently poor but there are potentially significant economic benefits to be derived from decisions based on more reliable forecast information, such as fog, convective rainfall and seasonal forecasting.
- Maintaining and increasing reach, noting the risks to PWS reach that exist within the competitive media and digital platform markets.
- International subscription costs, which now constitute 43% of the PWS price and are likely to increase further post-2020 with the introduction of next generation satellites.
- The success of the Met Office in winning competed business, which could lead to long-term reductions in the costs of the PWS, along with the risk of losing revenue from existing government contracts, especially where synergies exist with the PWS.

These are all long-term, rather than in-year, challenges and therefore having development plans aligned to a longer-term commitment of resources should help the PWS maintain or enhance its current excellent return on investment.

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1. Introduction

This review is aimed at informing future funding decisions for the Public Weather Service (PWS). Pressure on limiting government spending will remain strong and therefore a full understanding of the value for money of the PWS to the UK taxpayer is important for the PWS Customer Group (PWSCG). However, on the timescales required it is not possible to commission a new rigorous value for money study of the PWS. Fortunately, there are plenty of existing studies available from which conclusions can be drawn.

The value for money of a service can be thought of as the ratio of the benefits to the costs, and therefore this review will consider the value for money of the PWS from these two aspects. Firstly, the economic benefits of weather services to the UK will be reviewed using the evidence contained in existing studies. This will use updated information where available. Secondly, the review considers the costs of the PWS and how these are currently configured.

Finally, the study identifies potential risks to benefits and to costs over the medium-term, including improving forecasting accuracy through enhanced high performance computing (HPC), maintenance of reach, international subscriptions, and the success of other Met Office business.

2. The Public Weather Service

The purpose of the PWS is to help protect lives, property and infrastructure from weather impacts, and to contribute to UK economic growth through the effective use of weather information.

The PWS, as defined in the 2014/15 Customer-Supplier Agreement (CSA) between the Department for Business, Innovation and Skills (BIS), the PWSCG and the Met Office, is structured into six themes, which are:

1.The National Severe Weather Warning Service (NSWWS) - which aims to provide authoritative, accurate and timely warnings for wind, rain, snow, ice and fog impacts to people, businesses and infrastructure.

2. Weather Services for the Public – which aim to provide UK citizens at home and abroad with readily accessible weather forecasts, warnings and weather information to minimise the risk of weather related impacts to life and property, and to drive economic growth and prosperity.

3. Services to the Civil Contingency Community – which aim to provide the UK Civil Contingency Community, including central government, the devolved administrations, and category 1 and 2 responders, with accurate, consistent and timely weather information to minimise the risk of weather related impacts to life, property, businesses, and infrastructure.

4. Data Services – which make PWS data available for use by others either with an open data licence, or as a managed service through data wholesaling.

5. International Commitments and Infrastructure – which covers the UK's contribution to the global meteorological infrastructure through, primarily, its international agreements with the World Meteorological Organisation (WMO), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the European Centre for Medium-range Weather Forecasts (ECMWF).

6. National Capability – which aims to develop the infrastructure and capability required to sustain the UK's National Met Service. This underpins all Met Office services including PWS, Defence, Climate and wider government services. It includes maintaining the UK observational network, maintaining a world class science base, the development of state of the art Numerical Weather Prediction (NWP) models, the routine production of global and UK forecasts, the IT infrastructure required to generate and disseminate forecasts and data, and maintaining the UK's National Archive.

Figure 1 shows how these themes fit together in a simple value chain for the PWS. Themes 5 and 6 – International Commitments and Infrastructure, and the National Capability – underpin a broad range of services both funded through the PWS (themes 1,2 and 3) and also provided outside the PWS. The examples shown in Figure 1 are illustrative, and include services for defence, aviation and marine, contributions to flood forecasting by the respective national agencies, the Natural Hazard Partnership, and the Met Office Hadley Centre Climate Programme to name just a few. Theme 4 – data services – is key in making PWS funded data available to other weather service providers and developers, supplying services to many different weather dependent markets. This illustrates that all weather services in the UK are dependent on the PWS's investment in the National Capability, which in turn is dependent upon the International Infrastructure of global exchange of data and weather satellites. Even if the service is not directly driven by PWS data, accuracy of forecasts over the UK – wherever they are produced – is dependent upon UK observations from the Met

Office networks and satellite coverage over the UK and its environs provided by EUMETSAT, all of which are funded through the PWS. Therefore, when we consider the value for money of the PWS we can consider the value of the whole weather services sector which would not exist at a level which would provide any meaningful accuracy without the investment in the PWS national capability and international commitments.

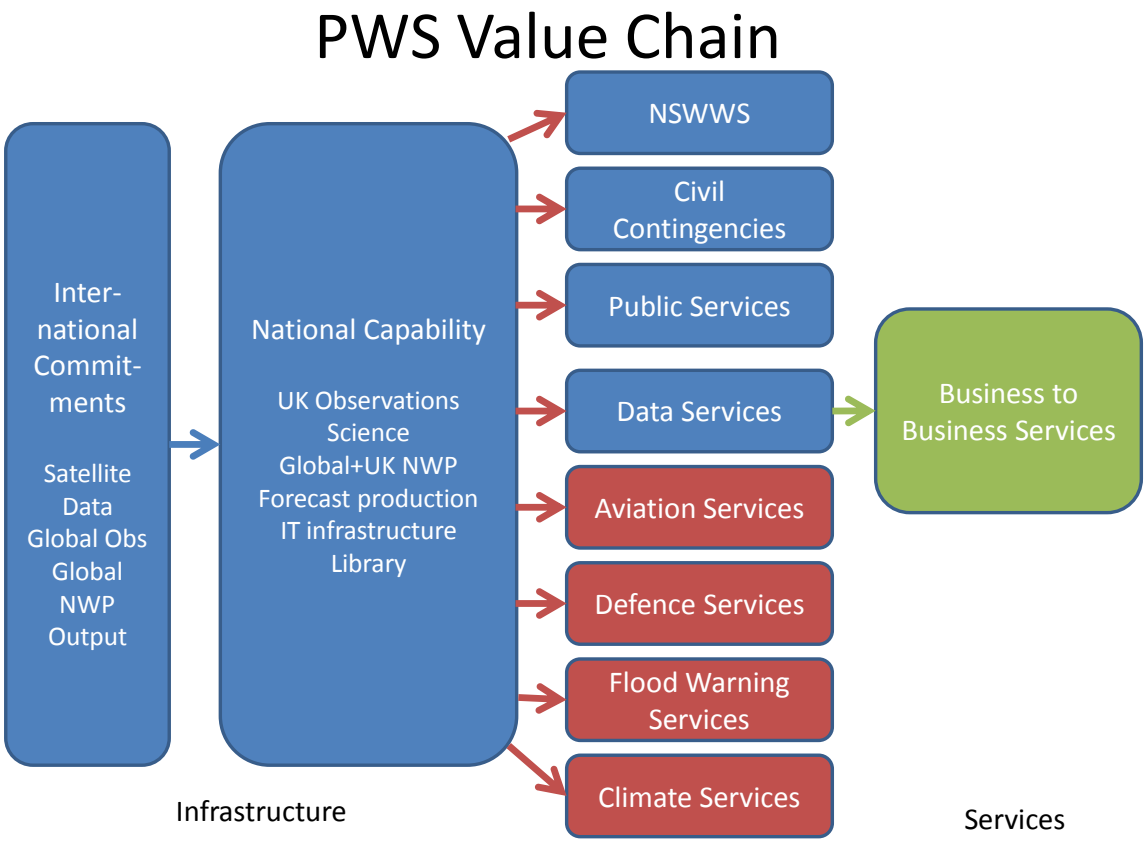

Figure 1: The PWS Value Chain.
Blue boxes represent the infrastructure and services funded through the PWS, red boxes those provided by or for other parts of government or the public sector (including by the Met Office) that are dependent on PWS capability, and the green box represents a broad range of value-added weather services provided by the Met Office and private sector providers to business based on PWS data.

3. Economic Benefits of the PWS

3.1 Methodology

This review draws on the outputs of several studies to assess the value for money of the PWS. One source is the study the PWSCG commissioned from PA Consulting in 2007[1] which considered the value of the PWS based on the perceived value of the public and cases studies from the Cabinet Office, Environment Agency and Civil Aviation Authority. Another source is a cost benefit analysis prepared by EUMETSAT for its Member States for the next generation polar satellite programme.[2] This attempts to assess the full economic benefits of weather forecasting across Europe and then attribute some of this benefit to the contribution of polar satellites to forecast accuracy. There are also some studies of specific market sectors available. These include a Met Office commissioned study by Helios on the economic benefit of weather services to the aviation sector[3], and an internal Met Office paper considering the reduction in flood damage costs resulting from improved weather forecasts[4]. Both of these studies were used in the business case for the Met Office's successful bid for additional HPC funding. These and other papers referenced in the report are used to assess the economic value of weather forecasts to the following sectors:

- Public
- Aviation
- Civil Contingency
- Land Transport
- Flood Damage Avoidance
- Storm Damage Avoidance
- Added Value to the Economy

Three different methodologies are used within the literature to assess economic impacts. In brief, these are:

- **Perception of Value**: This assesses a value of a public-facing free-at-the-point-of-use service based on what the users of the service say they would be prepared to pay to use the service. This has been widely used to assess the value of public weather forecasts, including in the PA study from 2007.
- **Cost-Loss model**: This is mainly applicable to business use of weather forecasts where there is a clear economic impact of a weather event if no action is taken, and an understanding of the costs and effect of mitigation. Events can fall into four categories:
    - Event does not occur, is not forecast (nil cost)
    - Event does occur, is not forecast (event cost)
    - Event does occur, is forecast (action + mitigation cost)
    - Event does not occur, is incorrectly forecast to occur (action cost)

  This can be used to assess the benefit of taking action for specific events given a known forecast accuracy over taking no action.

[1] "Met Office - the Public Weather Service's contribution to the UK economy", see http://www.metoffice.gov.uk/about-us/what/pws/value.
[2] "The case for EPS/METOP Second Generation: Cost benefit analysis", see http://www.eumetsat.int/website/home/Satellites/FutureSatellites/EUMETSATPolarSystemSecondGeneration/index.html.
[3] "Research of the value of Met Office weather services to the aviation industry", prepared by Helios on behalf of the Met Office in 2014. This is not publicly available.
[4] "Flooding damage costs and socio-economic benefits provided by improved future Met Office forecasts", compiled by Shane Vallance on behalf of the Met Office in 2013. This is not publicly available.

- **Value Chain Analysis**: Where an economic loss due to weather impacts is understood, this model attempts to identify the proportion of loss prevented by acting upon a weather forecast. This requires data on how people understand and use weather forecasts as well as the accuracy of the forecast. Value is lost at each stage in the value chain and the cumulative total provides an estimate of the effectiveness of the service in reducing costs. For example, if a forecast of accuracy 100% reaches 50% of the people of which only 50% take action which reduces cost, the cumulative effectiveness of the service is 100% x 50% x 50% = 25%.

In the following reviews by sector all these methodologies have been used.

3.2 Value to the Public

The primary output of the PWS is directed to the public with free at the point of use weather forecast products. The main products provided to the public are the weather warnings and weather forecasts. Since the PA study in 2007 there have been dramatic changes in the level of detail provided in forecasts, with five day forecasts available for 7000 UK sites with hourly forecast data for the first two days of the forecast period, and consistent forecasts available through the web, apps and social media, as well as continuing through traditional means such as TV and radio.

The public engagement with weather warnings is very strong. The PWS carries out ad-hoc surveys each year following weather warnings to assess public reach and response. On average, from 37 surveys between July 2008 and February 2014, the warnings reached 79% of the public. This ranged from 69% for rain, to 84% for wind and snow. 50% of the public said they took action as a result of snow warnings, 24% for rain warnings, with the average of all warnings being 38%. 89% of respondents said they found the warnings useful. Perception of accuracy is important in giving people confidence to take action as a result of the warning, and the accuracy perception was 94% for warnings, with snow higher at 97%.

The PWS also carries out annual public perception surveys and these show that around 90% of the public believe forecasts are fairly or very useful. 71% of the respondents judged the forecasts as fairly accurate, and 9% as very accurate. 80% of people see a forecast at least once a day, primarily through the TV (75%) although internet and apps are becoming more used (30% and 21% respectively) the latter especially amongst younger age groups (2013 data). Over 50% of respondents said they used weather forecasts on a day-to-day basis to inform short-term plans and decisions, whilst 30% engage with weather forecasts when planning activities more than a day in advance. In the 2013 survey 77% of the public said they took action as a result of the weather forecast. Although the biggest single action was to take an umbrella or change clothes as a result of the weather forecast (40%), other actions taken which had potential economic impact included changed travel plans (28%), altered work plans (9%), salted paths (4%) or checked risk of flooding (1%).

There is no doubt from these surveys that PWS forecasts have a value to the public. The PA study from 2007 quoted an estimated benefit to the public of £353.2m per annum. This was based on work carried out by ORC International which asked a survey group how much they felt the PWS was worth to them in terms of monetary value per year. The average amount was £7.30 per year. By multiplying this by the UK adult population of 48.4m this gave the value of £353.2m per annum. This figure can be updated using more recent survey data conducted by the PWS from 2012.The work classified the public into six market segments and, from the survey, gave an average value of weather forecasts for each segment. Table 1 below shows this breakdown.

Market Segment	Proportion	Average Value of Weather Forecasts per annum
Positive Everyday Users	18%	£16
Positive Planners	22%	£15
Positive Workers	22%	£11
Reluctant Users	12%	£6
Marginally Engaged	12%	£2
Disengaged	15%	£7

Table 1:
Average perceived value of weather forecasts from public survey for different market segments.

From these figures an average value of weather forecast is £10.61 per annum. If we set the value from the Disengaged segment as £0, a more reasonable figure than the £7 deduced from the survey given this sector claims not to use weather forecasts, then the average value falls to £9.56 per annum. The PA study figure of £7.30 from 2007 up-rated at an annual inflation value of 3% would result in a value of around £8.70 for 2013. This may suggest that improvements to weather forecast accuracy and digital presentation since 2007 have increased the perceived value of weather forecasts in real terms, despite the impact of the recession on the public's willingness to pay for something which is free. For a UK adult (over 16) population of 51m this provides an updated public value of weather forecasts of £488m per annum.

Similar surveys in other countries have provided a range of figures. Those quoted in the PA study ranged from £12.50 per annum for Australia to £65 per annum in Ontario, Canada. The EUMETSAT study quotes a survey by Lazo and colleagues in the USA to estimate the willingness of US households to pay for the weather information that is currently provided to them. They estimated that 50% of US households would be prepared to pay $280 per year on forecast data, whilst 80% of households would pay in excess of $30 per year. EUMETSAT used the output of that study to conclude that each European household would be prepared to pay €20 per year for weather information. Assuming 30m UK households, and using the current exchange rate of £1 to €1.25 (July 2014), that provides a figure for the public value of weather forecasts of £480m per annum, consistent with the above.

In summary, PWS forecasts continue to be of value to the public as measured in public perception surveys, and ad-hoc weather warning surveys commissioned by the PWS. The method of estimating the economic value of the use of these forecasts has been to survey the public to assess how much they would be prepared to pay for the free-at-the-point-of-use weather services they receive. The PA study from 2007 gave a definitive figure of £353.2m per annum. Using updated information from more recent surveys using the same methodology we can estimate that the public value of weather forecasts in the UK today is approximately £480m a year.

3.3 Value to Aviation Sector

The aviation sector directly contributes funding to the PWS. The contribution is agreed between the Met Office and the Civil Aviation Authority (CAA) and is paid from airlines' en-route charges over the UK collected via Eurocontrol. For 14/15 this contribution is £18.5m out of a total price of £119.7m.

Accurate weather forecasting is essential for efficient and safe operation of aviation (civil and military). Indeed, the United Nations specialised agency which regulates civil aviation, the International Civil Aviation Organisation (ICAO), defines a minimum set of meteorological

services which must be provided by its States for them to operate civil aviation. In principle, therefore, without the National Capability provided by the PWS it would be impossible to run safe and efficient civil aviation in the UK. The economic value of this sector is significant. The British Air Transport Association (BATA) outlines the annual economic value of aviation to the UK[5]. This includes £18bn of direct economic output from the airline industry, £17.5bn of benefits from inward tourism, and £116bn worth of trade to non-EU countries.
The Met Office services provided to aviation (which are dependent on the PWS National Capability) can be separated into services for the UK as the designated aeronautical meteorological service provider for the UK and services provided internationally as one of two World Area Forecast Centres (WAFC) and one of nine Volcanic Ash Advisory Centres (VAAC).

The PA study specifically looked at these international services in some detail in assessing economic benefits. Using the International Air Transport Association (IATA) figures for an average operating cost of £50 per in-flight minute, and annual global flights of 28.2m, it estimated that the Global Operating Cost Impact for a 1 minute reduction in flight time was £1.41bn. The PA study then used a Value Chain Analysis to approximate the value attributable to the PWS. The study assumed:

- The proportion of flights using WAFC London data was 60% (robust assumption from the area of the globe covered by WAFC London)
- The proportion of flights using data effectively to reduce flight time was 50%
- Estimate of proportion attributable to PWS was 25%, as one of four inputs for flight efficiency
- Direct service discount factor of 90.24% taking into account the CAA's direct service spend

This gave an annual net benefit from the PWS to aviation from reducing flight times as a result of the WAFC service of £95.5m per annum at 2007 prices. More recent figures from IATA put the cost of an in-flight minute at $100[6] (~£65) which, assuming all other factors remained the same, would put the benefits of the WAFC service at just over £124m per annum. Given that fuel prices – an important cost factor for aviation – are trending downwards again, it seems reasonable to judge the benefits to international aviation at around £100m per annum.

In preparation for its 2014 business case for HPC investment, the Met Office commissioned Helios, a management and technology consultancy whose work includes air traffic management and airports, to prepare a study on the value of Met Office weather services to the aviation industry. The Helios study examined weather impacts at airports due to low visibility, snow, strong winds, thunderstorms, cloud and ice. The cost of these weather impacts was calculated for planned and unplanned responses, along with the cost of mitigation measures when a weather forecast would trigger a planned response, at five airports typical of the UK: Heathrow, Stansted, Glasgow, Exeter and Norwich. Using data from the Met Office for the occurrence of these events during 2012 a Cost-Loss model was employed to calculate the benefits of Met Office forecasts for these weather impact events for the five airports. This was then scaled up to account for all UK airports. Economic benefits used in the study included aircraft costs (fuel, crew, maintenance), passenger costs (lost time), costs of cancellation and costs of diversion. Because the study was for the benefit appraisal of various HPC investment scenarios the study looked at what various improvements to forecast accuracy would have for the benefits to the aviation sector. The scenarios were:

- No Met Office case: all costs are for unplanned responses
- Baseline scenario: current Met Office accuracy for hit rates and false alarms

[5] http://www.bata.uk.com/uk-airline-industry/social-and-economic-benefits-of-aviation/
[6] http://www.iata.org/whatwedo/ops-infra/fuel/Pages/fuel-conservation.aspx

- Scenario 1: moderate improvement in Met Office accuracy for hit rates and false alarms
- Scenario 3: significant improvements in Met Office accuracy for hit rates and false alarms

For the purpose of this review, the No Met Office case and the Baseline case are of most interest. For the No Met Office case the total cost impacts for 2012 were calculated as £1,472m. For the Baseline case the total cost impacts for 2012 were calculated as £797m. As a headline figure, therefore, the total net direct benefits of Met Office services to aviation could be considered to be £675m per year. Analysis of the breakdown shows that most of this benefit is realised in reduced cost impacts for low visibility, strong winds and ice.[7] The analysis does not consider situations where multiple weather types contribute to the same cost (e.g. snow and ice) so there may be cases of double counting. Taking this into account, and that these services have a value-add component over the PWS contribution from the National Capability, benefits of less than 50% are attributed to the PWS, estimated at £300m per annum.

Combining the international and UK benefits to aviation from the PA and Helios studies respectively would give a total economic benefit of around £400m per annum. Compared to the annual figure of £18bn direct economic output of the aviation industry in the UK, this suggests that the PWS may add 2% of economic value to this sector. This proportion feels reasonable given that aviation is a highly weather dependent industry.

3.4 Value to Civil Contingencies

One of the PWS themes is the services to the Civil Contingency Sector, which consists of the Category 1 and 2 responders as defined under the 2004 Civil Contingency Act. This sector is critical in planning and responding to impacts of severe weather events at the local or regional level. The services provided for this sector by the PWS consist of both information through the Hazard Manager product and expert interpretation and advice from the PWS (or Civil Contingency) Advisors.

There is no doubt that this sector highly values the services provided by the Met Office on behalf of the PWS, especial the Advisors. Typical comments include “brilliant – it’s a face” and “best initiative that ever came out”. In 2012, the PWSCG commissioned Prof David Demeritt to prepare a study on the perception and use of the PWS by resilience professionals in the UK[8]. Demeritt’s report found that “Met Office weather forecasts are held in high regard by emergency and resilience professionals who look to PWS channels as their primary source of information.” There was “universal and enthusiastic praise for the Advisors who were seen to add considerable value to the weather warnings by providing additional, highly trusted and easy to understand information on the timing, location, character and impacts on particular local services of impending weather events.” The value of using the Advisors in planning or exercising was also underlined. The Advisors are clearly a vital part

[7] There is an anomaly in the model in that the cost impacts for snow show an increase in the Baseline case compared to the No Met Office case. The study authors attribute this to the crude way snow impacts are considered in the No Met Office case. Snow impacts are only considered where snow depth is greater than 2cm; for the Baseline case snow impacts may be considered for any level of snow and hence the costs are greater due to more preventative action taking place.

[8] “The perception and use of Public Weather Services by Emergency and Resilience Professionals in the UK”, see http://www.kcl.ac.uk/sspp/departments/geography/people/academic/demeritt/Publications.aspx.

of the service delivery chain which prevents the loss of value of forecast information between its production and receipt by the emergency planners and responders.

Despite this, Demeritt's report also remarked that the culture of emergency responders was reactive rather than preventative and found limited evidence of organisations responding pro-actively to warnings a few days ahead. Partly this may be because there is no need; in some authorities vulnerable areas are well-known and assets can be moved quickly, so more accuracy in the short-range forecast is more valuable than a longer lead time. However, one of Demeritt's recommendations was for the Met Office to provide case studies of best practices of pre-emptive actions which could be taken in response to weather warnings to mitigate risk.

There is the potential to carry out a fair amount of case study work in this sector to determine the economic value of this delivery chain. There is a limited amount of information available on the costs and benefits of responder actions to severe weather events, and that information which is available – such as the Kent County Council Severe Weather Impacts Monitoring System (SWIMS)[9] – focuses on costs only. For the purposes of this review, the high levels of trust and confidence with which the emergency planning and response community view the Advisors provides assurance that PWS information is reaching this community with little loss in value. Hence, the estimated benefits described in the following sections on mitigating the impacts of severe weather can be attributed with high confidence to the output of the PWS.

3.5 Value to Winter Land Transport

Several studies have considered the benefits of weather forecasting on winter weather disruption to land transport. Nurmi et al[10] estimated the value of weather forecasts to reducing accidents caused by adverse winter weather in Finland. In Finland, adverse weather conditions cause on average 47 more daily accidents when compared to "normal" weather conditions, four of which involve casualties. This corresponds to approximately 10% of wintertime accidents in Finland. Statistics from the Finnish Transport Agency put the cost of an accident without casualties at €2950 and the costs of accidents with casualties at €493000. Therefore the total winter related accident costs were estimated at €226m. Using a Value Chain Analysis the study found that the winter weather information had a value of 14% at the final stage, and hence the total savings from current winter forecasting was €37m per winter. Finally, the study applied their findings for Finland across Europe as a whole. Using the same 10% of accidents due to adverse weather the study estimated that weather information reduced the costs of accidents across Europe by €3.4bn.

Applying a model for the northern areas of Europe to the continent as a whole may not be completely robust, so it is interesting to see if the same assumptions can apply to the UK. The Winter Resilience Review[11] led by David Quarmby, which reported in October 2010, considered the economic impacts of winter weather on transport disruption in England. They considered "hard" economic value – that is, lost output, economic loss from accidents etc – and "welfare" costs for which individuals may be willing to pay to avoid but don't have an

[9] http://www.kent.gov.uk/business/Business-and-the-environment/severe-weather-impacts-monitoring-system-swims

[10] "Expected impacts and value of improvements in weather forecasting on the road transport sector", P. Nurmi, A. Perrels and V. Nurmi, Meteorol. Appl. 20: 217-223 (2013)

[11] http://webarchive.nationalarchives.gov.uk/20111014014059/http://transportwinterresilience.independent.gov.uk/docs/final-report/

impact on the economy. The conclusion from the study was that for a typical winter in England the hard costs were £450m and the welfare costs £500m. However, the largest single factor for the hard costs was not accidents, but reduced economic output from people not travelling to work or from journey delays (over £300m per annum). The impact of pedestrian accidents was estimated at between £10m-£100m per annum, whilst the impact of road accidents was estimated at less than £10m per annum. This low figure for road accidents compared to the Finnish study is explained by people choosing not to travel when winter weather is severe. A similar study by Transport Scotland[12] derived a central estimate for total welfare costs of winter weather in Scotland of £330m per annum, based on 11 snow days per year of daily GDP costs of £15.1m and daily welfare costs of £29.7m. As for England, the majority of costs were around reduced economic output from lost commuting and journey delays. Although the impacts in the UK are different to those in Finland, these can be mitigated by simple actions which can be informed by accurate forecasts, which could include planning to work from home, or staying overnight close to the workplace. Assuming that the way the UK public came to take mitigating actions regarding severe winter weather is similar to the way the Finnish public used weather information in Nurmi et al's study a value chain analysis figure of 14% can be used. Considering only the hard (GDP) costs of severe winter weather disruption in the UK and totalling these for England and Scotland to £616m per annum this would suggest that the economic savings through reducing the costs of winter travel disruption in England and Scotland due to weather information could be around £100m per annum.[13]

3.6 Value to Flood Damage Avoidance

Flooding is an impact of weather that causes significant economic damage. Although flood warning and incident management is the responsibility of the Environment Agency in England, Natural Resources Wales (NRW) in Wales, and the Scottish Environment Protection Agency (SEPA) in Scotland, one of the primary inputs into the flood warning models are precipitation forecasts provided through the PWS. Many studies have looked to estimate the flood damage avoided as a result of flood warnings, and using these methodologies and latest figures for the cost of flood damage, estimates for the benefit of the PWS to flood damage avoidance can be calculated. The PA study, the Met Office Flooding study and the EUMETSAT study all consider the benefits of flood damage avoidance.

The key assumptions required are how much potential flood damage can be avoided, pathways to avoid the flood damage and the factors which determine the effectiveness of the flood warning service (as in a Value Chain Analysis). The Environment Agency considers the following factors in the effectiveness of the flood warning service:

- Reliability and availability (percentage of properties receiving a useful warning)
- Uptake (percentage of properties with resistance measures)
- Operated (percentage of properties that take action)
- Effectiveness (percentage of damage avoided by taking action)

The reliability and availability of the flood warning is the element through which PWS precipitation forecasts have the main impact, but it is obvious that delivering benefits relies on the Environment Agency, NRW, SEPA and the public contributing throughout the rest of the benefits chain. In the PA study the aggregate of these performance factors quoted was 10.3%. Figures quoted within the Met Office Flooding study based upon the Environment Agency's Flood Incident Management Investment Review (FIM-IR) give an aggregate value

[12] "Estimating the cost of disruption to travel caused by severe winter weather", K. Johnston, J. Causley and S. Murchie, Transport Scotland.
[13] $x = 0.14\ (616+x) \Rightarrow x=(0.14/0.86)*616=100$

of 8.7%. The EUMETSAT study quoted a study from the 2002 Elbe and Danube floods which estimated that early warning and subsequent flood prevention measures reduced flood damage by 6%. It therefore seems reasonable to use a range of 6-10% to estimate the proportion of flood damage avoided as a result of flood warnings.

According to the PA study, in 2006 the average annual damage to property from fluvial and coastal flooding in England and Wales was £1.4bn in 2006. The Environment Agency added a 50% uplift to this figure to account for intangible damages to health and welfare which gave a total figure of £2.1bn. The Met Office Flooding study used an average annual damage figure of £3.2bn for 2012 from the FIM-IR which had a greater inclusion of non-property factors.

The PA study assumed that the Met Office contributed a proportional value of 25% to the flood warning service based on Environment Agency guidance that the Met Office contributed 15% to Fluvial flooding and 35% to the Coastal flooding services. Using these figures, the PA study estimated the value provided by the Met Office to flood warnings was £47.9m per annum, which also included downward adjustments for Net Present Value and direct service.

Using the same proportion of Met Office value for the 2012 average annual damage figure of £3.2bn with performance factors of 6-10% provides an updated figure for the value of the PWS to flood damage prevention in England and Wales of between £48m and £80m per annum, with a central value of £64m.

3.7 Value to Storm Damage Avoidance

A similar methodology to flood damage prevention can be adopted for storm damage prevention which, like flooding, is an impact of weather which causes significant economic damage. Unlike flooding, there are no rigorous studies of average annual storm damage, although, according to the EUMETSAT study, Swiss Re estimates the average cost across Europe is €2.6bn per year. The UK is more prone to windstorms than Europe as a whole being positioned under the North Atlantic storm track, and estimates of damage from past storms are significant. The “Great Storm” of October 1987 is estimated to have caused £2.2bn worth of damage, whilst the “Burn’s Day Storm” of January 1990 is estimated to have caused £3.4bn worth of damage.[14] There is no doubt that forecasting and warning has improved tremendously since those times, and the impacts of the 1987 storm as an un-forecasted event could be taken as a baseline for damage loss of life in similar storms today. Although not truly comparable to the 1987 storm, the St Jude’s storm of October 2013 was well forecast with high profile warnings in the media and extensive mitigation action taken against its potential impacts. This included shutting large parts of the rail network with a few days notice for most passengers to reduce the risk to life of trees falling on Monday morning commuter services. In the event, rail operators had to deal with about 200 fallen trees and services were mostly back to normal by the evening.[15] Whilst 18 people lost their life in the 1987 storm, only 5 people lost their lives in the 2013 storm. Damage from the St Jude’s storm was estimated at around £300-500m by Willis Re[16]. It would be disingenuous to suggest that by comparing the 1987 and St Jude’s storm that the accurate warnings and forecasts through the PWS are preventing storm damage in the order of billions of pounds,

[14] http://news.bbc.co.uk/1/hi/business/6380123.stm
[15] http://www.theguardian.com/uk-news/2013/oct/28/britain-storm-rail-disruption
[16] http://www.insuranceage.co.uk/insurance-age/news/2303612/willis-re-estimates-st-jude-storm-will-cost-insurers-gbp500m

but it is likely that mitigation action taken as a result of the warnings of the event reduced the economic damage in the order of hundreds of millions of pounds.

The EUMETSAT study used the Swiss Re figure as a basis for estimated the storm damage prevention as a result of weather forecasts and warnings across Europe. Assuming weather forecasts could reduce losses by between 10% and 50% they suggested the benefits of weather forecast across Europe for storm damage prevention could be between €0.26bn and €1.2bn per annum. If that figure was apportioned to the UK based on GDP (using the UK contribution rate to EUMETSAT of 13% as a proxy and an exchange rate of £1=€1.25) this would give a figure of between around £27m and £125m per annum, with a mid-point of £80m per annum. Using similar proportions on the losses experienced for the St Jude's storm for the UK would suggest a value of the PWS to storm damage prevention of between £30m and £250m per significant event. The PA Study from 2007 used a case study of potential lives saved in the construction sector through acting on warnings for high winds, and estimated the economic benefit of the lives saved at £34m per year for this sector.

Considering this case study, it seems reasonable to take the mid-point of the EUMETSAT study range for the UK of £80m as an average annual economic benefit for storm damage avoidance.

3.8 Value to the Economy

It is well known that weather has a direct impact on many aspects of the economy not discussed above including the agriculture, construction and energy sectors, and indirect effects on other sectors such as retail. A study by Ouwehand and van Ruth[17] analysed the effect of unusual weather on Dutch Gross Domestic Product (GDP). They found that cold winter weather would generally have a negative impact on GDP from the manufacturing and construction sectors due to the impact of frost on productivity, but positive in the mining and energy sectors as more heating was required during cold periods. Whilst in an overall cold winter these effects broadly cancelled each other out (winter of 2013), energy use would drop during milder/warmer spells which could lead to an overall negative impact on GDP if the temperature overall was average but there had been long spells of frost impacting on the construction and manufacturing sectors. The winter of 2012 experienced such conditions in the Netherlands and it was calculated to have a negative impact on GDP of about 0.6%.

The Dutch study did not consider the impacts on agriculture as they considered the sector too small in the Netherlands. However, this is one sector where the impacts of weather on output can be significant. The annual Agriculture in the UK reports from Defra[18] summarise the annual agricultural output of the UK. In 2012, the output dropped by 14% to £4.7bn, primarily as a result of a cold dry winter being followed by a wet summer. The figures for 2013 show a recovery to output of £5.6bn, broadly in line with the inflation adjusted 2011 figure, consistent with the weather impacts. Individual weather events can have significant impacts on agriculture. For example, heavy snow and bitter cold in late March 2013 had a devastating effect on livestock in the north of the UK: in Northern Ireland alone some 3000 animals died due to the effects of the snow.[19]

[17] "How unusual weather influences GDP", P. Ouwehand and F. van Ruth, Statistics Netherlands Discussion paper; 2014. See http://www.cbs.nl/en-GB/menu/methoden/onderzoek-methoden/discussionpapers/archief/2014/default.htm.
[18] https://www.gov.uk/government/collections/agriculture-in-the-united-kingdom
[19] http://www.metoffice.gov.uk/education/8192

The PWS public forecasts are used by Small and Medium Enterprises (SMEs) in planning their businesses. This could range from a self-employed builder deciding how to plan his work between outdoor and indoor jobs, to farmers deciding when to undertake activities such as crop spraying, irrigation, planting and harvesting, to the weather-dependent tourism and leisure sectors where information can be used to help plan and market various activities. In the PA study from 2007, ORC International conducted a survey amongst 501 SMEs to assess the value and use of weather forecasts. Overall 91% said that the weather had an impact on their business activities, with 53% stating it had “a lot” of impact (rising to 89% in the agriculture sector). 85% used weather forecasts to help their business from planning day-to-day activities, anticipating demand, ensuring safety of staff or customers, and effectively managing staff resources. Many larger businesses procure more specialised services to support their planning from the Met Office or other weather service providers. All these services are dependent upon the national capability funded through the PWS.

Despite the strong evidence of weather impacts on the economy, and the use of forecasts by weather dependent sectors to improve productivity, it is challenging to estimate what the economic benefit of the PWS could be. The EUMETSAT study estimated the economic benefits to the European economy by assuming that one third of the European economy is sensitive to weather and that weather forecasts could add value of between 0.25% and 1%. Using the EU-27 GDP figure in 2010 of €12.28Tn it estimated that the added value to the European economy would be between €10bn and €41bn per year.

Using the ONS 2013 Blue Book[20], which details UK economic activity in 2011 by sectors, an attempt is made to estimate the added benefit of weather forecasts to the UK economy for that year. The total value of the UK economy in 2011 was estimated at £1.36Tn. The largest sectors detailed in the Blue Book were Retail, Property, Financial Services and Manufacturing, all of which contributed over £100 billion to the UK economy, and which have no dependence on the weather, apart from where weather influences consumers’ behaviour. The size of sectors which are very weather dependent such as Agriculture, Construction, Utilities, Mining and Quarrying are detailed in the Table below.

Sector	**Value (£m)**
Agriculture	9,438
Construction	86,789
Electricity, gas, and water supply	33,289
Mining and quarrying	31,380
TOTAL	**160,896**

Table 2:
Size of UK economy according to 2013 Blue Book in weather dependent sectors.

Transport is also very weather dependent, but as we have already considered benefits to aviation and land transport in previous sections, this sector will be excluded from further analysis to avoid double-counting. Therefore, the size of the UK’s economy which is very weather dependent (excluding Transport) was about £160billion in 2011. Considering the range of figures used in the EUMETSAT study of 0.25% to 1% for the added value of weather forecasts, and that the sectors considered here are very weather dependent, a conservative mid-point of 0.5% added value would give an estimated economic value of weather forecasts to these sectors of £800m per annum. Assuming that the PWS makes a 50% contribution to the value of these services through the National Capability, we can

[20] United Kingdom National Accounts, the Blue Book, 2013 Edition - http://www.ons.gov.uk/ons/rel/naa1-rd/united-kingdom-national-accounts/the-blue-book--2013-edition/index.html

provide an estimate for the added value of PWS to the economy of around £400m per annum.

3.9 Other Benefits

Not all economic benefits of the PWS to the UK are derived from weather services. The UK is the host nation of ECMWF and the UK subscription to ECMWF is paid for through the PWS. A 1995[21] study of the economic benefit to the UK of hosting ECMWF calculated the benefit at over £25m for 1994 with a total increase in UK employment of 485 jobs. Using the same methodology on ECWMF's projected 2014 expenditure provides a figure of over £60m. However, ECMWF are currently reviewing their future accommodation requirements and this could have implications for the UK as host nation.

The UK space industry benefits from the UK's membership of EUMETSAT funded through the PWS. There are two methods by which return can come to the UK. Firstly, EUMETSAT ground segments and operations contracts are let on a competitive basis to companies domiciled in EUMETSAT member states. UK industry has had success in winning these tenders, with total contracts worth in the order of €15m over 5 years.

Satellite development and build is funded jointly by ESA and EUMETSAT, with ESA funding roughly 30% of the costs and EUMETSAT 70%. ESA expenditure on programmes is allocated on a geo-return basis: that is, member states subscribing to the programmes will expect contracts let to their national industry to an equivalent value of their investment. Therefore, the net national return on an ESA investment to a EUMETSAT programme would be around 7/3rds of the original investment. At the 2012 ESA Ministerial the UK committed £85m to the ESA component of the European Polar System – Second Generation (EPS-SG) programme. This investment has enabled UK industry to compete for and win significant contracts, most notably the Microwave Sounder prime contract worth €155m. Current estimates are for UK industry to win contracts to the value of €214m for EPS-SG development.

3.10 Summary of Economic Benefits

The study has reviewed available literature and studies which have looked at the economic benefits from weather services to the following sectors:

- The Public
- Aviation
- Civil Contingencies
- Land Transport
- Flood Damage Avoidance
- Storm Damage Avoidance
- Added Value to the Economy

The study has also considered other benefits arising from the UK hosting ECMWF and being a member of EUMETSAT. Different methodologies have been used within different sectors which means care must be taken when combining these figures to generate an overall

[21] "The economic benefit to the United Kingdom as host of the international organisation ECMWF the European Centre for Medium Range Weather Forecasts." 23 Feb 1995. - General Technology Systems (Netherlands) BV

benefit from the PWS to the UK economy. Table 2 below summarises the economic benefits discussed in the above sections.

Sector	Value (per annum)
Public	£480m
Aviation	£400m
Land Transport	£100m
Flood Damage Avoidance	£64m
Storm Damage Avoidance	£80m
Added Value to Economy	£400m

Table 3:
Summary of annual economic benefits of the PWS by sector.

The sum of the benefits itemised above is approximately £1.5bn per annum. The EUMETSAT study gave the total economic benefits to Europe of weather services of between €15bn and €61bn per year. Proportioning this to the UK based on GDP (using the EUMETSAT rate of assessment for the UK of 13% as a proxy and an exchange rate of £1=€1.25) would suggest benefits of between £1.6bn and £6.3bn per year.

The PA study derived a total value of £614m per annum at 2007 prices based on public value and three case studies (Cabinet Office, Environment Agency and Civil Aviation Authority). Furthermore it stated “given the prudent approach taken throughout this study and the many other areas of benefit that are provided by the PWS, the overall value can be expected to be many times more than this figure.” The figure of £1.5bn derived from this study is only just over twice the PA study figure at today’s prices, and so is well within the expected total figure from the conclusion of that study.

In conclusion, we can state with very high confidence that the economic benefits of the PWS to the UK are in excess of £1bn per annum. The benefits attributable to the PWS are more likely to be around £1.5bn, and for weather services as a whole the benefits are likely to exceed £2bn.

3.11 Reduced Deaths

The articulation of PWS benefits as a financial figure is important in being able to identify a return on investment in the PWS. However, one of the primary objectives of the PWS is the protection of life, and the primary output of weather warnings is aimed at providing the public and responders with appropriate advice to minimise risks to life. Fortunately, the UK climate is fairly moderate, and severe weather events that have a widespread threat to life are relatively rare. Nevertheless, tragically, a handful of deaths occur each year associated with high winds, high waves, or floods, but it is difficult to estimate how many lives have been saved due accurate forecasting and warning around these events.

One of the case studies considered in the PA study from 2007 was potential lives saved for construction workers on scaffolding during strong winds. The example quoted was for Waltham Forest Borough Council which in 2006 on receipt of a weather warning for high winds in excess of 70mph ensured all work on high level structures stopped. Scaffolding subsequently collapsed that would have had 5 workers on it. Using Met office statistics for 9 high wind/storm warnings during the year, assuming that five lives could be put at risk for each incident, and that the response to these warnings would be 50% the PA study estimated that 23 lives would be saved per year in the construction industry due to actions taken on storm warnings.

It is possible to compare similar extreme events from the recent past and those which have occurred with the benefit of accurate forecasting and warnings linked to emergency response. On the night of the 31 January 1953, the UK was affected by tremendous storm surge down the North Sea which led to the deaths of 307 people in the eastern counties of England, a further 19 in Scotland, and 133 fatalities from the loss of the ferry MV Princess Victoria east of Belfast. Over the 5-6 December 2013 a similar event occurred. The risk was seen in storm surge models coupled to weather forecasting models some seven days ahead. As confidence increased, Government and emergency responders were alerted to the possibility and the Flood Forecasting Centre issued a red flood risk (High Likelihood of Severe Impacts). The event occurred as forecast, with the storm surge lasting over three high tides. However, because of the advance warnings, the preparedness of the emergency responders, and improved sea defences since 1953, there were no flood related deaths and only one tenth of the level of property flooding compared to 1953.[22]

The 1953 East Coast flood remains the UK's worst short-lived natural disaster for loss of life in recent times, with the 2004 Boxing Day tsunami in the Indian Ocean claiming the lives of over 140 UK citizens overseas, and the 1990 Burns' Day Storm killing 47 people in the UK. However, far more lives are lost in the UK through extreme heat and extreme cold. These fatalities are normally described as "excess deaths" being deduced statistically from expected death rates and the actual death rates which occur during the extreme temperature event.

Excess winter deaths have been monitored for many decades by the Office for National Statistics.[23] There is a clear trend of reducing excess deaths from an average of around 60,000 in the 1950s and 1960s to between 20,000 and 30,000 today, with the vast majority aged over 75. There is also less of a correlation with temperature in recent years, presumably because many more homes are effectively insulated. However, winter excess mortality is dominated by influenza outbreaks, rather than direct temperature effects.

Excess deaths due to heat have recently been well studied following the August 2003 heat wave, for which an estimated 2,000 to 3,000 excess deaths occurred in the UK, and many more in Europe. As a result the Met Office established a heat-health warning, funded outside the PWS but dependent upon the PWS-funded National Capability. The PA study from 2007 used data from the US which showed that heat warnings in Philadelphia reduced excess deaths by about 2.6 per day of heat wave, or 4.6% of total fatalities. Using this factor, the PA study argued the Met Office heat warning service saved 31 lives in the July 2006 heat wave, based on 680 excess deaths. Recent heat waves in the summers of 2013 and 2014 were attributed to excess deaths of 760 in the first nine days of the July 2013 and 907 excess deaths in the first week of August 2014. Using the same methodology as the PA study, the lives saved through heat warnings in the summers of 2013 and 2014 can be estimated at 35 and 42 respectively.

An indirect weather effect which leads to a significant loss of life in the UK is air pollution. Public Health England has estimated that 29,000 annual deaths in the UK can be attributed to long-term exposure to poor air quality[24]. Although much of this may be associated with locally generated chronic pollution, acute poor air quality events can occur due to weather conditions either through trapping locally generated pollution in the boundary layer, or

[22] FFC Annual Review 2013/14, http://www.ffc-environment-agency.metoffice.gov.uk/media/pdf/FFC-Annual-Review-2013-14.pdf
[23] http://www.ons.gov.uk/ons/rel/subnational-health2/excess-winter-mortality-in-england-and-wales/2012-13--provisional--and-2011-12--final-/stb-ewm-12-13.html#tab-EWM-trends-in-England-and-Wales-
[24] https://www.gov.uk/government/publications/estimating-local-mortality-burdens-associated-with-particulate-air-pollution

importing high levels of pollution from elsewhere, for example in early April 2014[25]. Although this was a good example of how public awareness of a high pollution event that was forecast by the Defra-funded Met Office service was raised through the media, in its recent report, the Environmental Audit Committee[26] recommended that "The Government should work more closely with the Met Office, BBC and other broadcasters to ensure that high air pollution forecasts are disseminated widely via mainstream media in the same way pollen and UV forecasts are broadcast now." Given the high number of deaths attributed to air pollution in the UK, good air quality forecasts and warnings have the potential to reduce deaths on par with that estimated for heat-health warnings during heatwaves.

Many outdoor leisure activities expose participants to direct risk from the weather. One such area is marine, where the Met Office provides marine observations, shipping forecasts and in-shore waters forecasts under contract to the Marine and Coastguard Agency (MCA) in support of the MCA's role in minimising the rates of accidents, deaths and injuries at sea and along the coast. The National Water Forum collate statistics on water deaths each year, which show that over 100 people die each year at sea or on the coastline, although the statistics do not show where weather has been a contributing factor. Mountain walking and climbing is an activity for which the PWS provides specific forecasts. This provides a quantification of risk for a wide variety of weather elements, including blizzards, heavy snow, heavy rain, storm force winds, gales, severe chill effect, hill fog, thunderstorms and strong sunlight. The Scottish Mountain Rescue report that in 2012[27] they attended 720 incidents, in which there were 240 injuries and 25 fatalities. However, weather was a major factor in the incident in only 25, or 3.4%, of cases. A similar figure (3%) was recorded in 2011.This illustrates that it is likely that the provision of detailed warnings and forecasts for mountain areas is being effectively used by the mountaineering leisure community to minimise the risk to life from weather impacts.

Overall, it is difficult to quantify an average annual figure for the number of lives which are saved as a result of weather forecasts and warnings. However, modern forecast accuracy, dissemination of warnings and resulting mitigating action may be saving many tens of lives each year from direct impacts of the weather, with the case study of construction workers being one example. For extreme events, such as North Sea coastal flooding, hundreds of lives are potentially being saved. Also, excess deaths from heatwaves may be reduced by about 40 per event due to heat-health warnings. In any event, there is no doubt that the PWS saves lives, and to some users and stakeholders that is of greater value that the economic benefits described in the sections above.

[25] http://www.bbc.co.uk/news/uk-26844425
[26] Environmental Audit Committee 6th Report – Action on Air Quality, http://www.publications.parliament.uk/pa/cm201415/cmselect/cmenvaud/212/21202.htm
[27] Mountain Rescue Scotland 2012 Report, http://www.mountainrescuescotland.org/member-page/mrcos-documents/statistics/

4. Costs of the PWS

4.1 Overall Cost

The total price for the PWS outlined in the CSA for 2014/15 is £119.7m. This is funded by £91.4m from BIS, £18.5m from aviation (negotiated separately between the Met Office and CAA), a £6.8m capital grant from BIS for polar satellites, with the remainder revenue from wholesaling data or international research grants.

The current CSA splits the costs into three areas: Operations (£42.3m), Research and Development (£26.1m) and International subscriptions (£51.2m). Whilst superficially one mechanism to increase value for money is to reduce the costs of the PWS, this can only be considered by having a full understanding of the costs of the PWS, which costs can be reduced (short-term commitments) and what the impact to benefits would be from reducing those costs. Further detailed breakdown of these costs is described in the following section.

4.2 Breakdown of Costs

In Section 2, the PWS was broken down into 6 themes, of which four related to services (NSWWS, Public, Civil Contingencies and Data) and two to what can be described as the underpinning infrastructure necessary for the services: the National Capability and International Commitments. These last two themes cost a total of £110.6m of the total price of £119.8m as shown in Table 4 below.

Theme	**14/15 Cost (£m)**
International Commitments	**51.2**
National Capability	
Observations (inc Obs Network, Spectrum, Quality Control)	30.4
Model Development (Science)	14.5
Forecast Production (inc Forecasters, systems, HPC, central guidance)	14.5
Total of National Capability	**59.4**
Services	
Public Reach (inc web, apps, BBC and library)	5.9
Civil Contingency (inc advisors and warnings)	1.9
Total of Services	**7.8**
Management	**1.4**
TOTAL[28]	**119.7**

Table 4:
PWS costs attributed by theme.

These costs can be broken down further into those which are committed over the short-term (<2 years), medium-term (2-5 years) and long-term (> 5 years). Staff costs are assumed to be medium-term. Table 5 below shows how the costs shown in Table 4 can be attributed further.

[28] Figures may not add exactly due to rounding.

Theme	Short-term Costs (£m)	Medium-term Costs (£m)	Long-term Costs (£m)
International Commitments			**51.2**
National Capability			
Observations	2.5	18.5	9.3
Model Development		14.5	
Forecast Production	0.1	14.4	
Total of National Capability	**2.6**	**47.4**	**9.3**
Services			
Public Reach	0.2	5.7	
Civil Contingency	0.1	1.8	
Total of Services	**0.3**	**7.5**	
Management		**1.4**	
TOTAL[29]	**2.9**	**56.3**	**60.5**

Table 5:
PWS costs attributed between short-term, medium-term and long-term commitments.

From the breakdown, it can be seen that a significant portion of PWS cost is committed to medium and long-term expenditure, which is to be expected given that it funds the national and international infrastructure which underpins the services of the PWS.

4.3 International Subscriptions

The International subscriptions include the cost of UK subscriptions to EUMETSAT, ECMWF and WMO which the Met Office pays on behalf of the UK. These are subscriptions the UK is committed to pay due to being a signatory of the conventions of these intergovernmental organisations. The price the Met Office charges the PWS for EUMETSAT is not the actual annual cost of the EUMETSAT subscription but a charge based upon the annual administration costs of EUMETSAT (its General Fund), the operational costs of satellites and the capital depreciation of the operational satellites. This means that the PWS price remains relatively stable whilst the actual EUMETSAT subscription peaks markedly during the development phase of the satellite programmes.

In 2014/15, the EUMETSAT polar satellites were included in the price of the PWS for the first time. (These were previously treated separately within MOD and then BIS.) As part of the agreement for including these costs the price increase to PWS was offset by a capital grant of £6.7m per year from BIS. The inclusion of polar satellites has increased the proportion of international subscriptions within the total PWS price. In 2013/14 international subscriptions were 36% of the total price; in 2014/15 they are 43% of the price. These expenses are non-discretionary and although the UK has some influence on the size of international subscriptions it does not have control as the organisations' budgets are decided democratically by the member states who have acceded to the conventions of these organisations.

[29] Figures may not add exactly due to rounding.

5. Future Opportunities and Risks to Benefits and Costs

Maintaining and increasing the value for money of the PWS should be a major consideration in determining investment and strategy for the PWS over the longer-term. This section will consider what are the opportunities (and risks) to maintaining and increasing the value for money in the future through both benefits and costs.

5.1 Forecast Accuracy

Substantial investment is already committed to increasing forecast accuracy over the next five years. The Met Office has successfully bid for a capital grant from BIS for its next HPC investment from 2015 to 2020. The business case set out how capital investment of £97m in a new HPC for the UK would enable socio-economic benefits (SEBs) of some £2bn over five years. Firstly, four methodologically-rigorous case studies were commissioned from independent external experts to estimate SEBs enabled with improved forecasts to specimen sectors of the economy. Two studies (civil aviation and centennial climate forecasts) cover sectors already being served by mature Met Office services whilst two other studies (renewable energy, food supply chain) cover sectors where Met Office services are currently less mature. Secondly, the Environment Agency's *Evidence Base* for its *Flood Incident Management Investment Review* was used to derive an estimated value of improved FFC flood forecasts. In addition, a short in-house study was undertaken to assess SEBs deliverable with improved forecasts of UK severe winter weather events specifically in relation to road travel disruption costs. Some of these studies have been used as source material for this review. For example, the Helios study (see section 3.3) concluded that a new HPC could provide the aviation sector with discounted net benefit of over £275m over five years. Although the £2bn benefits over 5 years covers a range of Met Office services, and not just the PWS, the investment in the HPC should be expected to enhance the economic benefits of the PWS by accelerating improvements in forecast accuracy above the historical day's extra skill per decade.

On a longer time-scale, the next generation of meteorological satellites are expected to bring forecast accuracy improvements. The next generation geostationary satellites (Meteosat) is due to launch in 2020, and the next generation polar orbiter satellites (Metop) several years later. Although the business cases for these satellites have focused on continuity and existing benefits of satellite data to weather forecasting, experience has shown that the improved observations from new satellite instrumentation has been an important contribution to past gains in forecast accuracy. Unlike the HPC investment, though, the next generation satellites will lead to increased costs to the PWS (see below).

Exploiting these technological enhancements into improved forecast accuracy requires the strong science research base which the Met Office possesses. Although eroding this science base will not necessarily have major impacts in the short-term on forecast accuracy it will inhibit the Met Office's ability to continue to deliver forecast improvements in the longer-term. It is some of these longer-term areas that more economic benefits will be realised by enabling decisions to be taken based on forecast information which are currently not possible. For example, there is currently no effective surface water flooding warning service as there is little confidence in detailed forecast of convective precipitation. Similarly, the current challenge in forecasting fog at Heathrow has major impacts on the airport's operations and costs. Increased skill in winter seasonal forecasts could enable strategic planning decisions which will mitigate impacts and reduce costs which are currently not possible. Improvements in forecast accuracy need to focus on where they will lead to new decisions that have economic impacts to continue to grow the value for money of the PWS.

5.2 Reach

It doesn't matter how accurate a forecast is if it is not available to people to use. Maintaining and increasing reach is therefore an essential element of the PWS over the coming years. This is particularly at risk as reach channels (TV, radio, digital) are competitive markets and the Met Office reach is dependent on winning competed contracts. The way that people are accessing information is changing, and with many global providers in the digital marketplace, there is a question over whether reach can be maintained with a purely UK offering. From another perspective, should PWS be concerned about the attribution of reach as long as it is PWS-funded data (i.e. the best possible forecast data for the UK) that is ultimately being used for public-facing services through media and digital platforms?

However, a loss of reach, whether direct or indirect, would have a major impact on the value for money of the PWS. This would not just impact on the perceived public value of £480m, but also impact on many other sectors where reaching the public with a trusted and authoritative message is a key element in maintaining value in the service delivery chain.

5.3 International subscriptions

As a committed cost over which we do not have full control which is over 40% of the total price of the PWS, failure to control international subscriptions is a major risk to the value for money by increasing cost for no added value. Increases in costs from the next generation of EUMETSAT satellites are already expected. It is anticipated that the annualised cost of Meteosat will increase by £7m per annum when the next generation series becomes operational, whilst the annualised cost for Metop will increase by a further £14m per annum when that next generation series becomes operational. However, the improved forecast accuracy from the next generation satellites series may lead to increased benefits which provide a return on investment from these increased costs. Similar challenges exist for ECMWF subscriptions, although cost drivers such as relocation and pensions are not going to lead to improved outputs and potential increase in value.

5.4 Success of Met Office Business Model

The PWS price is subject to government rules on fees and charges which define the PWS price "mark-up". Met Office corporate overheads are generally allocated on revenue proportionate basis and so therefore the cost of the PWS can be dependent on the success of other parts of the Met Office business. Should the Met Office significantly increase its non-PWS revenue as a successful business then the PWSCG could expect the proportion of overheads charged to PWS to reduce and hence price to fall.

However, if the Met Office were to lose or have reduced existing government or competed contracts then any benefits to the PWS from the Met Office increasing its commercial revenue would be lost. Indeed, where synergies currently exist within the Met Office from holding several contracts (e.g. shared weather and climate research, model development and use of HPC) then the loss of some of these contracts would have an impact on the PWS.

6. Discussion and Conclusion

The current PWS provides a positive return on investment. Economic benefits of £1.5bn per annum for the UK have been estimated from existing studies covering a range of sectors including the public, aviation, flood damage avoidance, storm damage avoidance, land transport and added value to the economy. There is scope for further work including some case studies in the civil contingency sectors. The costs of the PWS for 1415 are nearly £120m, most of which fund the National Capability upon which all weather services in the UK depend (£59.4m) and International Commitments (£51.2m). Most of these costs are in long-term commitments such as satellites, or in medium-term commitments, such as observations and HPC infrastructure or staff. Nevertheless the extensive benefits represents a return on investment of over 10 to 1 for the current PWS cost of £120m. Whilst this is a reassuring conclusion, future plans and strategies for the PWS should aim to continue to increase its value for money both in enhancing benefits and maintaining control of costs.

There are several challenges to achieving this. Costs in international subscriptions are expected to increase post-2020 as the next generation of meteorological satellites becomes operational. Maintaining public reach of PWS data is a risk given the competitive media and digital markets that exist. The PWS benefits from synergies created within the Met Office with its other government contracts. Loss of those contracts may drive further costs into the PWS, or counter the prospect of reducing PWS costs from increased Met Office commercial revenue. On the other hand, investment in an enhanced HPC at the Met Office and in the next generation of meteorological satellites should lead to improved forecast accuracy. For this improved accuracy to enhance economic benefits it needs to “unlock” new areas where forecast accuracy is not currently good enough to enable decisions with positive economic impact to be taken. This could include better fog forecasting at Heathrow, better convective precipitation forecasts to enable surface water flood warnings, or reliable seasonal forecasts to enable strategic winter resilience planning. Such enhancements are not in-year developments. They require many years investment in science, infrastructure and understanding users’ needs. Having a long-term plan for development allied to a long-term commitment of resources would therefore assist the PWS in being able to enhance the current positive return on investment.

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