Defining the architecture and attributes of successful climate change adaptation surrounding long-lived infrastructure in the coastal zone

LOUGHBOROUGH UNIVERSITY

Department of Geography

Defining the architecture and attributes of ‘successful’ climate change adaptation surrounding long-lived infrastructure in the coastal zone

By

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Abstract

Climate variability and change threaten human and physical systems in coastal zones. With more than 10% of the global population now living and working in low elevation coastal zones, 'successful' adaptation to climate change is becoming a pressing issue, particularly for areas featuring critical, long-lived infrastructure. The aim of this research is to define the architecture and attributes contributing to successful adaptation to climate change. Here, success is measured in terms of the process rather than outcomes of adaptation initiatives.

The research features two empirical phases: adaptation framework analysis and an evaluation of factors affecting the adaptive capacity of stakeholder organisations. Framework analysis involved the development of a criterion tool based on recurrent features of different adaptation frameworks as described in research literature. Six hallmarks emerged as discriminators of Scenario-Led (SL), Vulnerability-Led (VL) and Decision-Centric (DC) frameworks. The criterion tool was then tested using four UK coastal case study areas, drawing on evidence from public domain adaptation documents. The Grounded Theory Methodology (GTM) was used investigate factors enabling or inhibiting stakeholder adaptation efforts by designing and iteratively adjust semi-structured interviews with stakeholder organisations in the Sizewell nuclear neighbourhood, Suffolk, UK. The findings from the two phases were brought together to identify opportunities to improve the adaptation processes.

Analysis of the adaptation architecture revealed that stakeholders rarely use one theoretical adaptation approach. A hybrid adaptation framework is adopted, with the DC/SL or DC/VL being utilised most frequently. Findings reveal a mismatch between theoretical frameworks and those implemented in practise. Semi-structured interviews exposed six key themes defining adaptation process. Stakeholder organisations reported 12 factors that affect their standpoints on each key theme. Standpoints were broadly consistent between similar stakeholder organisations. Stakeholder groups, key themes and influencing factors provide an evidence base for evaluating the complex social dynamics affecting 'successes' of the adaptation process, offering a route to pragmatic adaptation guidance. By considering the architecture and attributes of adaptation coastal stakeholders in neighbourhoods with long-lived infrastructure could strengthen the adaptation process, thereby realising their shared vision(s) of integrated coastal management.

There is scope for improving and advancing the research. It is acknowledged that the inventories of adaptation initiatives were uneven in size and scope, potentially limiting the evaluation of the criterion tool. This may be addressed by assessing other coastal neighbourhoods with long-lived infrastructure. When interviewing representatives from stakeholder organisations, it was difficult to differentiate between personal or professional views. Future research could investigate how the role of the individual influences adaptation efforts. Insights could further refine the architecture and attributes of adaptation.

Key words: Climate change, Coastal zone, Adaptation process, Frameworks, Infrastructure, Stakeholder analysis.

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Abbreviations and Definitions

Abbreviations

ACORN	A classification of Residential neighbourhoods
ATH	Aspirational Time Horizons
CAQDAS	Computer Assisted Qualitative Data Analysis Software
CCC	Committee on Climate Change
CSA	Climate Smart Agriculture
CGN	Chinese General Nuclear Power Group
DC	Decision Centric change adaptation frameworks
DECC	Department for Energy and Climate Change
DEFRA	Department for the Environment Food and Rural affairs
EA	Environment Agency
EDF	Électricité de France
EU	European Union
GDP	Gross Domestic Product
GHG(s)	Greenhouse Gas (s)
GIA	Glacial Isostatic Adjustment
GIS	Geographical Information Systems
GTM	Grounded Theory Methodology
IAM(s)	Integrated Assessment Model(s)
ICZM	Integrated Coastal Zone Management
IPCC	Intergovernmental Panel on Climate Change
KPI(s)	Key Performance Indicator(s)
LECZ	Low Elevation Coastal Zones
mAOD	Meters Above Ordinance Datum
NAO	North Atlantic Oscillation
NNB(s)	Nuclear New Build(s)
NNR	National Nature Reserve
NSI	Normative Social Influence

OECD	Organisation for Economic Cooperation and Development
OTH	Operational Time Horizons
PPMV	Parts Per Million by Volume
RCP	Representative Concentration Pathways
RCM	Regional Climate Model
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SL	Scenario Led climate change adaptation frameworks
SLR	Sea level rise
SMP	Shoreline Management Plan
SPA	Special protected Area
SRES	Special Report on Emission Scenarios
SSSI	Special site of Scientific Interest
STN(s)	Stakeholder Thematic Network(s)
UKCP09	United Kingdom Climate Projections 2009
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNPD	United Nations Policy Division
UNDP	United Nations Development Programme
VL	Vulnerability Led climate change adaptation frameworks

Definitions

Adaptation

The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects1. (IPCC 2001; 2014)

Mitigation

Anthropogenic intervention to reduce the source or enhance the sinks of greenhouse gasses (IPCC 2000; 2014)

Stakeholder

A person such as an employee, customer or citizen who is involved with an organisation, society, etc. and therefore has responsibilities towards it and an interest in its success (Cambridge Dictionaries 2016)

Wicked problem

A difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize. The use of term "wicked" here has come to denote resistance to resolution, rather than evil. (Australian Public Service Commission 2007)

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Chapter 1: Introduction – The importance of ‘successfully’ adapting coastal zones to anthropogenic climate change

1.1 The significance and vulnerability of coastal zones

Throughout history, coastal zones have been significant to the development and prosperity of civilisations. Effective management of coastal infrastructure along with resource production and consumption are essential in preserving the integrity of these zones. Coastal management is now a well-established concept. Populations have been implementing measures to enhance living in coastal zones since the expansion of ancient societies. Over the last 20 years, management practices have evolved to deliver a more sustainable approach (Groesbeck et al 2014; Nicholls et al 2013; Viles and Spencer 2014). However, coastal zones are facing unprecedented pressures from globalisation, population growth and, increasingly, the impacts of extreme weather events linked to climate variability and change (Nicholls et al 2012; Hallegatte et al 2013; Moser et al 2012; Wong et al, 2014; Nicholls et al 2015).

The coastal zone is defined by the United Nations Environment Programme (UNEP) as ‘…*the domain surrounding the land–sea interface extending to the landward and seaward limits of marine and terrestrial influences’* (Pirrone et al 2005, pp113). The spatial distribution of the global population is increasingly focused in these domains. Based on population estimates from 2000, low elevation coastal zones (LECZs) (land below 10 meters above sea level) account for only 2% of the terrestrial area of the planet, yet accommodate more than 10% of the world’s population (~600 million people at that time) (McGranahan et al 2007).

Sea level rise (SLR) and intense storm surges are already impacting on coastal communities and infrastructure (Cinner et al 2012; Hallegatte et al 2013). For example, storms in Sydney, Australia in June 2016 eroded 50 m of beach in 24 hours leaving properties at risk of falling into the sea (Levy 2016). Despite known risks, urban populations and coastal assets are growing faster than national average trends, largely due to coastal migration (IPCC 2013). Currently, eight of the world’s ten largest cities are situated in coastal zones, resulting in ~13% of the global population residing in urban LECZs (Ramesh et al 2015). Since 1970, continued growth of the coastal population has led to a 95% increase in the number of people and economic assets at risk from a 1 in 100-year extreme sea level event (Jongman et al 2012).

With such a small fraction of the world's surface supporting so much critical human activity, it is essential that management strategies are effective in addressing current threats and ensure that future developments address the expected impacts of anthropogenic climate change.

1.2 The climate-infrastructure-energy nexus

Population growth is a key driver of rising demands for energy (Asif and Muneer 2007). As the distribution of the world's population continues to concentrate in urbanised coastal zones, pressure is being placed on these regions to accommodate infrastructure and provide reliable sources of energy (Mee 2012). In order to meet energy demand sustainably, development must be decoupled from greenhouse gas (GHG) emissions. Mokness et al (2009) believes that this is feasible, asserting that coastal zones are an ideal location for low carbon energy production, such as from tidal barrages, offshore wind farms and nuclear power.

Figures published by the UNFCCC (2015) provide an overview of global GHG emission to date, further highlighting the importance of sustainable low-carbon development. Over the last 150 years, 2000 gigatonnes of CO_2 have been emitted into the atmosphere. To keep global warming below the dangerous 2°C level, the total budget for GHG emissions must not exceed 3000 gigatonnes (IPCC 2013). In other words, humanity has already spent two thirds of the allowable carbon budget! Many are now calling for climate change to be limited to 1.5°C (New et al 2011). To achieve this more stringent target, future global emissions must not exceed 600 gigatonnes. However, these estimates do not incorporate negative emissions achieved through techniques such as bio-energy with carbon capture and storage or afforestation (van Vuuren et al 2013).

Nuclear power has long been promoted as a reliable, low-carbon option for meeting future energy demands (Enkvist et al 2007). The development of nuclear power has expanded rapidly since the first reactors were constructed in the 1950s. Currently, there are 440 nuclear power plants operating in 31 countries, generating ~11% of the world's electricity (World Nuclear Association 2016). Some believe that nuclear energy has the potential to replace base-load fossil fuel electricity generation in many parts of the world (Sims et al 2003). Following the Climate Change Act (2008), there are plans for eight nuclear new builds (NNBs) around the UK coastline. The existing fleet of nuclear power stations and proposed NNBs must be situated in the coastal zone as vast amounts of water are needed for cooling systems. Inland waters are not an option because of the competition for water and potential ecological impacts. Therefore, the most significant climate change threats to nuclear infrastructure in the UK are marine hazards linked to SLR and severe storms.

When faced by the potential impacts of climate change the neighbourhood surrounding NNB will require advanced, integrated coastal zone management (ICZM) for the project lifetime. For critical national infrastructure such as ports and nuclear power stations, this could be in the region of hundreds of years. The combination of coastal location and longevity of nuclear infrastructure predispose such developments to the threats of climate variability and change. Therefore, adaptation strategies must be considered from the inception of a NNB project.

1.3 Stakeholder engagement and coastal management

Since the 1990s, intensifying anthropogenic pressures on coastal zones have been recognised. In 1992, the Earth Summit conceived Agenda 21, electing to pursue sustainable coastal development via ICZM approaches. These cover all aspects of the coastal zone and must be considered in management strategies for both physically and socially bounded coastal units (Vallega 2013).

Implementing ICZM under pressures of continued population growth, resource constraints and the potential impacts of climate change will require cooperation amongst a host of stakeholders (Maccarrone et al 2014). A comprehensive management strategy must include a portfolio of adaptation options that is responsive to a range of climate change scenarios. Flexible, low-regret adaptation initiatives are particularly attractive when attempting to safeguard long-lived infrastructure from the projected impacts of climate change (Hallegatte 2009; Wilby et al 2011). Such initiatives enable cost-effective adjustments and upgrades to be made to projects should the impacts of climate change be more severe or materialise more rapidly than expected.

Puente-Rodriguez et al (2015) assert that involving a range of coastal stakeholders is essential to ICZM as this enhances the *knowledge-practice interface*, enabling a broad spectrum of knowledge to be incorporated into the decision making process. However, stakeholders in the coastal zone are often diverse, pursuing their own agendas, frequently with varying levels of influence. For a diverse range of stakeholders to work together effectively and ensure the ‘success’ of climate change adaptation projects, an understanding of the working relationships between parties is essential (Reis et al 2014; Vanclay 2012).

1.4 Successful adaptation

Defining ‘successful’ climate change adaptation is a complex endeavour that has been subject to extensive, multidisciplinary research (e.g. Moser and Ekstrom 2010). Adaptation is multifaceted, unbounded and can be interpreted in numerous ways depending on the stakeholder (Adger et al 2005; de Franca Doria et al 2009). As such, the development of methods for best practice is difficult to track (Ford et al 2013). The nebulous nature of adaptation also means that it is rarely studied holistically, when attempting to define and measure success, research efforts have tended to focus on segments of the topic. To date, adaptation processes (Eakin and Patt 2011; Gramberger et al 2015), barriers (Biesbroek et al 2013) and/or outcomes (Eisenack and Stecker 2012) have been core lines of enquiry. Crucially, human indifference affects all lines of adaptation research that attempts to define adaptation success; an action that is successful for one individual, organisation or level of government may not be classed as successful by another (Adger et al 2005, pp 78). It is recognised that most communities are not far enough along to evaluate their adaptation outcomes, merely advancing along their adaptation plans can be a proxy for success (Ekstrom and Moser 2013). As such the importance of established success criteria is debated (Adger et al 2005). With this in mind here, successful adaptation is broadly defined as increasing the adaptive capacity of human and natural systems (IPCC 2014, pp 80). This research focusses on defining elements that enable a successful adaptation process towards increasing adaptive capacity.

1.5 Research aims

The overarching research aim of the PhD project is to '*define the key factors that govern the success of climate change adaptation in the neighbourhood of long-lived infrastructure, in the coastal zone*'. By defining these factors the research aims to develop knowledge to aid stakeholder organisations in achieving successful implementation of adaptation initiatives.

As the lifetimes of nuclear power stations are potentially on a centennial scale, measuring the tangible outcomes of adaptation efforts is clearly not feasible within the bounds of this study. Instead, this research will define the architecture and attributes governing the success of the adaptation process. By examining the decision-making landscape as a whole, this project aims to highlight factors affecting the complete adaptation process.

From here on, the "architecture of adaptation" refers to the frameworks by which adaptation initiatives are conceptualised. "Attributes of adaptation'' are defined by various terms; as nodes in the qualitative analysis phase of the research and key themes and/or factors here and thereafter. Both terms refer to the complex social dimensions at work in coastal zones that have the potential to enhance or inhibit adaptation efforts. To frame the research, research questions corresponding to the architecture and attributes of climate change adaptation are outlined.

1.5.1 *Research questions*

To achieve the overarching aim of the research and '*define the key factors that govern the success of climate change adaptation in the neighbourhood of long-lived infrastructure, in the coastal zone'* following research questions address the dual themes of the *architecture* and *attributes* of the adaptation process.

1.5.1.1 *Contextual questions*

1. What are the most significant threats posed by climate change to long-lived infrastructure in the coastal zone?

2. Who are the key stakeholders involved in managing the coastal zone surrounding long-lived coastal infrastructure?

1.5.1.2 *Regarding the architecture of adaptation*

3. How do framework approaches to adaptation differ?

4. What are the preferred adaptation frameworks adopted by stakeholders in the coastal zone?

1.5.1.3 *Regarding the attributes of adaptation*

5. To what extent does the presence of nationally significant, long-lived coastal infrastructure, affect stakeholders engaging in climate change adaptation?

6. What timescales are used by stakeholders when planning, implementing and monitoring climate change adaptation in the neighbourhood of long-lived coastal infrastructure?

7. What are the unique contributions (if any) made by each stakeholder organisation to the adaptation process?

8. What are the key motivations prompting stakeholder organisations to engage and collaborate on the issue of climate change adaptation?

9. How should the domains of coastal management be bounded – by social and/or physical perimeters?

1.5.1.4 *Regarding the role of climate shocks*

10. What (if any) changes in coastal management practises and levels of stakeholder engagement have occurred since the winter storms of 2013?

1.6 Structure of thesis

The rest of this thesis comprises of six more chapters. These fulfil the aims and objectives of the research by investigating the research questions and considering factors that inhibit or enable ‘successful’ climate change adaptation in the neighbourhood of long-lived, infrastructure in the coastal zones of the UK.

Chapter 2 provides a review of the literature. This begins with a synthesis of research into the broad field of anthropogenic climate change. Next, the review evaluates the likelihood that international efforts will mitigate climate change. The chapter recognises that mitigation and adaptation must now be implemented as a ‘twin tracked’ approach. The chapter then covers the theory and practise of adaptation. Here, the definition of ‘successful’ adaptation is explored in greater depth before potential barriers to climate change adaptation are identified.

Chapter 3 provides an introduction to the case study sites used in the PhD. Three of the eight NNB sites nominated by the UK government are introduced. These are Sizewell C in Suffolk; Hinkley Point C in Somerset; and Wylfa, on Anglesey. A fourth non-nuclear case study area, featuring long-lived infrastructure, is also included, namely Portsmouth Harbour, Hampshire. The chapter describes the physical properties and characteristics of each site before considering the key local threats posed by climate change.

Chapter 4 explores the ‘real-world’ applicability of climate change adaptation frameworks as covered by research literature. This chapter utilises all four study areas, described in Chapter 3, to investigate how stakeholder organisations employ framework approaches *in practice* when adapting to climate variability and change. The chapter presents a set of criterion, constructed from a review of the research literature. This tool helps to determine the framework approach adopted by stakeholders when planning and implementing climate change adaptation initiatives (Armstrong et al 2015). The criterion is used to categorise then analyse an inventory of adaptation initiatives compiled for each case study neighbourhood. The results of the categorisation enabled a comparative analysis of the framework architecture utilised by stakeholder organisations in different contexts. The chapter establishes the ‘real world’ application of adaptation frameworks and compares this against the academic literature.

Chapter 5 focuses on the Sizewell nuclear neighbourhood to investigate factors affecting the adaptive capacity of stakeholders, in that coastal domain. Adopting an iterative methodology, the chapter investigates the societal attributes affecting stakeholder organisations and factors shaping the adaptation process. Semi-structured interviews were conducted in iterative phases with 30 representatives from 16 stakeholder organisations in the neighbourhood of Sizewell nuclear power station. Data collection and analysis was undertaken simultaneously, in a participant-led format, one informing the other. Interview recordings were transcribed, coded and analysed using the computer assisted qualitative analysis software (CAQAS) NVivo 10. The findings were then used to inform the next round of stakeholder interviews. The chapter continues to present and discuss results and considers the implications for stakeholder organisations in the nuclear neighbourhood. The chapter evaluates some practical ways by to promote the successful implementation of adaptation initiatives.

Finally, Chapter 6 concludes the thesis. The chapter first situates the research in the broader context of adaptation science. A brief summary of the methodologies applied and headline findings are presented. The chapter then reflects on the wider implications of the research for organisations adapting to climate change in the neighbourhood of long-lived, coastal infrastructure and considers the transferability of the research findings to other coastal locations, scales and cultural settings. Finally, the main limitations of the study are acknowledged and opportunities for further research are identified.

Figure 1.1 outlines the work pathway of the thesis. Proceeding the introduction and literature review, adaptation document analysis was undertaken in the Sizewell neighbourhood. To add validity to the results, and test the transferability of the criterion tool, adaptation initiatives were then analysed in three additional coastal neighbourhoods. Additional document analysis took place simultaneously with stakeholder interviews in the Sizewell neighbourhood. The results from the adaptation inventories and interview transcripts were then used to suggest tangible recommendations to promote the successful implementation of adaptation initiatives. Conclusions were then made.

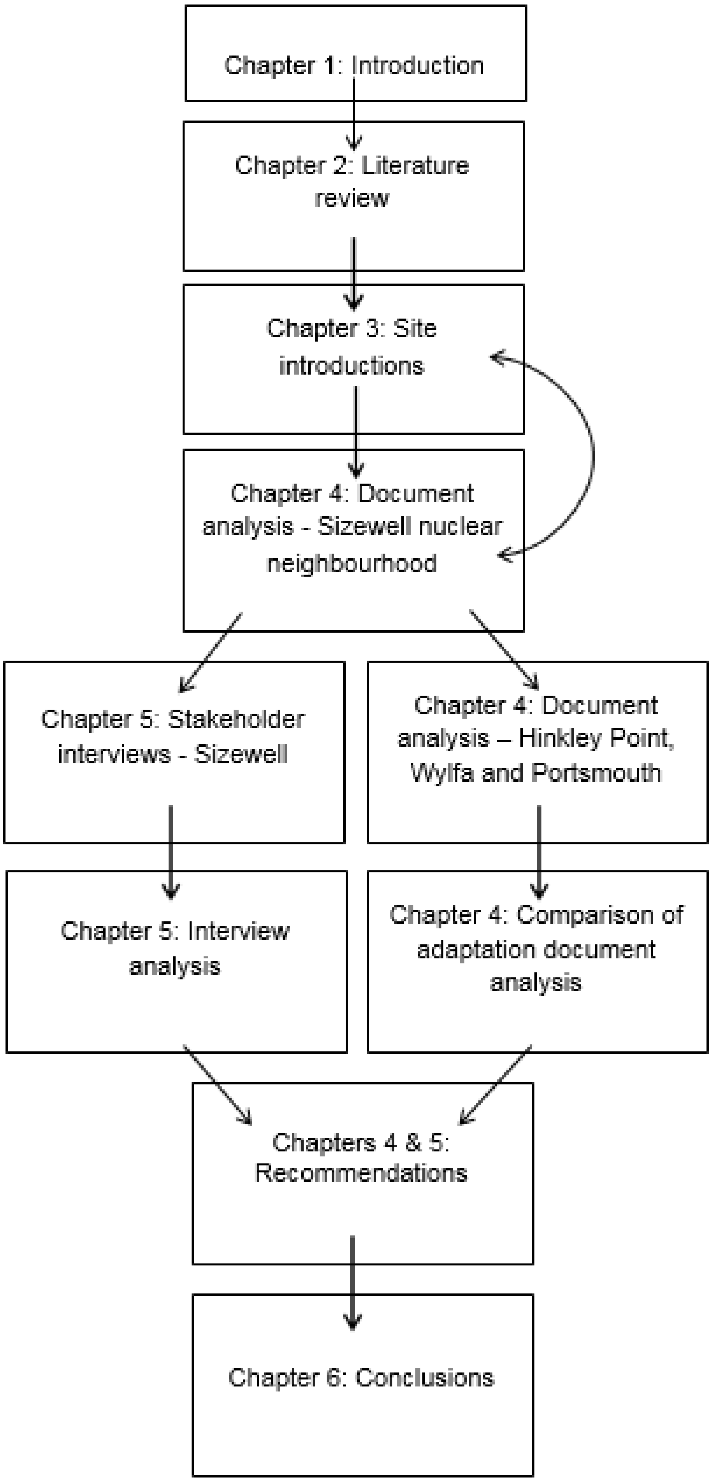

Figure 1.1 Thesis map showing work pathways of chapters.

Chapter 2: Literature review

2.1 Introduction

This literature review begins by outlining the intrinsic relationship between human activity and increasing demands for reliable energy sources with consequences for climate change. The review identifies targets set by the international community to mitigate GHG emissions to avoid dangerous impacts of a changing climate. Evidence from the academic literature proposing that world systems may be irreversibly altered by surpassing ‘tipping points’ is presented. A climate ‘tipping point’ occurs when a small change in forcing triggers a strongly nonlinear response in the internal dynamics of part of the climate system, qualitatively changing its future state (Lenton 2011, pp201). The specific consequences of the said ‘tipping points’ for coastal zones are then considered.

The review proceeds to highlight calls by both scientific and political spheres, for the potential impacts of climate change to be combatted by an integrated, ‘twin-tacked’ approach, implementing both mitigation and adaptation initiatives in tandem. To date, mitigation has been the forerunner in efforts to combat climate change. However, adaptation is increasingly being recognised as a critical aspect of addressing the impacts of climate change globally. Recognition of the need for a ‘twin-tracked’ approach is due to areas of the world already experiencing climate stresses threatening their current way of life; increasing concerns that human and environmental systems are already ‘locked in’ to some unavoidable climate change.

The remainder of the chapter explores the meaning of ‘successful’ climate change adaptation and methods of methods of best practice are described. Current adaptation methods utilised by stakeholders in multiple sectors are outlined and barriers that could affect the success of adaptation efforts are discussed. Such barriers centre on the complex social dimensions at play within vulnerable communities.

2.2 The Energy-Climate nexus

It is increasingly recognised that energy security and climate change are intrinsically linked at the global scale (Dyer 2014). This relationship between energy consumption and climate change is steadily rising on the agendas of governments internationally leading to adjustments in governing strategies to reflect both environmental and geopolitical aspects of energy security (Kuzemko 2013). During his 2013 inaugural speech, President Obama emphasised the need for the United States to 'respond and lead' on such issues. Similarly, within the academic sphere, Freidman (2009) asserts that humanity has entered a new epoch, the 'Energy-Climate Era' in which energy demand and associated emissions of GHGs are driven largely by economic and demographic growth. In 2011, the world population reached 7 billion and is expected to grow to 9 billion by 2043, placing ever-high demands on the Earth's resources (United Nations 2015). With this in mind, the United Nations Development Programme (UNDP) highlights the urgency to deliver sustainable energy sources. Development Goal 7 2030 Agenda for Sustainable Development aims to provide affordable and clean energy at a global scale (United Nations 2016).

The projected net population rise from present is expected to occur mainly in less developed nations. If citizens of these nations were to acquire the same lifestyles as those in developed regions, whilst maintaining a zero net impact on the environment, the resource equivalent needed would be between 3-5 planet Earths (Walker and King 2008). The rising demand for sustainable energy sources is further highlighted as the number of people with access to electricity has increased by 1.7 billion between 1990 and 2010 (UNDP 2016).

To provide perspective, for the next one billion people to turn on a single light bulb simultaneously, an additional 60,000 megawatts of energy would be required. To light a bulb for one hour per day, 10,000 megawatts would be required, the equivalent of 20 new 500-megawatt coal-burning power stations (Friedman, 2009). This example highlights the urgency of deploying low-carbon technologies, adapting our lifestyles to improve energy efficiency and lower consumption whilst assisting less developed nations to grow sustainably. Our efforts must achieve these aspirations to ensure the health of the planet and secure sufficient energy for tomorrow's world.

It is becoming increasingly clear that one of the ways in which energy supplies could sustainably and reliably meet future demands, whilst simultaneously reducing carbon emissions, is through nuclear power. Recent decades have seen a renaissance in the nuclear industry as world leaders recognise the potential for nuclear power to improve energy security and build a more balanced, decarbonised economy (Wilby et al 2011; Bredimas and Nuttall, 2008). Initially, nuclear power was highly concentrated in developed countries, such as Canada, France, Switzerland, the US, and UK. Currently, 440 nuclear reactors in 31 countries, provide 11% of the world's electricity (World Nuclear Association 2016).

The nuclear renaissance epitomises the essence of Freidman's (2009) 'Energy-Climate Era'. Rapidly developing nations such as China and Korea are developing their nuclear generating capacity, with currently 28 nuclear reactors under construction in China alone. The UK government has proposed eight nuclear new builds (NNBs) to replace the first generation of power stations built in the 1950s and 1970s, which are due to be commissioned in the near future. A degree of uncertainty still hangs over NNBs going ahead. However, the world's most expensive nuclear project, Hinkley Point C, just been granted the go ahead after being temporarily put on hold as the new UK government requested several weeks to consider the involvement of Chinese foreign investment (BBC News 2016).

All NNBs in the UK are situated in the coastal zone, as vast amounts of water are required for their cooling systems. This long-lived infrastructure has a centennial life cycle; therefore, it is necessary to consider how the coastline may evolve over the duration of its existence. The potential impacts of climate must be considered: SLR, higher sea temperatures and more extreme weather events are all expected to affect coastal zones internationally over the next two centuries (Wilby et al 2011, Wong et al 2014). Managing the risks of climate change in coastal zones requires comprehensive understanding of the causes. The following sections outline primary drivers and potential impacts of anthropogenic climate change and reviews international management strategies to date.

2.2.1 *Carbon Dioxide emissions*

According to the Mauna Loa observatory, Hawaii current atmospheric CO_2 concentrations are 404.39 (16th July 2016). Global CO_2 concentrations have been steadily increasing since the industrial revolution (Figure 2.1a).

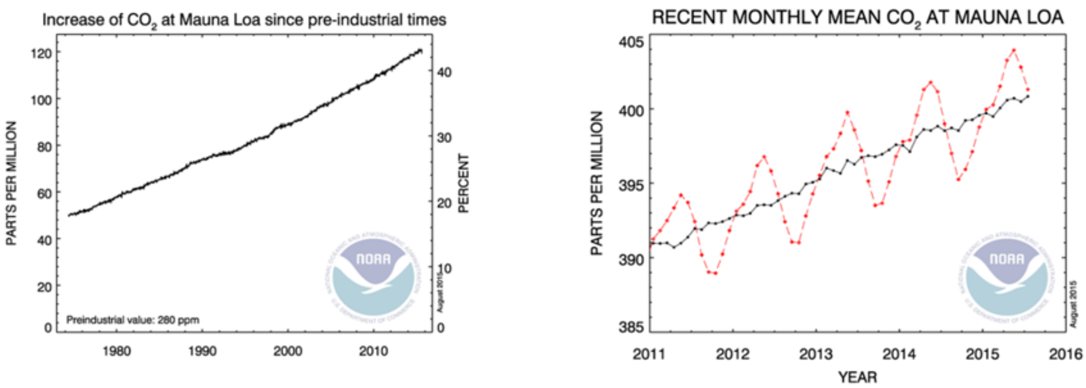

Figure 2.1a Atmospheric increase of CO_2 above 280 ppm in weekly averages of CO_2 observed at Mauna Loa Observatory, Hawaii (Left). Monthly mean CO_2 concentrations since 2011 measured at Mauna Loa Observatory, Hawaii (Right). Source: http://www.esrl.noaa.gov/gmd/ccgg/trends/weekly.html

Figure 2.1b illustrates that since 2013 CO_2 levels have peaked seasonally at more than 400ppm. If GHG emissions ceased tomorrow we would still be locked into a degree of climatic change (~0.6 ºC) before Earth's systems reached equilibrium (IPCC 2013). This is known as committed warming.

The world could follow a range of GHG emission scenarios. The Special Report on Emission Scenarios (SRES) published by the IPCC (2000) described four main families of emission pathways that society might take (A1, A2, B1 and B2). These scenarios were used in the IPCC's Third and Fourth Assessment Reports published 2001 and 2007 respectively. These scenarios are 'baseline' projections and do not take into consideration current or future attempts to limit GHGs. Representative Concentration Pathways (RCPs) were included in the IPCC Fifth Assessment Report (2014). RCPs describe four families of possible climate futures (Figure 2.2). These possible futures consider possible changes to anthropogenic GHG concentrations resulting from different combinations of economic, technological, demographic, policy, and institutional futures (IPCC 2014).

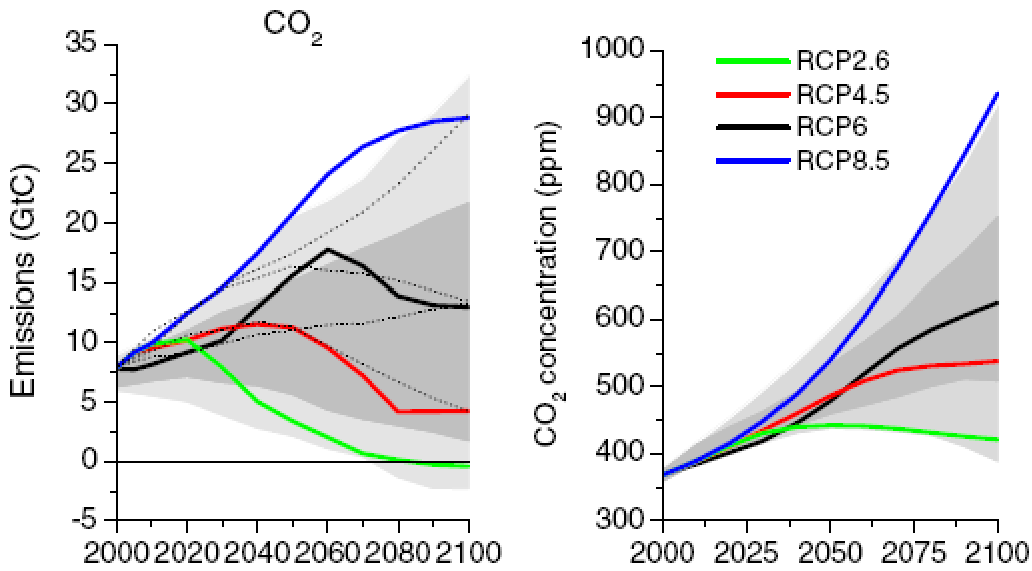

Figure 2.2. Emissions of CO_2 across the RCPs (left), and trends in concentrations of carbon dioxide (right). Grey area indicates the 98th and 90th percentiles (light/dark grey) of the literature. Dotted lines indicate four of the SRES marker scenarios. Source: van Vuuren et al (2011)

2.2.2 *Irreversible climate change*

There is concern that continued increases in GHG emissions may push Earth system components beyond 'tipping points' resulting in abrupt changes in environmental conditions. Examples include collapse of the North Atlantic Thermohaline Circulation, the decay of the Greenland ice sheet, collapse of the West Antarctic ice sheet. Such abrupt shifts in these systems could severely affect both anthropogenic and natural systems (Lenton et al 2005).

A 2°C increase in global temperature is regarded as a threshold for avoiding said tipping points (Solomon et al 2008). 2°C has been adopted as the universal benchmark to which climate change should be limited (IPCC 2013; EU European Commission 2007). However, some believe the 2°C benchmark is an unrealistic target as we may already be committed to an emissions trajectory surpassing such levels of warming (Guivarch and Hallegatte 2013). Anderson (2012) asserts the internationally accepted '2°C benchmark' undermines efforts to curb climate change. He argues that promoting a specific numerical target promotes disparity between the rhetoric surrounding said targets and awareness of the reality of meeting them.

Significant levels of apprehension and uncertainty surround tipping points, as the scientific community has not yet confidently established the thresholds at which the Earth's systems may be irreversibly changed (Lenton et al 2005). Both terrestrial and marine ecosystems could be irreversibly altered by a global mean temperature change of less than 2°C. For example, some climate models have indicated to preserve more than 10% of the world's coral reefs global temperature changes must be limited to 1.5°C (Frieler et al 2013). The United Nations (2015) presented evidence that we may have already surpassed 'tipping points' meaning we will face irreversible changes to the climate and major ecosystems.

One of the most threatening climate change impacts expected from increased GHGs is SLR (Nicholls and Cazenave 2010) (Section 2.4.2). Current levels of CO_2 concentrations are ~ 400 parts per million by volume (ppmv) (Figure 2.1a). If 21st century CO_2 concentrations exceed 600 ppmv it is expected that society will have to contend with global average SLR in the region of 0.4 to 1.0 m due primarily to thermal expansion (Solomon et al 2008; Nicholls et al 2013). Thus, to avoid dangerous climate change, unprecedented mitigation strategies for cutting GHG emissions must be implemented immediately (Meehl et al 2012).

2.3 International efforts to reduce greenhouse gas emissions

There have been numerous international attempts to implement effective global regimes to limit climate change by cutting GHG emissions. The United Nations are at the forefront of these efforts. In 1988, the IPCC was established by the World Meteorological Organization and the United Nations Environment Programme, to provide objective, state of the art, scientific climatic information and was subsequently followed by the establishment of United Nation Framework Convention on Climate Change (UNFCCC), set up as a result of the Earth Summit in 1992 – a first step towards combating climate change at a global scale. Since 1992, the UNFCCC has made attempts to agree international commitments to limit climate change and legally frame international targets to do so (Table 2.1).

Despite international efforts to broker legally binding agreements to mitigate climate change, GHG concertrations continue to rise (Figure 2.1). Krewitt et al (2007) demonstrated via an energy systems model and review of global energy supply and demand patterns, that it *is* possible to reduce global GHG emissions to target levels should effective international mitigation strategies be deployed immediately. With this in mind, literature commenting on the efficacy of international efforts to combat climate change is emerging; many are calling for radical reassessments of the approaches employed to tackle climate change (Grunewald and Martinez – Zarzoso 2016; Kutney 2014). Prins and Rayner (2007) believe that international treaties such as the Kyoto Protocol are fundamentally flawed as the architecture of the protocol is adopted from more bounded issues such as ozone depletion, acid rain and the development of nuclear weapons. Such frameworks are less suited for countering the pervasiveness of carbon-based energy production. UNFCCC conferences in Kyoto (1997) and Durban (2011) both called for the development of low-carbon technologies to meet energy needs whilst countering climate change. The fact that conferences 14 years apart are calling for the same actions is indicative of the slow progress.

Rosen (2015) regards the Kyoto Protocol as an institutional failure, claiming that its design promoted short-term attitudes and behaviours from member states. She attributes this to features of the treaties design: short time frames for action, the promotion of inflexible binding targets and lack provisions for future commitment periods. These factors put member states on inflexible, path-dependent, structures that have failed to make a substantial impact on the climate problem. Jamieson (2014) asserts that anthropogenic emissions have now committed our descendants to a world that is quantitatively different to the one that gave rise to humanity. He explores why, despite international treaties, we repeatedly fail to curb the rate of climate change, concluding that climate change is a multifaceted ‘wicked problem’ and therefore difficult for national and international political systems to address in full.

Year	International climate meetings	Key motions
1997	Kyoto Protocol	International treaty committing 192 state parties to reduce GHG, based on the premise that global warming exists and man-made CO_2 emissions have caused it. The Protocol stipulated that GHG should be reduced to 'a level that would prevent dangerous anthropogenic interference with the climate system'.
2008	Climate Change Act	The Act legally binds the UK government to ensure the reduction of the UKs net carbon emissions, for all six GHGs identified at Kyoto. The Act requires a reduction of at least 80% lower than the 1990 baseline by 2050. This is deemed the level needed to avoid dangerous climate change.
2009	Copenhagen Accord	The 15th Conference of the Parties recognised the long-term goal of limiting the maximum global average temperature increase to no more than 2°C above pre-industrial levels, subject to a review in 2015.
2010	Cancun Agreements	A set of significant decisions to reduce GHG emissions in a mutually accountable way. Commitment by the international community to address the long-term challenge of climate change, collectively and comprehensively over time, and to take concrete action now to speed up the global response.
2011	Durban	International breakthrough in the global community's response to climate change. The outcomes included a decision by Parties to adopt a universal legal agreement on climate change as soon as possible, no later than 2015.
2012	Doha Amendment (Kyoto Protocol)	Extension of the Kyoto Protocol. The renewal aimed to keep existing climate targets on course until new international agreement comes into effect in 2020. The Paris COP superseded this in 2015 (see below).
2014	Lima	Agreed plan to combat global warming that will, for the first time, commit all countries to cutting their GHG emissions. The plan was hailed as an important first step towards a climate change deal due to be finalised in Paris next year. The proposals call on countries to reveal how they will cut carbon pollution by 2015.
2015	Paris	For the first time all 195 participating countries agreed to cut GHG emissions. The Paris agreement will come into effect in 2020 and will require all countries to cut emissions regardless of their development status. The Agreement will not become binding on member states until the parties who produce 55% of global emissions approve the Agreement. The aim is to stabilise global warming below 2°C, less if possible.

Table 2.1 Summary of international agreements since the Kyoto Protocol, involving the UK, designed to address climate change.

On the other hand, it is important to consider the counterfactual reality of ‘no Kyoto’. Although there is much scepticism surrounding the successes of the Protocol, Aichele and Flebermayr (2013), pose the question of what would have happened to GHG emissions had the Protocol never have been conceived? Aichele and Felbermayr (2013) highlight the need to objectively determine the efficacy of frameworks employed by stakeholders to tackle climate change. Their question further illustrates opportunities for the development of pragmatic guidance for best practise for mitigation and increasingly adaptation.

Despite the scepticism surrounding the approaches used to combat climate change, the UK regards itself as a forerunner in aspiring to reduce GHG emissions. However, Pielke (2009) believes the targets set by the Climate Change Act (2008) to reduce emissions, are unrealistic when considering population growth, economic activity and technological change. He asserts that such progress would require steps of a magnitude that seem practically impossible. Again, this statement highlights the necessity of ‘successful’ climate change adaptation strategies.

Considering concern about Earth systems approaching irreversible tipping points plus international treaties failing to curb GHG emissions at the required rate, it is essential that societies are fully aware how threats posed by climate change may manifest and are mindful of how they can implement adaptation strategies to limit negative impacts (Section 2.6). It is important to understand the mechanisms of climate change adaptation implementation to prevent maladaptation. Coastal zones are at the forefront of concerns about climate-induced impacts (Klein and Nicholls 1999). The following section reviews the extent to which coastlines are vulnerable to the potential impacts of climate change.

2.4 Climate threats to the coast

Coastal zones situated at less than 10 m above mean sea level are vitally important to humanity. These areas alone contain approximately 10% of the world’s population with over half the world’s population living within 60 km of a shoreline (McGranahan et al 2007). The coastal population in many countries has been growing at double the national rate for almost a decade (Turner et al 1996) primarily due to coastal systems providing a range of goods and services valuable to society (Klein et al 2001). Currently eight of the top ten largest cities in the world are situated on the coast (Ramesh et al 2015).

In many cases, coastal zones are particularly susceptible to the impacts of climate change, threatening both human communities and nature conservation interests (Pye and Blott 2006; Rahman and Rahman 2015). It is highly likely that disruption of Earth systems will threaten established coastal populations and long-lived infrastructure situated in the coastal zone (Small and Nicholls 2003; Cooper and Lemkert 2012). The foremost threats posed to coastal zones by climate change are SLR and more frequent and severe storms (McGranahan 2007). These threats are forecast to be manifest through changes to sediment transport, which in many cases will result in increased erosion rates, flooding from various mechanisms such as overtopping and breaching of coastal frontages and defences and the transformation of the functioning of ecosystems via flooding and saline intrusion (Einsele 2013; Fitz Gerald et al 2008).

Hallegatte et al (2013) estimate that without upgrading present protection, asset loss to 136 of the world's largest cities could be of the order US$1 trillion per year by the 2050s. In addition, non-climate-related anthropogenic processes such as ground subsidence due to oil and water extraction, or reduced sediment supply to river deltas as a result of building dams, often enhance vulnerability of coastal populations to the risk of climate related impacts (Nicholls and Cazenave 2010). Montreuil and Bullard (2012) highlight that the positioning and structure of coastlines reflect processes operating at a range of magnitudes and frequencies. Therefore, it is imperative that we have a comprehensive understanding of both the processes and the geomorphological responses that climate change may impose.

Coastal zones are hubs of critical economic activity and, although coastal planners recognise current vulnerabilities, they are struggling to find ways to prepare for the potential impacts of future climate change whilst simultaneously dealing with more immediate pressures (Tompkins et al 2008). Climatic stressors are already affecting coastal zones in many locations around the globe, the impacts of which are projected to be exacerbated by climate change (McCubbin et al 2015). A comprehensive understanding is, therefore, particularly important when regarding threats posed to coastal communities and in particular coastal infrastructure, which have long life spans. Such an understanding of coastal processes is particularly pertinent for the UK energy sector as it has three times more energy generating facilities situated in the coastal zone than any other country (Brown et al 2014). The remainder of this section will firstly consider the current impacts of historic climate change before outlining the potential effects that SLR and increased storminess may have on coastal zones.

2.4.1 *Isostatic adjustment*

Historical climatic responses have the potential to exacerbate contemporary climate change impacts. Glacial Isostatic Adjustment (GIA) refers to the ongoing movement of land once burdened by ice-age glaciers (NOAA 2015). GIA occurs everywhere on the surface of the Earth but is especially relevant to the coastlines of northern Europe, North America and Greenland (Wu et al 2010). In the UK, the last glacial maximum extended southwards reaching Derbyshire, meaning most of Southern Britain was situated underneath the British-Irish Ice Sheet and is now sinking (Masselink and Hughs 2003) (Chapter 3, Section 3.2).

The US Atlantic coast is currently experiencing GIA from the retreat of the Laurentide ice sheet that covered North America during the last glacial maximum. The forebuldge of the ice sheet extended southward to modern day New York. Currently the Great Lakes are situated on the ‘hinge line’ with Hudson Bay experiencing uplift in the range of 15 mm/year whereas mid to east USA is experiencing subsidence of -2 mm/year. North America is also experiencing horizontal movement as the tectonic plate recovers from deformation caused by the last ice age (Stella et al 2007).

GIA is deemed so significant to contemporary SLR that sea level projections from different locations should not be combined without correcting for differential isostatic effects (Lambeck et al 2012; Peltier 2001). Therefore, methods used to quantify SLR as an impact of modern climate change reflect the effects of GIA; relative SLR refers to the change in sea level related to the level of the continental crust. Absolute SLR refers only to changes in the sea level and does not consider GIA (Stammer et al 2013).

Practitioners recognise the implications of historic climate change and incorporate GIA into planning management strategies for future SLR. For example, GIA is factored into the Environment Agency's (EA) flood risk allowances (EA 2016). When coupled with SLR, much of the Southern coastline of the UK are increasingly vulnerable (Lowe et al 2009). The following sections outline how SLR, waves and storminess, and associated storm surges are predicated to affect coastal zones globally.

2.4.2 *Sea level rise (SLR)*

Observed trends and anticipated consequences of accelerated SLR pose a serious threat to the future of communities and industries that locate in coastal areas (Woodroffe and Murray-Wallace 2012). The impacts of SLR are now projected to be of such significance to coastal developments that the IPCC has recognised in its Fifth Assessment Report (2013) as an urgent issue (IPCC 2013, pp 366). The dominant drivers of SLR in the 20th century were from thermal expansion of the oceans and glacial melting (Figure 2.3) (IPCC 2013). The potential impacts of SLR include flooding of deltaic and low-lying coasts, over-topping of atolls, alterations of sediment transport patterns, and saline intrusion of low-lying land adjacent to the coastal zone such as wetlands (Brunn 1962; Haigh et al 2009).

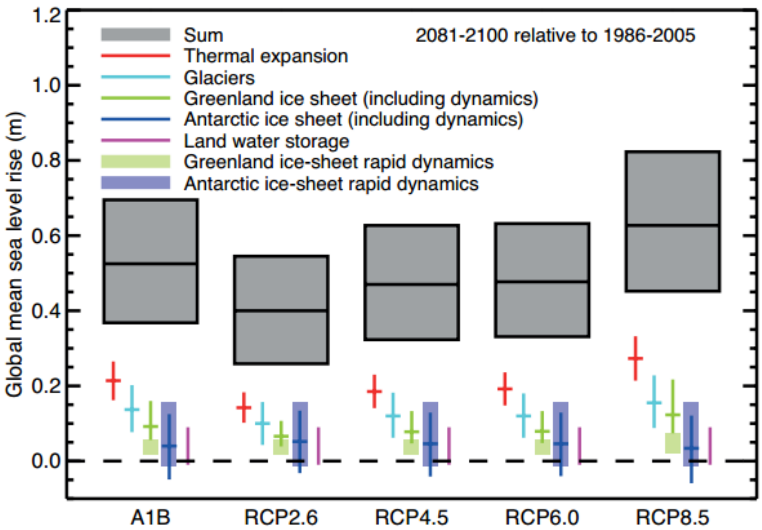

Figure 2.3 Projections from process-based models showing likely ranges and median values for global mean sea level rise and its contributions in 2081–2100

relative to 1986– 2005 for the four RCP scenarios and scenario SRES A1B used in the AR4. Source: IPCC (Church et al 2013)

Densely populated less economically developed countries (LECZs) frequently feature nationally important, long-lived infrastructure such as ports and harbours. More recently, nuclear power stations are being developed in LECZs such as Bangladesh, Indonesia, Vietnam and Sri Lanka (World Nuclear Association 2016). SLR would affect coastal infrastructure and communities globally threatening billions of dollars of coastal developments (Ranasinghe et al 2012).

GHG emissions have now committed the oceans to a certain degree of SLR. Sea levels will continue to rise regardless of which emission pathway society takes (Solomon et al 2008). Figure 2.3 illustrates the magnitude of possible levels of SLR under the RCP projections. However, the projected impacts of climate change from SLR are not spatially or temporally uniform (Lambeck and Chappell 2001). Although it is accepted that climate change will drive an increasing occurrence of sea level extremes and could lead to the collapse of Antarctic ice sheets and global oceanic currents (Church et al 2013), the last decade has witnessed a slowdown in the rate of SLR. This 30% reduction in the rate of rise coincided with a plateau in the Earth's global mean surface temperature (Cazenave et al 2014).

In addition, sea level has fluctuated spatially and temporally over past millennia. Currently, the relative sea level of the south east coast of England is 30 m higher than it was 9000 BP (Pye and Blott 2006). The global mean sea level has been 6 - 9 m higher than today as recently as the last interglacial (130 ka – 115 ka) (DeConto and Pollard 2016). The IPCC (2013) indicate that global average sea level rose by approximately 1.8 mm/year between 1961 and 2003. Along the east coast of England, the average is lower than this at 1 mm/year (Montreuil and Bullard 2012). Increases in the rate of SLR have been detected in the USA, in Miami SLR has increased from 3 ±2 mm/year before 2006 to 9 ±4 mm/year post 2006 (Wdowinski et al 2016). However, as the sea level fluctuates over the observed levels of SLR need to persist for several decades to be significant.

It is important to note here that SLR projections are prone to uncertainty and different sources yield varying estimates. UKCP09 (2012) state that absolute sea level rise could be between 0.93 m and 1.90 m for the UK by 2100. The focus of the scientific community to date has been on modelling and producing credible estimates of future SLR. Woodruffe and Murray-Wallace (2012) highlight not only the importance of accurately forecasting SLR but also simultaneously determining how the coast will geomorphically respond to the rise. It is only when this is achieved that integrated management/adaptation strategies can be developed for vulnerable coastal areas.

Focussing efforts solely on achieving accurate modelling and forecasting is not sufficient for tackling SLR in places that are already experiencing the impacts of SLR (Nunn 2013; Mimura et al 2007). SLR is currently affecting the nation's identity and sovereignty, the impacts of climate change are reducing the nations productivity, meaning life is becoming unsustainable (Barnett and Adger 2003). The South Pacific atoll nation of Kiribati consists of 32 atolls and one raised coral island. With a population of 100,000 people dispersed over 3.5 million km^2 this nation is expected to be among the first of the victims of forced climate migration. Intermediate projections suggest that 55% of the main island could be vulnerable to inundation and storm surged by 2050. The economic damages, as a direct result of climate change, could reduce the nation's gross domestic product (GDP) by 34% (Wyett 2014).

The threat of SLR to atoll nations is so severe that there is an emerging discourse of mass migrations as a form of adaptation (Birk and Rasmussen 2014). It has been estimated that the number of people being forced to migrate due to climate stresses could surpass all known refugee crisis in terms of the number of people affected (Biermann and Boas 2012). Myers (2002) predicted that there could be 200 million climate change refugees, mainly from low lying deltaic regions, by 2050. Similar figures have been suggested by international organisations such as Christian Aid (2009), United Nations Environment Programme (2007). Furthermore, the matter of climate change refugees was formalised by the UNFCCC in 2007. On the other hand, Farbotko and Lazrus (2012) assert that the notion of 'climate refugees' is a western concept that fails to take into consideration the impacted populations' sense of homeland and place. Citing the case of Tuvalu in the South Pacific, they claim that the world stage is not in tune with small islands and atoll nations experiencing the impacts of climate change today and those nations are actually more resilient than media and governance institutions portray.

This section of the literature review has recognised SLR as a primary threat to coastal zones globally. Although spatially variable, SLR has the potential to realign coastlines significantly impacting coastal communities, ecosystems and infrastructure. SLR is already affecting multiple LECZs and in some locations is accentuated by GIA. The following sections outlines how climate change may induce more severe and frequent storms, wave activity and associated surges.

2.4.3 *Waves, wind and storm surges*

When considering the risks coastal zones may face as a result of climate variability and change, it is important to consider the possibility of increased frequency of severe storms, more aggressive and destructive wind and wave action and therefore an increased frequency and magnitude of associated surges (IPCC 2013). In addition to increases in intensity, perturbations in stratospheric and tropospheric circulations could cause storm tracks to migrate polewards, changing the locations that are impacted, increasing winter storms over mid-latitudes (Scaife et al 2012). This section discusses the likelihood of climate induced increases to the frequency and severity of storm event and the capabilities/limitations of climate models to simulate how future storms may impact coastal zones. The section will then outline the extent to which climate change could affect wave and storm surges.

Although the fundamental processes driving SLR have been established, there is uncertainty surrounding how storm frequency and severity might be influenced by climate change. Determining relationships between climate change and increased frequency and severity of storms events has so far been hampered by a lack of continuous wind records and modelling limitations (Thompson and Frazier 2014). There is concern that modelling limitations could lead to substantial underestimation of the risks posed by increasing severity of storms (Stern 2013). Uncertainties in storm predictions are reflected by the IPCC (2013) who assert that predicted changes in climate are more *likely* than not to bring increasingly stormy weather but this cannot yet be adopted as fact as confidence in the assertion is low. For instance, Yang et al (2015) found no evidence to support the notion that the winter storms of 2013/14, over the US, were exacerbated by climate change. However, they did find that strengthening of tropical Pacific trade winds, which substantially increases the probability of extremes weather over North America, were linked to global warming.

Research to better understand how anthropogenic climate change and storms may be linked is ongoing. In the USA, Barnard et al (2014) have developed the Coastal Storm Modelling System. This complex high-resolution model is based on a series of downscaling and nested approaches for hindcast, operational and future climate studies. Originally developed for the coast of California the system is capable of identifying finite sections of vulnerable coastline (100s meters) and therefore may be used to aid emergency responders and coastal planners alike in the management of the coastline under extreme events and future climate scenarios.

Skinner et al (2015) argue that for some applications a more simplified, economical model may be used. They employ a 2D storage cell model (Lisflood-FP) to the Humber Estuary successfully modelling the impact of the storm surge of 5th December 2013. The accuracy of the model indicates that when incorporated into the CAESAR-Lisflood GUI, the 2D model is capable of operating on decadal to centennial timescales. Until now models have been unable to operate on these timescales in estuarine environs. Ultimately, the study indicates that more simplified models can be used for the evolution of flood risk over the long term. Also in the UK, the Hadley Centre has developed a new system to attribute extreme weather events in near real-time. Christidis et al (2013) report that a new development of the Hadley Centre model (HadGEM3-A-Based System) accurately simulated recent high impact events such as the 2009/10 cold winter in the UK, and 2010 heat wave in Moscow. However, it is not without limitations as it was unable to model the floods in Pakistan in July 2010. Although there have been significant advancements in modelling, Zwiers et al (2013) assert that reducing uncertainty should be prioritised. They regard the study of historical changes in extremes necessary to confidently predicting perturbations in storminess over the next century. Under current modelling limitations, it has been suggested that probabilistic modelling methods could be employed to infer how increased storminess may affect the coastal zone. For example, the probabilistic method has been advocated as the most appropriate method to model the effect of waves on the Dutch coast (Li et al 2014).

Although models cannot yet comprehensively incorporate the potential climate change impacts into the evolution of coastal zones, it is acknowledged that SLR coupled with increased storminess, will place additional pressure on coastal zones potentially causing significant damage to coastal communities and infrastructure (Lowe and Gregory 2005). When SLR, GIA and storminess are combined, some areas of the coastal zone are more vulnerable than others (Batstone et al 2013). Figure 2.3 demonstrates that areas of southern Britain experiences higher levels of extreme SLR events than northern Britain, (Figure 2.4) due to the orientation and exposure of the coastline. In this case ‘extreme SLR’ has been derived from the Skew Surge Joint Probability Method. The ‘skew surge’ refers to the absolute difference between the maximum recorded sea-level during a tidal cycle and the predicted maximum astronomical tidal level for that cycle, irrespective of differences in timing between the two. For the purpose of the analysis, seiches, swells and wind waves were filtered out. The configuration of the east coast of the UK creates a funnelling effect in the North Sea. This enhances storm surges tracking south and as a result, the south east experiences higher storm surges than the north east. Dolata et al (1983) first established that this is due to winds tacking eastward towards the North Sea and moving around the North Sea basin in an anticlockwise direction, coupled with a funnelling effect of the narrowing of the North Sea. History has seen this in action producing severe storm surges in 1953 and 1978 that caused extensive damage and modification to the south east coastline of the UK. This funnelling effect also affects the Severn Estuary, UK (Figure 2.4).

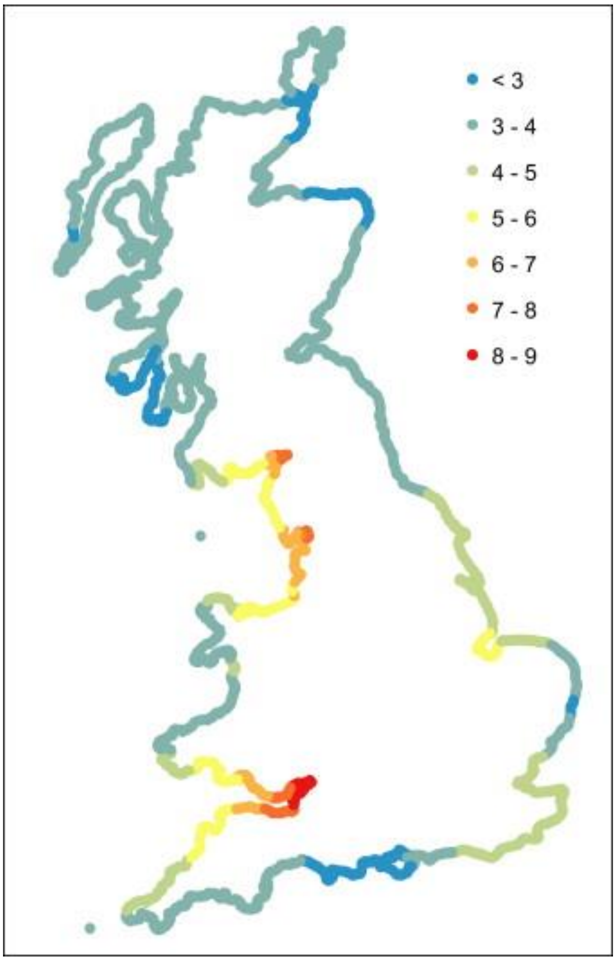

Figure 2.4. One in 100-year sea level extremes around the UK. Values are shown in meters above Ordnance Datum Newlyn relative to mean sea level in 2008. Source: Batstone et al (2013).

Similarly to SLR, the geomorphological responses of coastlines to storms and surges are not linear – they can vary significantly at different locations along the same coastline. The various ways in which storms may affect the sediment budgets of a coastline are relevant when considering the long-term management of a coastline particularly around long-lived infrastructure such as nuclear power stations, ports and harbours. One area may experience heightened erosion and, therefore, net loss of sediment whereas another location, within the same sediment cell, may experience accretion therefore net gain in sediment. For example, after the winter storm on the 5th December 2013 the Sefton Coast, on the west of the UK, experienced both erosion and accretion of the dune system. Sediment budget calculations based on LiDAR data indicated a net loss of 127×10^3 m^3 from the beach and 268 × 10^3 m^3 from the frontal dune system at Formby point but some sediment gains were recorded to the south of Formby Point (Pye and Blott 2016).

In addition to quantifying the geomorphological impacts of single storm events it is also important to consider the coastal impacts of storm clusters, should the frequency of storms increase as a result of climate change. Studies have shown that the strength of an individual storm is not the dominant factor driving coastal change (Karunarathna et al 2014). Instead, modelling reveals that the period of time in between storms is the critical factor governing morphological impacts (Dissanayake et al 2015). Splinter et al (2014) confirm these findings using the Xbeach modelling system that was able to remodel the dry beach erosion, caused by four named cyclones that hit the Gold Coast of Australia over a six-month period in 1967, to within 21% and shoreline retreat within 10% of its original state. When the model ran storms in different sequences results indicated that storm sequencing did not significantly affect the total eroded volumes. Such examples illustrate the complexities of coastal feedbacks in response to storm events. In addition to coastal geology, orientation and exposure to SLR and GIA, consideration of the physical parameters of storm conditions must also be taken into account. Anthony (2013) describes the variability of storm characteristics as 'bewildering', rendering the response of coastal zones to individual storms as largely unpredictable.

According to the National Oceanic and Atmospheric Administration's Hurricane Centre (2016) storm surges can be defined as the "abnormal rise of water generated by a storm, over and above the predicted astronomical tides". Storm surges occur as part of a low-pressure system over the ocean and are governed primarily by two main meteorological factors: the long fetch of winds and atmospheric pressure at the centre of a storm. These two factors cause the surface of the sea to 'bulge' under the low pressure which tracks with the storm system. When a storm makes landfall the storm surge can cause severe coastal flooding, creating high tides and damaging wave activity. Storm surges have the potential to cause the greatest damage in low lying, undefended coastal zones in less developed nations. The deadliest storm surge in the 21st century was caused by Cyclone Nargis, which killed more than 138,000 people in Myanmar in 2008 (Fritz et al 2009). Similarly, in 2013, a storm surge caused by Typhoon Haiyan (Yolanda) killed over 6,300 people in the Philippines and caused over $14 billion dollars of economic loss despite early predictions of the severity of the storm (Lagmay at al 2015). Studies have suggested that storm surges impacting the UK may be linked to the phase of the North Atlantic Oscillation (NAO) (Phillips et al 2013). Recent storm surges in the UK have caused significant shoreline realignment. For example, in December 2013, a storm surge on the south east coast caused a shoreline translation landwards equivalent to about 10 years of 'normal' shoreline retreat (Spencer et al 2015).

Wind force and direction are intrinsically linked to storm surges. High wind speeds combined with high water levels causes extensive property damage to increasingly populated coastal zones (Nicholls 2006). However, in comparison to other risks associated with coastal storms the potential impacts of the wind is relatively under documented, reflecting the limited consideration of wind damage in insurance policies for coastal properties (Petrolia et al 2015). In line with other storm characteristics, the physical parameters of stormy winds are difficult to model and therefore forecast (McCall et al 2014). In the UK, modelling has so far been hampered by a lack of continuous wind records (Montreuil and Bullard 2012; Pineau-Gillou et al 2015). However, Pye and Blott (2006) concluded from long term weather measurements that warmer phases of weather are associated with a greater frequency of winds from the Southwest, West and Northwest. They concluded that when the wind is from a westerly (offshore) direction less coastal erosion occurs on the east coast of the UK and therefore sediment transport is more balanced. Cooler periods are governed by wind and therefore wave direction from the north and northeast. Such period (as occurred during the Little Ice Age) are associated with greater wave energy, more frequent storm surges and greater coastal erosion and flooding.

Wave action is another fundamental factor governing the hazard risk and morphological evolution of a coastline (Pineau - Gillou et al 2015). When considering the potential of increased storminess, the role of waves is intrinsically linked to wind. The size and energy of waves are governed by the wind duration, strength and fetch. Waves can be constructive or destructive depending on the strength of both the swash and backwash. Waves under storm conditions are usually destructive in nature occurring in high energy environments with strong winds. Storm waves usually travel over a long fetch breaking on the shoreline, downwards with great force, meaning the backwash is stronger than the swash - resulting in sediment loss.

During storm events the wave set up, which refers to the presence of waves increasing or decreasing the level of water, can significantly contribute to the total water elevation and therefore potential flood and erosion risk (Brown et al 2013).

The interaction between waves, storminess and the geomorphological response of a coastline is difficult to monitor during extreme storm conditions when most erosion usually occurs (Earlie et al 2015). It is, therefore, essential that the key functions of wave actions are incorporated into storm models to deliver outputs that reflect reality as closely as possible. Efforts have been made to analyse the presence of different wave types under storm conditions and their contribution to the impact of a storm (Bertin et al 2015). However, due to the practical difficulties of observing storm waves in an event and lack of continuous high-speed wind records, key parameters and coefficients within wind models vary. This lack of consensus creates uncertainty of the precise role waves play in storm events and makes it difficult to predict what perturbations we may experience as a result of a changing climate (Pineau - Gillou et al 2015).

As discussed, the potential impacts of climate change pose significant risk to coastal zones. Both anthropogenic and natural systems may, and in some cases already are being affected. Coastal zones globally are critical areas for the globalized economy. For example, ports serve as a catalyst for economic growth and development, They are responsible for transporting 80% goods worldwide and are at the heart of international trade (Becker et al 2013). Therefore, these zones will require trans-boundary cooperation by neighbouring nation states to appropriately manage the projected impacts of climate change (Millman et al 2013). In the face of uncertainty and forecasting limitations, coastal zones globally must prepare for the potential impacts of climate change by mitigating the potential adverse impacts by employing low-regret adaptation initiatives (Barnett et al 2014).

2.5 Coastal zone management

It is now widely accepted that coastal zones will be one of the first and most severely impacted regions as a result of climate change. Coastal areas are projected to be exposed to increased risks of coastal erosion and flooding due to SLR and more frequent and severe storms (IPCC 2013) (Section 2.4). The challenges facing coastal zone management are twofold. Firstly, to determine how a given coastline might evolve in terms of flood and erosion risk. The other to understand how such perturbations may affect the social, economic and environmental integrity of the coastal zone. Both of these elements must be addressed to implement meaningful adaptation measures (O'Riordan et al 2008).

Currently, the UK Shoreline Management Plans (SMPs) guide decision makers how to manage our coastlines in the face of climate change and variability. They outline four main options for coastal management; (i) no active intervention (ii) hold the line (iii) managed realignment and (iv) advance the line (Environment Agency 2015). Within these four options decision makers face a range of nuances that complicate coastal zone management. Kuklicke and Demeritt (2016) assert that these stem from institutional tensions between adaptive management approaches which promote robust, low-regret decision making in the face of uncertainty and alternative policy options on the one hand and on the other hand risk-based options that transform uncertainties into calculable risks whose management can be rationalized through cost-benefit analysis and nationally consistent, risk-based priority setting. In some locations these tensions in coastal zone management strategies are being stretched. For example, Milligan and O'Riordan (2007) highlight an example from the erodible soft coasts of the UK where the government has accepted that in these areas where population density and ecological value are low coastal realignment is now unavoidable however, coastal residents have broadly come to assume that they will be defended if they make enough fuss. The government is currently unwilling to fully compensate those who may lost their assets to coastal erosion. This example illustrates the tensions between national frameworks of coastal governance and local participation in low regret coastal management and adaptation.

Established at the 1992 Earth Summit of Rio de Janeiro, Integrated coastal zone management (ICZM) is an approach that seeks to incorporate all aspects of the coastal zone, including geographical and political boundaries, in an attempt to achieve sustainability and overcome the tension outlined above. In theory this approach should incorporate the interests of all stakeholders in the coastal zone however many report difficulties in achieving truly sustainable management.

Shipman and Stojanovic (2007) outline four challenges facing the ICZM approach: i) the complexity of responsibilities at the coast continues to prevent agencies from taking a “joined-up” approach; ii) a policy vacuum is constraining implementation from national to local scales; iii) informational obstacles are significant in preventing co-ordination between science and policymakers, and between different sectors; iv) a lack of consultation in the working practices of coastal stakeholders is delaying the implementation of management decisions as there is there little opportunity in decision making for public comment or local accountability. Maccarrone et al (2014) recognise these challenges and propose an analysis tool, the Balanced Scorecard method, to help stakeholders make decisions and implement ICZM at the local level.

This section outlines the challenges associated with coastal zone management and highlights the need close gaps and relieve the tensions between both national and local management initiatives and between different stakeholders in the coastal zone. Eakin and Patt (2011) believe the best way to achieve this is to conduct innovative and collaborative research which engages networks of academics, policy makers, at-risk populations, and other stakeholders to actively participate in understanding the process of adaptation and build on learnings from such research.

2.6 Twin-tracked approach to addressing unavoidable climate change

There is growing agreement between the scientific and political spheres of society that the potential impacts of anthropogenic climate change must be addressed via a twin-tracked approach, deploying mitigation and adaptation strategies simultaneously (Pielke Jr et al 2007; VijayaVenkataRaman et al 2012; Watkiss et al 2015). As previously mentioned (Section 2.2.2.), this derives from an increasing realisation that the Earth’s systems are being pushed close to tipping points which, once exceeded, the impacts of climate change may be irreversible (Lenton et al 2008; Solomon et al 2008). There is also recognition that if impacts only grew linearly with SLR we would still need to implement adaptation as many locations are already experiencing the impacts of climate change (Akerlof et al 2013). Increasing awareness of the need to implement ‘successful’ adaptation initiatives is reflected by an exponential growth in academic literature on adaptation (Figure 2.5) (Wilby and Keenan 2012).

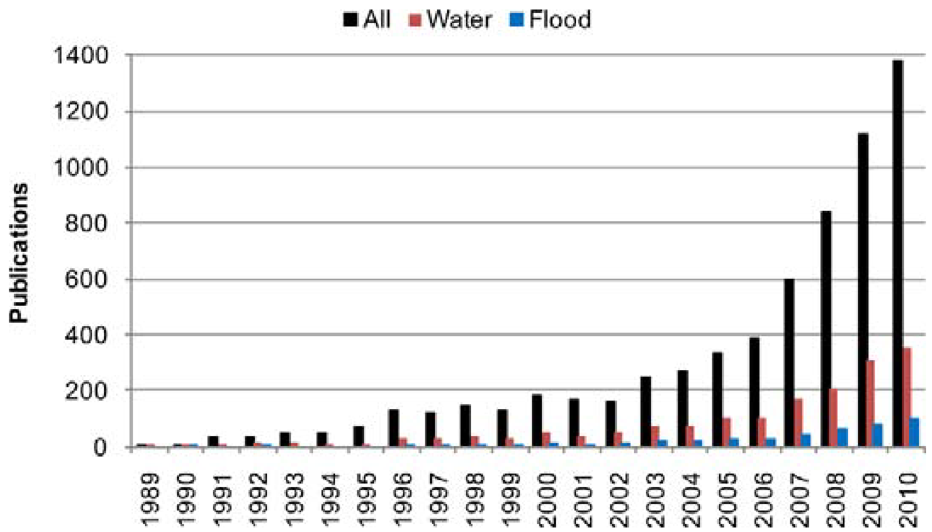

Figure 2.5. Annual number of peer-reviewed publications addressing all aspects of adaptation to climate change, water-sector issues (including flooding), and flooding (only). Source: Wilby and Keenan (2012)

Despite increasing awareness that adaptation initiatives are essential, there are concerns that adaptation efforts may fall into the same trap as attempts to mitigate GHG emissions. Concerns centre on flaws in legal frameworks, including national regulations and international protocols (Table 2.1). Should the same flaws present themselves in efforts to implement adaptation, the challenge of limiting any detrimental impacts of climate change may become unattainable (Brasseur and Granier 2013). Following the limited success of political frameworks such as the Kyoto Protocol in reducing global GHGs emissions, the role of adaptation in addressing climate change has been given greater prominence and urgency (Hasson et al 2010; Prins and Rayner, 2007). Nicholls and Lowe (2004) support the notion of the twin-tracked approach. They assert that implementing climate change mitigation and adaptation initiatives simultaneously will provide a more robust response to anthropogenic climate change for the coastal zone than either policy in isolation. With this in mind, adaptation initiatives implemented today must consider their legacy and provide a good foundation of adaptation on which future generations can develop to combat climatic threats.

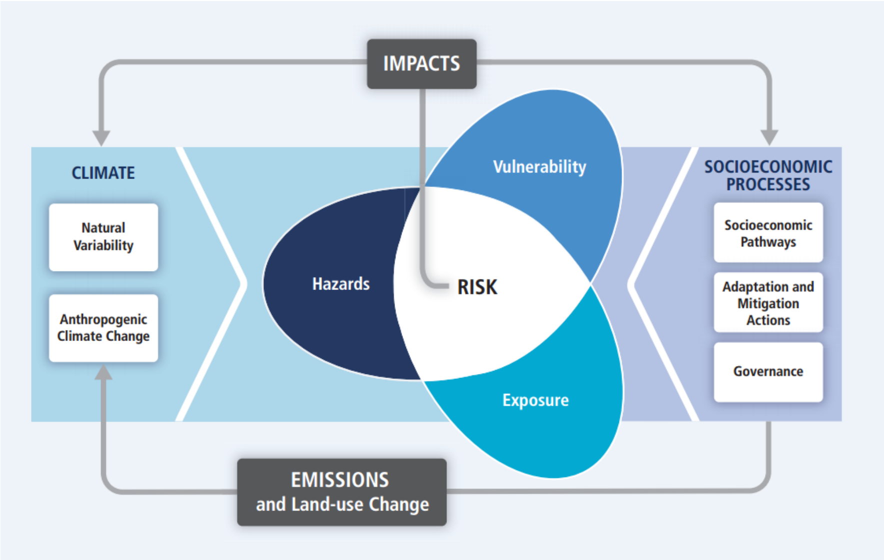

Figure 2.6 Risk of climate-related impacts results from the interaction of climate-related hazards with the vulnerability and exposure of human and natural systems Source: IPCC AR5 (2014).

There are multiple definitions of adaptation (Smit and Wandel 2006). With reference to climate change, adaptation can be defined as ‘‘adjustments in ecological-socio-economic systems in response to actual or expected climatic stimuli, their effects or impacts’’ (IPCC 2001; Pielke 1998, p16; Parry 2007). This is the definition of adaptation that is adopted in this thesis (pp xii). In addition, adaptation refers to ‘‘adjustments in individual groups and institutional behaviour in order to reduce society's vulnerability to climate’’ (Fankhauser et al 1999, p74). The role of climate change adaptation in reducing society's vulnerabilities was illustrated by the IPCC (2014) in Working Paper Two of the AR5 (Figure 2.6).

Adaptation to climate change is not a new phenomenon; there are currently multitudes of adaptation schemes that address a wide range of climatic risks. Existing adaptation initiatives span all types of adaptation, from anticipatory to reactive adaptation, private and publically funded adaptation, and autonomous and planned adaptation (IPCC 2013). Adaptation initiatives are instigated to address both climate extremes and variability at a range of scales across different sectors of society, and spanning international initiatives to community based adaptation partnerships (Adger et al 2005).

It is necessary to note that whilst the potential impacts of anthropogenic climate change are projected to be severe, even under low emission scenarios, some locations globally may experience benefits in the short term such as increased agricultural productivity (Barange et al 2014). As well as taking deliberate actions to reduce the adverse consequences of climate change adaptation must also encompass harnessing any beneficial opportunities (Shardul and Samuel 2008). For example, nations that are highly dependent on fish production, increased yields are predicted for the West coast of Africa but decreases in Southeast Asia. Similarly, the forests of Northern Europe are expected to experience increased productivity whereas decreases are anticipated for Southern Europe (Schelhaas et al 2015).

This is particularly pertinent for developing regions (Stern 2000). For example, Barange et al (2014) show that model predictions of global fish harvests indicate increased productivity in higher latitudes and decreased productivity at lower latitudes. In addition to the benefits experienced as a result of climate change, Luisetti et al (2014) highlight that adaptation initiatives in the coastal zones have the potential to increase ecosystem services and recreational values. For example, in the Blackwater and Humber estuaries, managed realignment has recreated intertidal habitats allowing the enhancement of ecosystem services provided by saltmarshes. Although efforts have been made to quantify adaptation costs and benefits by sector they remain uncertain and spatial coverage is uneven (Shardul and Samuel 2008). In some cases, the discourse of climate change opportunities may disguise the severity of the issue, making climate change seem less severe or urgent to decision makers. Therefore, perception of possible opportunities arising as a result of climate change further complicates management decisions when attempting to implement ‘successful’ climate change adaptation at a range of scales within society.

2.7 Adaptation as wicked problem

Environmental decisions involving risk, impact assessments and action planning are notoriously unstructured, multi-dimensional and complex (Vrana et al 2012). This complexity can be attributed to the intricacy of real world systems meaning that a multi-disciplinary approach to environmental issues is typically required. There are often multiple stakeholder perspectives involved in a decision, whose perspectives are shaped by varying priorities and objectives of their host organisation. Climate change is arguably one of the most complex, contemporary environmental issues confronting decision makers, largely due to inherent uncertainties and dynamics we do not yet fully understand (Incropera 2015).

Climate change is such a complex issue that it has been considered a ‘wicked problem’ or in some cases a ‘super wicked problem’ (Lazerus 2008; Levin et al 2012). The term ‘wicked problem’ was first coined by Rittel (1973) and can be defined as a social or cultural problem that is difficult or impossible to solve because of: (i) incomplete or contradictory knowledge; (ii) the number of people and opinions involved; (iii) the large economic burden, and; (iv) the interconnected nature of these problems with other problems. When asking policy makers, planners, managers and other decision makers what makes climate change adaptation successful? Moser and Boykoff (2013) found that there was no straightforward scientific or political answer.

The last decade has witnessed a plethora of methods for identifying strategies to ‘successful’ climate change adaptation. These address joint knowledge production between different sectors (Hegger et al 2012), understanding the mechanisms behind decision-making (Grothman and Patt 2003), and ways of measuring adaptation ‘success’ (Adger et al 2005). However, the inherent complexity and uncertain nature of climate change has resulted in decision makers adopting risk-based adaptation approaches rather than attempting to comprehensively define and react to potential impacts (Pidgeon and Fischhoff 2011; Ranger et al 2013). The remainder of this literature review will discuss the means by which climate change adaptation is being addressed and implemented and review efforts made to establish advice for best practise. Section 2.7 will focus on adaptation pathways before discussing the frameworks stakeholders currently employ to implement adaptation initiatives in Section 2.8. Section 2.9 will further explore the meaning of adaptation success before outlining factors known to help and hinder climate change adaptation initiatives.

2.8 Adaptation pathways

The literature review so far has highlighted a multitude of uncertainties associated with anthropogenic climate change. These uncertainties do not only centre on determining the magnitude of potential impacts, but also quantifying how mitigation and adaptation initiatives implemented by decision makers will impact upon society. It is these uncertainties that form the foundation of the 'super wicked problem' (Lazerus 2008; Levin et al 2012). The scientific community predicts, to the best of its ability, how the potential threats of climate change may impact societies in the future. However, these future projections do not always consider the interim period (Barnett et al 2014). Although horizon planning is essential in setting long-term targets, care must be taken to consider changes that may occur during the interim. Embarking on an adaptation strategy based on a linear cost-benefit analysis could increase the vulnerability of a population or location should it become unsuitable as time progresses. With this in mind, adaptation methods must be flexible to a range of future conditions (Hallegatte 2009). External factors such as population growth, new technologies, economic developments and conflict have the potential to impose 'known unknowns' on adaptation strategies (Haasnoot et al 2014; Ranger et al 2013). Although there is an awareness of these extraneous variables, to date, factors such as weather extremes have been omitted from or crudely added to cost-benefit analyses so incorporation into climate policies and adaptation plans have been limited (Bouwer 2011).

When considering adaptation options there are a range of approaches that can be taken to confront the uncertainty surrounding the severity of climate change impacts and the way in which society might respond to stresses. These include 'low regret', 'flexible' and 'robust' adaptation strategies to avoid maladaptation whilst simultaneously enhancing adaptive capacity (Hallegatte 2009; Kwakkel et al 2014; Wilby and Keenan 2012). Such approaches focus on enhancing a community's ability to cope with climatic change without committing unnecessary resources to uncertain targets and time horizons. 'Low regret' adaptation initiatives and policies are designed to benefit a population in the short term and should circumstances change, adaptation measures are readily altered and updated.

Adopting flexible adaptation strategies is particularly pertinent when regarding long-lived infrastructure located in vulnerable places such as flood plains or coastal zones. Hallegatte (2009) recommends five methods when planning new developments: (i) selecting "no-regret" strategies that yield benefits even in the absence of climate change; (ii) favouring reversible and flexible options; (iii) incorporating "safety margins" in new investments; (iv) promoting soft adaptation strategies; and (v) reducing decision time horizons. Such methods can be applied to every sector of society when making decisions in the face of deep uncertainty. In recent years, efforts have been made to incorporate these principles into adaptation pathways (Watkiss et al 2014; Dittrich et al 2016).

Such is the concern regarding the severity of climate change impacts that a discourse of *transformational adaptation* is now emerging in the literature. The IPCC (2012) recognised and defined transformational adaptation in the SREX report as a fundamental qualitative change, or a change in composition or structure that is often associated with changes in perspectives or initial conditions (O'Brien et al 2012). Under these circumstances, incremental adaptation methods are abandoned in favour of more radical strategies operating at a much larger scale and intensity transforming places and shifting locations (Kates et al 2012). Transformational adaptation now features on the agenda of the IPCC (2013) and attempts to address the root causes of vulnerability through action that 'changes the fundamental attributes of a system in response to the climate and its effects' (Agard et al 2014). One example of transformational adaptation is evident in the UK SMPs. The policy of managed realignment allows the shoreline to erode but manages retreat in certain areas. These areas can experience transformational change in many cases shifting from fresh to salt water environments (Morecroft et al 2012).

The international community has now recognised that adaptation initiatives will play a key role in reducing the adverse effects of climate change globally. Despite this recognition, on-the-ground adaptation implementation has not been substantial over the last decade (Wise et al 2014). Adaptation plans may be hindered by a range of factors and barriers related to human behaviour (Section 2.9) and governance (Section 2.3). The next part of the literature review will examine existing frameworks used by stakeholders to deliver climate change adaptation initiatives. The strengths and weaknesses of each framework will be evaluated (Section 2.8) before outlining barriers that inhibit engagement with climate change adaptation (Section 2.9).

2.9 Adaptation frameworks

There are many frameworks designed to aid climate change adaptation. Existing frameworks predominantly focus on adaptation efforts in a specific context by prescribing tools and methods that may be used to enhance selected initiatives. For example, some frameworks focus on barriers to adaptation (Moser and Ekstrom 2010, Measham et al 2011), or attempt to establish what makes climate change adaptation 'successful' (Adger et al 2005) and define key terminology used in the assessment and implementation of adaptation initiatives (Füssel 2007). These frameworks are often sector specific and are bounded by situational variables such as regional demographics, resource availability and politics.

To provide pragmatic guidance to aid the implementation of adaptation initiatives and understanding of the ways in which adaptation initiatives are currently structured must be established (Research question 3). One review of the adaptation literature asserted that there are three distinct framework approaches which stakeholders utilise: Scenario Led (SL), Vulnerability Led (VL) and Decision Centric (DC) (Armstrong et al 2015). These frameworks are not sectorally or regionally specific. The following sub-sections outline the nature of these three adaptation frameworks and key literature from the review, which form the basis of the identification criterion (Chapter 4, Table 4.1).

2.9.1 *Scenario - Led adaptation frameworks (SL)*

These frameworks apply conventional methods of regional climate downscaling from climate model projections under a range of GHG emissions scenarios. Downscaled scenarios are then fed into impact models to examine how changes in climate might affect a given region and impact metric(s) such as crop yield or stream flow. Only then are adaptation options considered and implemented. Wilby and Dessai (2010) highlight that although the SL framework is the approach most widely used by the scientific community (to date) there are few examples of actual adaptation decisions arising from this route. They contend that the vast majority of research stops at the impact assessment stage. The most likely reason is that SL approaches are plagued with limitations surrounding uncertainty, largely due to the technical ability of the models themselves (Wilby et al 2002; Jones et al 2014). The range of uncertainty expands with each step of the adaptation process (Wilby and Dessai 2010). This means that decisions governing adaptation responses must deal with a wide range of uncertain futures (Figure 2.7). Uncertainty proceeds from variable socio-economic and demographic futures, their translation into concentrations of atmospheric greenhouse gas (GHG) concentrations, expressed climate outcomes in global and regional models, translation into local impacts on human and natural systems, and implied adaptation responses (Wilby and Dessai 2010).

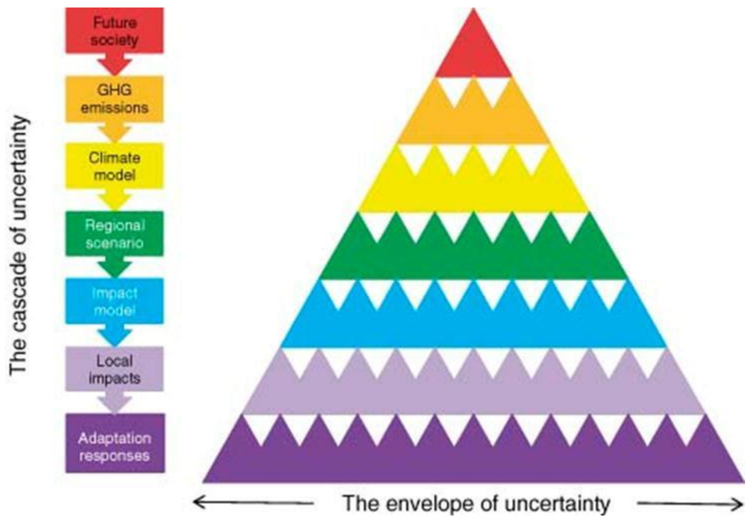

Figure 2.7 Cascade of uncertainty. The increasing numbers of triangles at each level represent the growing number of permutations and hence expanding envelope of uncertainty. Source: Wilby and Dessai (2010)

The limitations of the SL approach have been recognised for some time. Dessai and Hulme (2004) state that climate modelling remains uncertain. Therefore, the role that climate modelling plays in adaptation planning largely depends on stakeholders understanding the limitations of the framework and the capabilities of a given initiative to incorporate and consider probabilistic predictions of future climate scenarios.

2.9.2 *Vulnerability- Led adaptation frameworks (VL)*

VL frameworks seek to identify and reduce vulnerability to past and present climate variability. VL frameworks recognise that complex socio-ecological factors that must be considered when implementing appropriate and effective adaptation to the potential effects of climate change. As such, the focus of this framework is on identifying factors that govern communities' ability to successfully cope with climate related threats, commonly involving a community risk assessments (van Alst et al. 2008). Adaptation occurs in the form of improving coping strategies, lowering sensitivity, and/ or by reducing exposure to known threats.

However, lengthy observations are needed to assess magnitudes and frequencies of extreme events as well as their associated societal and environmental consequences. In practice, climate vulnerability is determined by multiple factors such as economic status, social equity, food security, education, access to natural resources and technology, physical and institutional infrastructure (Brooks et al 2005). The profile of these vulnerability variables are context specific, meaning that one assessment cannot be readily transferred to other regions due to variations in socio-economic and cultural factors (van Aalst et al 2008).

In addition, Wilby and Dessai (2010) highlight that in many regions climate variability is already stressing human and environmental systems. For example, parts of North Africa and the Middle East are already facing a water crisis due to demographic and economic pressures. Kummu et al (2010) claim that in eastern Asia, Africa and the Middle East, the effects of population growth on water scarcity is four times more important than changes to water availability based on long-term climate change. Consideration of complex socio economic structures is not only necessary at the risk assessment stage but also when thinking about socio economic development over long time horizons (Eakin and Patt 2011). O'Neill et al. (2014) highlight this and propose the use of conceptual frameworks using Shared Socio-economic Pathways (SSPs). They define SSPs as reference pathways used for plausible alternative trends in the evolution of society and ecosystems over a century timescales in the absence of climate change and climate policies.

2.9.3 *Decision-centric adaptation frameworks (DC)*

These adaptation frameworks are situated between SL and VL approaches (Brown et al. 2012). Decision-centric or stress-testing frameworks attempt to overcome the irreducible uncertainty associated with climate change projections by focusing attention on identifying vulnerabilities/coping capacities and managing risks through robust, low-regret adaptation methods.

This climate risk management approach begins with the identification of the vulnerabilities in a given neighbourhood by asking stakeholders and appropriate experts the degree to which the given area could cope with changes in boundary conditions and establish what levels of climate change would require substantial infrastructure investment and/or, policy shifts. The identified vulnerabilities and thresholds are then formalised into a model that relates changes in the physical climatic conditions to the performance of these metrics corresponding to vulnerabilities (Brown et al 2012). The importance of the identification of critical thresholds that may affect the resilience of a system is an aspect of the adaptation process that is currently being given more credence in the face of uncertainty (Brown and Wilby 2012).

One advantage of the DC framework is that it may be updated immediately if conditions governing risk change. The framework is also useful when trying to determine which uncertainties are most important from the viewpoint of the decision maker as individual metrics can be stress tested. One pioneering case study, in which a DC approach was successfully utilised, was the International Upper Great Lakes Study (IUGLS), which established rules for regulating water levels in the Great Lakes (Brown et al 2012).

Defining control rules for the Great Lakes was problematic due to significant levels of natural variability along with poorly understood lake dynamics. This meant that potential climate impacts on hydroelectric power, navigation and ecosystems were difficult to predict. Because of this uncertainty, an optimal plan based on identifying the most probable future scenario was rejected. Instead, a plan was devised in three main phases; i) stakeholder groups identified key vulnerabilities and defined acceptable and unacceptable lake levels for each impact area; ii) a dynamic regulation plan was developed that is responsive to a wide range of climate conditions; and iii) an adaptive management process was established for reviewing the performance and updating the dynamic regulation plan (Brown et al 2012).

The DC approach encompasses climatic change projections, potential impacts and community responses as an interlinked system. As such, this framework is inherently multi-disciplinary often involving multiple stakeholder groups. This complex approach, therefore, requires engagement and promotes interdisciplinary learning between cross-sectorial participants.

2.10 Adaptation ‘success’ – factors helping and hindering

Greater attention is being paid to climate change adaptation. International research projects such as the Future Earth programme, Horizon 2020 and the Dutch Knowledge for Climate programme all incorporate adaptation as a fundamental research focus. However, defining and measuring the ‘success’ of climate change adaptation is difficult, in some cases the outcomes of an adaptation initiatives may not be realised for many years. Moser and Boykoff (2013) recognise the complexities of defining ‘success’ in a uniform manner as there are social, ecological, economic, political, technical, institutional, psychological and cultural dimensions to consider - measuring success by one dimension may affect another. Dupuis and Biesbroek (2013) recognise that measuring adaptation is difficult due to the fuzziness of its scope and boundaries. Due to the diverse plethora of stakeholders engaged in adaptation, in any given case there is no single adaptation option to implement and subsequently no one action to judge. Therefore, it is widely recognised that achieving, defining and measuring successful adaptation involves a long-term iterative process of learning and change (Moser and Boykoff 2013; Smith et al 2011; Tschakert and Dietrich 2010). To date an integral part of the process of learning and change has focused on defining barriers to adaptation and promoting collaboration between disciplines researching and implementing adaptation. The remainder of this section will consider these elements.

Pidgeon and Fischhoff (2011) claim that the practical value of climate-related research depends on the ability of stakeholder groups, policy makers and the general population to comprehend the risks and the inherent uncertainties within the field. They believe that only then will society be able to rationalise the application of academic research when adapting to the potential impacts of climate change. To overcome this disconnect and facilitate the ‘successful’ implementation of climate change adaptation initiatives across multiple sectors, joint responsibility must be taken to develop relationships that promote co-production of knowledge between scientific, governing and decision-making groups.

Currently there are two principles for joint learning and cross-sectorial collaborations. The first prescribes that adaptation research should be transdisciplinary and solution orientated, aiming to solve ‘real world’ problems rather than simply advancing knowledge. The second is that adaptation should integrate knowledge from natural and social disciplines (Hinkel et al 2016). There are a wide range of methods employed to conduct climate change research in line with these principles including: participatory, experimental, decision analysis, behavioural analysis, institutional analysis and climate and impact simulation methods (Hinkel and Bisaro 2016). However, there is less consensus amongst the academic community as to how to put these principles into practise.

With this in mind, it is important to consider the factors that could affect the ‘successes’ of a given adaptation initiative. Decision makers are progressively requesting climate change scientists to incorporate socio-economic factors into climate change scenarios (Moss et al 2010; Borris et al 2016). Therefore, consideration of such variables becomes more relevant. Because of such consideration, the degree of complexity surrounding adaptation is likely to increase. Such variables are commonly referred to as barriers. Moser and Ekstrom (2010, pp 22026) define barriers to climate change adaptation as ‘obstacles that can be overcome by concerted effort, creative management, a change of thinking, changed priorities, or related shifts in resources, land use, and institutions’. Understanding how barriers hinder adaptation is important to finding strategic ways of overcoming them (Biesbroek et al 2013).

It is widely accepted that the distribution of vulnerability, resilience and adaptive capacity to climate change is not equal across societies and/or space as each community faces distinct sets of challenges and barriers (Nelson et al 2002).

However, our current understanding of these complexities are limited and fragmented across the academic community (Biesbroek et al 2013). Significant efforts have been made to define, categorise and provide tools to diagnose barriers to climate change adaptation. For example, Moser and Ekstrom (2010) presented a framework that utilises three interconnected elements, namely context, actors and systems, as a means of bounding barrier complexities. They provide a series of questions to pinpoint where barriers occur within the decision making process. However, they note that it is not only the identification and ability to overcome said barriers that is important; the means by which they are overcome is also crucial. Adger et al (2009) further assert that barriers can be overcome with sufficient political will, social support, resources, and effort but care must be taken to ensure adaptive capacity is enhanced and to prevent new barriers from being inadvertently created.

To ensure 'successful' implementation of climate change adaptation initiatives, it is important to be aware of the potential barriers that may impede the adaptive capacities of stakeholders, when planning, implementing, and maintaining initiatives. The following sections present some of the most important factors identified by research literature. These are deemed to inhibit stakeholder ability to engage and collaborate on adaptation issues (Figure 2.8). For the purpose of this task, barriers have been categorised as: i) social, ii) political, iii) economic or iv) technological following Masters and Duff (2011). It is recognised that this categorisation is a simplification of 'real-world' situations. In reality, these areas are dynamically interlinked and individual adaptation strategies exposed to a complex web of barriers depending on the situation and nature of the initiative.

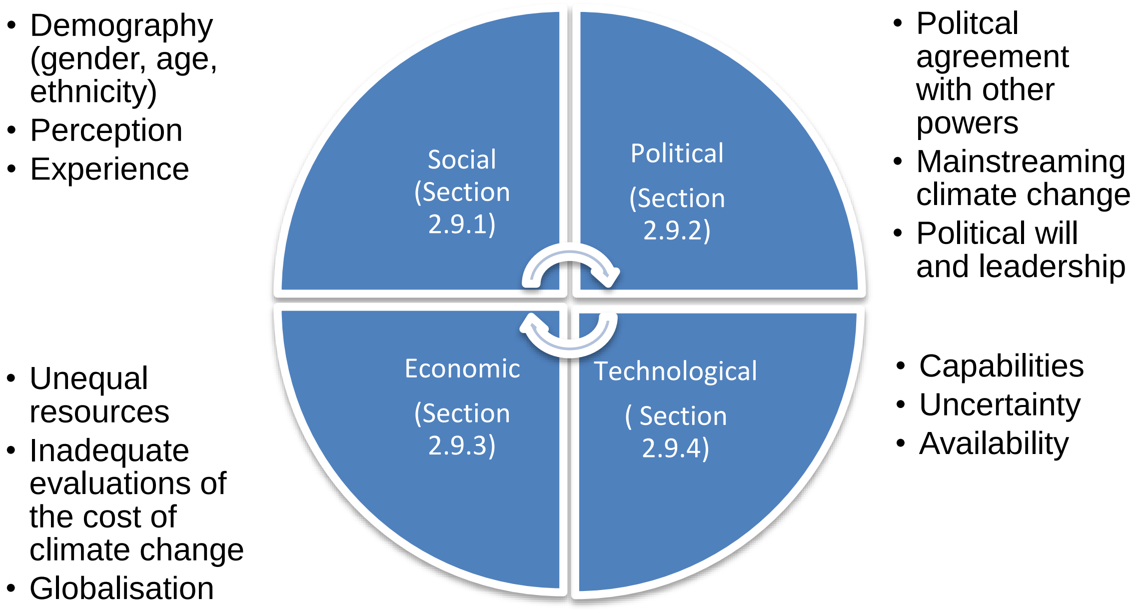

Figure 2.8. Climate change adaptation barriers can be: 1) social, 2) political, 3) economic and 4) technological as discussed in the relevant sections.

2.10.1 *Social barriers to climate change adaptation*

Over the last decade, awareness that widespread social changes are needed, including individual efforts, to combat potential impacts of climate change has become evident (Faaij et al 2013). Studies have shown that although there is a general awareness of climate change in developed nations (only 1% of the English population claim not to know about the issue), knowledge of potential impacts are better established than knowledge of causes (DEFRA 2002). Without knowledge of cause it is difficult to communicate ways in which organisations and lay persons alike should adapt their everyday lives to combat a changing climate (Reiter et al 2015). When attempting to understand factors that affect the adaptive capacity of stakeholders it is important to determine what controls and shapes their opinions and understanding and therefore their adaptation actions (Marshall et al 2013).

There is an extensive literature exploring social dynamics and barriers that affect a community's ability to engage with and implement 'successful' climate change adaptation initiatives (Clar et al 2013; Biesbroek et al 2013; Eisenack et al 2014; van der Linden 2015). These barriers can be grouped in three key areas: 1) demography, 2) perception, and 3) experience (Figure 2.8).

2.10.1.1 *Demographic* The social fabric of an organisation or community can impact the potential to engage with and implement 'successful' adaptation initiatives (Adger et al 2013). Efforts have been made to categorise cultural aspects of communities by demographic factors such as gender, age, ethnicity, literacy rates and life expectancy in order to establish patterns in levels of vulnerability and adaptive capacity (Marshall et al 2014). Analysis of such indicators can be used to generate geodemographic profiles for specific locations, which in turn inform decision makers about the social fabric of an area. This information may then be used to infer the baseline resilience of a community and hence shape the design of appropriate adaptation initiatives.

Generating such geodemographic segmentations has traditionally been achieved by statistically processing census and lifestyle data using algorithms and assigning demographic profiles to post codes (Vickers et al 2005). A major challenge of place-based planning stems from overly simplistic notions of community implying a homogenous, socially fixed social group that shares a consciousness (Measham et al 2011). Planning theorists, however, emphasize that a multiplicity of communities may exist within one locality, differentiated by factors such as gender, ethnicity, class and age (Lane and Corbett 2005). Addressing this, a geodemographic segmentation tool has been developed by the CACI information technology company (2013) which is able to categorise the UK population into dynamic demographic types. Similarly, the tool A Classification of Residential Neighbourhoods (ACORN) has the ability to allocate households, postcodes and neighbourhoods to six demographic categorises, 18 groups and 62 types reflecting various social situations. By analysing significant social factors and community behaviour, these tools provide precise information and enables a greater depth of understanding of stakeholder networks present within a given community.

Such tools could prove invaluable when attempting to achieve 'successful' climate change adaptation by enabling barriers to be better understood and overcome. In addition to such tools, it is important that we understand not just what the social demographic indicators are but also how they affect the ability of an organisation, community or individual to engage with the topic of climate change and implement adaptation initiatives.

The demography of a community, individual or organisation affects the means by which climate change and therefore adaptation are considered. Gender plays a key role too. Denton (2002) asserts that on a global scale, climate negotiations can be seen as a parody of the unequal world economy, in which men, and larger developed nations, define how they participate in environmental problems whereas women and the smaller, less developed nations observe from the outside with virtually no power to change or influence the scope of the discussion. It is these largely accepted societal dynamics and norms that can lead to marginalised groups experiencing limited access to decision-making, resources and exposure to agencies supporting communities exposed to the potential impacts of climate change (Baćanović 2015).

Other studies show that men and women engage with climate change in different ways and therefore face different barriers when attempting to implement adaptation (Carr and Thompson 2014). Research shows that when households experience impacts such as flooding, women can be more vulnerable. Increased vulnerability is attributed to women having a stronger link to the home in terms of time spent there, as well as greater responsibilities and emotional investment in comparison to men, due to looking after children and elderly relatives (Bradford et al 2012; Medd et al 2014). These social cultural backgrounds can place greater responsibility on females to coordinate the recovery from extreme climatic events. Communities who have settled in the UK from developing countries bring their social norms, where in terms of attitudes and behaviour for the recovery and adaptation after an extreme event, women disproportionately carry out the majority of the work. The need to empower women to engage in climate change adaptation initiatives was highlighted by research into Asian women in living in Banbury in the UK. The study by Bardshaw and Fordham (2013) revealed that the level of knowledge of the risk of flooding is ‘non-existent’. Result from such studies should be shared with the decision makers to create more inclusive policies and community support mechanisms that enhance the adaptive capacity of the whole community, including minority groups.

The age of an individual affects their perception of risk and therefore the nature by which they engage with climate change adaptation initiatives. Hence, various age groups may face different barriers to climate change adaptation. For example, elderly people may not regularly use the internet, instead relying on lower technology means of engaging with initiatives such as television, word of mouth or local media. Conversely, younger generations utilise the internet and social media frequently. Agencies and decision makers must be aware of this to prevent maladaptation and increase community resilience to the impacts of climate change.

For example, the Environment Agency (EA) (2015) found that young people (16-24) are less likely to have links to authorities via community groups, or to be signed up to early warning systems. They are more likely to access information on the internet via sites such as YouTube. Furthermore, research into social media communication revealed the Environment Agency's use of hashtags '#' are not in keeping with the way that young people use them. Findings revealed that young people would not search #rain or #floodaware but are more likely to use more place specific hashtags such as #Toonflood that were used by the public and authorities, established by Newcastle City Council in the 2012 floods (EA 2015). In addition, Semenza et al (2008) found that in the USA, age was a controlling factor of awareness and behavioural change when addressing climate change. They found that younger, more highly educated individuals were more likely to adapt their behaviours mainly by reducing energy use in their homes (43%) and reducing gasoline consumption (39%) in comparison to older and/or less educated members of society

2.10.1.2 *Perception and past experience* Individuals or organisations' world views have the potential to act as a barrier when engaging with climate change adaptation initiatives. This is because psychological perceptions of environmental issues and associated risks posed are largely shaped by past experiences, behaviours and social norms (Boillat and Berkes et al 2013; Dessai et al 2004; Thaker et al 2016).

There are various theories as to how the past behaviour of a stakeholder may govern their responses to environmental issues. The Theory of Planned Behaviour postulates that an individual's beliefs determine their intention to act and consequent behaviour. However, this theory has been subject to criticism. It is thought of being overly individualistic, over simplifying and rationalising reasons behind displayed behaviour (Guagnano et al 1995). Stern (2000) attributes present behaviour and interaction with climate change issues to be governed largely by, personal capabilities and habits. The effects of past behaviour is present both at international and individual levels of society. For example, on an international scale wealthy nations have developed through consumption of fossil fuels and therefore have a significant historical responsibility for current atmospheric CO_2 concentrations. Following a high emission development pathway has made it very difficult for these nations to now decarbonise at the prescribed rate. At an individual level, if a person is aware that using their car, as opposed to public transport, will exacerbate climate change they are less likely to change their behaviour if they use a car frequently as it is habitual and convenient (Gifford 2015).

Whilst it has been established that people associate climate change with negative consequences, a high proportion of UK residents believe that the effect of climate change is not an immediate threat (Lorenzoni and Pidgeon 2006). Because of this perception, other issues may have greater immediacy; hence issues such as finance and health may take priority. Of the minority of people who conserve energy, most do so for health and financial reasons rather than for environmental causes (DEFRA 2002). The literature addressing public understanding and engagement regarding climate change also provides examples of cognitive dissonance (Adger et al 2013; Ross et al 2016). Although there is now widespread awareness of climate change and general concern, there is limited evidence of behavioural responses. This could be due to the nature of concern and perceived risks. Studies have revealed that established migrant communities in the UK perceive flood risk to be low in industrialised countries, compared to more extreme events experienced elsewhere (Bardshaw and Fordham 2013). Pinto (2015) argues that western governments themselves exhibit cognitive dissonance at international meeting such as the Paris Conference of the Parties by continuing to support the fossil fuel companies they strive to phase out. This example highlights that people with different cultural values may have different beliefs yet still act similarly. For example, both concerned individuals and critics are more than likely to act than non-interested people (Pidgeon and Fischhoff 2011). On the other hand, Milfont et al (2012) found, when analysing 5,815 people in New Zealand, that there was a direct correlation between belief in climate change and proximity of living near the coast. People living closer to the ocean showed a greater belief in climate change and supported the government’s policies to reduce emissions. Results indicated that the physical place in which someone lives has a strong influence on belief and engagement in climate change and is more influential than, education, political orientation and gender.

Lorenzoni et al (2007) assert that there is radical need for changes of values and behaviours of both institutions and the general population towards low consumption and adaptive lifestyles. To enable this paradigm shift to materialise, a high proportion of the population need to be engaged, motivated, and enabled to move towards a low carbon future. Obradovich and Guenther (2016) observed that when collective responsibilities for action combatting and adapting to climate change were emphasised, pro-climate monetary donations increased by 7% amongst environmental group members and 50% within the public. These results contradict assumptions that promoting personal responsibility for climate change increases engagement and willingness to act and supports the efficacy of actions called for by Lorenzoni et al (2007).

2.10.2 *Political barriers to climate change adaptation*

Governance structures can have a significant effect on the adaptive capacity at both the national and international level (Bulkeley and Betsill 2013). Internationally, the political sphere is increasingly focussed on combatting the potential impacts of climate change through adaptation initiatives. For this momentum to succeed world powers must successfully collaborate and build on lessons learnt from the weaknesses of international mitigation frameworks (Section 2.3). To date, efforts to address the impact of climate change have been launched from contemporary political and administrative systems. These systems have been developed to deal with other societal issues and now must be morphed themselves to be capable of handling the issues surrounding climate change adaptation (Meadowcroft 2009).

Political will, leadership and trust play a key role in facilitating ‘successful’ climate change adaptation. International governments and opposing political parties must be united in prioritising adaptation. This is not an easy task, as the complexities of issues surrounding climate change do not reflect the structures of governments nor the spatial and temporal boundaries on which they operate (Adger 2001). When considering climate change governance, such complexities go beyond previous experience. Termeer et al (2013) reflects the scale of the governance challenge by referring to the climate change governance challenge as a ‘wicked problem par excellence’.

Internationally, the political will of countries to incorporate initiatives to combat the impacts of climate change into mainstream policies varies. Meadowcroft (2009) attributes this to a sense of ‘institutional inertia’ displayed by governing organisations. He asserts that such inertia stems from political and scientific uncertainties, long time scales and the complexity of reaching international decisions, which in turn hamper the effective and timely responses required to implement ‘successful’ initiatives. Such variance can also be attributed to unequal historical responsibility of GHG emissions. During their growth, developed nations relied heavily on the consumption of fossil fuels, therefore, much of the atmospheric CO_2 reflects the legacy of this growth. Simulations with Earth Systems Models have demonstrated that developed countries have contributed 60 to 80% of global temperature rise, upper ocean warming and sea-ice reduction by 2005, whereas developing countries have only contributed 20 to 40% (Wei et al 2012). Emerging powers known as the BASIC countries (Brazil, South Africa, India and China) been reluctant to commit to international treaties seeking to limit GHG emission due to their rapid economic development, growing power and political ambitions (Hurrel and Sengupta 2012). As the BASIC group of countries develop, they are becoming increasingly influential on the global political stage complicating international efforts to reach agreements to combat climate change.

Governance systems must find ways to ’successfully’ instigate and implement adaptation initiatives in areas that are already experiencing adverse effects of climate change such as coastal zones. In the UK, the competence of the government to lead on such issues has become ever more important since the vote to leave the EU. The political relationship with the rest of the EU is in a state of flux that will continue to evolve as the UK instigates Article 50 and embarks upon a divorce from the EU. Currently (July 2016) there is limited, post Brexit information on how a divorce from the EU might affect the UK’s environmental and climate related policies. However, one early casualty has been the abolition of the UK governments Department for Energy and Climate Change (DECC), a move which has been condemned by former ministers as a major setback for the British efforts to combat global warming (The Guardian 2016).

Studies show that local stakeholders regard the instigation of climate change adaptation initiatives as the responsibility of national governments and other powerful organisations (Lorenzoni and Pidgeon 2006). In many cases, they regard their individual efforts negligible as climate change is frequently portrayed as a 'global problem'. This opinion is consistent with Schultz et al (2014) who found that the layperson exhibits spatial bias when regarding environmental issues such as climate change – there is a tendency to perceive environmental problems to be more serious on a global scale or at other locations. Spatial bias serves to temper the severity of environmental problems in one's own area. In an earlier international study, Gifford et al (2009) found such perceptions to be true in 15 of the 18 counties sampled. This illustrates the importance of governments leading by example, and providing clear guidance to the population, which is not always the case. For example, out of 1007 UK citizens surveyed in 2004, 60% felt that climate change should be addressed at the global scale whereas only 5% felt that climate change could be suitably addressed by the EU (Lorenzoni and Pidgeon 2006).

A lack of collaboration between political parties could affect the trust the general population holds in government, leaving communities uncertain about how to engage with and implement climate change adaptation strategies. For example, Nisbet (2010) explains that there appears to be 'Two Americas' on climate change as a result of politically polarised opinions. In this case, political identity governs opinions and actions towards the environment. Over the last decade, Republicans have increasingly questioned the validity of climate science and dismissed the urgency of the problem, whereas an increasing number of Democrats accept climate science and express concern about the issue. As a result, this partisan divide has become a mark of what it means to be Republican or Democrat. This example demonstrates the influence that the political sphere has on a populations' attitude and will to implement climate change adaptation initiatives. This supports the notion that climate change must be mainstreamed into all aspects of policy to ensure communities incorporate adaptation practices in their daily lives.

The need to mainstream adaptation into government policies is becoming increasingly urgent as areas of the world start to suffer from effects of climate change. For instance, mainstreaming climate change adaptation into development planning has been established for many years. Development agencies actively screen their project portfolios to ensure that adaptation is addressed within projects to aid developing countries and help grow sustainably (Klein et al 2007). However, there is still much work to be done to mainstream climate change adaptation even in developed countries. This was highlighted by the winter storms of December 2015 where over 16,000 houses flooded in the UK, with over 9,000 in Yorkshire and Lancashire (The Guardian 2015). Although the country experienced unprecedented levels of rainfall, the scale of disruption the floods caused highlighted the lack of community preparedness.

With climate change expected to bring warmer and wetter winters to the UK, government must reflect potential impacts in government policy enhancing the adaptive capacity and resilience of communities. In addition, a significant weakness of the UK's democratic political system's ability to objectively address the potential impacts of climate change was exposed by the winter floods of 2013/14. In the following months, rivers in the Somerset levels were dredged in response to public outcry, contrary to the advice of the regulator and entire hydrological community. A lack of timely institutional assistance when attempting to implement adaptation initiatives is exhibited in other developed countries. In Sweden, citizens are increasingly acting on their own to implement adaptation, even outside legal frameworks. For example, the Vellinge and Helsingborg communities connected their roof runoff water to the municipal storm water system via illegal downpipes (Wamsler and Brink 2014). Although proactive, such projects run the risk of maladaptation and may be counterproductive in the long term.

Each of the preceding examples illustrates a functionality gap between governing organisations and local communities. To overcome said gaps, Amundsen et al (2010) believes that institutional capacity must be increased to deal with climate change adaptation at the municipal level, in turn enabling a multi-level governance framework that would enable proactive adaptation and contribute to overcoming barriers. Gaps in the governance system must be addressed to enable timely 'successful' adaptation initiatives to be implemented. With this in mind, there is significant scope for research to focus on defining and overcoming the said gap. When writing about citizen involvement in the US planning process Arnstein (1969) created a theoretical ladder of participation which categorised participation from high to low, citizen control to manipulation. By referring to Arnstein's ladder of (1969), policy and decision makers may be able to determine where such gaps originate enabling them to productively reduce such gaps to promote the implementation of adaptation initiatives.

In light of such findings McEwen et al (2014) argue that social science and arts and humanities approaches are well-placed to educate and explore creative solutions to risk. They believe that creative, 'bottom up' solutions are needed to bridge gaps between science, policy and public understanding. The 'Slow the Flow' community scheme deployed in Pickering and Sinnington, North Yorkshire illustrates the value of such schemes. In partnership with the Forestry Commission the local community planted trees and made natural dams on the watercourse upstream of Pickering to slow the run off and reduce flooding downstream (DEFRA 2015). The scheme was implemented in response to the Pitt Review (2007) which called for changes in land use and land management to reduce flooding. In addition, the community was aesthetically opposed to proposed plans to install concrete flood defence walls in the town. Despite the severity of the winter storms in 2015, both areas were unaffected. The 'Slow the flow' project provides further support for those calling for a greater understanding of the interactions between social scientific knowledge, conceptualisation of sustainability, and the uneven distribution of impacts on affected communities managing the physical effects of climatological events (Emery and Hannah 2014). It is especially important to understand how these social relationships were exhibited in the 'Slow the Flow' project to avoid maladaptation (Milman and Warner 2016).

2.10.3 *Economic barriers to climate change adaptation*

The economic implications of climate change are well documented as highly complex, cross sectorial and impacting multiple levels of society from local to global scales (Stern 2007; Tol 2009; Fankhauser 2013). Weitzman (2009) asserts that, to date, there has been an inability to meaningfully evaluate the economic impacts caused by temperature changes higher than the dangerous 2 ºC. He stresses that the uncertainties in cost projections of climate change largely mirror the deep structural uncertainties associated with the climate change science. However, should international efforts to limit climate change to less than the dangerous 2 °C fail, the cost of adaptation is expected to rise exponentially (Stern 2007). Therefore, efforts must be made to accurately calculate the potential economic impacts climate change may impose.

Economic resources have a direct impact on the adaptive capacity of individuals, communities and organisations. Trying to quantify the cost and benefits that climate change may impose on different countries is difficult as there is no standardised method of valuation. Stern (2013) recognised the difficulty faced and called for a new generation of models in climate science, impacts and economics with a stronger focus on lives and livelihoods. He has also deemed it necessary to incorporate the risks of large-scale migrations and conflicts. To date Integrated Assessment Models (IAMs) have been used to try to forecast the economic cost that may be incurred as a result of climate change and therefore quantify the costs and benefits of adaptation initiatives. These mathematical models are able to calculate the consequences of multiple outcomes and interrelate many factors simultaneously. However, IAMs are based on poorly quantified assumptions about how the modelled system operates and are therefore subject to the scientific uncertainties associated with climate science across a range of disciplines (Rogelj et al 2013). Pindyck (2013) believes that the assumptions associated with IAMs make them critically flawed for policy analysis applications and accuse IAM-based analysis of creating a perception of knowledge and precision that is illusory and misleading. However, Mastrandrea and Schneider (2004) have long recognised the limitations associated with IAMs and recommend that outputs from models should be used in a probabilistic way, observing trends rather than specific values. Today IAMs are limited by the speed of computers – present computation times mean it is not feasible to integrate the most advanced GCMs with demographic data (Paltsev et al 2015).

Tol (2012) shows that ‘experts’ advocate a range of methodologies to determine the economic cost of climate change. One approach, the *enumerative* method, assesses the ‘physical effects’ of climate change from natural science papers and then gives each physical impact a price. This method can be used for trades, goods and services but is difficult to apply to other sectors of society such as health or the environment. An alternative method is to employ a *statistical* approach. This has the advantage of being based on ‘real world’ differences in the climate and selected indicators of societal change such as income. The use of a statistical approach enables adaptation initiatives, to model results that are more realistic. For example, Below et al (2012) used statistical methods to develop an activity-based adaptation index to explore the relationship between socio-economic variables and African farmers' adaptation behaviours. Although effective, the statistical method is limited as it cannot incorporate the cross-societal relationships associated with climate change adaptation. Below et al (2012) recognise this stating that their index provides a *simple* but promising way of capturing the complexity of adaptation processes. The UK government has recognised the necessity of economically evaluating the natural environment. A Committee for Natural Capital was established to monetise different sections of the environment to determine outcomes from investments, such as how a watercourse might respond to a flood alleviation scheme.

The ongoing process of economic globalization further complicates the adaptive capacity of a given population, in many cases modifying or exacerbating existing vulnerabilities to climate change (O'Brian and Leichenko 2000). On an international scale, countries projected to be hit hardest by climate change are least able to afford the costs associated with adaptation. It is these less developed nations that require the most assistance to cope with climate change, that have the least historical responsibility for GHG emissions. Gardiner (2006) referred to the complexity of this dynamic of climate change adaptation as the 'perfect moral storm'. The concept of the 'perfect moral storm' can be applied to varying scales of adaptation from national and international to local initiatives.

The responsibility for the legacy of GHG emissions has been recognised by the developed world and is reflected by a number of international initiatives set up by government bodies to aid adaptation in the developing world. For example, the Climate Green Fund set up by the UNFCCC (2010) is committed to raising US$100 billion per year to aid less develop nations with the impacts of climate change and to develop sustainably. Although such financial instruments help less developed nations to overcome economic barriers impeding climate change adaptation, Van Asselt (2007) argues that these well-intended agreements undermine efforts to seek legally binding frameworks to address climate change internationally as they are pursuing the same agenda, using two different approaches, therefore duplicating efforts.

Analyses suggest that some regions could experience increased productivity as the climate warms before experiencing substantial losses (Tol 2012). With this is mind, Deressa et al (2009) found that for farmers in the Nile Basin of Ethiopia the main barriers to climate change adaptation were information on adaptation methods and financial constraints. Considering such findings together, it is reasonable to be concerned that temporary increases in productivity could lead to false interpretations of climate change, in areas such as the Nile basin. Lack of knowledge and misinterpretations of the predicted impacts and manifestation of anthropogenic climate change may increase the vulnerability of such communities. Even when access to the most up to date information is possible, misunderstandings surrounding embedded assumptions, present in climate change models, can act as a barrier for decision makers who desire accurate figures from which to work (Dessai et al 2009).

2.10.4 *Technological barriers to climate change adaptation*

Limited availability and access to technological resources experienced by some communities and organisations can be regarded as significant barrier impeding adaptation to the potential threats of climate change.

Technological barriers largely centre on the capability of climate models to simulate future climate change scenarios accurately and thus the uncertainties associated with such projections (Section 2.7.1.). It is also important to consider the interpretation of uncertainty as a barrier impeding climate change adaptation. Uncertainty may be regarded differently by different sectors of society. For example, unlike the scientific community - which is aware that uncertainty is an integral part of the process of discovery and debate – a layperson may regard uncertainty as an excuse for avoiding taking anticipatory action to combat climate change (Lorenzoni et al 2007). A lack of appreciation of scientific uncertainty may leave uninformed stakeholder groups vulnerable to influence from untrustworthy information and therefore manipulation by sources such as the media. Similarly, film producers' visions of future climate can distort public opinions about climate change. The 2004 film, The Day After Tomorrow, which depicts an abrupt onset of a new ice, changed people's attitudes to climate change. After watching the film, belief in the likelihood of extreme events occurring due to climate change was reduced; even so, many viewers expressed motivation to act on climate change (Lowe et al 2006).

It has long been established that technology has a critical role to play in adaptation to climate change. Klein et al (2001) recognise that technologies are involved in multiple aspects when addressing the potential impacts to climate change. For example, computational technology in the form of GCMs may be used to inform and design adaptation strategies. Technological equipment for constructing and implementing initiatives will also be essential for monitoring and evaluating performance, therefore access to state of the art technology is critical when attempting to increase the adaptive capacities of communities vulnerable to climate change. In addition, Giddens (2009) asserts that the ‘next industrial revolution’ must deliver technologies to protect against the future dangers of climate change. He insists that technological innovation has to be a core part of any successful adaptation strategy. Although there have been significant improvements in climate forecasting via enhanced modelling capabilities, many less economically developed regions of the world do not have access to the technical resources vital to the enabling of successful climate change adaptation initiatives.

Technological resources come in a variety of forms, ranging from virtual information systems to physical assets and equipment. Access to both are essential to successfully enhance communities’ adaptive capacity. One contemporary example of the combination of virtual and physical technologies is the application of climate-smart agricultural (CSA) practices. CSA can be defined as an approach that “sustainably increases productivity, enhances resilience, reduces GHGs, carbon sequestration and increases food security and development goals” (United Nations Food and Agriculture Organisation 2010, pp2). Implemented largely in developing regions, CSA involves virtual climate assessment and forecasting as well as the deployment of technologies such as genetically modified crops, increasingly resilient farming techniques and the use of technologies such as solar power to increase production (Mwongera et al 2016). Although the absolute efficacy of CSA is yet to be defined (Long et al 2016) the approach demonstrates the potential for technological means by which to enhance the adaptive capacity of vulnerable communities.

Adger et al (2009) asserts that technological availability is inherently linked to knowledge flows. For example, access to the internet provides infinite resources and virtual tools to aid adaptation; however internet access is not universal. In June 2016, only 46.1% of the global population had access to the internet. Less developed, more vulnerable regions of the world exhibit a lower average: only 28.6% of the population have access to the internet in Africa and only 44.2% in Asia (Internetworldstats 2016). With the most limited internet access occurring in less developed nations these communities face a significant barrier and disadvantage when attempting to implement appropriate and successful climate change adaptation initiatives. This disadvantage is highlighted further when compared to the 85% of UK adults that used the internet in 2012 (Office for National Statistics 2012a). Decision makers without internet access are unable to utilise the growing number of climate change decision support tools such as the UK based Climate Just map tool[1], the UKCP09 User Interface[2] and the Environment Agency's interactive mapping tools[3].

Access to technologies in the form of equipment and tools are also necessary for vulnerable communities to enhance their adaptive capacity. With reference to the agricultural sector, Brown and Funk (2008) assert that technological sophistication determines a farm's productivity far more than its climatic and agricultural setting. It has been determined, on a global scale that primary food crops such as wheat, maize and barley reduce with a rise in temperature (Lobell and Field 2007). However, in tropical regions, farmers using fertilizer and pesticides, biotechnology-enhanced plant varieties, and mechanization experience far higher productivity than those using manual/traditional methods. Hence, vulnerability to the potential impacts of climate change is not wholly determined by climatic conditions. It is possible to reduce the vulnerability of a community via technological availability and advancement at both local and global scales.

As technology advances and becomes available to a growing number of people, information and global news becomes more accessible. Information services, therefore, have an important role to play in informing and educating people about

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[1] http://www.climatejust.org.uk/
[2] http://ukclimateprojections.metoffice.gov.uk/
[3] http://maps.environment-agency.gov.uk/wiyby/wiybyController?ep=maptopics&lang=_e

climate change. Lorenzoni et al (2004) found that the UK public possess distrust in information services, such as the media, as a result of exaggeration, sensationalism, bias and contradictory framing. An example of this is the documentation of extreme weather events by the media. Better public understanding of effects, rather than the causes creates confusion in the wake of extreme weather events. Such confusion and lack of leadership when implementing climate change adaptation initiatives act as barriers as stakeholders may not feel empowered to engage and act (Eisenack et al 2014).

2.10.5 *Risks of maladaptation*

In an effort to overcome the barriers associated with climate change adaptation it is important that stakeholders recognise the risks of maladaptation. Maladaptation can be defined as outcomes that 'impact adversely on, or increase the vulnerability of other systems, sectors or social groups' (Barnett and O'Neill 2010, pp 210). Techniques have been established to undertake adaptation, when facing significant barriers, that neutralises the risk of maladaptation. These techniques centre around adopting 'low-regret', 'robust' strategies (Hallegatte 2009). These are strategies that will benefit the current challenges of society and enable adaptation to any future climate scenario. These strategies may be employed to implement adaptation in the face of barrier such as the uncertainty associated with future climate projects (Füssel 2007; Wilby and Dessai 2010). For example, the flood alleviation scheme in Leeds, UK has upgraded the flood walls in the centre of the city in response to high levels derived from climate variability. The upgraded walls coincide with the agreements of the Government and the Association of British insurers, which requires a flood protection level of 1 in 75 year return period. However, the design of the flood defences enable the level of protection to be retrofitted should the city require a higher level of flood protection under future climate scenarios. Therefore, the risk of maladaptation is negated (Leeds City Council 2013).

However, consideration of maladaptation should also be at the forefront of the minds of decision makers, regardless of the barriers faced. Stakeholders vary in their vulnerability to climate change therefore adaptation priorities may be different (Kelly and Adger 2000). As such the adaptation efforts of one group may hinder that of another leading to maladaptation. Kalra et al (2014) assert that robust decisions, avoiding maladaptation can be achieved by inverting the decision making process by first collaboratively analyse options and seek agreement second. In this way and increase collaboration between stakeholders and decision makers, by could reduce the risk of maladaptation. The following section explores the potential for collaboration across sectors to overcome the barriers discusses so far in the chapter.

2.11 Collaborations across societal sectors to address climate change

As discussed above, barriers to climate change adaptation may affect some locations and sectors more than others. All barriers are interlinked by dynamic and complex factors influencing their manifestation within society. Figure 2.9 illustrates that there are multiple sectors of society addressing the potential impacts of climate change and implementing efforts to increase the adaptive capacity of their community. However, the positionality of different stakeholders in various sectors inhibit collaborations and therefore adaptation ‘successes’. To overcome the barriers associated with gaps between sectors (Figure 2.9) Nisbet et al (2010) called for a restructuring of societal interactions primarily via enhancing communication between stakeholders and they believe enhancing communication will increase the adaptive capacity of society as a whole. They assert that an improved communication infrastructure will empower stakeholders to (i) learn more about climate change, (ii) take personal responsibility of the issue (iii) constructively deliberate and participate in adaptation actions and (iv) engage and partake in collective actions for adaptation.

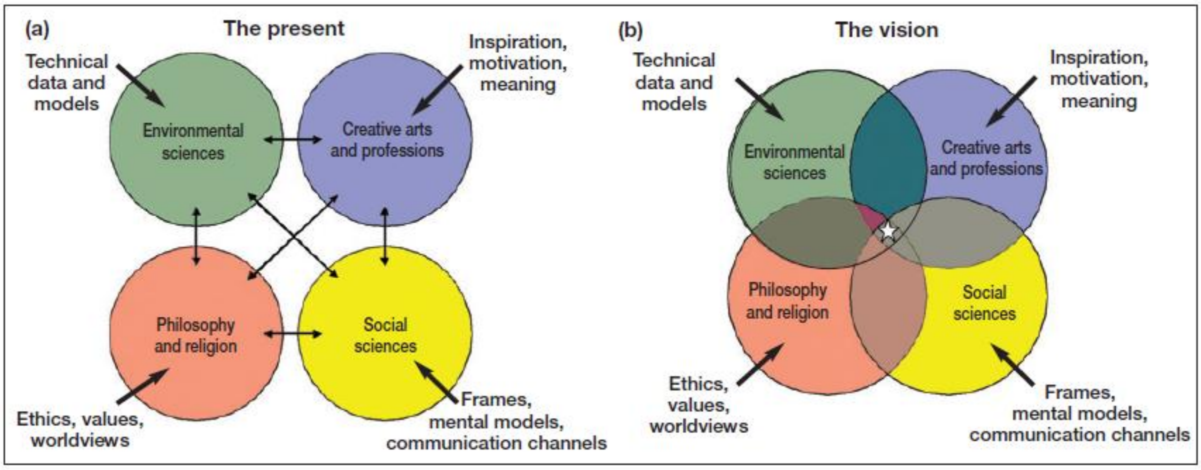


Figure 2.9.Transformation in four 'cultures' of society needed from the present to the future (vision) to successfully address environmental problems such as climate change. Source: Nisbet et al (2010).

Furthermore, Reiter et al (2015) asserts that knowledge gaps, regarding climate change impacts and adaptation techniques, exist among the natural, physical and social science research communities and the policymakers, whose decisions affect the communities and ecosystems vulnerability. These gaps present opportunities to better align research agendas with decision-making needs and enhance decision-making capacity. Faced with 'wicked' environmental problems that have profound implications for the future, new organizational mechanisms are needed to more effectively link scientific understanding to natural resource management. Boundary organizations such as think tanks and consultancies exist at the interface of research and policy organizations and foster linkages necessary to help fill such gaps. These linkages may provide the foundation for the development of successful formulas for implementing climate change adaptation at a range of spatial and temporal scales.

2.12 Conclusions

This review has covered the physical drivers of anthropogenic climate change, outlining changes in atmospheric CO_2 concentrations and describing some of the potential impacts for Earth systems, including the transgression of 'tipping points'. The review summarised how climate change has the potential to impact coastal zones primarily via SLR and storms with concomitant flooding, accelerated rates of erosion, saline intrusion and loss of habitats.

The chapter then explained the rationale for a ‘twin tracked’ approach to climate mitigation and adaptation, to counter projected climate change impacts. Currently, all sectors of society are grappling to find a method/framework by which to deliver both successful mitigation and adaptation simultaneously. The review has explored reasons why the international community is struggling to reach agreement on deploying effective strategies to limit climate change to below 2°C. In the absence of accurate forecasting of the potential temporal, spatial and intensities of climatic change, nations are largely concerned with their own self-interest rather than the collective benefit of taking action (Barrett and Dannenberg 2012).

Primarily focussing on adaptation, the review found that whilst there are methods to incorporate uncertainties associated with climate change into adaptation planning (such as low/no regret options), necessary assumptions regarding climatic forcing and societal responses must be made at all stages of the adaptation process. Such assumptions, therefore, could have the potential to inhibit all scales of adaptation efforts.

Faced with potentially unavoidable climate change, the review found that increasing prominence is being placed on the ability to implement adaptation initiatives under uncertainty. Key frameworks by which stakeholders and decision makers plan and implement initiatives include scenario-led, vulnerability-led and decision-centric approaches. Identification and classification of these frameworks offers an insight as to how stakeholders currently plan, implement and monitor adaptation initiatives. The review acknowledged that there are a number difficulties associated with defining and measuring adaptation success. Due to complex interlinking societal factors and the diverse nature of stakeholder involved in adaptation, the review recognises that defining, measuring and achieving successful adaptation will involve a long-term iterative learning process.

The review then identified other factors that have the potential to inhibit the adaptive capacities of international institutions, competent authorities and individuals. These factors, termed barriers, must be overcome to ensure the safeguarding of communities against the adverse impacts of climate change. There is an extensive literature attempting to diagnose and categorise said barriers. This review focused on four main types: i) social, ii) political, iii) economic and iv) technological. The review highlighted that there are many ways to categorise and study barriers affecting climate change adaptation. However, no standardised method has been accepted to diagnose and address this to date. It is recognised that the literature review will be subject to unintentional bias due to the positionality of the researcher (Biesbroek et al 2013). In order to address this limitation, care has been taken to provide examples from various sectors and range of locations.

This Literature Review has highlighted significant obstacles that society must address when faced with uncertain climate change. There is still a significant amount of research to be conducted to further develop techniques and methodologies to ensure the ‘successful’ implementation of climate change adaptation initiatives. Chapters 4, 5 and 6 examine some of the processes that contribute towards this outcome. First, however, Chapter 3 introduces four case study areas, all featuring long-lived infrastructure, located in coastal zones around the UK. The location and geological context of each site is outlined before discussing the potential climate change impacts the site is likely to experience during the lifetime of the infrastructure. These four case study areas are used throughout the research to address the aims, objectives and research questions.

Chapter 3: Case study areas

3.1 Introduction

Synergies emerging from an intensifying climate-energy nexus are becoming ever more pertinent for nations globally. In the UK declining domestic coal production is contributing to an increasing dependence on energy imports. In 2014, the UK imported 46% of its coal, gas and oil to use in energy production compared to 2000 when the UK had a resource surplus of 17% (DECC 2015). This growing dependency on imported energy is largely due to changes in the energy generating mix of the UK, a decline in oil gas and coal production and the closures of key refineries. To reduce carbon emissions by 80% by 2050, authorities are actively encouraging the population of the UK to increase their energy efficiency though behaviour changes such as increasing recycling, using public transport to commute to work or insulating homes. The Committee on Climate Change (2015) believe that improving efficiency and small changes to consumer behaviour can greatly reduce the cost of meeting the 2050 targets. Although these strategies have the potential to reduce overall energy demand, when faced with a growing population, it is essential that the UK prioritises the further development of sustainable energy generating capabilities. Failure to do so could contribute an 'energy gap' and inhibit the UK reaching carbon reduction targets (National Grid 2015).

One way the UK government intends to enhance energy production and, therefore, security is by expanding the nation's fleet of operational nuclear power stations (Chapter 2, Section 2.2). In the fourth quarter of 2015 nuclear energy accounted for 21% or the UK's electricity supply (DECC 2016). This is a strategy that has been employed successfully by other European countries. For example, France currently generates over 75% of its electricity via nuclear power (World Nuclear Association 2015).

The UK is unable to construct nuclear power stations inland due to the high demand for cooling water. The volumes required would prove unsustainable for the UK's inland waters; the thermal plume (created by the cooling water outflow) alone could breach thermal standards for freshwaters with unacceptable ecological consequences (Environment Agency 2010). For this reason, the UK's nuclear power stations must be situated in coastal zones. There are additional benefits to situating NNB next to existing nuclear infrastructure in the coastal zone. For example, proximity to existing nuclear infrastructure could lower construction costs, the surrounding population would be acclimatised to living and working in a nuclear neighbourhood.

In 2010 the UK government announced plans for eight coastal sites for NNB. All proposed sites are located in the immediate vicinity of existing nuclear infrastructure (Figure 3.1). Hinkley Point C and Sizewell C NNB projects are the frontrunners in the government's nuclear development programme. To date (June 2016), EDF has been awarded a nuclear site licence for Hinkley Point C, financial investors for the NNB have been agreed; EDF will invest 66.5% and the Chinese General Nuclear Power Corporation (CGN) 33.5%. However, concerns over the security of investments have led to significant delays to the construction of Hinckley Point C. As a result, the operational start date is now predicted to be 2025, 8 years later than the originally scheduled. At Sizewell C, EDF and CGN have signed investment agreements in principle; with EDF investing 80% and CGN 20%. The progress of DCO's and investment decisions, for all NNBs in the UK, has entered a state of uncertainty following the European Union (EU) referendum and the vote for the UK to leave the EU (World Nuclear News 2016). The first public consultation was conducted pre-referendum, and the second consultation stage was expected to commence in the near future. However, there could be delays due to Brexit.

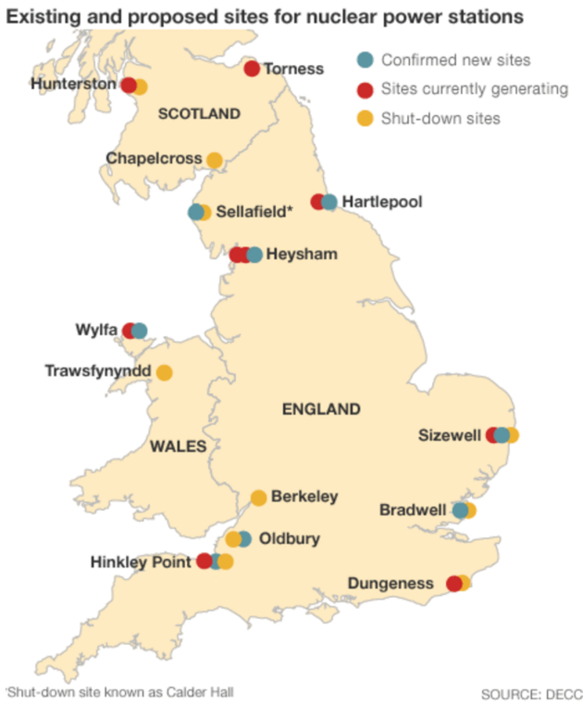


Figure 3.1. Nuclear power stations in the UK (decommissioned, operating and new build proposals. Source: DECC (2010)

The cradle-to-grave life-cycle of nuclear power stations is in the region of 150 years. Therefore, consideration of the future evolution of the coastal zone is essential (Wilby et al 2011b). Such consideration is required when regarding any long-lived infrastructure on the coastline, including harbours and container ports. Coastal managers and decision makers in coastal zones surrounding long-lived infrastructure must consider its long-term implications, including the potential effects climate change may have on the evolution of the coastline. Examples of such storms have recently affected the south east coast of the UK in December 2013 and January 2014 (Brown et al 2014; Wadey et al 2015). The increasing frequency of severe winter storms have prompted the UK Met Office to introduce a storm naming system. The prompt was due to the mainly 17 deaths caused in Europe after the St Jude's day storm on 27 – 28th October 2013.

This chapter addresses the contextual research questions (Questions 1 and 2) by determining the most significant threats posed by climate change to long-lived infrastructure in the coastal zone and outlining key stakeholders involved in managing the coastal zone surrounding long-lived coastal infrastructure.

The chapter introduces four UK case study sites that feature long-lived infrastructure. Three sites have been identified for NNBs and one is a nationally and historically significant harbour as follows: (1) Sizewell nuclear power station, Suffolk, England; (2) Hinkley Point nuclear power station, Somerset, England; (3) Wylfa nuclear power station, Anglesey, Wales; and (4) Portsmouth Harbour, Hampshire, England. These four sites were selected for a number of reasons. As outlined by this chapter, they are located in geographically contrasting regions and are exposed to different climatic conditions. Moreover, the proposed NNBs are at different stages of the planning process meaning that construction and operational commission dates will vary. Portsmouth harbour is crucial to the UK's Naval force. It has been included in this study as a comparison with nuclear sites and to highlight the vulnerability of various types of long-lived infrastructure to the potential impacts of climate change. Encompassing a range of sites therefore provides a meaningful basis by which to investigate 'successful' climate change adaptation.

There are multiple stakeholders concerned with the long-term management of the coastal zone. These stakeholders are inherently linked and involved in various capacities in the management of the coastline surrounding the study sites. Statutory bodies such as the EA, Natural England and the Marine Management Organisation have duties to regulate the management of the coastline and work with local authorities, community groups and NGO's in order to make decisions and implement collaborative coastal management strategies. All coastal management decisions are guided by Shoreline Management Plans (SMPs). The second generation of SMPs prescribe four main options for coastal management; (i) no active intervention (ii) hold the line (iii) managed realignment and (iv) advance the line (Environment Agency 2015).

To fully investigate the research questions, encapsulate and understand the roles and interactions of various stakeholders, it was deemed appropriate to consider the immediate neighbourhood surrounding each development. It is recognised that the neighbourhood surrounding each site can be defined in a number of ways and its extent could therefore be subjective (Sandelowski 1995; MacCallum et al 1999). For example, the 'neighbourhood' could be demarked using social factors such as the boundaries of local constituencies or postcodes (Wilmot 2005). Other methods to outline the 'neighbourhood' could reflect physical processes such as a coastal sediment cell (Cooper and Pontee 2006). This approach is adopted by the SMPs, which structure management practices within sediment cells. For the purpose of this study the ‘neighbourhood’ around each site was site was defined as a 20 km buffer surrounding each proposed NNB and harbour. This radius is adopted as standard in all case studies in this thesis to standardise the study area following EDF in their Ecological Impact Assessment (EIA) Report for the NNB at Sizewell, Suffolk (EDF 2012). This radius was used when investigating the research questions through both document analysis and interviews with stakeholders.

The remainder of this chapter describes the essential features of each study site, beginning with the location and geological context of the area. It is essential to consider the geological setting as this partly determines the nature and extent to which a coastline will be affected by physical processes under climate change. Geomorphological features such as the formations of cliffs and deposition patterns of sediment reflect coastal processes of erosion and deposition. These processes operate at a range of magnitudes and frequencies depending on the geological composition of an area and severity of climatic and meteorological events (Masselink et al 2014). The physical properties of a site such as the geological profile and dominant land use also affect the degree to which the site may be impacted. To effectively manage potentially accelerated rates of coastal change, decision makers must have a comprehensive understanding of the physical processes and geomorphological responses of coastlines surrounding long-lived infrastructure.

After describing the location and geological setting of each case study site, the chapter outlines the potential impacts each site may experience as a result of climate change. The chapter focuses on the potential impacts of SLR, increasing storminess, and wave action.

3.2 Glacial isostatic adjustment

It is important to mention GIA here. Although not a result of contemporary anthropogenic climate change, GIA can accentuate SLR and make a site more or less vulnerable to the impacts of future changes in storminess, surges and wave attack (Figure 3.2) (Lambeck 2014).

Vertical land movements occur naturally for a number of reasons, independent to current anthropogenic climate change drivers (i.e. seismic activity on faults lines and tectonic plate boundaries and crustal distortion via loading and unloading such as volcanic eruptions or pumping of groundwater). Much vertical movement in the UK can be attributed to the legacy of past climatic change (Lowe et al 2009). Here, the Earth's crust is experiencing an on-going adjustment to the deglaciation at the end of the last ice age. This movement is known as isostatic adjustment and is actively affecting the UK (Figure 3.2).

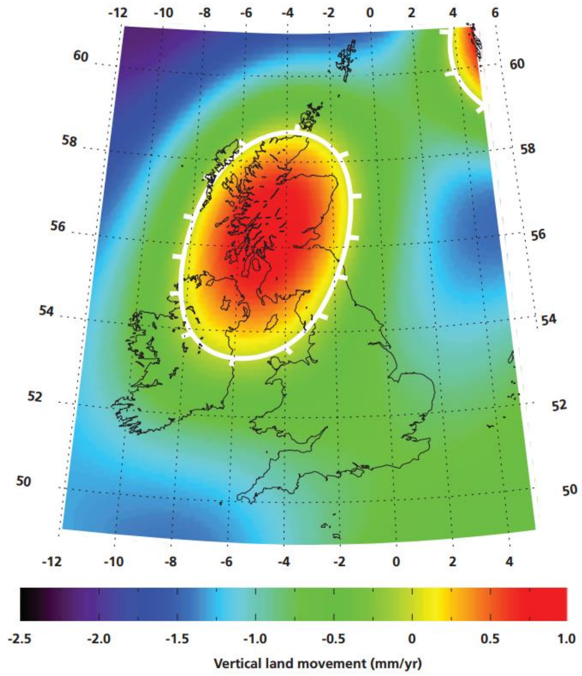


Figure 3.2. Contemporary vertical land movement (mm/year) due to GIA for the UK. Adapted from Bradley et al. (2009). Source: UKCP09 2009.

Most of southern Britain was situated on the fore bulge of the last glacial maximum ice sheet (Masselink and Hughs 2003). As the ice sheet retreated starting ~18 ka ago the land below the ice sheet started to rebound. This process is still in effect today: the vertical movement ranges between approximately -2 mm/year in south east England and +2 mm/year in northwest Scotland (Figure 3.2). These rates are assumed to remain constant over the 21st century (Lowe and Gregory 2005) and must be considered when evaluating SLR impacts.

The UKCP09 employed results of a GIA model (Bradley et al 2009) to estimate land movements around the UK. All four case study sites are experiencing isostatic adjustment. They concluded that the east coast of England is subsiding at a rate of 1 mm/year. Since the 11th century, the once thriving town of Dunwich has become submerged, most of the land has been lost to coastal erosion and retreat as a result of SLR (Bailey 2008). Holyhead near to Wylfa nuclear neighbourhood also exhibits negative land movement, subsiding at 0.62 mm/year. At Hinkley Point the coastline is currently subsiding at an average rate of 0.76 mm/year (Shennan and Horton 2002). However, contrary to the model of isostatic adjustment (Figure 3.2) the land movement reported at Portsmouth was positive, rising at +0.05 mm/year (Bingley et al 2001) supported by Haigh et al (2011). Allen and Gibbard (1993) theorise that observed uplift could be attributed to the interaction between geological terrace formations.

3.3 Sizewell, Suffolk, England

The Suffolk coastline features existing two nuclear power stations with a third NNB proposed; Sizewell A (decommissioned), Sizewell B (operational), plus Sizewell C (proposed) (Figure 3.3; 3.4). The nuclear power stations are situated approximately 6.4 meters above ordinance data (mAOD). mAOD is based on mean sea level at Newlyn, Cornwall, UK between 1915 and 1921. Both A and B power stations are situated in a rural part of the county close to the small fishing village of Sizewell. The proposed site for Sizewell C is immediately adjacent to, and north of Sizewell B (Figure 3.3).

Figure 3.3. Aerial photograph of Sizewell A and Sizewell B nuclear power station, Suffolk, England, UK. Source: Historic England (2010)

Sizewell A, owned by Magnox Ltd, was commissioned in November 1960 and was operational for 40 years between 1967 until 2006 when it was decommissioned. Sizewell B, owned and operated by EDF, was commissioned in 1987 and came on stream in 1995. The plant is currently scheduled to be operational until 2035 however EDF have expressed interest in extending its lifecycle an extra 20 years until 2055. Sizewell C, also an EDF enterprise, is currently in the planning phase. At the time of writing, construction is thought unlikely to commence before 2018 due to uncertainties surrounding financial investments (Section 3.1). This time-line has become even more uncertain due to Brexit.

The area within the 20 km neighbourhood surrounding the Sizewell nuclear estate largely consists of protected ecological sites. For instance, Minsmere nature reserve which is owned and managed by the Royal Society for the Protection of Birds (RSPB) is immediately adjacent and north of the nuclear plant. This is a flagship RSPB reserve, attracting the BBC Springwatch programme in 2014. The 9.6 km^2 nature reserve is primarily lowland heath, reed bed, wet grassland, and shingle vegetation. It is one of the UK's premier bird watching locations and is protected by Special Site of Scientific Interest (SSSI), Special Area of Conservation (SAC), Specially Protected Area (SPA) and Ramsar Site conservation statuses (Figure 3.4). The 20 km neighbourhood is sparsely populated, containing only a few villages. The largest settlements in the nuclear neighbourhood are Aldeburgh and Southwold and Orford situated on the coast and Saxmundham with a combined population of 9,082 according to the 2011 census (Office for National Statistics 2012b). The main land use is arable agriculture growing mainly cereal crops (Wadey et al 2015). The Suffolk coastline is a popular destination for holidaymakers, especially the coastal town of Aldeburgh (Figure 3.4). Hence, a proportion of the residencies in the neighbourhood are second homes or holiday rentals therefore not permanently occupied.

3.3.1 *Geological context*

The Suffolk coastline is comprised of Pliocene and early–middle Pleistocene Crags with an underlying, eroded Cretaceous Basement. This geological make-up constitutes highly erodible 'soft rock' cliffs. The erodible properties of 'soft rock' cliffs make it complex and challenging for stakeholders to manage the land over receding cliffs. 'Soft rock' cliff recession is not restricted to the UK and has been reported in the US, Canada, Japan, New Zealand, Russia, and Germany (Brooks and Spencer 2012). The recession rates of 'soft rock' cliffs in Suffolk are amongst some of the highest recorded in the UK and globally (French 2001). DEFRA (2012) claim that 54% of the Suffolk coast is currently eroding at rates varying between 0.4 m and 2 m per year. Brooks et al (2012b) reported that for the 'soft rock' cliffs erosion higher erosion rates were observed ranging from 3.5 – 4.7 m/year. The Crown Estate (2010) regards the coastline in the Sizewell neighbourhood to be one of the greatest future management challenges for the region, in particular, and the UK as a whole as it undergoes such rapid retreat. Thus, the geological characteristics of the Suffolk coast make it highly vulnerable to the potential impacts of climate change and therefore a prime location to focus a case study investigating climate change adaptation and coastal management surrounding long–lived coastal infrastructure.

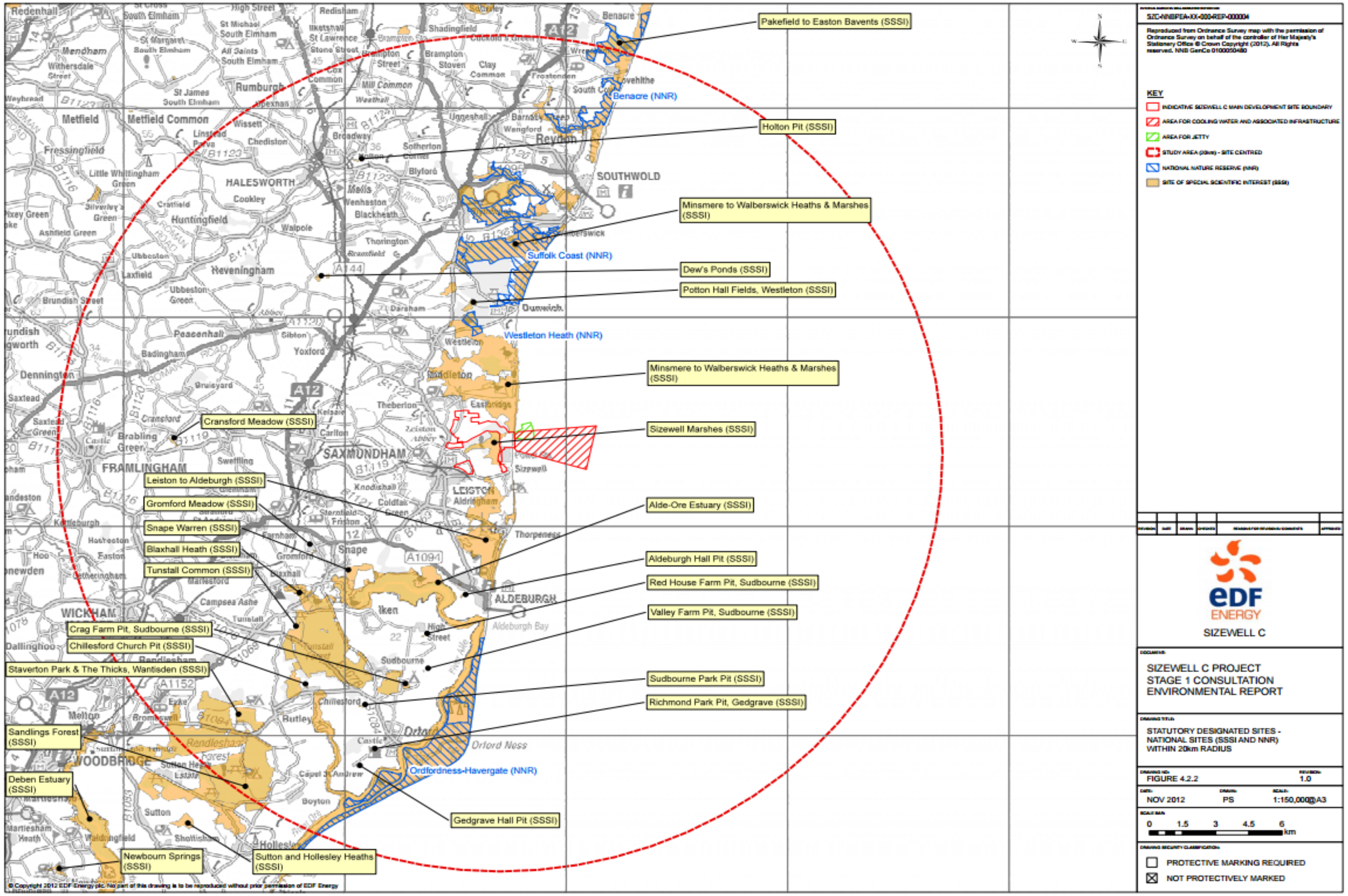


Figure 3.4. Suffolk coastline featuring nuclear Sizewell nuclear power stations. Nuclear neighbourhood represented by EDF 20 km environmental impacts buffer. Source: EDF, Stage 1 Consultation documents, Environmental Report Appendices (2012).

An important feature on the coast of the Sizewell neighbourhood is the man made sluice in the Minsmere reserve. Built to drain the Minsmere Levels, this structure is located approximately 3 km north of the Sizewell site. At the present time, the sluice acts as a point of resistance on the coast stabilising the frontage of the Minsmere reserve. However, should the sluice become compromised it is expected that the locally low rates of erosion would accelerate even under current conditions (Pye and Blott 2006). The offshore bathymetry at Sizewell is also relevant when considering the potential impacts of climate change (Section 3.3.2).

The relative height of the sea level (i.e. corrected for vertical land movement) along the Suffolk coast has fluctuated over past millennia. Currently the sea level is 30 m higher than it was in 9000 BP (Pye and Blott 2006). According to the UKCP09 Marine and Coastal Projections report (2009), the rate of relative sea level rise around the UK was approximately 1 mm/year, lower than the global average of 1.8 mm/year (IPCC 2013). However, the rate of SLR between 1990 and 2000 was higher than this average indicating acceleration of SLR (Jenkins et al 2008). Along the east coast of England, the rate of SLR is at 1 mm/year (Jenkins et al 2008). The IPCC (2013) have observed that currently SLR has accelerated to 3.1 mm/year. Considering these trends and the geological context of the Suffolk coast it can be inferred that the east coast of the UK is extremely vulnerable to SLR today (Brooks and Spencer 2010).

As discussed the nuclear neighbourhood at Sizewell features a nationally significant nature reserve, Minsmere. Such low lying, estuarine lands are at particular risk of increased erosion, floods and saline inundation. Saline inundation would not only have consequences for the physical structure of the site but would affect conservation statuses as specific habitats are needed for protected bird species. Prior to the EU referendum a failure to maintain conservation statuses could result in the UK government being taken to the European Courts under the Habitat Directive (1992). It is recognised that this procedure could change post referendum.

It is important to note here that global and regional SLR projections are prone to uncertainty resulting in large ranges in estimations and discrepancies in predictions generated by different models. UKCP09 (2012) estimate that sea level could rise by 0.9 m to 1.9 m for the UK by 2100.

3.3.2 *Waves, wind and storm surges*

Establishing a relationship between climate change and increased storminess for the east coast of the UK has so far been hampered by a lack of continuous wind records (Montreuil and Bullard 2012). As such, speculation that changes in climate are to bring increasingly stormy weather to the east coast of England should be examined in detail before being adopted as fact and used in policy or adaptation strategies. This said, it is now widely asserted that an increase in the frequency of storm events should be considered in coastal management strategies (Masselink and Russell 2013; Pye and Blott 2008). Advancements in modelling are enabling the relationships between climate change and increased storminess to become more defined. Using downscaled Regional Climate Model (RCM) and wave and storm models, driven by historic climate reconstructions, both provide a higher resolution platform with which to explore past and future climate, respectively (Wolf et al 2015). Such methods have been used in the UKCP09 (Lowe et al 2009). However, despite advancements in modelling Nicholls et al (2013) assert that uncertainties are high and many more simulations are required to properly sample possible future conditions. At the present time, the regional climate and possible future changes in surges and waves are highly uncertain (Nicholls et al 2013).

Other research has shown that the North Atlantic Oscillation (NAO) determines the frequency of storm surges in the Atlantic and thus the pace of morphological change on the east coast of the UK. Large storm surges can develop off the UK's east coast in the North Sea. Dolata et al (1983) hypothesised that this is due to winds tacking eastward towards the North Sea and moving around the North Sea basin in an anticlockwise direction, coupled with a funnelling effect of the narrowing of the North Sea. Storm surges have the potential to cause considerable economic damage and modification to the coastline. However, such extreme events are relatively rare. The most recent severe surges to affect the Sizewell nuclear neighbourhood were in 1953, 1978 and 2013 (Spencer et al 2015). Storm surges can exceed 2 m on the Suffolk coast and are accentuated by a spring tide. The spring tide range is 1.94m increasing from the north of the county to the south (Wadey et al 2015).

The impact of surges is increased under high tide and wave activity. Therefore, it is imperative that we understand how potential changes in wave height and direction could affect geomorphological development of the coastline. It has been observed that the climate can effect wave direction. Pye and Blott (2006) concluded from long term meteorological measurements, that warming phases, such as the Medieval Warm Period, have been associated with a greater frequency of winds from the southwest, west and northwest concluding that wind from a westerly (offshore) direction causes less coastal erosion meaning sediment transport is more balanced. Conversely, cooler periods are governed by wind and wave direction from the north and northeast. Hence, cooler periods (including the Little Ice Age) are typically associated with greater wave energy, more frequent storm surges and greater coastal erosion and flooding on the east coast. In addition to the observed climatic driven changes in wave height and direction the offshore bathymetry may also have a significant impact on wave activity. The interaction between tidal dynamics and coastal erosion have given rise to a linear sandbank lying parallel to the coast in front of the Sizewell nuclear development and surrounding neighbourhood (Lees 1982). Wadey et al (2015) state that the inshore wave heights, period and approach, are strongly controlled by this offshore bathymetry hence influencing the erosion and deposition pattern along the coastline. They assert that the offshore Sizewell–Dunwich bank plays a key role in reducing the wave energy that reaches the coast. Wave shoaling and breaking is frequent over the variable elevation and width of the bank (Tucker et al 1983). The barrier may play a key role in protecting the coastline against an increasing frequency in storminess and wave activity. Although explaining long term barrier dynamics remains challenging (Brooks et al 2016) the Sizewell–Dunwich bank have shown considerable change in historic times (Horillo-Caraballo and Reeve 2008; Pye and Blott 2006). Recent observations indicate a growth in the banks which has been cited as a potential reason why coastal recession rates have slowed in the area (Brooks 2010).

The geomorphologic responses of a coastline to storms surges are not linear and may vary at different locations along the same coastline. One area may experience accelerated cliff retreat (i.e. net loss of sediment) whereas another site, within the same sediment cell, may experience a net gain in sediment as the storm releases increased amounts of sediment into the sub-cell system. For example, Pye and Blott (2009) highlight that the offshore submarine Dunwich-Walberswick gravel-dominated barrier system, which has been managed for the last 40 years, is progressively losing sediment and is becoming increasingly difficult to repair after storm events. This is leading to breeching and overtopping of the gravel barrier. Overtopping events occurred in February 1993, September 1995, February 1996, December 2003, February 2005, December 2005, November 2006, March 2007, November 2007 and December 2013. Other studies suggest that storms and surges are not necessarily as destructive as previously thought. For example, Montreuil and Bullard (2012) highlight that although salt marsh retreat at Saltfleetby was recorded during stormy periods (such as 1996 to 1998 and 2005 to 2007) a significant seaward advance has been witnessed over the last 12 years in locations where marshland is not constrained by dunes. These non-linear natural systems make effective coastal management a complex endeavour.

3.4 Hinkley Point, Somerset, England

Hinkley Point is the second nuclear neighbourhood selected as a case study for this research. Hinkley Point is a headland on the coast of Somerset (Figure 3.5). Situated in the Bristol Channel downstream of the Severn Estuary this site has been used as a case study in various climate change studies to date (e.g. Ahmadian et al 2014; Knight et al 2015; Quinn et al 2013). It is a complex coastal environment which it a valuable location to research the potential social and physical impacts of climate change (Thomas et al 2015; Phillips et al 2013).

Figure 3.5. Aerial photograph of Hinkley Point nuclear power station, Somerset, England, UK. Source: Western Daily Press (2015)

Currently, Hinkley Point features two nuclear power stations: Hinkley Point A (decommissioned) and Hinkley Point B (operational). A further power station, Hinkley Point C has been proposed for development at the site (Figure 3.5). The nuclear infrastructure at the site is situated at approximately 11 mAOD. Construction of Hinkley Point A began in 1957 and was completed in 1965. Operated by Magnox, Hinkley A was operational until it was decommissioned in 2000. The construction of Hinkley Point B began in 1967 and began generating electricity in February 1976. This station, owned by EDF, is currently in the operating phase of its lifecycle, providing the UK with approximately 1% of total national electricity supply. The station is due to be decommissioned in 2023. In 2010, the UK government named Hinkley Point C as a potential location for NNB. The NNB proposal is the forerunner in the government's plans to increase the UK's nuclear fleet and before the EU Referendum result was projected to be operational by 2023. Once constructed the combined energy output of Hinkley Point C and Sizewell C could equate to 13% of the total UK electricity supply (World Nuclear News 2008).

Similar to the site of the Sizewell nuclear power stations, the land surrounding the nuclear infrastructure at Hinkley Point is protected by various conservation statuses. Land to the north, east and southeast falls within the Bridgwater Bay conservation designations, SSSI, SPA, and National Nature Reserve (NNR). Land to the north falls within the Severn Estuary SAC, SPA and Ramsar site. The entire area is a popular location for bird watching and fossil hunting (Figure 3.6). These designated areas feature a range of habitats supporting nationally and internationally significant numbers of over-wintering birds including waders and water fowl. The area forms an integral part of the Severn Estuary SPA and Ramsar system (Figure 3.6). The nuclear neighbourhood surrounding the site is primarily used for arable agriculture. The complexity of the physical processes acting on this site make it a prime location to investigate the ways in which stakeholders manage the coastline and plan and implement climate change adaptation initiatives.

Figure 3.6. Somerset coastline, including the Hinkley Point nuclear power stations and nuclear neighbourhood (20 km buffer).

3.4.1 *Geological context*

The British Geological Survey (2006) determined that the geology of Hinkley Point is primarily comprised of grey and brown clay soil with limestone fragments overlaying solid geology (Jurassic rocks comprising of mudstone and limestone). There is also drift material at the site comprising of silt and clay. Cobbles and boulders of limestone are found within the drift material. The top soil at the site is between 2 to 9 m deep. The variation in depth is attributed to Made Ground which was created during the excavation of Hinkley Point A and B.

Although the solid geology underlying the top soil at Hinkley Point provides a firm platform on which to locate a nuclear power station (Figure 3.5) it is also important to consider the overlain soil types, there are concerns that global warming might significantly increase the potential for soil erosion particularly in areas with increasing trends of precipitation and storminess. Such changes may affect long term land use and associated management practices in the area (Yang et al 2003; Garbrecht et al 2015).

Directly to the south east of the proposed site for Hinkley C are wetlands which are underlain by marine and estuarine alluvium. These deposits are approximately 5 m deep and comprised of soft to firm organic clays. Beneath the estuarine alluvium are fluvial and glacial sandy gravel and sandy silty clay ranging in thickness from 2.4 m to 5 m (Royal Haskoning 2009). Below the top soil and Made Ground the solid geology of the area is Jurassic rock made up of interbedded mudstone and thin limestone of the Blue Lias Formation. The Blue Lias Formation outcrops onto the foreshore. There is shingle material on the foreshore concentrated mainly near to the cliffs (Royal Haskoning 2009). To provide perspective, of the coastline surveyed from Morte Point to Bean down, which is comprised of the above geological profile, 15% of the points surveyed were eroding at >1 m/year whereas 62% of the coastline exhibited little change. In comparison, the coastline on which Sizewell is situated (Weybourne to Felixstowe) the same study found that 19% of the coastline is eroding at >1 m/year with 57% of the coastline exhibiting little change (Thorne et al 2007).

3.4.2 *Sea level rise*

In keeping with global trends, sea level in the Severn Estuary and the Bristol Channel has been rising throughout the current interglacial period. However, there is some discrepancy in rates of rise. The UKCP09 have observed the current rate of rise is 2 – 2.5 mm/year, if this were to continue SLR would be less than the medium scenario projected level of 0.17- 0.21 m by 2100. However, a recently installed tidal gauge at Hinkley Point nuclear power station reported that the annual SLR to be 4 mm/year which equates to 0.34 m by 2100, assuming the observed rate remains constant (Kirby 2010).

With regards to extreme SLR, Quinn et al (2013) predicted that although the likelihood of extreme SLR due to melting ice sheets is low the resulting hazard could be significant (assuming a sea level rise scenario of up to 1.9 m by 2100). They assert that mass loss of ice sheet cover could lead to a ~30% increase in the probability of a 1:200 year event in the Severn Estuary alone.

In addition to the risk of SLR via thermal expansion and ice sheet loss the Severn Estuary and the Bristol Channel also experiences the second largest tidal range in the world with an average mean spring tidal range of 12.3 m (Langston et al 2010), peaking at over 14 m (Ahmadian et al 2014), making the coastal zone a hyper tidal system (range >6 m) (Archer 2013). In addition to being hyper tidal, the enclosed coastline exacerbates extreme sea level events such as storms and their associated surges. Batstone et al (2013) assert that Avonmouth, Newport and Hinkley Point – all situated on the Severn Estuary – are the most susceptible to such events (Table 3.1; Chapter 2, Figure 2.2). Other enclosed coastlines were reported to have similar but not as extreme events (Chapter 2, Figure 2.2). Other sites at risk of extreme sea level events include Holyhead and Heysham, both in close proximity to other proposed NNB sites (Batstone et al 2013).

Location	20 year	100 year	200 year	1000 year
Hinkley Point	7.51	7.74	7.84	8.09
Avonmouth	8.67	8.98	9.11	9.43
Newport	8.00	8.28	8.41	8.72

Table 3.1. Estimated extreme storm sea levels in the Severn Estuary, measured in meters above Ordnance Datum at Newlyn. (Source: Batstone et al 2013)

3.4.3 *Waves, wind and storm surges*

The location on the Bristol Channel and proximity to the Severn estuary makes the nuclear site and surrounding 20 km neighbourhood particularly exposed to storms and associated storm surges.

Due to the coastal configuration, Hinkley Point is exposed to an array of threats from waves and storminess. The funnel shaped configuration of the coastline and orientation to prevailing winds, coupled with the tidal setting enhance the height of storm surges tracking from east to north-east (Bryant and Haslett 2007; Thomas et al 2015). Historically these site-specific factors have contributed to severe coastal flooding events. For example, in 1607 a catastrophic surge event flooded an area of 500 km^2 and killed 2000 people around the Bristol Channel (Bryant and Haslett 2007).

As discussed, the geography of the Somerset coast predisposes the nuclear neighbourhood at Hinkley Point to the future impact of storms and associated surges. UKCP09 have utilised surge model trends and a statistical analysis methods to project climate-driven changes to surges. Building on the work of Flather et al (1998) they concluded, with greater confidence and for all ranges of return periods, that the probability of severe surge events increasing in frequency, solely by chance, is negligible (Lowe et al 2009).

3.5 Wlyfa, Anglesey, England

Cemaes Bay on the northern coast of the island of Anglesey features the Wylfa nuclear power station (Figure 3.7). Construction of the power station began in 1963 and commercial operation commenced in 1971. Operated by Magnox for the duration of its operational lifecycle the decommissioning phase began in 2012 with the second of the two reactors being retired on 30 December 2015. The current nuclear site covers 21 hectares. In 2011, an additional 255 hectares of the land surrounding the current plant was bought by the UK nuclear development company, Horizon Nuclear Power who are proposing a NNB.

Figure 3.7. Aerial photograph of Wylfa nuclear power station, Anglesey, Wales, UK. Source: The Telegraph (2016)

The current power station and proposed NNB site are bordered to the north, northwest and northeast by the Irish Sea. To the south, southeast and southwest the site is surrounded by agricultural areas that are for the most part low lying and gently undulating. The nearest centre of population is Tregele village 1 km to the southwest and Cemaes village 2 km to the west. The nearest town with a population greater than 10,000 is Holyhead, ~ 10 km to the southwest (Figure 3.8).

The coastline bordering the site owned by Horizon Nuclear Power is approximately 2 km in length of which 750 m is immediately adjacent to the existing nuclear power station. The coastline primarily comprises of rocky headlands with small bays some of which are sandy (Magnox 2012).

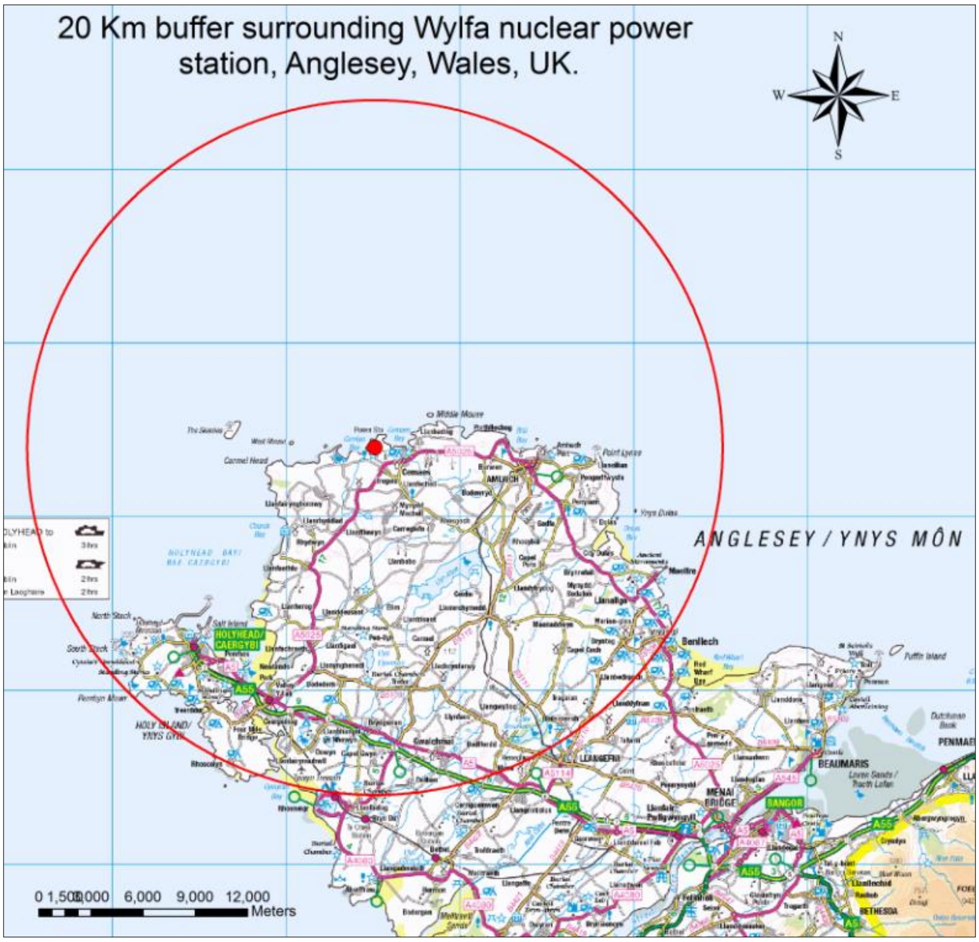


Figure 3.8. Anglesey coastline featuring Wylfa nuclear power stations, Anglesey, Wales, UK. Nuclear neighbourhood represented by EDF 20 km EIA buffer as for Sizewell.

3.5.1 *Geological context*

The geological composition of Anglesey is very different to that of the previous two nuclear neighbourhoods (Hinkley Point C and Sizewell C). The Welsh coastline is 1300 km long, of which 45% is dominated by hard rocky cliffs, which are present on Anglesey (Farrar and Vaze 2000). During the period 19 ka to 11 ka Wales was submerged under the glacial maximum of the Irish Sea Glacier. Harris (1991) concluded that the geological profile of the Wylfa neighbourhood is a direct result of processes from the Late Devensian, warm based, Irish Sea Glacier. The glacier flowed from northeast to southwest (Harris 1991). Northwest Anglesey was directly under the ice stream of the Irish Sea Glacier. The Irish Ice Stream was one of several ice streams that drained the interior of the last British Irish Ice Sheet. This area of faster flowing ice led to the sculpting of bedrock substrate and the development of streamlined bedrock features such as roche moutonée and rock-cored drumlins (Lee et al 2015). During the original site investigation for the Wylfa nuclear power plant widespread examples of these glaciotectonically deformed bedrock features were uncovered in exploratory trenches (Harris 1991). In their Preliminary Environmental Information Report, Horizon Nuclear Power (2014) concluded that, as result of the hard geology at the site, there is currently low risk of coastal erosion. However, they recommended that this should be monitored given the potential impacts of climate change.

Sediment above the bedrock comprises of glacial till which varies in thickness but is generally less than 2 m (Magnox 2012). The glacial till in the area has been identified as lodgement till which consists of orange-brown silty sand and grey laminated fresh water silts (Harris 1991). The top soil in the Wylfa area comprises of freely drained sandy loam that is generally between 0.05 and 0.4 m and becomes discontinuous towards the coast (Magnox 2012). The existing site and the designated NNB site are situated on low-grade agricultural land (DECC 2010). The surrounding neighbourhood is primarily permanent pasture.

3.5.2 *Sea level rise*

The geological profile of the coast of Anglesey predisposes the coastline to be relatively robust to climate driven SLR. Average SLR is predicted to rise 86 cm around the coast of Wales by 2080 (DECC 2010). Regarding the existing nuclear power station and NNB the most pertinent threat in terms of sea level are extreme high water events. At present the existing nuclear power station at Wylfa is approximately 12 mAOD (Horizon Nuclear Power 2014). To provide perspective, Batstone et al (2013) demonstrated that the expected levels of extreme SLR events caused by storm events are projected to be the 9th highest in the UK behind Hinkley Point in 3rd place (Table 3.1). Batstone et al (2013) assert that extreme SLR could reach 3.83 m in the next 100 years.

3.5.3 *Waves, wind and storm surges*

As noted above, the hard rock cliffs of Anglesey provide a resistant, natural defence to SLR. Hence, the coastline surrounding the current and proposed nuclear power stations at Wylfa is considered to be at ‘low risk’ (DECC 2010). When considering the construction of the original Wlyfa nuclear power station, Chapman et al (1969) regarded the bay in front of the power station to be relatively surge free during storms. However, more recently DECC (2010) stated that the effects of storm surges should be considered when contemplating SLR scenarios.

Today, the site is still considered to be resistant to coastal erosion (DECC 2010). However, when considering predicted SLR (Section 3.4.2) coupled with an increase in the frequency and severity of storms, associated surges and wave activity the site may be more vulnerable than previously thought. Future waves could reach areas of the cliffs that have not previously been exposed to wave attack and may increase the erosion rate of the cliffs (DECC 2010).

3.6 Portsmouth, Hampshire, England

Portsmouth Harbour is situated on the south coast of the UK in the county of Hampshire (Figure 3.9). The majority of the land surrounding the harbour is low lying, approximately 3 mAOD. The large natural harbour provides access to the Solent and the English Channel. The harbour is nationally significant and has been known as the home to the Royal Navy since medieval times. The harbour is in a favourable position, strategically situated behind the Isle of Wight which provides protection from storms, surges and waves in the English Channel (Figure 3.10).

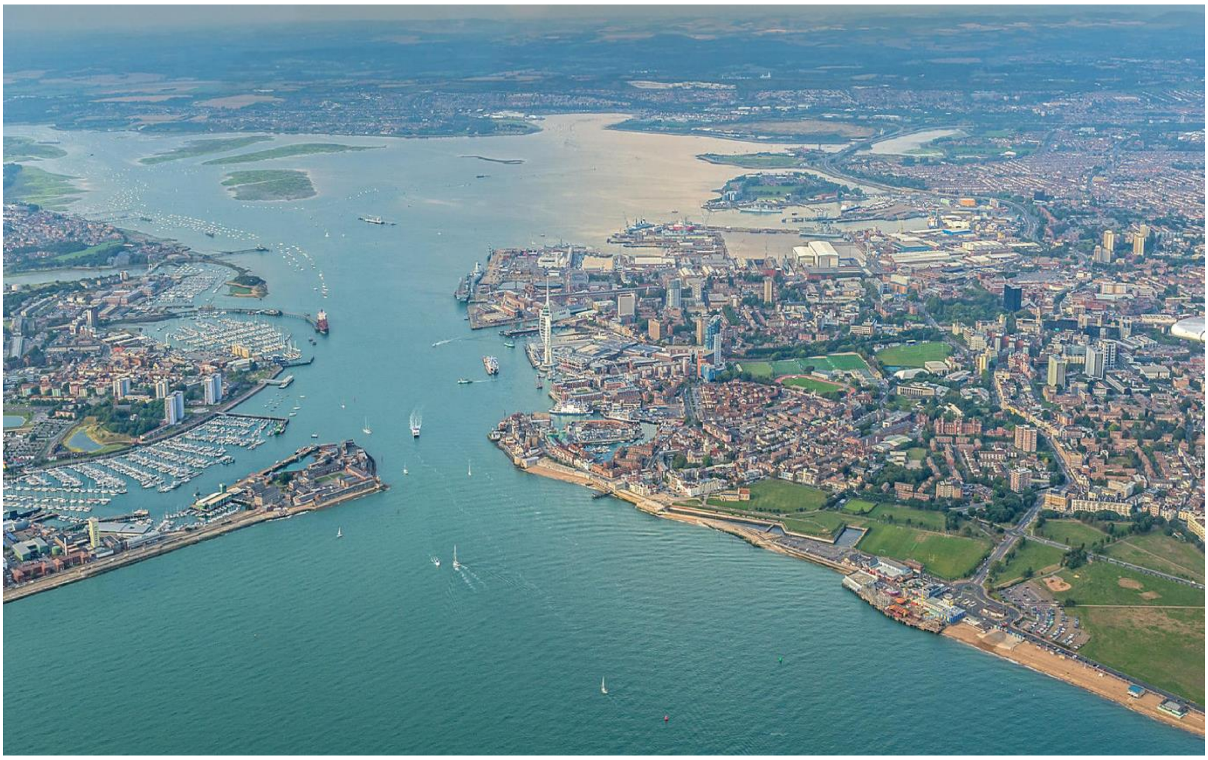


Figure 3.9. Aerial photograph of Portsmouth Harbour, Hampshire, UK. Source: Upixphotography (2016)

The 20 km neighbourhood of Portsmouth Harbour is significantly different to the three other case study areas (Figure 3.10). The city of Portsmouth surrounds the harbour, and according to the most recent census (2011), it has a population of 205,400 and is the only city in the UK to have a population density greater than London (Hampshire County Council 2013). Many areas within the neighbourhood are low lying are protected from coastal and riverine flooding by pumping and drainage systems and manmade flood defences. Consequently thousands of residential properties and commercial properties are currently located in the tidal flood zone (Portsmouth City Council 2014; Stevens et al 2015). In addition, the Solent has been identified as one of the busiest stretches of water in the UK for both commercial maritime and recreational vessels. The city of Portsmouth itself has 45 km of open coastal frontage (Figure 3.9).

Although Portsmouth harbour is protected to certain degree by the positioning of the Isle of Wight, wind and storm surges do have the potential to disrupt the functioning of the harbour. A survey of 88 maritime disruption events in the UK, between 1950 and 2014, revealed 48% were due to wind and storm surges, 65% of which occurred between November and January (Adam et al 2016). The established long-lived infrastructure of Portsmouth harbour therefore provides a meaningful case study to use as a control and comparison to the previous three rural, nuclear case study sites. The remainder of this section describes the geology of Portsmouth harbour neighbourhood before highlighting the potential climate change threats posed to the long lived static infrastructure; harbour walls, transport links, coastal defences and urban developments.

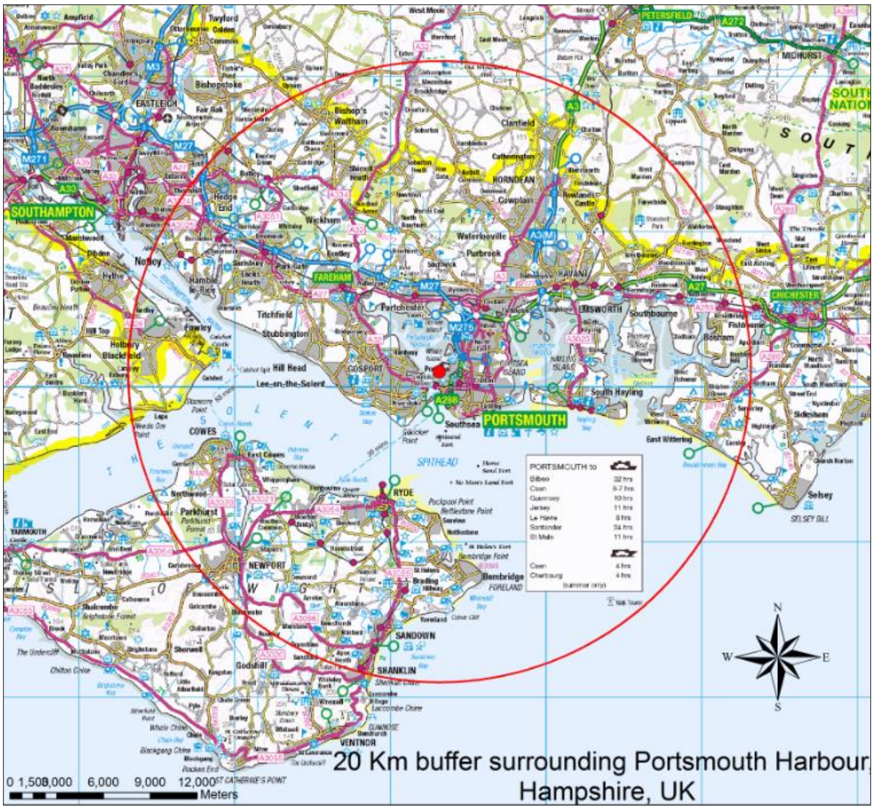


Figure 3.10. Hampshire coastline featuring Portsmouth Harbour, Hampshire, UK. Neighbourhood represented by the 20 km environmental impacts buffer as at Sizewell.

3.6.1 *Geological context*

Portsmouth Harbour is situated in a large geological area known as the Hampshire Basin. This formation extends beneath the northern English Channel and much of Southern England. As well as Portsmouth Harbour, the basin includes the large coastal settlements of Portsmouth, Southampton and Bournemouth. It is primarily composed of sedimentary rocks from the Late Cretaceous and Paleogene (British

Geological Survey 2006). The area below Portsmouth harbour and much of the Hampshire comprises of Cretaceous chalk.

3.6.2 *Sea level rise*

Unlike the other case study sites the neighbourhood surrounding the long lived static infrastructure is urban, densely populated with a highly modified coastal zone. There is increasing concern for densely populated areas such as the south coast of England where rising sea levels interact with growing populations and economies (Haigh et al 2011; Wadey et al., 2012). A strategic flood risk assessment undertaken by Atkins (2007) found that approximately 47% of the city's land area is designated within the Environment Agency's Flood Zones 2 (defined as land assessed as having between a 1 in 100 year and 1 in 1000 year annual probability of river flooding and a 1 in 200 to a 1 in 1000 annual probability of sea flooding) and 3 (defined as land assessed as having a 1 in 100 or greater probability of river flooding and a 1 in 200 year or greater probability of sea flooding). The main flood risk to Portsmouth comes from coastal flooding. However, the city is also prone to flooding by surface water. Failures in infrastructure such as flood defence walls and pumping stations can lead to significant areas being flooded, causing socio-economic distress though damage and loss of properties and businesses; in September 2000, 21 street and 114 properties were flooded after 60 mm of rain fell in 24 hours. Properties were under 1.5m of water due to a failure in pumping systems (Portsmouth City Council 2012). On 10 March 2008, high tide reached 5.53 m (2.8 m above mean sea level) and heavy rainfall combined with spring tides causing coastal flooding (Portsmouth City Council 2012). This was exceeded by the storm on 5th December 2013 by a high tide of 2.83m and equalled on the 14th February 2014 (Sibley et al 2015). Stevens et al (2015) now estimate that approximately 20,000 properties in the Portsmouth area are currently at risk from coastal flooding.

Although there is a heightened risk to people and property due to the densely populated coastal zone, the neighbourhood surrounding Portsmouth Harbour is at a relatively low risk of extreme SLR events in comparison to other coastal locations around the UK. The 1 in 100-year extreme sea level relative to mean sea level is projected to be 3.05 m. The only other coastal locations in the UK to have an extreme sea level lower than Portsmouth are Bournemouth and Weymouth (1.81 m and 2.20 m respectively) (Batstone et al 2013). Nonetheless, Portsmouth has the greatest amount of property at risk from coastal flooding (aside from London). More than 750 properties flooded on the 15th September 2000 in Portsmouth due to failure of pumping systems (Wadey et al 2013). It is therefore vital that measures are taken to defend the city from both SLR and extreme sea level events.

3.6.3 *Waves, wind and storm surges*

Much of the coastline of the Solent is protected from large waves by the Isle of Wight and the managed shingle barrier to the west known as Hirst Spit. The Solent is renowned for its complex tides (Wadey et al 2013). Although protected from extreme weather by the Isle of Wight, the Solent is still susceptible to storm surges. These mainly occur as a result of low pressure systems that move from the Atlantic eastward over southern England but are rarely over 1 m in height. Surges can also occur as a result of storms in the North Sea funnelling water southwards through the Dover Strait (Haigh et al 2004; Wadey et al 2015).

Under high tide and wave conditions the south coast of the UK can be extremely vulnerable. Ozsoy et al (2016) recognise the risk of high frequency sea level events highlighting that cyclical meteorological conditions can cause flooding during neap tides when such occurrences had previously thought to have been impossible. This has significant implications for the densely populated and highly engineered coastlines of the Solent which are prone to overtopping and inundation in extreme circumstances. For example, on 10th March 2008, 37 district areas across the Solent were flooded. This was primarily due to overflowing and outflanking of defences (Wadey et al 2013). In 2012, Portsmouth City Council reported that Portsmouth has been exposed to 17 storms and gales, in the last 16 years that have caused extensive damage across the city affecting schools, residential properties and civic offices. Since this report storms have continued to impact Portsmouth, the winter of 2013/14 witnessed a series of storm which disrupted Portsmouths' port and transport network. In response the government mobilised £146, 868 to aid the recovery of the transport network (Department for Communities and Local Government 2014).

The discussed vulnerabilities of the Portsmouth neighbourhood to waves and storminess make the region a suitable case study for contrasting with the nuclear neighbourhoods situated in coastal zones around the UK.

3.7 Conclusions

To successfully manage the coastline and implement appropriate and successful adaptation strategies it is imperative that any morphological changes to the positioning of the coastline, relative to the preindustrial era, are monitored. This notion has long been established and is recognised by the UK government. In 2002, the DEFRA Flood and Coastal Defence Research and Development Programme concluded that '*in order to manage coastal cliffs it is important to have access to accurate and reliable information on past and future cliff recession patterns and trends*' (DEFRA 2002b, p3). Using a preindustrial base line enables trends and changes to the coastline, which may be attributed to anthropogenic climate change, to be detected and illustrated. Identifying such trends requires the development of 'analytical methods of predicting cliff erosion rates for the wide variety of eroding cliffs around the coast' (Brooks and Spencer 2012).

This chapter introduced the four study sites used to investigate the research questions, aims and objectives. These are: Sizewell, Suffolk; Hinkley Point, Somerset; Wylfa, Anglesey Wales and Portsmouth, Hampshire. Three nuclear neighbourhoods were selected, alongside Portsmouth Harbour for comparison. The chapter outlined the characteristics of each case study site including the geographic context and geological profile. The chapter then outlined the degree to which each site is vulnerable to SLR, increased storminess and wave attack as well as assessing how isostatic adjustment impacts each case study neighbourhood. Key details for each study site are summarised in Table 3.2. These summarised details provide answers to research question 1: What are the most significant threats posed by climate change to long-lived infrastructure in the coastal zone?

	Sizewell, Suffolk, UK. (Nuclear)	Hinkley, Somerset, UK. (Nuclear)	Wylfa, Anglesey, Wales, UK. (Nuclear)	Portsmouth, Hampshire, UK. (Harbour)
Dominant geology	Pliocene and early–middle Pleistocene Crags with an underlying eroded Cretaceous Basement. Highly erodible soft cliffs.	Top soil overlaying solid geology consisting of grey and brown clay soil with limestone fragments.	Hard rocky cliffs reflect the legacy of the last ice age. Glacial lodgement till which of orange-brown silty sand and grey laminated fresh water silts	Sedimentary rocks from the Late Cretaceous and Paleogene (Cretaceous chalk).
Height above sea level	6.4 mAOD	11 mAOD	12 mAOD	3 mAOD
	(mAOD = based on mean sea level at Newlyn, Cornwall, UK 1915 – 1921).			
1 in 100 year SLR event (Skew surge)	3.07 m (Batstone et al 2013)	7.74 m (Batstone et al 2013)	3.83 m (Batstone et al 2013)	3.05 m (Batstone et al 2013)
Isostatic adjustment	~ 1 mm/year (Bradley et al 2008b)	0.76 mm/year (Shennan and Horton 2002)	-0.62 mm/year (Bingley et al 2001)	+0.05 mm/year (Bingley et al 2001)
Primary land use	Rural - Nature reserve/ Agricultural (Arable – Cereal crops)	Rural - Nature reserve/ Agricultural (Arable – Cereal crops)	Rural - Agricultural (Pastoral - Permanent pasture)	Urban – Densely populated
Rate of coastal erosion	0.4 – 2 m/year (DEFRA 2012) Cliff retreat – 3.5 – 4.7 m/year (Brooks et al 2012b)	Soft sediment <1.36 cm/year (Kirby and Kirby 2008) Resistant rock platform <1.5 mm/year (Jacobs 2010)	N/A at present due to hard rock cliffs Rate not currently known (Magnox 2013)	N/A due to complex coastal systems and human defence of the coastline
SLR (medium emission scenario)	Recent acceleration of 3.1 mm/year observed on the Suffolk coastline (UKCP09 2013).	0.7 m by 2100 however, current the rate is rising at 2 – 2.5 mm/year, if this were to continue SLR would be less than the medium projected level (UKCP09).	Absolute sea level rise 210 – 680 mm by 2095 (2.7 – 8.6 mm/year) (UKCP09)	470 mm by 2100 (5.6 mm/year) for Portsmouth Water area. Approximately 17% (80 mm) of this is driven by vertical land movement from GIA (UKCP09).

Population demographic: Degree level or higher education	16, 316 (16%) of the Suffolk Coastal Ward (2011 Census)	3,564 (12%) of the West Somerset Ward (2011 Census)	3, 564 (12%) of the Anglesey Ward (2011 Census)	24, 324 (15%) of the Portsmouth Ward (2011 Census)
Population demographic: Dominant age of residents	45 – 59 = 24, 103 people (20.93%) of Suffolk Coastal Ward (2011 Census)	45 – 59 = 7, 506 (21.40%) of the West Somerset Ward (2011 Census)	45 – 59 = 14, 321 (21.43%) of the Anglesey Ward (2011 Census)	30 – 44 = 42, 662 people (22.85%) of the Portsmouth Ward (2011 Census)
Population Demographic: Percentage of the population over 65 years old	20.8% (2011 Census)	27.21% (2011 Census)	18.85% (2011 Census)	15.38% (2011 Census)

Table 3.2. Summary of key characteristics and primary impacts of climate change at each study site.

Chapter 4: Applicability of climate change adaptation frameworks in 'real-world' practice

4.1 Introduction

Coastal zones globally are forecast to endure the worst of the potential impacts of climate change. The IPCC Fifth Assessment Report (AR5) outlines that as a result of climate induced SLR coastal zone may experience all or a combination of accelerated rates of erosions, saline inundation, increased flooding, high water tables, increased extreme sea levels and wave activity, habitat loss and forced migration (Wong et al 2014) (Chapter 2, 2.4). It is therefore essential that adaptation initiatives are appropriately designed and successfully implemented to reduce the potential risks to vulnerable communities, ecosystems and infrastructure.

A review of the literature has revealed that there are multiple methods by which stakeholders may implement climate change adaptation (Chapter 2, 2.6 – 2.8). Concepts of coastal adaptation focusing on strategic retreat, accommodation and protection have been on the international agenda since the conception of the IPCC (Dronkers et al 1990). However, scientific and governing bodies, at multiple levels within society, are struggling to prescribe methodologies for best practise (Pasquini et al 2015). Although the literature has documented a significant emergence of adaptation plans from many countries, only some have implemented concrete actions (IPCC 2014). Subsequently, decision makers are lacking practical guidance when implementing adaptation initiatives in their jurisdictions. The cumulative knowledge and awareness, amongst both scientists and practitioners, of the need to implement 'successful' climate change adaptation strategies has not translated into tangible on-the-ground action (Brügger et al 2015; Porter et al 2015).

The interactions of coastal communities with management strategies are said to be relatively poorly understood (McElduff et al 2013). Zsamboky et al (2011) highlight that comparatively, until now, coastal communities have received little attention either from policy-makers or the research community, particularly in comparison with rural and urban areas and declining industrial areas. To contribute to the development of pragmatic guidance, for stakeholders and decision makers in coastal zones, in particular those managing neighbourhoods featuring long-lived infrastructure, it is necessary to determine the means by which climate change adaptation decisions are currently undertaken.

Armstrong et al (2015) have shown that climate change adaptation initiatives typically display characteristics of three theoretical framework approaches; Scenario-Led (SL), Vulnerability- Led (VL) and Decision-Centric (DC) (Chapter 2, 2.8). This chapter identifies the types of stakeholders participating in coastal adaptation and analyses the ways by which adaptation efforts are implemented, in turn, determining the 'real-world' efficacy of the three theoretical adaptation frameworks: SL, DC and VL.

This chapter is structured as follows. It first outlines the methodological approach employed for this section of research before presenting a set of criteria to categorise framework approaches employed by stakeholders. The four study sites outlined in Chapter 3 were used as case study neighbourhoods for this section of research (i.e. Hinkley Point in Somerset, Portsmouth Harbour in Hampshire, Sizewell in Suffolk and Wylfa on the Isle of Anglesey). An inventory of online adaptation documents, from each neighbourhood, was compiled and categorised using the criterion tool (Table 4.2a – e). Analysis draws comparisons between the framework approaches utilised in adaptation projects in each study area before comparing study areas for variations in the way stakeholders implement adaptation (Section 4.3). This was achieved by analysing framework approaches adopted for each hallmark of an adaptation initiative. Longitudinal analysis was also undertaken in the Sizewell nuclear neighbourhood where an inventory of adaptation documents was compiled in 2013 and again in 2016 (4.3.6). The chapter then features a discussion of the results.

4.2 Methodology: Defining climate change adaptation frameworks in theory and practice

To ensure this thesis contributes towards implementing 'successful' climate change adaptation, it was deemed necessary to survey and analyse the means by which contemporary adaptation initiatives occur in the coastal zones of the UK. To gain such understanding, a scoping exercise was undertaken in the four study areas outlined in Chapter 3. Each site features long-lived infrastructure. This phase of the research followed a three-step methodology (Figure 4.1). The methodological details of this phase of research are explained in the following sections.

First, a review of the academic literature was conducted to identify key characteristics of planning, deploying and maintaining climate change adaptation initiatives. This stage also involved the identification of adaptation plans present in the study areas (Section 4.2.2). Second, the findings from the literature review were tabulated into a criterion tool outlining the fundamental hallmarks of climate change adaptation (Table 4.1). Thirdly, this tool was then used to determine the characteristics of adaptation projects highlighting similarities and differences to other initiatives. Categorization using a standardised tool enables clear comparison between adaptation projects at different localities and times. The criteria were then applied to 'real-world' adaptation scenarios present in the four study site areas; Sizewell, Hinkley Point, Wylfa and Portsmouth Harbour.

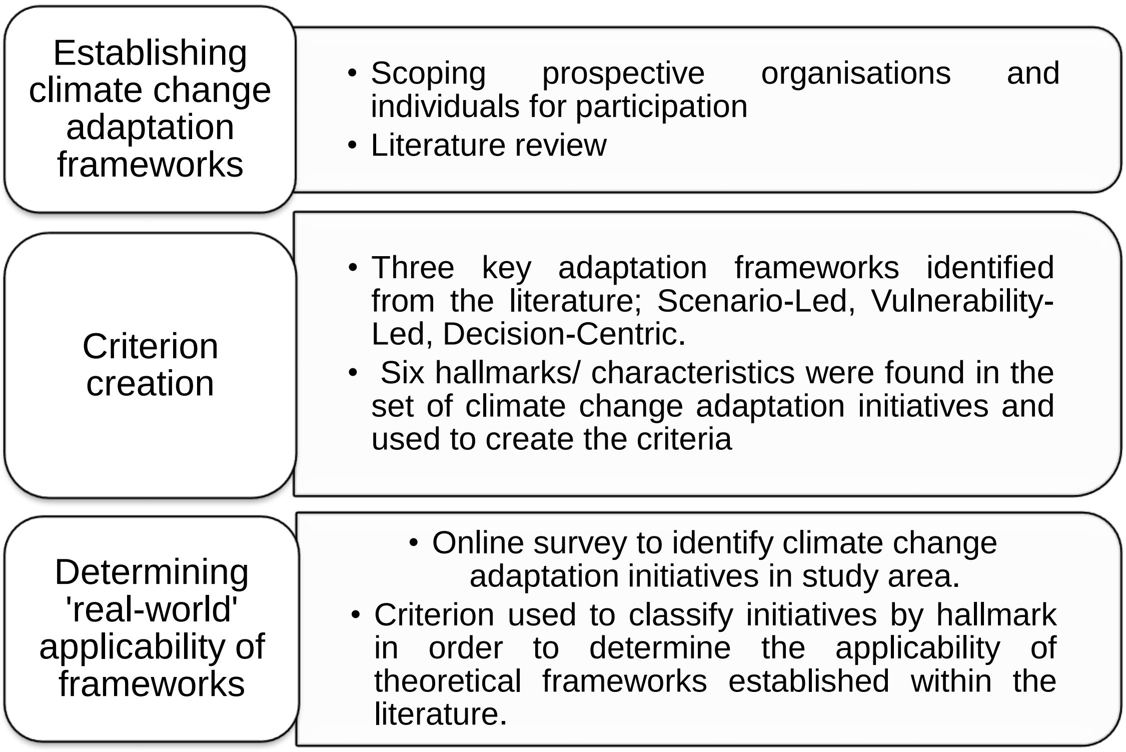


Figure 4.1.Scoping work pathway

4.2.1 *Criterion creation: A tool to outline the typology of adaptation frameworks*

The aim of the first phase of the scoping exercise was to determine how climate change adaptation frameworks are structured. To establish this, a review of the academic literature was conducted. A range of frameworks designed to aid climate change adaptation exist within the literature. Existing frameworks predominantly define adaptation in different contexts and propose tools that may be used to aid climate change adaptation. For example, current frameworks outline barriers to adaptation (Moser and Ekstrom, 2010; Measham et al, 2011) or attempt to establish what makes climate change adaptation “successful” (Adger et al, 2005) and define key terminology used in the assessment and implementation of adaptation initiatives (Füssel, 2007). These frameworks are often sector specific and are bounded by situational variables such as regional demographics, resource availability and politics. In order to provide the needed practical guidance on implementing adaptation initiatives, a thorough understanding of the nature of current adaptation efforts must first be established.

The literature indicated three key framework approaches are utilised by stakeholders: SL, VL and DC (Armstrong et al 2015). The review encompassed literature documenting the nature of adaptation initiatives internationally, over a range of sectors (Chapter 2, Section 2.8). It is recognised here that this review only reveals a snap shot of the approaches stakeholders adopt when implementing adaptation initiatives and that adaptation initiatives are not stationary; initiatives may change or mature with time as adaptation progresses, climate change information evolves and/or the coping capacities of a community change.

From the literature review into the nature of adaptation initiatives, the main characteristics of adaptation frameworks were identified. Six key characteristics of any given adaptation initiative, referred to here as hallmarks, were defined. The nature of each hallmark varied depending on the adaptation framework (SL, DC and VL). The essence of each hallmark, according nature of the different adaptation frameworks were then tabulated (Table 4.1). This table formed a criteria to be used as a tool to distinguish and categorise the three adaptation frameworks as identified in the literature.

The six key hallmarks of the criterion, outlining the characteristics of a given adaptation project, are as follows: 1) *Use of climate model information* refers to the extent by which adaptation initiative incorporate outputs from GCMs and climate scenarios such as UKCP09; 2) *Analysis indicators* refers to the metrics and units used to determine the level of risk or severity of potential impacts posed by climate change. These may vary from physical metrics such as temperature, precipitation or erosion rates. Alternatively analysis indicators may reflect levels of vulnerability such as impacts on development, health, GDP or literacy rates; 3) *Level of socio-economic knowledge* refers to the extent to which local demographic factors are considered and incorporated; 4) *Degree of stakeholder engagement* refers to the extent and at what stages in the adaptation process stakeholders are involved and consulted (which may vary between extensive consultation from the inception of an initiative to zero consultation); 5) *Adaptation implementation mechanisms* refer to the means by which initiatives are implemented. These may include the commissioning of ‘hard’ adaptations such as flood defence and alleviation schemes or ‘softer’ social adaptations such as engaging and empowering communities; 6) *Scale of implementation* refers to the area over which the adaptation initiative is implemented from site-level such as the development of infrastructure through to a national-level policy reforms (Table 4.1).

The six criteria were assigned to each adaptation plan, which was also classified as a SL, VL or DC framework. Similar efforts have been made to develop frameworks to aid the process of defining ‘successful’ climate change adaptation. However, earlier attempts focus on defining the ‘barriers’ to climate change adaptation. Unlike the research efforts of this chapter, existing framework and diagnostic tools tend to focus on sections of the adaptation process either *planning* (Burton 2005; Moser and Ekstrom 2010) or *actions/outcomes* (Eisenack and Stecker 2012; Smit and Skinner 2002) and do not encompass the adaptation process as a whole.

4.2.2 *Online survey: Compiling climate change adaptation inventories for the four case study areas*

To determine the extent to which the theoretical frameworks (SL, VL and DC), are applicable to the ‘real-world’ climate change adaptation practises of decision makers an online document analysis was undertaken. This exercise surveyed climate change adaptation documents published on the internet. Documents from all four case study areas were compiled into an inventory (Table 4.2a – 1e).

The search engine Google was utilised for the internet survey. Combinations of key words were inputted into the Google search bar to identify climate change adaptation schemes, planned and/or operational in all four case study neighbourhoods. Key words inputted into the search engine included: 'adapt', 'adaptation', 'project', 'initiative', 'management', 'climate change', 'flooding', 'erosion', 'adjustment', 'hazard', 'storm', 'adaptive capacity', 'vulnerability', 'vulnerable', 'environment' and 'behaviour'. Location specific words were also used for each of the four study areas. Employing an online surveying method provided a standardised, approach for gathering online documentation on climate change adaptation initiatives in each study area (Ford et al 2011; Tompkins et al 2010). Although the use of specific search terms eradicates any bias that may be associated with the document selection process, it is recognised that the process is not exhaustive and that some initiatives and stakeholder organisations may have been overlooked should they not have a noteworthy online presence. For example, informal events and community based initiatives such as local parish or neighbourhood meetings. Informal adaptation initiatives, with little to no online presence, are captured later in the research (Chapter 5).

4.2.3 *Categorisation of adaptation inventory*

Inventories of adaptation initiatives, planned and/or operational were compiled for each study area, achieved by the online survey (Section 4.2.2). For each adaptation initiative identified, the following administrative information was recorded: the lead organisation and any other organisations affiliated, title, geographical scale, state of completion, outcomes, type and size of the document identified and a brief description of the purpose of the project. This information is recoded in Tables 4.2 a-e.

The nature of the outcomes of adaptation initiatives were recorded in all four adaptation inventories. This enables analysis of any relationship between the framework approach adopted by stakeholders and the means by which adaptation efforts are implemented in each neighbourhood (Figure 4.4a – e). Similarly Baker et al (2012) categorised the outcomes of local adaptation initiatives in southeast Queensland, Australia using a multi-criteria analysis framework. Outcomes from adaptation initiatives in the four study areas; Sizewell, Hinkley Point, Wylfa and Portsmouth were categorised into six types: (i) *Scoping*, where adaptation efforts seek to determine by what means and to what extent the area may be at risk from climate change; (ii) *Planning*, by which adaptation efforts plan the implementation of future initiatives but no actions are enacted, (iii) *Advice*, where adaptation efforts result in the publication of advice to stakeholders as to how they should consider adapting, (iv) *Facilitation*, by which adaptation efforts promote stakeholder collaboration and/or enable the implementation of adaptation efforts; (v) *Development*, where adaptation outcomes result in tangible actions such as infrastructure/habitat development and/or the inception of working partnerships and (vi) *Evaluation*, where outcomes focus on the evaluation of previous adaptation initiatives or actions to inform an iterative approach to adaptation implementation. The products from some initiatives span multiple adaptation outcome options. In these cases, all outcomes displayed in a single adaptation project were noted (Table 4.2a – e).

Adaptation inventories for each neighbourhood were then analysed using the criteria in Table 4.1. Each adaptation initiative identified in the study areas was categorised by the six characteristic hallmarks. Categorising adaptation initiatives by hallmark indicators enabled the researcher to determine how frequently the theoretical frameworks (i.e. SL, VL, and DC) are adopted by stakeholder organisations in practice. Having studied an assortment of adaptation initiatives from the literature, across a range of sectors and scales, the six hallmarks were considered central and evident in climate change adaptation efforts: i) Use of climate model information; ii) Analysis indicators; iii) Level of socio-economic knowledge incorporated into decisions; iv) Degree of stakeholder engagement; v) Adaptation implementation mechanisms; vi) Scale of implementation of an adaptation project. This was achieved by reviewing each adaptation document against the criterion tool individually (Table 4.1). Evidence of each hallmark was identified in turn, the nature of said evidence was then evaluated to determine which adaptation framework was being employed. As each of the six hallmarks are categorised individually for each adaptation project is possible for adaptation initiatives to feature hallmarks from multiple frameworks. The most dominant framework in each initiatives was recorded.

The criteria and classification approach were piloted using adaptation plans found in 2013 for the neighbourhood of the Sizewell nuclear power station (Armstrong et al. 2015; Appendix 4). To further establish the transferability and validity of the criterion tool, it was deemed necessary to reapply the methodology. In 2016, the methodological process was reapplied to the Sizewell area and two other nuclear neighbourhoods; Hinkley Point and Wylfa as well as the non-nuclear, coastal static infrastructure, of Portsmouth Harbour. Applying the methodology to various locations as well as revisiting Sizewell provides a more comprehensive basis to analyse the methods stakeholders utilise to implement adaptation initiatives. The spatial and temporal dimension added to the study by reapplying the methodology are presented and discussed in the remainder of this chapter.

4.3 Results: 'Real-world' applications of theoretical climate change adaptation frameworks

The proceeding section in this chapter contains the results from the initial scoping phase of the PhD. The results and discussion are supplemented by additional evidence from three case study sites (Chapter 3). The adaptation inventories from the four study areas recording the primary organisations involved in climate change adaptation provide an answer to research question 2.

4.3.1 *Criteria generation and adaptation inventories*

Following the literature review (Section 2.8) a criterion tool was created (Table 4.1). The criterion may be used to identify to what extent theoretical climate change adaptation frameworks, established within the academic literature, are employed in 'real-world' practice (Research questions 3 and 4). The hallmarks of adaptation frameworks, established from the literature are sought in the documents complied in the online inventory (Table 4.2a- e). The characteristics of each hallmark vary depending on the adaptation framework adopted by each stakeholder. The characteristic of each hallmark are prescribed within the criterion below (Table 4.1).

Hallmarks	Scenario – Led	Vulnerability - Led	Decision – Centric
1. Use of climate information	Widespread use of regional downscaling	Processing of climate model output does not occur. Focus on natural variability of climate.	Climate models are used to relate changes in physical boundary conditions to system coping thresholds Climate model information is often collated into representative climate futures which are then used to assess the sensitivity of vulnerable communities.
2. Analysis metrics/units	Use of predicted impact metrics e.g. Physical and Biophysical parameters; crop yield, precipitation rate etc. Historical datasets often used as baseline.	Identification of factors which govern the ability to cope successfully with climate related threats. Identification of socio-economic implications that govern resilience thresholds.	Encompasses metrics used in SL and VL frameworks. Sensitivity or stress testing utilised. Performance metrics used to monitor the efficacy of adaptation initiatives. Determines thresholds by which substantial investments or policy shifts would be required
3. Socio-economic knowledge	Does not assess socio-economic factors affecting coping capacities.	Develops an understanding of the dynamic factors that may affect the coping capacity of a community.	Prioritises identification of coping capacities of vulnerable populations.
4. Stakeholder engagement	Typically occurs in the final stages of the process as part of risk communication.	Extensive consultation throughout. Community involvement to actively manage risk and implement adaptation. Projects instigated and managed by the affected population.	Extensive consultation throughout. Identification of coping capacities by stakeholders and experts from the beginning of the adaptation process. Statutory organisations and bodies most commonly engaged.
5. Adaptation implementation mechanisms	Advising the decision maker of potential changes in boundary conditions.	Improving coping strategies of stakeholders.	Adaptation occurs via stress testing options with systematic monitoring and review of options performance.
6. Tier of adaptation implementation	Most commonly national or international in scale. International initiatives span national borders such as EU initiatives or regulations. Centralised decision-making	Most commonly local governance scale. Adaptation initiatives can be informal responding to the (perceived) risks of the local community.	Most frequently on a regional scale. Most often focussed on individual initiatives or specific areas. Adaptation initiatives are cross-sectorial. Immediate updates to adaptation strategy should conditions governing risk change.

Table 4.1 Criterion for determining climate change adaptation frameworks - defining the hallmarks of each adaptation framework (Armstrong et al., 2015).

Document or project title	Lead organisation	Number of author organisations	Classification of adaptation initiatives by framework						Stage	Scale	Dominant framework displayed	Outcome of adaptation efforts	Document type/size
			1	2	3	4	5	6					
Futurescapes	RSPB	1	VL	DC	VL	VL	DC	DC	Actions (Ongoing)	National initiative regional focus.	VL/DC	Development Facilitation	National & local webpages
The Suffolk Shoreline Management Plan 7 (SMP 7)	SCDC	3	DC	DC	VL	DC	DC	DC	Actions Monitorin g (Ongoing)	National initiative regional focus.	DC	ALL	Specific webpages
SMP7 (MIN 12-13) Minsmere flood risk management scheme	EA	1	SL	SL	DC	DC	SL	SL	Actions Monitorin g (Ongoing)	National plan, regional/l ocal focus.	SL/DC	Scoping, Planning, Facilitation, Development .	PDF 18 pages
Minsmere Sea-Defence initiative	RSPB	2	SL	SL	DC	SL	DC	DC	Actions (Complet e 2012)	Regional	SL/DC	Scoping, Planning,	PDF 8 pages
Future landscapes – Climate change impacts and adaptation in the Suffolk Coast and Heaths AONB.	The East of England Climate Change Adaptation Partnership.	5	SL	SL	DC	DC	DC	DC	Actions Complete (2012)	Regional	DC	ALL	PDF 12 pages
National Flood and Coastal Erosion Risk	EA	1	SL	SL	SL	SL	SL	SL	Actions Ongoing	National	SL	Scoping, Planning, Facilitating	PDF 63 pages

Management Strategy													
East Suffolk Internal Drainage Board: Holistic management plan	IDB	3	VL	VL	DC	VL	VL	VL	Actions Ongoing	Regional	VL	Planning	Specific webpages
EU Stress Test – Sizewell B	EDF	1	SL	SL	SL	SL	DC	DC	Actions	Internatio nal	SL/DC	Scoping, Planning	PDF 136 pages
Report on Adaptation Under the Climate Change Act 2008	EDF	1	SL	SL	SL	DC	DC	DC	Process (Ongoing)	Internatio nal	SL/DC	Scoping, Planning, Develpment	PDF 172 pages
Alde and Ore Estuary Futures	AOEP	7	VL	VL	VL	VL	VL	VL	Actions	Local	VL	Facilitation, Development , Planning	Specific web pages. PDF 116 pages
Deben Estuary Plan	DEP	4	SL	DC	VL	VL	DC	DC	Actions	Local	VL/DC	Planning, Facilitation	Specific web pages
East Lane Enabling Development	DEP	6	DC	DC	DC	VL	DC	DC	Actions	Local	DC	ALL	PDF 10 pages
Touching the tide	AONB	1	VL	VL	VL	DC	VL	DC	Actions	Local	VL/DC	Planning, Advice, Facilitation, Development	Specific web pages
Sluice maintenance - Minsmere	EA	1	DC	SL	SL	SL	SL	DC	Actions	Local	SL/DC	Planning, Development	PDF 2 pages

Table 4.2a Inventory of adaptation initiatives in the Sizewell nuclear neighbourhood (2013)

Document or project title	Lead organisation	Number of organisations involved	Classification of adaptation initiatives by framework						Stage	Scale	Dominant framework displayed	Outcome of adaptation efforts	Document type/size
			1	2	3	4	5	6					
Suffolk Climate Change Partnership	SCDC	3	DC	DC	DC	DC	VL	VL	Actions Ongoing	Regional	DC	Advice, Evaluation	Specific webpages
Suffolk Coastal Climate action plan	SCDC	55	SL	SL	SL	DC	SL	DC	Ongoing	Regional	SL	Scoping, Planning	PDF 24 pages
East of England climate change adaptation network (Sustainability East)	DEFRA	150 members from public, private and 3rd sector.	NA	VL	VL	VL	DC	VL	Actions ongoing	Regional	VL	Facilitation, Development	Specific webpages
Waveney Pathfinder	DEFRA	17	DC	DC	VL	DC	DC	VL	Actions complete	Local	DC/VL	ALL	PDF 347 pages
Climate change adaptation manual	NE	4	SL	SL	DC	SL	SL	SL	Advice ongoing	National	SL	Scoping, Planning	PDF 222 pages

Table 4. 2b Inventory of adaptation initiatives in the Sizewell nuclear neighbourhood (2016)

Document or project title	Lead organisation	Number of organisations involved	Classification of adaptation initiatives by framework						Stage	Scale	Dominant framework displayed	Outcome of adaptation efforts	Document type/size
			1	2	3	4	5	6					
Severn estuary flood risk management strategy	EA	1	DC	DC	DC	DC	DC	DC	Complete	Regional	DC	Scoping, Planning.	PDF 70 pages
Severn Estuary Partnership	Multiple organisations	14	SL	DC	DC	DC	DC	DC	Ongoing	Regional	DC	Facilitation	Specific webpages
Severn Estuary Coastal Group	Local authorities in the area as well as consultants and engineer groups.	5	SL	DC	DC	DC	DC	DC	Ongoing	Regional	DC	Facilitation	Specific webpages
Somerset and the Sea	EA	1	SL	SL	SL	SL	SL	SL	Complete	Regional	SL	Evaluation	PDF 11 pages
Watchet community cultural strategy	Community based		VL	VL	VL	VL	VL	VL	Complete	Local	VL	Advice	PDF 14 pages
Living landscape/living coast	SWT		SL	SL	SL	SL	DC	SL	Ongoing	National initiative -regional version	SL	ALL	Specific webpages
WAVE	Somerset County Council,	6	SL	SL	DC	SL	SL	DC	Ongoing	Regional	SL	Scoping, Advice	Specific webpages
Shoreline management plan	EA	1	SL	SL	DC	DC	SL	SL	Actions	National plan - regional	SL	Scoping, Advice.	PDF 5 pages

Table 4. 2c Inventory of adaptation initiatives in other nuclear neighbourhoods: Hinkley, Somerset, UK (2016)

Document or project title	Lead organisation	Number of organisation involved	Classification of adaptation initiatives by framework						Stage	Scale	Dominant framework displayed	Outcome of adaptation efforts	Document type/size
			1	2	3	4	5	6					
The Solent forum	Local authorities, member organisations from multiple levels of society	Many – specific number not available	NA	NA	VL	DC	DC	DC	Ongoing	Regional	DC	Facilitation, Advice, Development	Specific webpages
Portsmouth Climate Change Strategy	Portsmouth City Council	1	SL	DC	DC	DC	DC	DC	Ongoing	Local	DC	Scoping, Planning	PDF 50 pages
Portsmouth Water: Climate Change Adaptation	Portsmouth Water	1	DC	DC	DC	DC	DC	DC	Ongoing	Local	DC	Scoping, Planning, Evaluation	PDF 36 pages
Portsmouth sustainability action group	Portsmouth City Council	Many – specific number not available	NA	DC	NA	DC	DC	DC	Ongoing	Local	DC	Scoping, Advice, Evaluation	Specific webpages
Portsmouth Climate Action Network (Lobbying body)	Consortium including Friends of the Earth, Oxfam and Green Party	6+	NA	DC	NA	DC	NA	DC	Ongoing	Local	DC	Advice, Facilitation	Specific webpages
The Portsmouth Plan (Scoping report)	Portsmouth City Council	1	SL	SL	SL	SL	SL	DC	Scoping	Local	SL	Scoping	PDF 98 pages
South Southsea and Portsea Island Coastal flood and erosion risk management schemes	Portsmouth City Council	4	DC	DC	DC	DC	DC	DC	Scoping	Local	DC	Scoping, Facilitation	PDF 28 pages

NA= hallmarks do not apply to the initiative in a comprehensive manner/not enough information available on initiative

Table 4.2d Inventory of adaptation initiatives in a non-nuclear neighbourhood: Portsmouth, Hampshire, UK (2016)

Document or Project Title	Lead organisation	Number of organisation involved	Classification of adaptation initiatives by framework						Stage	Scale	Dominant framework displayed	Outcome of adaptation efforts	Document type/size
			1	2	3	4	5	6					
The vision for Anglesey	AONB	1	NA	SL	SL	SL	SL	SL	Ongoing	Regional	SL	Scoping	PDF 7 pages
Anglesey local flood risk management strategy	Isle of Anglesey county council,	4	SL	SL	SL	SL	SL	SL	Ongoing	Regional	SL	Scoping	PDF 97 pages
Living landscape	North Wales Wildlife Trust	5	SL	SL	SL	SL	DC	SL	Ongoing	National initiative at local scales	SL	Multiple – all outcomes	PDF 19 pages
Anglesey and Gwynedd joint local development plan	Isle of Anglesey and Gwyned local councils.		SL	SL	SL	SL	NA	NA	Ongoing	Regional	SL	Planning	PDF 19 pages

NA= hallmarks do not apply to the initiative in a comprehensive manner/not enough information available on initiative

Table 4.2e Inventory of adaptation initiatives in neighbourhood of coastal infrastructure: Wylfa, Anglesey, Wales (2016)

4.3.2 *Presence, scale and nature of adaptation implementation*

The following series of results analyse the abundance, spatial scale and implementation strategies of climate change adaptation initiatives for each of the four study areas (Table 4.2a – e). When analysing the presence and scale of adaptation efforts the results from the two inventories carried out for Sizewell in 2013 and 2016 were combined (Figure 4.2 and 4.3). This was deemed necessary as the 2016 inventories, of the three comparison study areas, compiled the total number of adaptation documents with an online presence; these documents spanned both time intervals of the Sizewell surveys. When analysing the outcomes of adaptation efforts the Sizewell inventories were presented separately to enable temporal analysis (Figure 4.4a and Figure 4.4b).

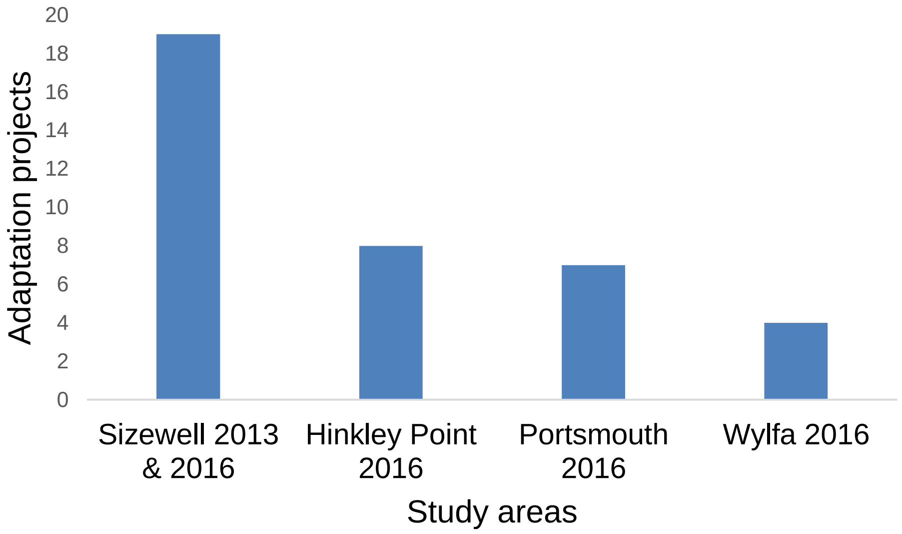


Figure 4.2 Number of adaptation initiatives surveyed in the four study areas.

The online survey compiled 38 adaptation initiatives across the four study areas. The Sizewell nuclear neighbourhood featured the greatest number with 19 (14 initiatives were identified in 2013 and a further five in 2016). The neighbourhood surrounding Portsmouth Harbour featured a similar number of initiatives to Hinkley Point: seven and eight respectively. The neighbourhood surrounding the Wylfa nuclear power station featured only four initiatives (Figure 4.2). Hence, there is very little online evidence of climate change adaptation taking place on the island of Anglesey. Instead, the Wylfa online survey uncovered more evidence of scoping documents predicting how climate change may affect the neighbourhood in the future (Figure 4.4e). As the number of adaptation inventories varied between the four study neighbourhoods percentage was applied to the framework analysis throughout. This enabled in depth comparable analysis and the identification of trends within the data.

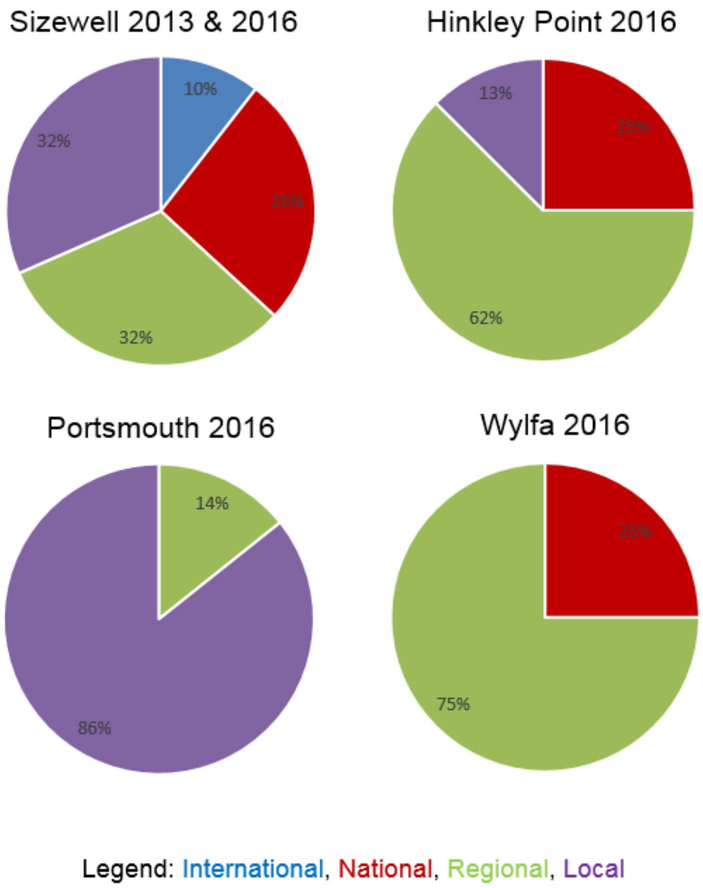


Figure 4.3 Spatial scales of adaptation initiatives surveyed in the four study areas.

Analysis of the spatial scales of adaptation initiatives documented reveals that the majority of initiatives operate at either a regional or local scale (Figure 4.3). In all three nuclear neighbourhoods, initiatives are most frequently implemented on a regional scale, on average 56%. In the non-nuclear neighbourhood surrounding Portsmouth Harbour adaptation initiatives were deployed at a more specific spatial scale, in this case 86% of initiatives were classified as local as evidenced by the specific implementation in the Portsmouth area such as Portsmouth sustainability action group and Portsmouth Water: Climate Change Adaptation Review (Table 4.2d). Upon further inspection there appears to be a relationship between the spatial scale of the adaptation initiatives and the operational level of the lead author. The presence of local scale adaptation correlates with local government organisations leading on a substantial number of initiatives in all four study areas (Figure 4.5).

For the purpose of this section of the results, the adaptation inventories from the Sizewell nuclear neighbourhood were analysed individually to enable comparisons to be undertaken between 2013 and 2016.

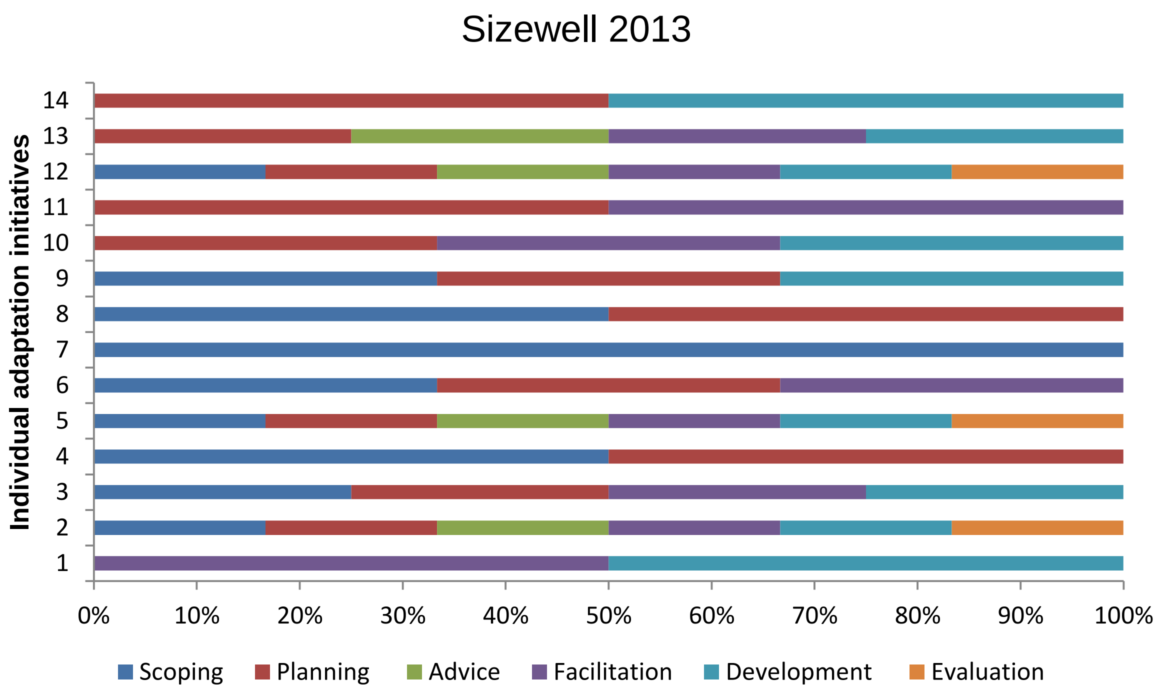


Figure 4.4a Nature of outcomes from adaptation initiatives deployed in the Sizewell study areas in 2013

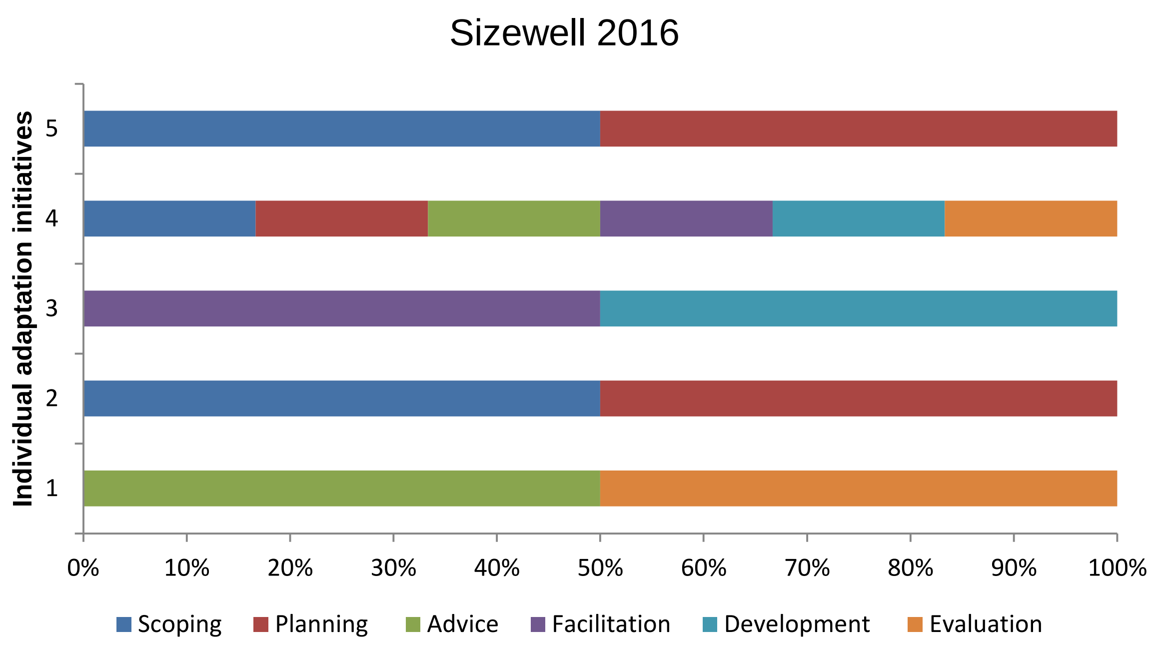


Figure 4.4b Nature of outcomes from adaptation initiatives deployed in the Sizewell study area in 2016

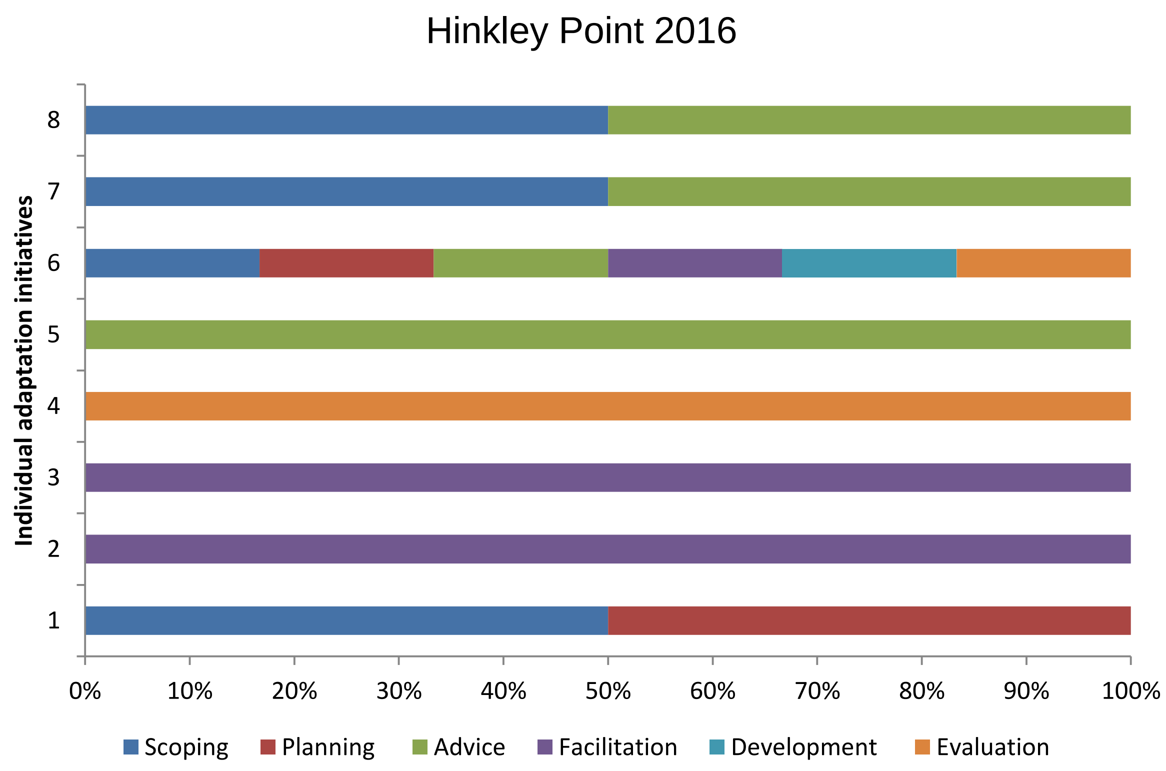


Figure 4.4c Nature of outcomes from adaptation initiatives deployed in the Hinkley Point study area 2016

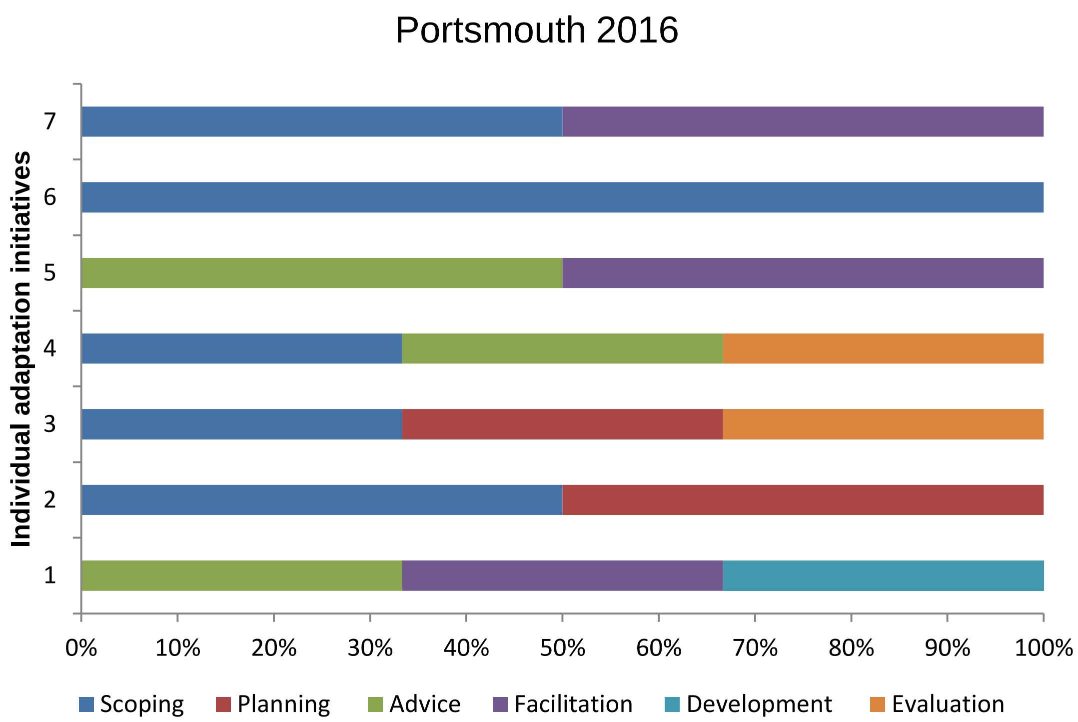


Figure 4.4d Nature of outcomes from adaptation initiatives deployed in the Portsmouth study area in 2016

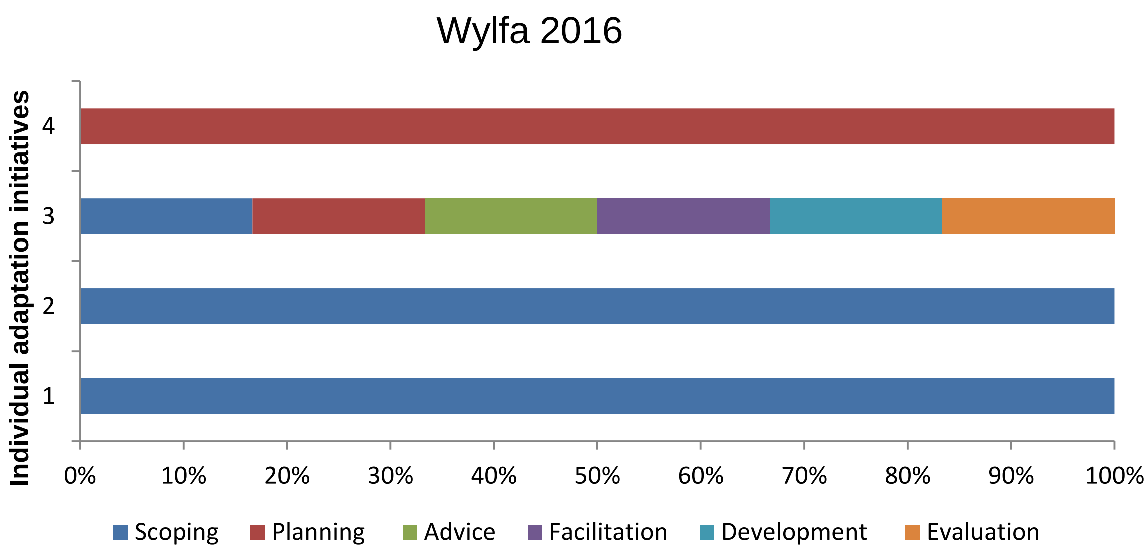


Figure 4.4e Nature of outcomes from adaptation initiatives deployed in the Wylfa nuclear neighbourhood in 2016

Results from the analysis of the adaptation inventory (Table 4.2a – e) indicate that 76% of adaptation initiatives in the four study areas have multiple implementation strategies, 13% of which exhibit all six outcomes. When analysing the adaptation inventory as a whole, results (Figures 4.4a – e) illustrate that most frequently (40%)

initiatives result in a combination of two outcomes of which the combination of scoping and planning are the most common features as evidenced by the Suffolk Coastal Climate Change Strategy, Minsmere Sea Defence Project and the Severn Estuary Flood Risk Strategy (Table 4.2a – e).

In 2013, in the Sizewell nuclear neighbourhood, 21 % of adaptation efforts resulting in all six outcomes followed by 20 % in the 2016 survey, the similarity in these figures suggest that the approaches and therefore outcomes stakeholders utilise remained similar during the interim period from 2013 to 2016. When comparing the four study neighbourhoods, the 2013 inventory exhibited the most diverse combinations of outcomes. The adaptation inventory from the 2016 was less diverse with 80 % of initiatives resulting in two outcomes half of which were scoping and planning (Figures 4.4a and 4.4b).

The Hinkley Point nuclear neighbourhood also showed a range of adaptation outcomes, however, the combinations of which differ from Sizewell as 50% of adaptation efforts surveyed only exhibit one outcome, 38 % exhibited two outcomes and 12% exhibited all six outcomes (Figure 4.4c).

The outcomes of adaptation efforts in the non-nuclear neighbourhood surrounding Portsmouth Harbour were more similar to the Sizewell nuclear neighbourhood as 88% of adaptation initiatives exhibiting more than one type of outcome, 43% of initiatives exhibited two outcomes with equal percentages exhibiting three outcomes. 14% of initiatives surveyed only exhibited one outcome (Figure 4.4d).

The adaptation initiatives compiled in the Wylfa nuclear neighbourhood exhibited outcomes most similar to the Hinkley Point nuclear neighbourhood, 75% of initiatives resulted in just one outcome whereas the remaining 25% resulted in six outcomes. Of the three adaptation efforts exhibiting one outcome, two were scoping exercises and the outcome from the remaining initiative was classified as a planning (Figure 4.4e).

4.3.3 *Sectors of society implementing climate change adaptation initiatives*

Upon compiling adaptation inventories for the four study areas the type of stakeholders involved in each initiative were recorded (Table 4.2a – e). This data can be used to establish the key stakeholders involved in climate change adaptation in the coastal zone (research question 2). Stakeholders from various sectors were involved in adaptation initiatives. In the majority of initiatives surveyed, a range of stakeholders were involved. However, to establish the leading stakeholders involved in climate change adaptation efforts, only the lead authors of adaptation documents were incorporated. Analysis of the adaptation inventory revealed stakeholders from multiple sectors of society including; environmental, government, Infrastructure, local government, NGO's and community groups lead on in adaptation initiatives (Figure 4.5).

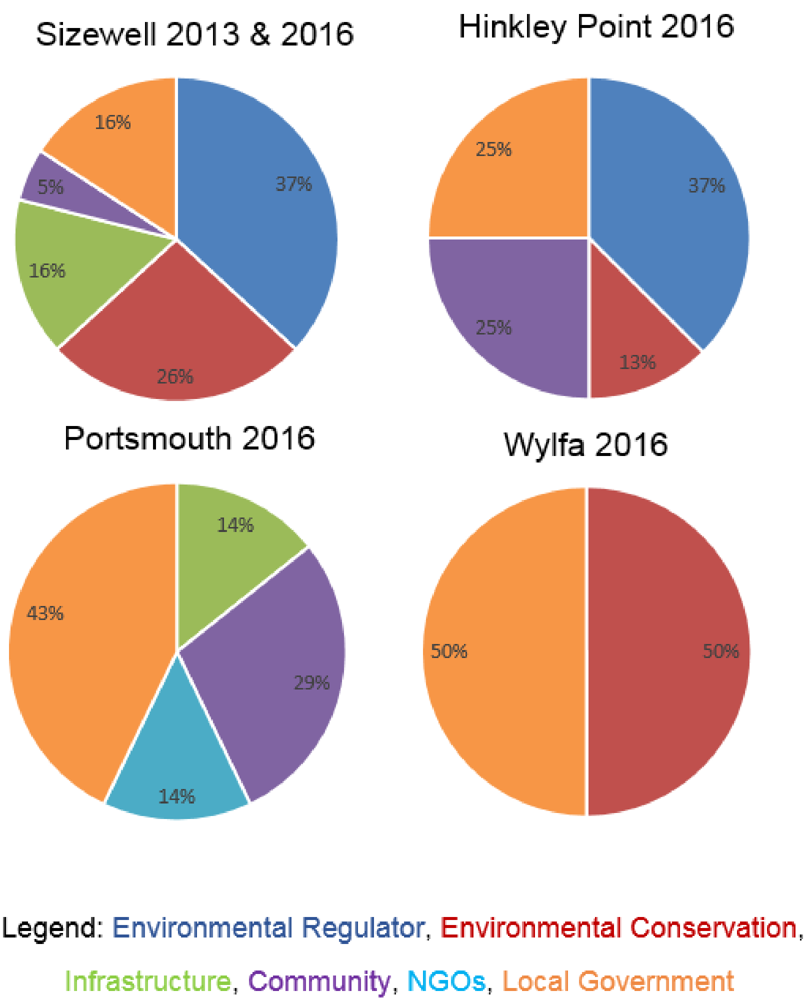


Figure 4.5 Sectors of society implementing climate change of adaptation initiatives in the four study areas.

Results indicate that within the environmental sector, both conservation and regulatory organisations are responsible for leading ≥ 50% of adaptation initiatives in the three nuclear study areas; Sizewell (63%) Hinkley Point (50%) and Wylfa (50%). All three, nuclear study sites are rural, sparsely populated and feature multiple environmental conservation areas (Chapter 3, Sections 3.3 – 3.5). On the other hand, local government organisations (42%) are the primary leaders of adaptation in the urbanised, non-nuclear case study area of Portsmouth (Figure 4.2). Local government organisations lead on a substantial percentage of adaptation initiatives in all four study areas. Most significantly at Wylfa (50%) and 16% and 25% at Sizewell and Hinkley Point respectively.

Community groups have substantial presence in adaptation efforts at Portsmouth (29%) and Hinkley (25%). At Sizewell, results indicate that community groups have a lower level of involvement in adaptation, leading on just 5% of the initiatives. Further investigation reveals community groups are involved in 20% of adaptation initiates.

From a total of four initiatives (Figure 4.2), there are no community lead adaptation initiatives at Wylfa.

The infrastructure sector was only responsible for leading adaptation initiatives in the Sizewell (16%) and Portsmouth (14%) study areas; EDF and the Internal Drainage Board were responsible for these initiatives (Table 4.2a and d). Despite featuring nuclear infrastructure neither Wylfa nor Hinkley Point features adaptation initiatives lead by the infrastructure sector. At Wylfa the low involvement of the infrastructure sector could be due to the nuclear neighbourhood currently being deemed resilient to climate change (Section 3.5).

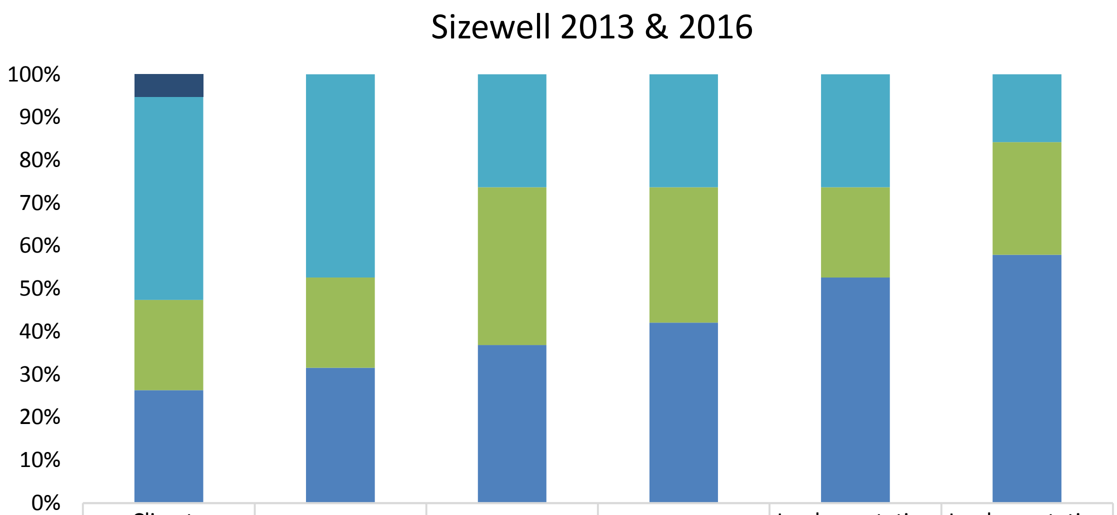
The only occasion where NGO's only lead adaptation initiatives was in the neighbourhood surrounding Portsmouth Harbour. One of the seven adaptation initiatives *Portsmouth Climate Change Action Group* is led by a consortium of environmental NGO's (Table 4.2d).

4.3.4 *Occurrence of theoretical framework utilisation*

This section presents the analysis of the extent to which stakeholders employ the theoretical frameworks (SL, VL and DC) in their climate change adaptation initiatives.

First, the results from analysis of the hallmarks of adaptation initiatives in each study area are presented. Figures 4.6a – e show the frequency with which stakeholders adopt elements of the SL, VL and DC frameworks in their adaptation efforts. These graphs were constructed using the categorised adaptation inventories (Table 4.2a – e). Each hallmark of each adaptation initiative was categorised into SL, VL and/or DC. The breakdown of framework approaches employed was then calculated for each hallmark (Figure 4.6a – 4.6d). An overall analysis of the hallmark classification for the four study areas is provided in Figure 4.6e.

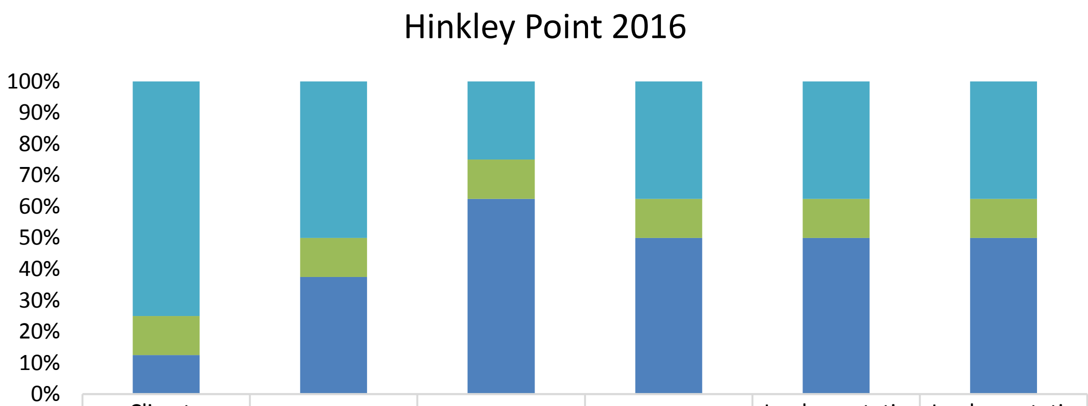
Second, the degrees to which theoretical frameworks are incorporated into individual initiatives are presented (Figure 4.7a – d). Analysis of the frameworks stakeholders employ in adaptation initiatives enables the observation of general trends in framework utilisation and in turn determines the penetration of each theoretical adaptation framework into 'real-world' practise. As before, the two adaptation surveys conducted in the Sizewell nuclear neighbourhood are combined for the purpose of this analysis.



	Climate information	Metrics	Knowledge	Engagement	Implementation method	Implementation scale
NA	1	0	0	0	0	0
SL	9	9	5	5	5	3
VL	4	4	7	6	4	5
DC	5	6	7	8	10	11

Frameworks present in each hallmark

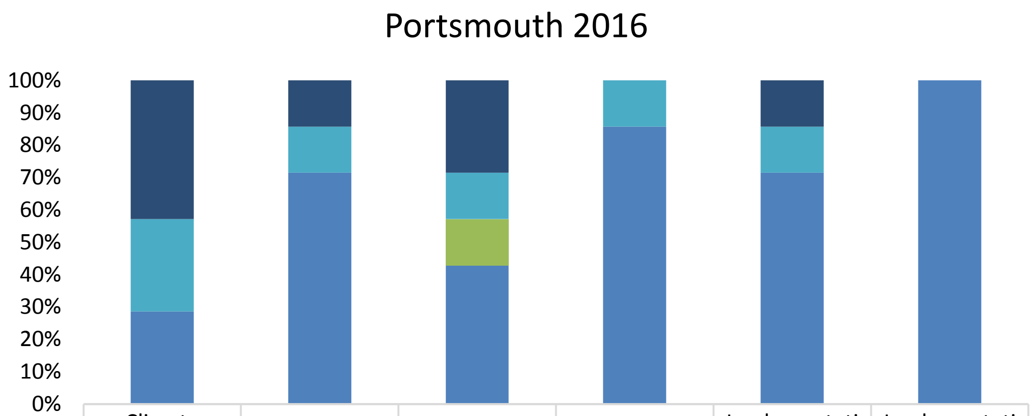
Figure 4.6a Occurrence of frameworks adopted in adaptation initiatives in the Sizewell nuclear neighbourhood categorised by hallmarks 1 to 6 (Table 4.2a and b)



	Climate information	Metrics	Knowledge	Engagement	Implementation method	Implementation scale
NA	0	0	0	0	0	0
SL	6	4	2	3	3	3
VL	1	1	1	1	1	1
DC	1	3	5	4	4	4

Fameworks present in each hallmark

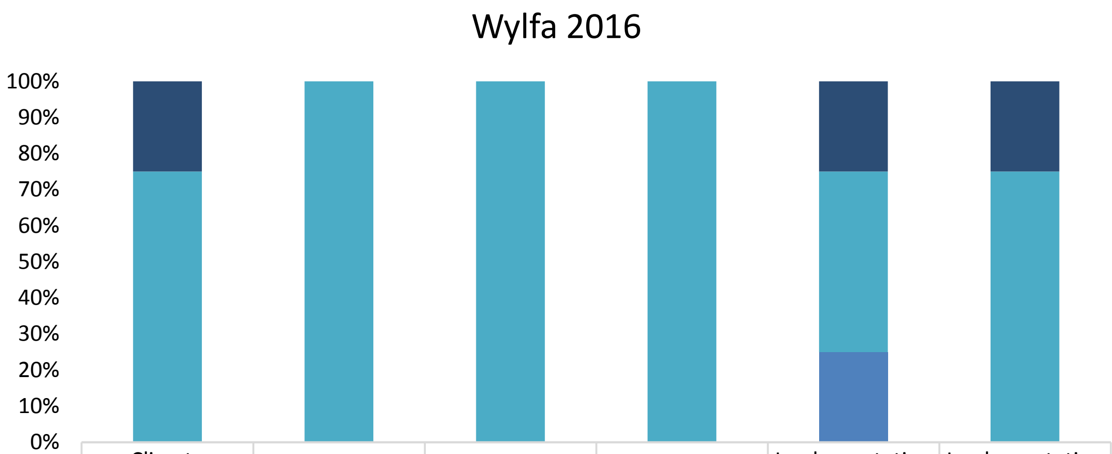
Figure 4.6b As in Figure 4.6a but for Hinkley Point (Table 4.2c)



	Climate information	Metrics	Knowledge	Engagement	Implementation method	Implementation scale
NA	3	1	2	0	1	0
SL	2	1	1	1	1	0
VL	0	0	1	0	0	0
DC	2	5	3	6	5	7

Frameworks present in each hallmark

Figure 4.6c As in Figure 4.6a but for Portsmouth Harbour (Table 4.2d)

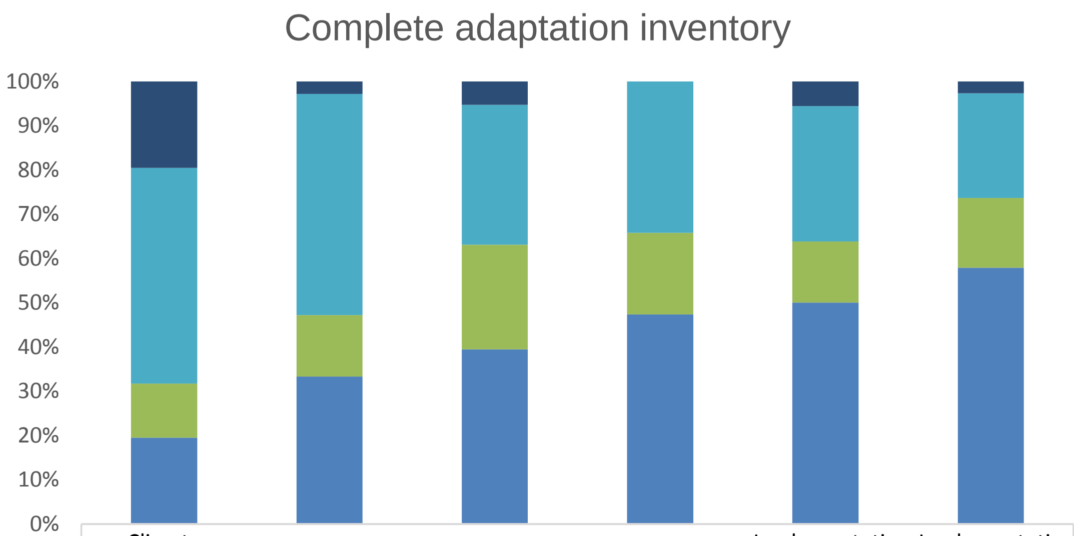


	Climate information	Metrics	Knowledge	Engagement	Implementation method	Implementation scale
NA	1	0	0	0	1	1
SL	3	4	4	4	2	3
VL	0	0	0	0	0	0
DC	0	0	0	0	1	0

Frameworks present in each hallmark

DC VL SL NA

Figure 4.6d As in Figure 4.6a but for Wylfa (Table 4.2e)



	Climate information	Metrics	Knowledge	Engagement	Implementatio n method	Implementatio n scale
NA	8	1	2	0	2	1
SL	20	18	12	13	11	9
VL	5	5	9	7	5	6
DC	8	12	15	18	18	22

Frameworks present in each hallmark

Figure 4.6e As in Figure 4.6a but for all sites combined.

Analysis of the adaptation inventory for the Sizewell study area (Table 4.2a and b) shows that stakeholders utilise all three adaptation frameworks (SL, VL and DC) when implementing adaptation. The dominant framework used when implementing adaptation initiatives is the DC approach (Figure 4.6a). However, both the SL and VL frameworks combined account for 58% of the framework allocation. Table 4.3 demonstrates that hallmarks signalling a DC framework are encompassed within an adaptation initiatives 84% of the time.

Analysis of the adaptation inventory for the Hinkley Point nuclear neighbourhood (Table 4.2c) indicates that similarly to the Sizewell neighbourhood stakeholders also utilise all three frameworks when implementing adaptation initiatives (Figure 4.6b). SL and DC frameworks are adopted equally (44%) by stakeholders although vary between hallmarks. For example, hallmark one and two (use of climate information and analysis metrics/units respectively), exhibit a higher proportion of SL framework approaches, 60% and 50% respectively whereas the DC approach was dominant in hallmark three to six. Stakeholders also utilised the VL framework approach in all six hallmarks, the extent was equal in each hallmark but minimal (12%) in comparison.

When analysing a breakdown of the frameworks used in each hallmark, for the non-nuclear neighbourhood of Portsmouth Harbour, the DC framework approach is the dominant framework in all six hallmarks, overall accounting for 67% of adaptation efforts (Figure 4.6c). Hallmark six is the only hallmark in the entire inventory where stakeholders adopt the DC approach throughout. Portsmouth Harbour has substantial differences in the hallmark profile when compared with Sizewell and Hinkley Point. For example, the VL led framework approach is only evident in hallmark three, socio – economic knowledge. In addition, it was not possible to categorise some hallmarks of adaptation initiatives by theoretical framework. Hallmarks one, two, three and five featured a degree of non-applicably (N/A) equating to 16% of the Portsmouth inventory (Figure 4.6c). The presence of N/A brings into question the overall efficacy of SL, VL and DC frameworks as well as the criteria for classifying some ‘real-world’ plans.

Analysis of the adaptation inventory for the Wylfa study area (Figure 4.6d) illustrates that there are significant differences in the framework approaches that stakeholders use in comparison to the three other study areas. Featuring approximately half the number of initiatives (Figure 4.2), stakeholders in the Wylfa study area predominantly adopt the SL framework approach (83%) in all adaptation hallmarks. Only hallmark five (adaptation implementation mechanisms) feature the DC framework approach. Similarly to Portsmouth, some of the adaptation initiatives in the Wylfa study area feature N/A characteristics when trying to categorise hallmarks into one of the three adaptation frameworks (13%).

As discussed, all four neighbourhoods feature similarities and differences when analysing the characteristics of adaptation hallmarks. When analysing the overall profile of all plans combined, the results show that characteristics from each of the three theoretical adaptation frameworks are present in each hallmark (Figure 4.6e). The overall presence of N/A accounts for 6% of all adaptation hallmark categorisation. Hallmark one (use of climate information) exhibits the greatest extent of N/A whereas hallmark six (tier of adaptation implementation) is the only hallmark not to exhibit N/A (Figure 4.6e). Although Portsmouth, Wylfa and Sizewell all exhibited a degree of N/A (16%, 13% and 1% respectively), the overall applicability of the criteria can be rated as 94%.

The next set of graphs further illustrate the degree to which stakeholders in the study areas incorporate characteristics of SL, VL and DC frameworks into adaptation initiatives (Figures 4.7a – 4.7d). The following analysis demonstrates the framework approach adopted by individual adaptation initiatives. Similarly to the previous analysis, the two surveys in the Sizewell study area have been combined to give an absolute representation of adaptation efforts.

These graphs were constructed using the categorised adaptation inventories (Table 4.2a – e). Each hallmark of each adaptation initiative was categorised into SL, VL and/or DC. Each hallmark catagorisation was given a percentage weighting of 17%. By this means, the percentage breakdown of adaptation frameworks used in each initiative could be established, illustrated and comparisons made.

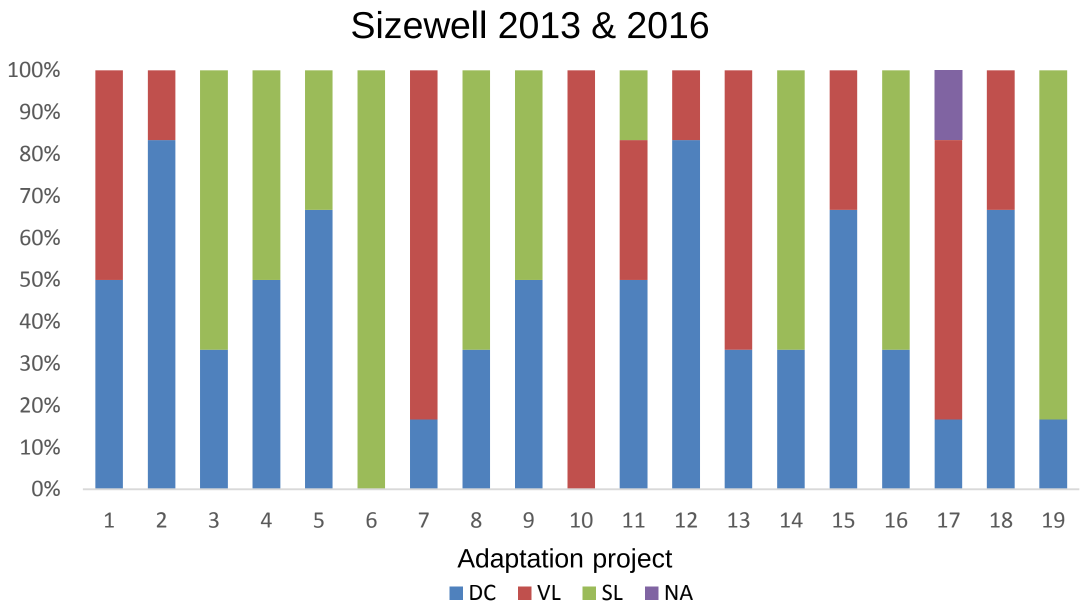


Figure 4.7a Adaptation frameworks utilised by Sizewell adaptation initiatives (Table 4.2a and b).

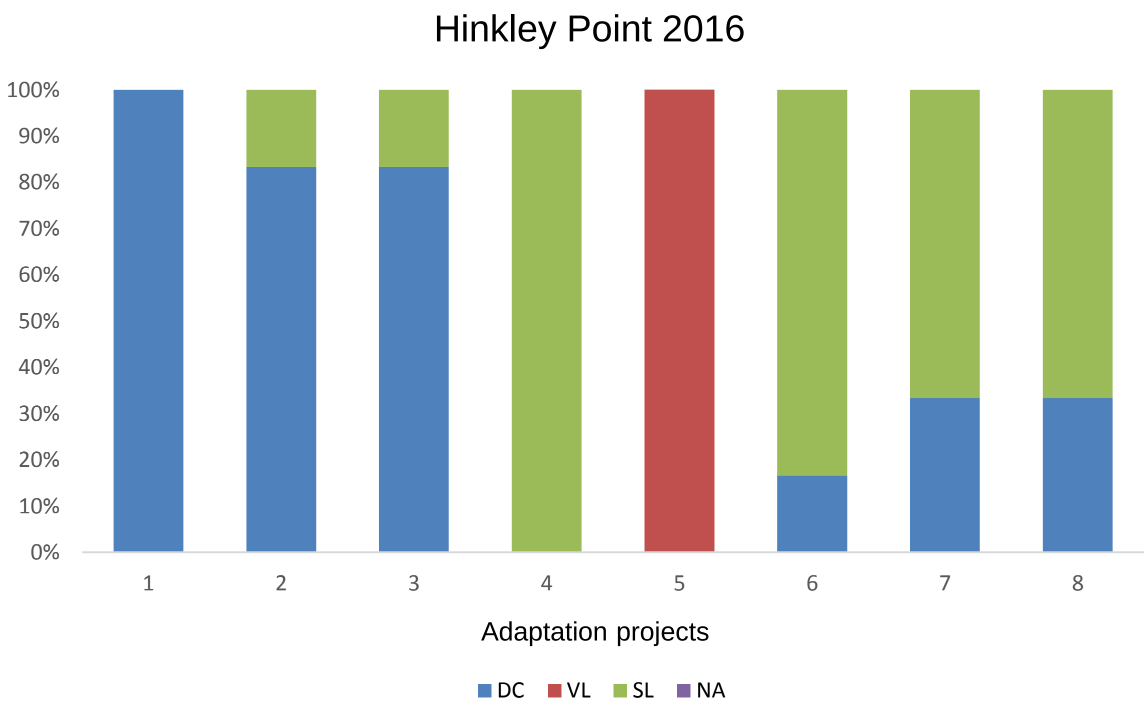


Figure 4.7b Adaptation frameworks utilised by Hinkley Point adaptation initiatives (Table 4.2c).

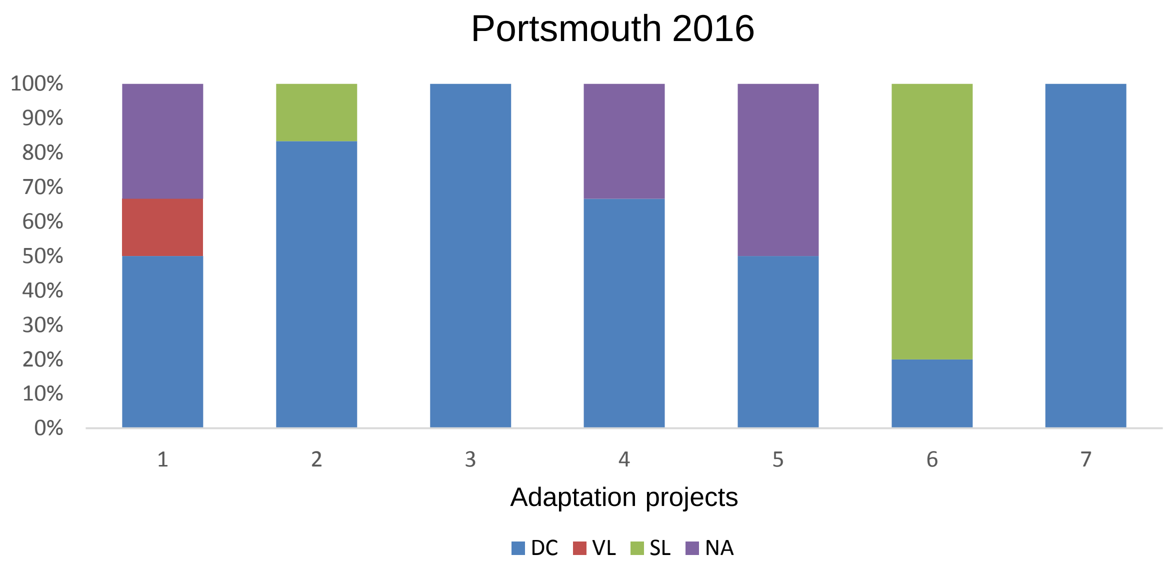


Figure 4.7c Adaptation frameworks utilised by Portsmouth adaptation initiatives (Table 4.2d).

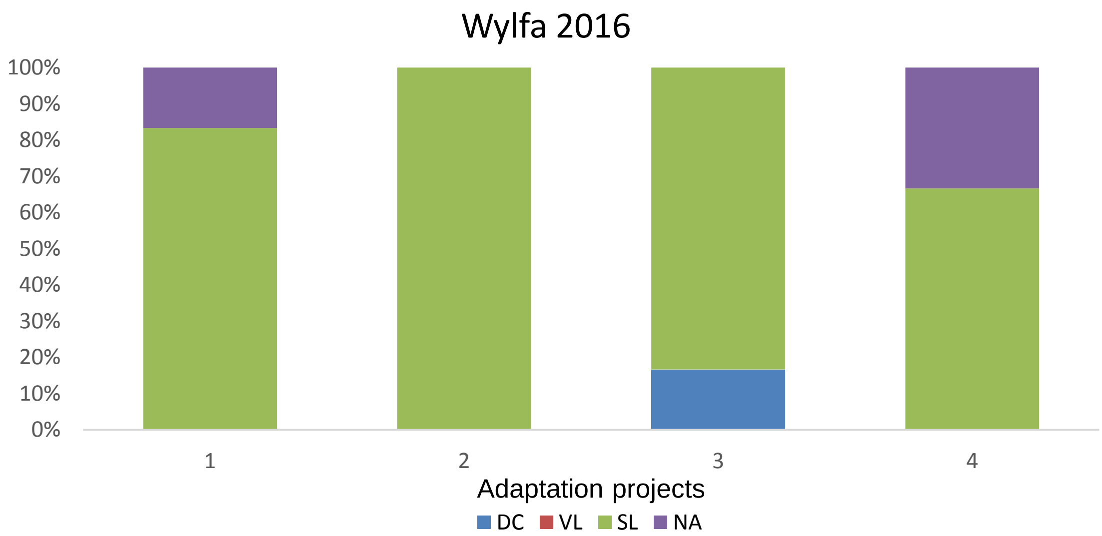


Figure 4.7d Adaptation frameworks utilised by Wylfa adaptation initiatives (Table 4.2e).

Results for the 19 adaptation initiatives, surveyed in the Sizewell study area, show that stakeholders utilise all three framework approaches (Figure 4.7a). However, only in one initiative did stakeholders use all three framework approaches in a single initiative, this was the community led Deben Estuary Plan (Table 4.2a). The majority of initiatives are employing a combination of either SL/DC (42%) or VL/DC (37%) approaches. There are two initiatives that only use one framework approach one being SL and the other VL and there is one initiative that has an element of N/A these were the National Flood and Coastal Erosion Risk Management Strategy and the Alde and Ore Estuary Futures initiative respectively .

Eight adaptation initiatives were compiled in the inventory for the Hinkley Point study area (Figure 4.7b). Three initiatives (37%) adopted a single framework approach for the duration of the initiative, one SL one VL and the other DC. The other five initiatives (63%) adopted SL and DC frameworks in partnership.

The adaptation frameworks adopted by stakeholders in the non-nuclear study area surrounding Portsmouth Harbour predominantly employed the DC framework (Figure 4.7c). Analysis shows that four of the seven (71%) adaptation efforts employed the DC framework in isolation. However, two of these initiatives featured elements of N/A. The remaining adaptation efforts utilised the DC/SL (29%) and the DC/VL (14%) frameworks in partnership although the latter also exhibited elements of N/A.

The neighbourhood surrounding the Wylfa nuclear power station featured the least amount of adaptation initiatives. Only four were identified in the online survey. The SL adaptation framework was most frequently employed by stakeholders in the study area. Three of the four adaptation efforts utilised the SL framework in isolation, although two of these initiatives feature elements of N/A. The remaining initiative adopted a combination of DC/SL frameworks.

Results illustrate that it is possible to apply the criterion tool to categorise individual adaptation initiatives, by majority, into one of the three established frameworks. However, in all four study areas adaptation initiatives exhibit hallmarks from more than one framework (Figure 4.7a - d). From the 38 initiatives identified and compiled into the inventory 8 (21%) exhibited elements of N/A. Therefore, it can be inferred that overall the criterion tool is 79% applicable to 'real-world' adaptation plans sampled.

The above results demonstrate that the majority of stakeholders, in the coastal zones surveyed, employ multiple adaptation frameworks when combatting the potential impacts of climate change. It is therefore proposed that in 'real-world' situations it may not be appropriate to determine the efficacy of each adaptation framework individually as it appears that a hybrid framework approach is being adopted in coastal zones of the UK that feature static long-lived infrastructure.

4.3.5 *Hybrid framework approach to climate change adaptation*

The adaptation inventories, compiled from online survey, established that in 'real-world' practice stakeholders in coastal zones surrounding long-lived infrastructure do not use one adaptation framework in isolation (Research question 4). In practice a hybrid approach is usually evident in the hallmarks of any one climate change adaptation initiative (Figure 4.6 and 4.7). The following analysis investigates the concept of the hybrid approach and explores the composition of frameworks to further establish how stakeholders instigate and deploy 'real-world' adaptation efforts (Tables 4.2a – 4.2d).

To illustrate the composition of the hybrid approach to adaptation and draw comparisons between all four study areas the combinations of hybrid approaches, evidenced in the inventories was tabulated (Table 4.3). Due to the uneven number of adaptation documents in each inventory a percentage weighting was applied.

Further analysis of the adaptation inventories reveals tendencies in the frameworks adopted by stakeholders. The majority of adaptation efforts implemented by stakeholders in the study areas adopt one or more frameworks when implementing adaptation (Table 4.3). When considering all adaptation efforts compiled only 19% utilised a single framework whereas 40% utilised two adaptation frameworks, 1% utilised three adaptation frameworks. The remaining 40% used a combination of frameworks but featured a degree of N/A.

The majority of initiatives employing two adaptation frameworks in partnership most frequently apply the DC framework in partnership with either the SL or the VL frameworks (Figure 4.8). It appears that in all four study areas SL and VL framework are mutually exclusive and do not appear within the same initiative simultaneously. The Sizewell and Hinkley Point nuclear neighbourhoods exhibited this relationship most explicitly with 84% and 75% of initiatives respectively (Table 4.3).

Sizewell 2013 & 2016	DC	VL	SL	NA
DC				
VL	37.3 %	5.2 %		
SL	42.5 %		5.2 %	
NA				

Hinkley Point 2016	DC	VL	SL	NA
DC	12.5 %			
VL				
SL	28.6 %			
NA	42.8 %			

Portsmouth 2016	DC	VL	SL	NA
DC	28.6 %			
VL				
SL	28.6 %			
NA	28.6 %			

Wylfa 2016	DC	VL	SL	NA
DC				
VL				
SL	25 %		25%	
NA			50%	

NB: One adaptation project (5.2 %) in the Sizewell nuclear neighbourhood exhibited all three frameworks.

NB: One adaptation project (5.2 %) in the Sizewell nuclear neighbourhood exhibited DC/VL/NA hallmarks

NB: One adaptation project (14.2 %) of adaptation projects from the Portsmouth nuclear neighbourhood exhibited DC/VL/NA hallmarks

Table 4.3 Percentage use of climate change adaptation frameworks in the four study Areas.

Stakeholders in the non-nuclear study areas surrounding Portsmouth Harbour predominantly (71%) employed the DC framework when implementing adaptation (Table 4.3). Some initiatives also employed characteristics of the SL (29%) and VL (14%) frameworks in partnership with the DC approach.

Stakeholders in the neighbourhood surrounding the Wylfa nuclear power station also employed a hybrid approach to adaptation (Figure 4.8). Table 4.3 illustrates that stakeholders in the Wylfa study area rely heavily on the SL approach (as seen in Figures 4.6d and 4.7d). Of the four adaptation initiatives in the inventory 75% employ the SL approach in isolation (Table 4.3).

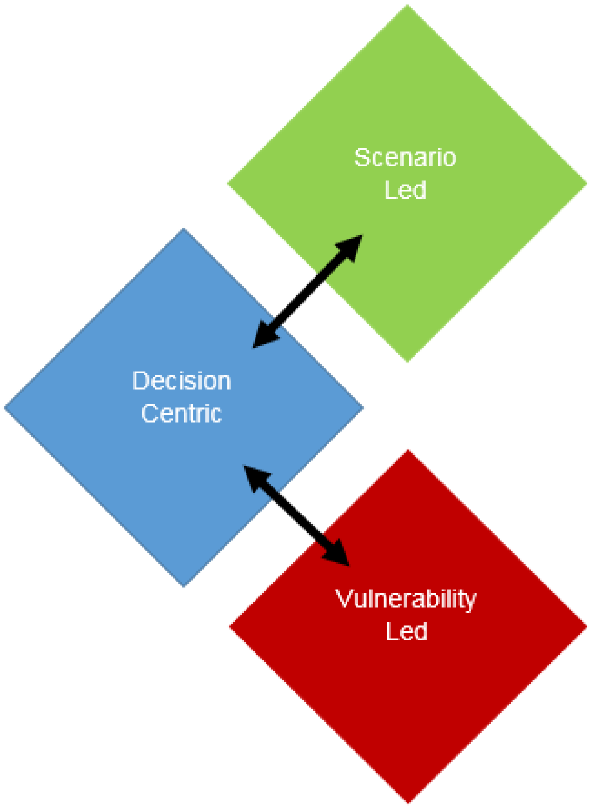


Figure 4.8 Primary framework hybrids utilised in climate change adaptation initiatives in the four study areas.

4.3.6 *Non-applicability when categorising adaptation inventories*

The criterion tool for the categorisation and identification of framework approaches employed by stakeholders in the coastal zone was produced from a review of the literature in 2012/2013. The criterion was 100% applicable when compiling the adaptation inventory in the Sizewell nuclear neighbourhood in 2013. However, some aspects of adaptation initiatives in the subsequent inventories have been difficult to categorise into one of the three framework approaches. There were two primary reasons for this: (1) either the information required to make the categorisation was not available or (2) the methods used by stakeholders were not encompassed by the description of a framework hallmark. For example, The Solent Forum documents reflect various stakeholders adaptation efforts, therefore it proved not possible to categorise some hallmarks of adaptation as stakeholders involved in the forum may employ a different combination of frameworks in their adaptation efforts.

When analysing the extent of this non-applicability it was found that 16% of adaptation initiatives surveyed had an aspect of N/A within the categorisation process. N/A was the most pronounced in the Wylfa nuclear neighbourhood with 50% of adaptation initiatives featuring some degree of N/A (Table 4.3). In the non-nuclear neighbourhood surrounding Portsmouth Harbour 43% of initiatives featured some degree of N/A. On the other hand, all adaptation initiatives compiled in the nuclear neighbourhood at Hinkley point were categorised using the criterion and for the second adaptation inventory in 2016, 99% of adaptation inventories were categorised using the criterion tool (Figure 4.9).

4.3.7 *Temporal comparison (Sizewell 2013/2016)*

The development of climate change adaptation initiatives is an ongoing endeavour in coastal zones. Two online surveys were conducted in the Sizewell nuclear neighbourhood to investigate the means by which stakeholders are developing their approaches to climate change adaptation over time. The first survey was conducted in 2013 and the second in 2016. In the three years since the first survey was conducted five additional climate change adaptation initiatives were identified. Some of the initiatives in the 2016 survey were write ups or summaries of adaptation initiatives that were taking place at the time of the first survey but did not have an online presence (Table 4.2a – b).

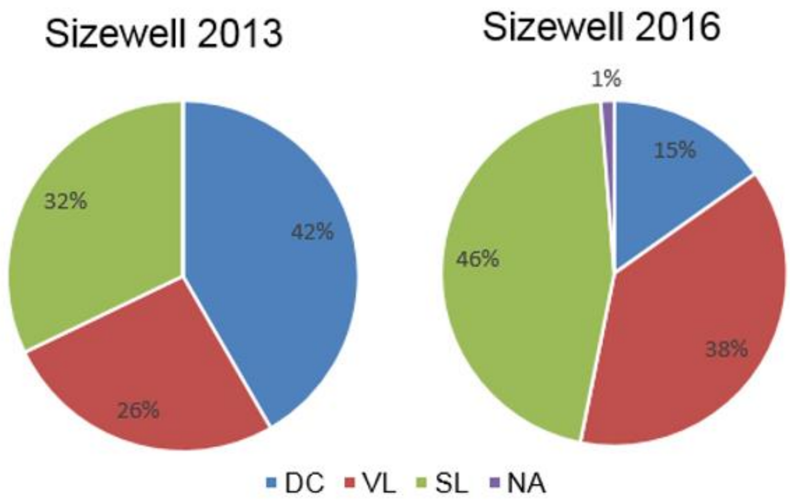


Figure 4.9. Comparison of the preference for different adaptation frameworks at Sizewell in 2013 and 2016.

The results show that there has been a shift in the way stakeholders adopt SL, VL and DC frameworks when adapting the coastal zone. Figure 4.9 illustrates that the percentage use of the DC framework approach has decreased from 42% to 15% whereas the prevalence of SL and VL framework approaches have increased 14% and 12% respectively. However, due to the small sample size these changes must be interpreted with caution.

The criterion tool successfully categorised 100% of adaptation initiatives in the 2013 survey. However, in 2016 there was an instance where it was not possible to categorise using the first hallmark (use of climate information). Similarly to the Solent Forum documents the adaptation initiative in question was the East of England climate change adaptation network. The network is comprised of over 150 members made up of both public and private organisations. Again, these organisations utilise climate change information in a variety of ways therefore it was impossible to categorise the preferred approach into SL, DC or VL approaches.

4.3.8 *Regional comparison*

Analysis of the adaptation inventories enables evaluation of how regional variations affect the framework approaches stakeholders adopt when implementing adaptation to climate change. Figure 4.10 displays the results from the adaptation framework analysis and illustrates spatial variations between each study neighbourhood.

When analysing the categorisation of adaptation initiatives by hallmark, stakeholders in the Sizewell neighbourhood Hinkley Point study areas appear to employ adaptation frameworks in a similar manner; hallmark analysis illustrates that stakeholders in these neighbourhoods employ all three frameworks and the presence of N/A is limited. Results from the Sizewell and Hinkley nuclear neighbourhoods promote the validity of the criterion tool and 'real-world' application of adaptation frameworks established within the academic literature (Figure 4.10).

In contrast the other study neighbourhoods, Wylfa and Portsmouth Harbour display different classification profiles. These two neighbourhoods exhibit a higher presence of N/A and a more limited use of the hybrid approach, instead relying more on a single framework when implementing adaptation. These results query the 'real-world' applicability of the SL, VL and DC frameworks and question the validity of the criterion tool.

When considering the regional distribution of adaptation preferences it must be noted that the Wylfa nuclear neighbourhood is geologically different to that of both Sizewell and Hinkley; Chapter 3 (3.5) established that the geomorphology of the Wylfa nuclear neighbourhood is more resilient to the impacts of climate change than that of Hinkley and Sizewell. In addition, the Portsmouth non–nuclear neighbourhood is more urbanised with a much larger population than the three nuclear neighbourhoods (Chapter 3, 3.6). Further debate of possible reasons why adaptation profiles seem to vary regionally can be found in the discussion (4.4)

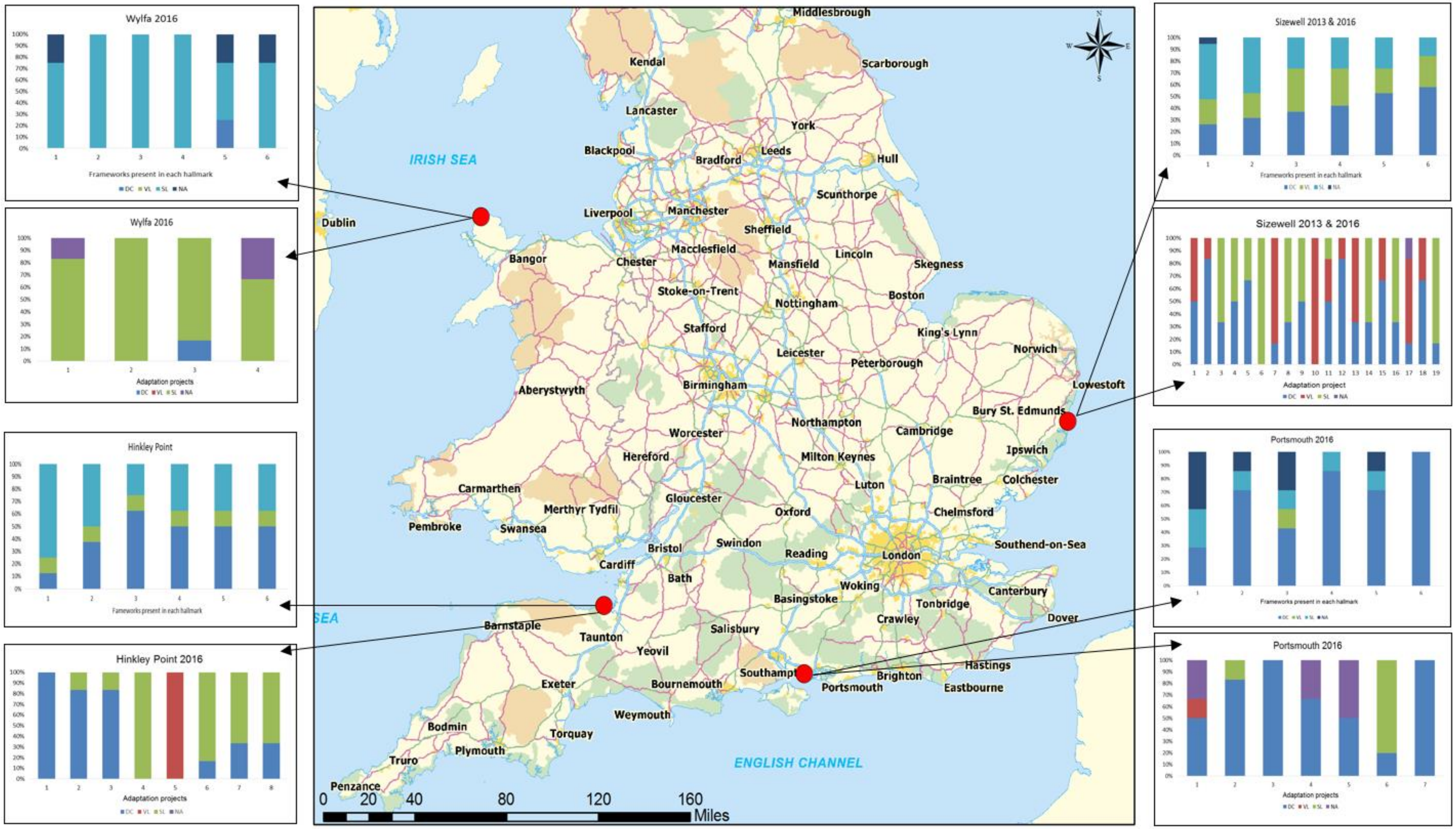


Figure 4.10 Spatial distribution and stakeholder adaptation preferences in case study areas.

4.3.9 *Nuclear – Non Nuclear comparison (Sizewell/ Wlyfa/Hinkley vs Portsmouth Harbour)*

Framework analysis illustrates that stakeholders in nuclear neighbourhoods employ a significantly different composition of adaptation frameworks to those in non-nuclear neighbourhoods (Figure 4.10). Therefore, for this section of results the Wylfa study area has been omitted as adaptation efforts on Anglesey are minimal in comparison to the two other nuclear neighbourhoods (Figure 4.2). It is recognised here that the small sample sizes involved in this study must be taken into account when considering the transferability to different coastal neighbourhoods, they may not be representative of general constitutions elsewhere (Chapter 7, Section 7.4.1)

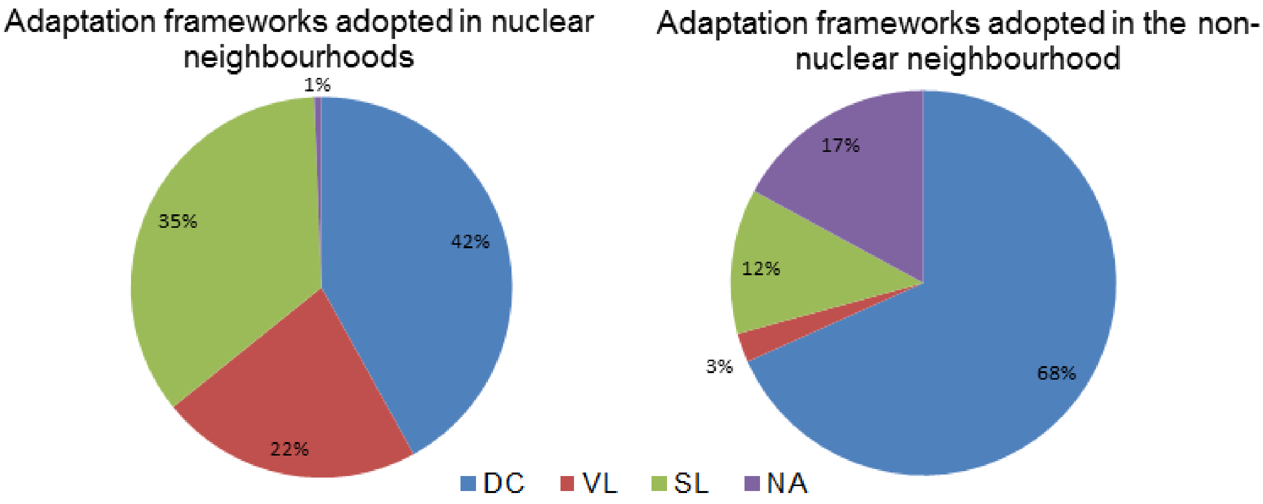


Figure 4.11 Comparison of nuclear and non-nuclear case study areas. NB: The Wylfa study area has been omitted.

When comparing framework approaches adopted by stakeholders in nuclear neighbourhoods and the non-nuclear neighbourhood, it is evident that both areas incorporate all three frameworks when implementing adaptation (Figure 4.11). However, the configuration of framework approaches differs: the non-nuclear neighbourhood exhibits a 36% higher dependency on the DC approach and a marked lower (19%) dependency on the VL approach.

The presence of N/A in the non-nuclear neighbourhood is significantly higher (17%) than that in the nuclear neighbourhood (1%). This raises two issues: first, the transferability of the criterion tool to other coastal zones featuring long-lived infrastructure; second, the efficacy of the SL, VL and DC frameworks in ‘real world’ situations.

4.4 Discussion

The results of this document analysis show that the means by which stakeholders implement climate change adaptation is complex. In ‘real-world’ situations climate change adaptation is a multifaceted endeavour in which stakeholders employ a range of techniques and approaches. This section will discuss the findings, focussing on: the types of stakeholders who are implementing climate change adaptation; the hybrid approach to adaptation; the efficacy of the criterion tool and; the ‘real–world’ application of the three adaptation frameworks (SL, DC and VL).

4.4.1 *Who is implementing climate change adaptation and why?*

Compiling climate change adaptation inventories for four coastal neighbourhoods around the coastline of the UK provided an opportunity to examine what kind of stakeholders are engaging with climate change adaptation and to analyse the governance structures by which adaptation is being implemented.

Results support the view that adaptation is typically a multi-agency endeavour (Hallegatte 2009; Huntjens et al 2012). In all four study neighbourhoods stakeholders from a broad cross section of civil and public society are involved in climate change adaptation. A configuration of statutory, non-statutory and community-based organisations (representing a range of sectors), were engaged in adaptation initiatives (Figure 4.5). However, stakeholder involvement in adaptation was not even across sectors.

In all four study areas, local government is heavily involved in adaptation efforts (Figure 4.5). This reflects the dominant level at which adaptation is implemented (Figure 4.3), as in all four study areas the majority of adaptation efforts occur on a local or regional scale. Tompkins et al (2008) stresses the importance of recording information on the scale and nature of adaptation initiatives as such information gives an indication to what degree adaptations are instigated either from a centralised or local administration. They assert that such information provides a platform for further analysis to establish the most appropriate scale from which adaptation is administered.. Few et al (2007) found that in Christchurch Bay on the South coast of England and in the Orkney Islands, the geographical scale of an initiative affected the degree to which local stakeholders are willing to engage with the organisers of an adaptation initiative.

Similar relationships between scale and sector were found in the results of the present study. There is evidence of the government's policy to encourage localism and diffuse powers from London, by empowering local government authorities such as local councils (House of Commons 2010; 2015). Pahl-Wostl and Knieper (2014) raise concerns that despite government reforms encouraging decentralisation, methods to analyse alterations in governance systems are lacking in particular the importance of coordination. The results show that in all three nuclear neighbourhoods the proportion of initiatives that might be classified as national scale accounts for ~25% of the sample (Figure 4.5). In contrast to Pahl-Wostl and Knieper (2014), these results suggest that coastal management practices *are* nationally standardised, to some degree. when a coastline features critical infrastructure of the nuclear kind. However, in the absence of nuclear infrastructure, Figure 4.3 illustrates the contrast in the scales of management as Portsmouth has no national or international scales of adaptation were recorded in the inventory. Furthermore, results from the Portsmouth inventory illustrate that all adaptation efforts are regional and local in scale. The high percentage of NGO's and community group participation again supports the presence of a decentralised approaches to adaptation.

When consulting the literature, it appears that decentralised, locally implemented adaptation is not widespread. However, the results from this study illustrate it is possible to implement international, national and local initiatives simultaneously (Figure 4.3). In developing coastal regions may struggle to implement local adaptation initiatives as strong and reportedly corrupt hierarchical systems hamper local authorities and administrative systems (Goedecke and Welsche 2016; Kumar and Geneletti 2015).

In the three nuclear neighbourhoods the environmental sector is the dominant group involved in adaptation. The environmental sector is comprised of both regulators and conservation stakeholders. Environmental regulators are only involved in adaptation in the Hinkley Point and Sizewell neighbourhoods whereas environmental conservation groups make up the majority at Wylfa. There are various reasons that might explain this. First, NNB plans are most advanced at Hinkley point and Sizewell therefore require the presence of environmental regulators whereas NNB plans at Wylfa are embryonic. Second, the neighbourhood surrounding Wylfa is deemed to be at low risk from the potential impacts of climate change. Third, the environmental sector has experienced significant cuts in government resources following the economic recession of 2008.

The current economic situation has led to decreased centralised funding of coastal management and adaptation, prompting an increase in local community, NGO and environmental conservation responses to coastal change, as in the case of the Deben Estuary Partnership in the Sizewell nuclear neighbourhood. Community-led adaptation generally adopts a VL framework promoting community engagement in decision-making (Armstrong et al 2015; Bruno and Cheyne 2010). Although the participation and empowerment of the local community is widely regarded a positive factor for climate change adaptation (Few et al 2007), in some cases the employment of the VL approach on the Suffolk coast has led to actions being implemented that are not in line with the recommendations of national guidance documents such as the SMP. For example, some land owners have installed hard defences at the base of cliff faces in an effort to mitigate the effects of erosion. Such local actions may be deemed acceptable to the land owner as the SMP is not a statutory document.

Despite the current economic climate, the absence of key actors from the Wylfa adaptation inventory raises questions about the spatial and temporal degree of consideration given to the potential impacts of climate change. The online inventory only documented four adaptation initiatives in the Wylfa neighbourhood, instigated by local government and environmental conservation organisations, leading to scoping and planning outcomes. This adaptation profile suggests that stakeholders in the Wylfa nuclear neighbourhood have not or do not consider extreme impacts of climate change, which may be induced beyond tipping points in earth systems.

The sparse infrastructure on Anglesey coupled with the embryonic planning stage of a NNB could be a key reason behind this lack of adaptation efforts. This in turn could constrain climate change adaptation as reactive rather than proactive, putting the neighbourhood at greater risk from the potential impacts of extreme climate change. Hurlimann and March (2012) identified spatial planning as a critical mechanism for facilitating climate change adaptation. This highlights the importance of engaging stakeholders in the coastal management and adaptation on Anglesey despite the area only being sparsely populated and NNB plans embryonic. They assert that spatial planning has the ability to act on matters of collective concern, manage competing interests, cut across scales and act and reduce factors of uncertainty. However, adaptation planning is not without challenges, such as developing conviction, facilitating climate change consideration into planning outcomes and transforming the planning system from a passive to a proactive process. All of these are necessary to counter the adverse impacts from climate change (Hurlimann and March 2012; Kumar and Geneletti 2015).

Bierbaum et al (2013) report that in the USA there is a substantial amount of adaptation planning taking place in various sectors but few measures have been implemented and even fewer have been evaluated. Similarly in the UK, the potential to enhance the resilience of a community by building adaptation into planning policy is recognised. There are many research programmes underway, at a European level, to advance this field. For example, initiatives funded though the Adaptation and Resilience in a Changing Climate (ARCC) programme include: PREPARED which looks at water and sanitation under climate change; SUDPLAN which concentrates on adaptation via long term urban planning; and ARCoES which aims to develop a decision tool to aid stakeholders in coastal planning over long time horizons. In light of the findings of Bierbaum et al (2013), to capitalise on the findings from these research programmes increasing efforts must be made to facilitate implementation of adaptation and produce subsequent evaluations.

4.4.2 *The hybrid approach*

The sample of adaptation studies suggest that, in most cases, stakeholders implementing climate change adaptation in coastal zones surrounding long-lived infrastructure in the UK, utilise more than one adaptation framework in a hybrid approach (Figure 4.8). This section will discuss possible reasons why stakeholders adopt this approach.

First, as discussed in the literature review (Chapter 3), each theoretical adaptation framework (SL, VL and DC) has inherent strengths and weaknesses. When applied to real-world situations limitations of these theoretical frameworks must be overcome to enable informed and robust adaptation decisions. Therefore, decision-makers may implement a hybrid approach to overcome weaknesses associated with aspects of individual frameworks. Results show that adaptation efforts in the neighbourhoods surrounding both the Hinkley Point and Sizewell nuclear power stations, that SL and VL framework approaches are widely used and supported by the DC framework (Figure 4.10). SL and VL frameworks are rarely utilised in partnership (<3% of the time) and are only observed when all three frameworks are implemented simultaneously.

It appears that stakeholders, knowingly or unknowingly, choose to use elements of multiple frameworks to overcome the weaknesses associated with aspects of a single framework. This can be termed the ‘compensation theory’. This theory is important because, as discussed, the framework approach adopted can have direct correlations to the outcomes of adaptation initiatives (Section 4.4.2.1). This theory of employing multiple frameworks to overcome weaknesses in one specific approach is also observed at Wylfa and Portsmouth, however, the composition of framework utilisation varies. At Wylfa stakeholders primarily adopt the SL framework, whereas in Portsmouth the DC framework is favoured. This theory should be communicated to stakeholders implementing adaptation initiatives so they are fully aware of the strengths and weaknesses of adaptation frameworks and can make informed decisions regarding the approach they adopt.

Uncertainty is a factor that hampers adaptation decision making. It affects variables of both the inputs and outputs of adaptation initiatives. There is an extensive and established literature outlining the various facets of uncertainty affecting climate change adaptation both in physical and social disciplines (e.g. Barrett and Dannenberg 2012; Dessai and Hulme 2007; Deser et al 2012; Heal and Milner 2014; Incropera 2014). Uncertainty is a significant barrier to adaptation decision making that the effectiveness of an adaptation strategy is often measured by the robustness to uncertainty and the flexibility or ability to alter should circumstance change (Adger et al 2005; Hallegatte 2009).

Technical uncertainty surrounds the SL framework as it relies most heavily on the ability of models to project future changes in climate. Uncertainty stems from insufficient resolution and inability of climate models to accurately simulate the complete set of processes and phenomena centrally important for the attribution of past climate changes and therefore projection of future climate (Bader et al. 2008; Martens 2013). Uncertainty is also present when considering the effects future forcing may have on both natural and anthropogenic systems (Shepherd 2014). In addition, conventional SL framework approaches do not always incorporate the impact of efforts to mitigate and adapt to climate change (Moss et al. 2010).

Although technical advancements are ongoing, uncertainty originating from climate model outputs amplifies as decision making progresses. Ultimately, the cascade of uncertainty (Figure 2.6) confounds predict-then-act strategies (Wilby and Dessai 2010). At the decision-making interface the physical outputs from a SL framework face a complex array of social variables, on which decisions made will impact. Hence, there are few examples of adaptations emerging from a SL framework.

The VL framework involves collating the social variables, from a potentially vulnerable community, that affect their coping capacities. However, to establish the factors governing vulnerability, considerable resources are required. This task cannot be standardised across communities as each community has a unique profile of factors affecting vulnerability. These factors can be subject to instantaneous change should boundary conditions and/or change coping capacities. Similar to the SL approach, some uncertainties can be quantified, but many simply cannot due to limitations in socio-economic knowledge, which in turn, denotes a level of irreducible uncertainty in our understandings of future climate change adaptation (Dessai and Hulme 2004; Heal and Milner 2014).

It is recognised that that society can and must still make adaptation decisions even in the absence of accurate climate change predictions (Dessai and Hulme 2007; Dittrich al 2016). The DC framework approach may be a constructive means to overcome the weaknesses associated with SL and VL adaptation frameworks because it provides a platform for flexible and robust climate change adaptation enabling decision to be made in the face of irreducible uncertainty. Moss et al (2010) supports the use of an adaptation framework that incorporates possible climate change scenarios simultaneously with socio-economic impacts and feedbacks. These may improve the analysis of the costs, benefits and risks of different policy choices, in relation to emerging climate and socioeconomic conditions. The DC adaptation framework can incorporate such dimensions via stress testing systems and options using a range of plausible climate futures. With regards to sea ports, Becker et al (2013) deems such refinements necessary to enable adaptation to be proactive rather than reactive.

Knowingly or unknowingly, stakeholders in all four study areas adopt the proposed hybrid approach, incorporating the DC framework approach into their adaptation efforts within their neighbourhood. Overall 66% of the 38 adaptation initiatives in the inventory exhibit one of the hybrid approaches illustrated in Figure 4.10.

Many of the adaptation initiatives held in the inventory are integrated into projects that are not specifically designed for climate change but to simultaneously address other societal issues. This is also recognised by stakeholders as evidenced by the Suffolk coastal climate change strategy (Table 4.2b) initiative run by the SCDC in the Sizewell nuclear neighbourhood. This initiative first asked the local community about main concerns were about living in the area. Issues such a broadband and transport were raised as well as issues about climate change and a changing coastline. Issues were categorised and advice issued non-climatic issues. The rest of the initiative was then about to centre on climate change and future coastal management strategies. Although climate change is deemed one of the most urgent risks we face today, analysis of UK public perceptions indicate that the population perceive climate change as distant – temporally, spatially and geographically (Spence et al 2012). The House of Commons (2015) outlined energy and climate change as one of the key issues for the new parliament amongst issues of social protection, education, health, defence and economy and public finance. Brügger et al (2015) found that increasing awareness and emphasising the urgency of climate change is not necessarily an effective way to increase an individual’s willingness to take action on climate change through. These findings contradict previous studies showing increased awareness would encourage engagement and increase actions (Scannell and Gifford 2013; O'Neil et al 2013). Findings from Brügger et al (2015) suggest that it may be constructive to align climate change adaptation with other societal initiatives and emphasise the experiences of individuals such as their previous exposure to flooding.

4.4.2.1 *The hybrid approach and adaptation outcomes* Results indicate that there is a relationship between the framework approach adopted and the resulting adaptation actions taken. Projects employing a predominantly SL framework approach tend to result in planning exercises, advice notes and scoping reports rather than on-the-ground adaptation actions. For example, in the Wylfa nuclear neighbourhood, three out of the four initiatives adopt the SL approach in isolation. VL hallmarks were not present and only one initiative exhibited DC characteristics in hallmark five, adaptation implementation mechanisms. The only adaptation initiative exhibiting a hybrid approach DC/SL was the Living Landscapes initiative, a national initiative operating on a local scale. This was the only initiative resulting in more than one outcome. The SL adaptation efforts; The vision for Anglesey, The Anglesey local flood risk management strategy and The Anglesey and Gwynedd joint local development plan all resulted in scoping and planning outcomes.

On the other hand, VL led approaches to adaptation tend to lead to empowerment of local groups to take action such as, the *Alde and Ore Futures Projects* and the *Deben Estuary Partnership* both in the Sizewell neighbourhood (Table 4.2a and b). Although empowering and engaging more stakeholders in climate change adaptation is usually deemed a positive, in some cases mass engagement can be counterproductive. As evidenced an adaptation inventory in the Sizewell nuclear neighbourhood. The East Lane initiative at Bawdsey was conceived by the concerns of local empowered stakeholders concerned about the vulnerability of a coastal hamlet Shingle Street and an ancient Martello tower. The adaptation initiative involved the instalment of rock revetments in order to protect the hamlet and tower. Upon completion in 2010, all involved deemed the initiative a success. However, although this bottom up initiative has provided protection to the tower and hamlet, erosion to the south has accelerated due to the sediment supply being cut off. A new bay is now developing around the end of the defences which, if left to erode, it is predicted that the Martello tower could end up on a peninsular (Jenman 2016).

The preceding examples support the importance of stakeholders adopting a balanced hybrid approach to climate change adaptation to overcome weaknesses associated with the use of a single framework approach. Employing the DC framework is an important way of overcoming weaknesses as the framework incorporates robust dimensions such as stress testing and flexibility. To date, adaptation studies have not led to a sufficient rate of implementation and on the ground actions (Wise et al 2014). To ensure 'successful' adaptation initiatives are implemented results from this study recommend that elements of a DC adaptation framework are used in combination with SL initiatives to facilitate the translation of scoping and planning assessments, produced by SL frameworks, into meaningful on the ground actions. The Living Landscapes initiative, run by the Wildlife Trust (Table 4.2e) adopted a SL/DC approach in the Wylfa nuclear neighbourhood being the only initiative with actions other than scoping assessments and documents. Similarly the Severn Estuary Partnership and the Water Adaptation is Valuable to Everyone (Table 4.2c) achieved outcomes of facilitation and advice by adopting a SL/DC hybrid framework approach. In addition, combining elements of the DC and VL frameworks could simplify complex socio-economic assessments. This could be achieved by truncating possible future climate and scenarios and socio-economic pathways by this means a matrix of generalised future scenarios could be generated to aid the decision maker. In this way, the DC framework approach enables factors of uncertainty and stringent cost-benefit analyses to be factored into adaptation plans.

4.4.3 *Criterion tool*

The criterion tool enables analysis and comparison of the adaptation techniques of stakeholders in coastal neighbourhoods surrounding long-lived infrastructure. As recognised in the literature review, there are other tools within the academic literature that have been applied to diagnose and categorise climate change adaptation initiatives. However, previous efforts have not incorporated all aspects of adaptation efforts from the inception to implementation of a given initiative (Smit et al 2000). The criterion tool (Table 4.1) presented here, has the capacity to analyse and categorise the adaptation architecture employed by stakeholders across six fundamental hallmark of adaptation initiatives covering a variety of dimensions of the adaptation process. In this sense, the criterion tool broadens the horizons of diagnostic tools used to assess and evaluate the climate change adaptation efforts of stakeholders.

Although deemed 79% effective at categorizing adaptation initiatives by framework approach, the criterion tool is not without limitations, because in 21% of initiatives surveyed there was some degree of N/A where the criterion tool was unable to assign the characteristics of a hallmark of adaptation into one of the three adaptation frameworks proposed by the literature. There are a number of factors that could contribute to the presence of N/A which in turn impact the overall efficacy of the criterion tool. First, the online survey might not glean enough information to inform the categorisation process. This could be due to the selection of the ‘key’ search words or simply adaptation initiatives not having a sufficiently detailed online presence. Second, the description of the hallmarks in the criterion tool may not have been specific enough to reflect the exact characteristic of adaptation approaches. Therefore, a level of ambiguity may have inhibited framework classification. Both factors could potentially be addressed by further refinement and testing against adaptation studies in other sectors and areas. Finally, the presence of N/A may simply reflect the limited ‘real-world’ applicability of the three theoretical frameworks.

The presence of N/A is not constrained to one hallmark or study area. When examining the applicability of the criterion tool in the four study neighbourhoods the results showed that the presence of N/A was most prevalent in the neighbourhoods surrounding Wylfa and Portsmouth. At Wylfa, N/A was present in two of the four adaptation initiatives surveyed and applies to three hallmarks. In the Portsmouth inventory, N/A was present in four hallmarks across 42% of initiatives. N/A poses questions about the validity and transferability of the criterion tool, possible reasons are discussed below.

The two study areas with the lowest N/A were Hinkley Point which had zero presence of N/A and Sizewell with only 5% N/A. These study areas are different to the other neighbourhoods which exhibit a greater level of N/A. In terms of geomorphological characteristics and land use the Wylfa nuclear neighbourhood is considered to be at low risk from the potential impacts of climate change (Chapter 3.5) therefore many of the adaptation documents in the inventory were found to have less immediate outcomes of scoping and planning. The non-nuclear neighbourhood surrounding Portsmouth harbour is different as it is densely populated and urbanised. These variations in land use and geomorphological profiles may be fundamental factors contributing to the N/A present in adaptation efforts at Portsmouth and Wylfa. This may be because the criterion tool was created for and refined by the adaptation inventory from Sizewell, 2013 (Armstrong et al 2015). Therefore, the variations in land use at Portsmouth and vulnerability at Wylfa may not suit the defined hallmarks of the criterion tool. Applying the tool to additional coastal neighbourhoods featuring various types of long-lived infrastructure would further would determine the validity and transferability of the tool and enable refinements to be made if appropriate.

The variable characteristics of the study neighbourhoods can be used to explain the presence of N/A. However, such instances test the validity of the criterion tool, as well as the theoretical frameworks proposed by the literature and the transferability of the research. More extensive work on the criterion could refine the hallmarks further, enabling the tool to be applied to other communities implementing climate change adaptation and thereby reduce the incidence of N/A.

4.4.4 *Real world applicability of theoretical frameworks (SL, DC and VL)*

The purpose of creating the criterion tool was to establish the ‘real-world’ application of theoretical framework approaches to climate change adaptation as advocated in the academic literature.

The emergence of a large number of adaptation plans utilising a hybrid approach has both practical and theoretical implications. Practically, stakeholders should be aware of the limitation compensation theory; choosing to use elements of multiple frameworks to overcome the weaknesses associated with an aspect of a single framework. Theoretically, the ‘real-world’ applicability of the SL, DC and VL adaptation frameworks can be regarded as barometers gauging the relevance of links between the academic sphere and what is happening in industry and influencing ‘real-world’ practice. The importance of links between the academic and practitioner spheres have been recognised and multi-discipline research projects that focus on the management and adaptation of the coastline are being undertaken. For example, the umbrella project of this PhD Adaptation and Resilience of the Coastal

Energy Supply (ARCoES) which is developing a decision tool to aid stakeholders in the long-term management and adaptation of the coast surrounding nuclear infrastructure in the UK. Also, the integrated COASTal Sediment System Project (iCOASST) brings together a number of UK universities, research laboratories and leading consultants, to develop new methods for characterising and forecasting long-term changes to coastal sediment systems. The development of the criterion tool and the identification of the hybrid approach to adaptation further raises the awareness and necessity for increased partnership working to ensure the success of the adaptation process.

Matching supply and demand for knowledge between science, politics and citizens, especially in the fields of global change, is a challenging task (Hegger et al 2012; Pielke Jr 2007). Hegger et al (2012) asserts that this is due to differences in working practices regarding timeframes, epistemologies, objectives, process-cycles and criteria for judging the quality of knowledge. For example, there are questions surrounding the usability and relevance of SL adaptation tools. For instance, the *Portsmouth Water Project* (2015) (Table 4.2d) expressed concerns that the risks identified by climate modelling tools such as UKCP09 do not consider the immediate future and, therefore, other methods must be used to assess risk and aid adaptation.

Results from the framework analysis have determined that the fundamental hallmarks of the theoretical adaptation frameworks, established within the academic field, are present in ‘real-world’ practice. However, the means by which the stakeholders implement adaptation does not appear to match theoretical literature. As mentioned before, stakeholders rarely approach climate change adaptation using a single theoretical framework. Instead, results illustrate that stakeholders most frequently adopt a hybrid approach to adaptation (Figure 4.10). This indicates that the practical application of theoretical climate change adaptation frameworks appears to be more complex than that outlined in the literature.

Therefore, the results of this study illustrate that although the academic literature reflects what is happening on the ground, there are opportunities for more sophisticated collaborations between societal spheres, engaged in climate change adaptation. Primarily between the academic and practitioner communities as well as local and centralised division of government. This in turn will help to narrow information gaps and effectively bridge supply and demand for knowledge.

4.5 Conclusions

This component of the research has fulfilled requests for a systematic examination of the adaptation process (Ford et al 2011). Using four coastal neighbourhoods around the UK, this chapter has investigated the nature of the architecture by which stakeholders implement climate change adaptation in practice. A criterion tool, enabling stakeholders to categorise the type of framework approaches employed for adaptation initiatives, was created and implemented to contribute towards calls to sharpen our understanding of the process of adaptation and highlight what we know, don't know and what we need to know (Ford et al 2011, pp 335).

A criterion tool was created and applied to analyse the framework approaches stakeholders take when planning and implementing adaptation efforts. The tool was applied to four coastal neighbourhoods, all featuring long-lived infrastructure. Based on an inventory of adaptation plans, it is shown that elements of theoretical adaptation frameworks are present in real-world situations. However, there appears to be some discrepancies between the defined frameworks within the literature and the nature of 'real-world' adaptation initiatives. Adaptation efforts in all four study areas rarely utilise one framework in isolation. In reality, a mixture or hybrid of approaches are employed by coastal stakeholders, primarily involving SL/DC or VL/DC configurations (Figure 4.10). The hybrid approach offers a pragmatic way to overcome weaknesses associated with SL (top-down) and VL (bottom-up) approaches to adaptation which, when used in isolation, are limited in their outcomes (Urwin and Jordan 2008). The main limitations of the SL framework centres around the uncertainties associated with climate models. Therefore the role of climate modelling plays in adaptation depends on stakeholders understanding the limitations of framework and their capabilities to incorporate and consider probabilistic predictions of future climate scenarios (Dessai and Hulme 2004). On the other hand the limitations associated with the VL centre around the lengthy observations are needed to assess magnitudes and frequencies of extreme events as well as their associated societal and environmental consequences. Vulnerability variables are context specific, meaning that one assessment cannot be readily transferred to other regions due to variations in socio-economic and cultural factors (van Aalst et al 2008).

When determining the efficacy of the criterion tools itself, it can be concluded that it is most helpful when applied to neighbourhoods that are actively engaged in the public planning process of NNBs. The other two neighbourhoods, Wylfa and Portsmouth harbour exhibited areas where the criterion tool was unable to categorise adaptation initiatives. The presence of N/A raises questions about the transferability of the tool to other communities implementing climate change adaptation. A second coder could be introduced to classify adaptation initiatives, this would enable inter-coder reliability to be established, increasing the robustness of the method (Armstrong et al 1997). A second coder would increase the validity of the results, further test the applicability of the criterion tool and audit the presence of N/A. However, N/A considered, the overall applicability of the tool across all four case study neighbourhoods was 79%. Therefore, the tool itself is deemed to be an effective way of investigating the means by which stakeholders are adapting their coastal neighbourhoods to reduce the risks posed by climate change.

It must be noted here that the documents compiled from the online survey only reflect a snapshot in time for each adaptation initiative. Therefore, it is not possible to provide an analysis of an initiatives progress, as a longitudinal process, from inception to implementation and monitoring. It is recognised that factors unforeseen in this study may play a role in shaping adaptation initiatives in the four study areas. For example, perturbations in national administrative systems such as changes in leading political parties and priorities or the effects of economic recession, as experienced in 2008.

This section of the research has produced results based on observations of the methods and techniques stakeholders utilise when implementing climate change adaptation. Although theories have been discussed, the reasons behind why stakeholders adopt a given framework to climate change adaptation remains undetermined. The next chapter builds on the findings from this analysis of online adaptation inventories and seeks to uncover key factors governing 'successful' climate change adaptation, from the viewpoint of stakeholders engaged in coastal management, in neighbourhoods surrounding long-lived infrastructure.

Chapter 5: Navigating pathways to 'successful' climate change adaptation in a nuclear neighbourhood – social factors

5.1 Introduction

The scoping phase of this research (Chapter 4) determined that factors contributing to the 'successes' of adaptation initiatives are complex and not readily mapped to the theoretical climate change adaptation frameworks described by academic literature. Based on these findings, it was deemed inadequate to define indicators of climate change adaptation 'successes' based simply on the framework selection of stakeholders. The findings from the framework analysis illustrated the intricate nature of climate change adaptation and highlighted that there are additional factors that have the potential to significantly influence the 'success' of adaptation. With these findings in mind, additional research questions were posed to further investigate adaptation 'success' in coastal zones featuring long-lived infrastructure (Section 1.5).

To date the literature has highlighted the complex nature of climate change branding it a 'wicked' or 'super wicked problem' that is difficult for national and international political systems to address in full (Lazerus 2008; Levin et al 2012; Rittel 1973). The importance of implementing of 'successful' adaptation initiatives by establishing pragmatic guidance for decision makers is becoming ever more prominent (Dupuis and Knoepfel 2013; Figueres 2013; Johnson and Wilby 2015 and Wilby et al 2010).

Measuring the success of adaptation initiatives by the outcomes of said actions may not be a viable way to establish methods of best practice as the outcomes from adaptation actions may not be realised for many years. Instead, focussed research on the process of adaptation, often termed 'route maps' and 'pathways' could provide pragmatic guidance to improve the adaptation decision making landscape, facilitating partnership working between stakeholders and overcoming the associated barriers to adaptation (Eakin and Patt 2011; Wise et al 2014).

There is an extensive literature on the barriers to adaptation however, similarly to measuring the success of adaptation, existing research to define barriers tend to focus on sections of the adaptation process either *planning* (Burton 2005; Moser and Ekstrom 2010) or *actions/outcomes* (Eisenack and Stecker 2012; Smit and Skinner

2002) and do not encompass the adaptation process as a whole. The literature highlights a complex network of barriers to adaptation affecting social (Section 2.9.1), political (Section 2.9.2), economic (Section 2.9.3) and technological (Sections 2.9.4) of society. The ways in which stakeholders interact with such barriers are non-linear and interlinked.

To rationalise the process of adaptation and develop pragmatic guidance to aid stakeholders in the successful implementation of adaptation initiatives, this chapter focuses on key attributes enhancing and inhibiting the adaptation process in the Sizewell nuclear neighbourhood, Suffolk, UK (Section 3.3). The chapter discusses the approaches and methods employed before presenting the results. Semi-structured interviews revealed six key themes that have the potential to affect the adaptive capacities of stakeholder organisations. The implications of these six themes are discussed with reference the published academic literature. The chapter concludes by considering the real world efficacy of the findings and their practical worth to stakeholder organisations, discussing how they may be used to increase successful climate change adaptation implementation.

5.2 Methodology

Figure 5.1 illustrates the work flow for this body of work. A reassessment of the literature was conducted, upon the findings of Chapter 4, to determine influential factors currently thought to enhance and inhibit climate change adaptation plans (Chapter 2, Sections 2.9 – 2.10). The Grounded Theory Methodology (GTM) was then employed to explore these factors in detail. Semi-structured interviews were carried out with stakeholders identified in the framework analysis phase of the research. Iterative analysis of the interview transcripts was undertaken throughout the data collection period, using NVivo 10 software. This analysis was then used to inform subsequent stakeholder interviews. Each step of the methodology is described in more detail below.

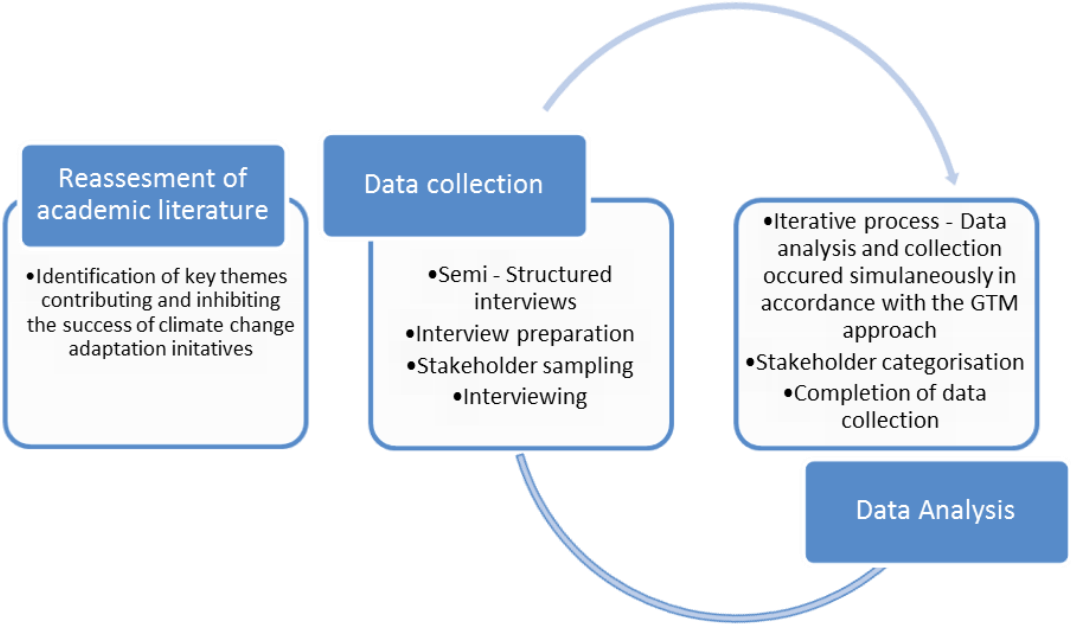


Figure 5.1. Work flow for stakeholder analysis. First, a reassessment of the academic literature, followed by data collection and data analysis, which were carried out simultaneously, one informing the other in accordance with the GTM approach

5.2.1 *Reassessment of the academic literature*

A literature review was undertaken to define the current meaning of climate change adaptation ‘success’ and to establish factors said to enhance and inhibit such ‘successes’. Key factors identified in the literature and advocated to contribute to the ‘success’ of climate change adaptation were identified to be explored in semi-structured interviews with stakeholders in the study area (Figure 2.8). These factors were then used in the development of the first iteration of an interview template. This approach is known as a Grounded Theory Methodology (GTM).

5.2.2 *Grounded Theory Methodology (GTM)*

To fully explore the complex, non-linear relationships governing the 'success' of climate change adaptation the GTM was employed (Glaser and Strauss, 1967). GTM is a general methodology for developing theories that are grounded in data (Strauss and Corbin 1994). The general theory is of constant, comparative analysis and dictates that data collection and analysis are conducted simultaneously, one informing the development of the other (Glaser and Strauss 1967).

The GTM studies peoples experiences and reaction to process or phenomena and combines theory and method. The method provides guidelines for identifying key relationships and links in the data via strategies of constant comparative analysis, sampling coding and memo writing. The theory in generated by the coding process. The theory provides the framework to understand the concept or the phenomena that is being studied (Merriam and Tisdell 2015). GTM is versatile as various types of data can be analysed to provide an depth perspective into the topic under investigation e.g. interviews, focus groups, videos, images diaries, existing text from documents, participant observations or even the spoken word (Cresswell and Poth 2017). The GTM has evolved since its conception in the 1960's there are two main branches of the approach; Straussian and Glassarian (Stern 1994). The Straussian form has a balanced focus on the data and formal theory with emphasis on the practice, coding and causative model underpinning the developed theory. On the other hand, the Glassarian form has fundamental focus on data, coding actions are less formalised and no board causative model is produced (Merriam and Tisdell 2015).

The GTM allows for existing theories to be incorporated into the data collection and new theories developed simultaneously, enabling established theories to be queried, modified or elaborated (Strauss and Corbin 1994). Adopting the Straussian form of the GTM approach allows for existing theories, said to enhance or inhibit the 'success' of climate change adaptation, to be examined and extensively explored, in the neighbourhood of coastal nuclear infrastructure.

GTM has received acceptance for comparable climate change adaptation and management studies that focus on developing adaptation and resilience capacity.

For example, Petheram et al (2010) used aspects of GTM for sampling. Initial participants approached to take part in the research were defined by the research situation (contacts and available participants), and later guided by emergent data and theory – in a process of 'theoretical sampling'. Whereas Kezar (2005), although not directly climate related, utilised GTM to explore how radical changes within governance systems have been conducted finding included four key frameworks that can be used for evaluating change.

Further supporting the use of GTM, Strauss and Corbin (1990) asserted that because grounded theories are drawn from data they are likely to offer insight, enhance understanding and provide a meaningful guide to action. As established in the literature review, stakeholders are lacking pragmatic guidance to aid the implementation of climate change adaptation. Adopting the GTM therefore increases the likelihood of tangible initiative outcomes that will be valuable and relevant to stakeholders and decision makers. This is because the data collected and subsequent findings are generated entirely from stakeholders knowledge and experiences of coastal management and adaptation based on in their own neighbourhood surrounding static, long-lived coastal infrastructure.

The Straussian form of GTM was deemed the most appropriate methodological approach to employ for this line of research as it enables the direction of the research to be piloted by the interviewees themselves. In addition, the iterative nature of GTM decreases the possibility of researcher bias as it incorporates an extensive range of participant led opinions and views at every stage of the research. Providing interviewees with a platform to express their views and experiences in detail is particularly important when investigating complex, unbounded and subjective topics such as climate change.

5.2.3 *Data collection (Sizewell only)*

When conducting qualitative research there are several means of collecting and subsequently analysing data. For example, questionnaires, focus groups and interviews. Many of these techniques were considered when adopting the GTM approach. This section critically assesses the techniques employed and discusses the justification for utilising the chosen methods, as opposed to alternative options.

The section first discusses methods of participant sampling before interview preparation, techniques and the procedure by which interviews were conducted.

5.2.4 *Participant sampling*

This part of the research focused exclusively on the neighbourhood surrounding the Sizewell nuclear infrastructure on the Suffolk coast of the UK. Considering the time constraints of the research, it was decided that focussing on a single nuclear neighbourhood would enable a deeper investigation into the influential factors affecting climate change adaptation - the researcher would be able to immerse themselves in the stakeholder dynamics of the neighbourhood.

There are numerous stakeholders situated in the neighbourhood surrounding the Sizewell nuclear development. Stakeholders range from individuals to multi-national corporations and span multiple sectors of society. It has long been recognised that it is not possible to include every participant with an invested interest in the research topic. The GTM research design should ensure that the sample is a true representation of the views of the larger population, which are beyond the bounds of this study (Miles and Huberman 1984). With this in mind, probabilistic and randomised methods of sampling selection such as postcode and telephone lotteries were discounted as this would result in an unrepresentative sample of stakeholders as not all candidates selected via such randomised methods would be involved in climate change adaptation or coastal management. Ensuring a representative sample of stakeholders, involved with the topic of investigation, is in itself a bias controlling exercise, limiting outliers and therefore increasing the validity of results.

Participants were selected at a stakeholder organisation level. Sampling individuals representing an organisation in the study area also limits as the possibility of individuals solely expressing extreme personal views and grievances. Attaining a representative, non – biased sample of participants is particularly relevant for this study as the presence of a NNB in the coastal zone can be a contentious issue.

For the first round of interviews, stakeholder organisations were listed from the online adaptation documents identified in the scoping phase of the research. It is important to consider here the varying statures of stakeholder organisations within the nuclear neighbourhood. This is known as ‘stakeholder salience’ and comprises of three aspects; power, legitimacy and urgency. Mitchell et al (1997) proposed that stakeholders can be ranked via the possession of these three attributes. Power refers to the ability to influence others; legitimacy to the credibility of stakeholder organisation; and urgency to the priority of the stakeholders remit. Not every stakeholder organisation possesses the same salience when making management decisions in the coastal zone. With this is mind, not every individual within a stakeholder organisation will possess equal levels of salience with regards to adaptation decision-making. To overcome this and control stakeholder salience within the study, comparable individuals from stakeholder organisations were selected to take part. Managerial positions within each stakeholder organisation were identified and invited to take part in the research. Interviewing mangers also ensured an in depth knowledge of adaptation initiatives between organisations was surveyed during the interview process. This purposive sampling method also highlights participants that are knowledgeable about the research topic enabling a detailed exploration research questions (Ritchie and Lewis 2003) (Chapter 1, Section 4).

In total 16 stakeholder organisations from the Sizewell nuclear neighbourhood took part in 30 semi-structured interviews. This phase of the data collection took place from April to September 2014:

	STAKEHOLDER ORGANISATION	**ACRONYM**
1	Alde and Ore Estuary Partnership	AOEP
2	Area of Outstanding Natural Beauty	AONB
3	Committee on Climate Change	CCC
4	Deben Estuary Partnership	DEP
5	EDF Energy	EDF
6	Minsmere Levels Stakeholder Group	MLSG
7	National Farmers Union	NFU
8	National Trust	NT
9	Natural England	NE
10	Regional Flood and Coastal Committee	RFCC
11	Royal Society for the Protection of Birds	RSBP

12	Suffolk Coast Against Retreat	SCAR
13	Suffolk Coastal District Council	SCDC
14	Suffolk County Council	SCC
15	The Environment Agency	EA
16	Waveney District Council	WDC

Table 5.1 Stakeholder organisations that took part in semi structured interviews in the Sizewell nuclear neighbourhood.

There were additional stakeholder organisations that were invited but unable to take part in the research. The Crown Estate were invited but declined to take part; the Marine Management Organisation (MMO) were also invited to take part but were not able to provide a participant for interview.

In practice, it was not always possible to enforce this sampling strategy. Interviewing comparative managerial individuals from each stakeholder organisation was not realistic. In part, this was down to practicalities of comparative individuals being available to take part in the research but in some cases the individual involved in the initiative no longer worked at the organisation. In these cases the most relevant and available individuals was interviewed. In total 30 interviews were conducted, in some cases more than one individual from the same organisation was interviewed, albeit representing different elements of the given organisations adaptation strategy.

5.2.5 *Interview preparation*

There are many methods that qualitative research studies employ to collect data from participants. Among the most frequently used are focus groups, questionnaires, and interviews. Each method of data collection has various advantages and disadvantages. It is important to determine which methods and techniques are most applicable to a given line of research.

Conducting focus groups provides a stimulating environment for participants to engage with each other and discuss topics of interest to the researchers. However, for the investigation of this study it was deemed an inappropriate method of data collection. This is due to the sensitive nature of coastal management in the neighbourhood surrounding a nuclear power station. The proposal of a NNB adds to and enhances this sensitivity. Some believe that when researching sensitive topics such as health, a focus group environment can gain insights that might not be accessible using other data collection techniques (Kitzinger 1995; Wellings et al 2000). However, the sensitivity of the NNB was not the focus of this study and it was deemed likely that discussions proposed in a focus group environment may veer off-track as the planning application process for the NNB is such a prominent topic for stakeholders in the neighbourhood. In addition, there are issues surrounding stakeholder salience; stakeholders possess varying degrees of knowledge and influence on the coast, having multiple stakeholders from different backgrounds and situations in the same focus group may lead to one stakeholder being more vocal or opinionated than others. This dynamic may in turn lead to some stakeholders withholding their opinions and concerns on certain issues surrounding coastal management and adaptation, meaning the data collected from a focus group might not be representative of the coastal management and adaptation dynamics in the nuclear neighbourhood. Unrepresentative data would decrease the overall validity of the research. In addition, it was deemed inefficient to coordinate numerous representatives, from varied stakeholder organisations, to meet in the same location at the same time as many individuals have busy schedules requiring them to frequently travel.

After discounting mass data collection events, with groups of stakeholders attending the same session, it was decided that individual data collection events would be more appropriate. Individual data collection events would allow sensitive and contentious issues, that might distract a group from the research topics, to be explored in a controlled manner. Various alternative options were identified such as distributing questionnaires, conducting telephone interviews and face to face interviews. Questionnaires were deemed unsuitable for the line of research as the complex and sensitive issues intertwined in coastal management cannot be fully explored and developed, largely as there is no direct interaction between the researcher and the participant (Kitchen and Tate 2000). In addition, questionnaires are known to have low completion and return rates (Sivo et al 2006).

The recent exponential growth of new forms of tele communication has led to increases in remote interviews (Opdenakker 2006), interviews can now be conducted long-distance using teleconferencing software such as Skype. Interviews via teleconferencing have become popular as they are are time and cost effective eliminating the need to travel to and from interviews (Randell et al 2015; Redlich-Amirav 2014). However, much like questionnaires, they do not enable a rapport to be built up between the researcher and the participant, meaning that data collected may not be as fruitful. Williams (2014) recognises the challenges associated with response rates and expresses particular concern regarding telephone interviews, asserting that an unfamiliar voice may cause an interviewee to disengage as they associate such with unsolicited sales calls. It was recognised in some cases telephone interviews may be necessary as it may not be convenient or possible for a face to face interview to take place given the time constraints and schedules of participants. In these cases an appointment was made to overcome hostility associated with cold calling. Conversely, Sturges and Hanrahan (2004) assert that telephone interviewing could be advantageous when researching sensitive topics as they feature a greater level of anonymity. Added anonymity could prove beneficial when talking to stakeholders about sensitive topics surrounding the NNB.

It was decided that face to face, one to one interviews were the most appropriate means by which to investigate the research questions. There are a various different classifications of interview styles. Patton (1990) identified four interview strategies which all varying in structure; i) closed quantitative, ii) structured open ended, iii) interview guide approach and iv) informal conversational. All interview techniques were considered for the data collection. The extent to which the interview was structured was the primary consideration. Conducting structured interviews enables direct questions to be asked and answered, interviews are able to be standardised between participants making analysis more straightforward (Kitchen and Tate 2000). However, a participant may not feel that they have had the opportunity to divulge the full extent their knowledge and experiences. On the other hand, conducting an interview without structure may lead to the participant veering off topic. It was for these reasons it was decided that a semi-structured interview technique was most appropriate interview style to fully investigate the research questions. The semi – structured interview format enables the participant to elaborate on specific questions asked, identifying new ways of seeing the research topic from a different perspective (Cohen and Crabtree 2006). In this way the semi-structured interview complements the GTM approach as emerging key themes, gleaned from detailed interviewee responses, were then used to update the interview template for the next round of interviews.

The semi-structured interview technique is frequently used in socially orientated research studies which explore planning, implementation and management of climate change adaptation initiatives (e.g. Baker et al 2012; Bauer et al 2012; Metcalf et al 2014; Park et al 2012). Conducting semi-structured interviews on a one to one basis enables a portfolio of stakeholders, often with polarised views on certain issues, to participate in the research in a neutral environment. The one on one format allows stakeholders to participate without being exposed to the discussed issue of stakeholder salience nor normative social influence (NSI), a type social influence that can lead to conformity. NSI is defined in social psychology as, the influences of other people that lead us to conform with them to be liked and accepted (Aronson et al 2005). The effect of NSI is often under-detected across a wide range of sectors (Nolan et al 2008) and is prevalent when addressing issues associated with climate change (Stern 2011). Adopting a one to one interview technique reduces this influence and, thereby improves the validity of the data collected. The semi-structured interview technique also enables the researcher to cover the same topic areas consistently from interview to interview but also allows additional information and thoughts to be contributed by the participant (Corbin and Strauss 2014). Semi-Structured interviews provide a fitting method to explore themes established in the literature and provide a platform from which new themes may be extrapolated from the data and queried.

Indicators thought to influence ‘successful’ climate change adaptation in the literature (Figure 2.8), were reflected in the first interview schedules. These include: the definition, classification and monitoring of ‘success’ (Moser and Boykoff 2013); the structure of climate change adaptation initiatives (Agrawal 2010); the extent of stakeholder collaborations (Few et al 2007); the effect extreme weather events have on the motivation to implement adaptation initiatives (Adger et al 2005); and motivations to initiate climate change adaptation efforts (Adger et al 2005; Grothman et al 2005).

Once the interview schedule had been developed, pilot testing was conducted in order to refine the interview schedule and delivery technique. This was undertaken in February 2014 with two researchers involved in similar coastal management projects in the UK. Conducting pilot interviews reduces the risk and uncertainty associated with the delivery of research projects. The selected methodological strategies can be tested before commencing data collection (Turner 2005). The pilot interviews ensured that the number of questions asked matched the time allocated for each interview (90 minutes maximum) and also ensured that the questions were worded in an appropriate style for participants. This stage in the methodology allows for modifications to be implemented, increasing the reliability of the data collected.

5.2.6 *Conducting semi - structured interviews*

Stakeholders were first contacted via email (Appendix 1), informed about the nature of the project, what their involvement would require and then invited to participate. It was not possible to interview comparative individuals from each stakeholder organisation as not all managerial stakeholders contacted were able to take part in the research. In these cases recommended alternative contacts within the same organisation or affiliated to the specific adaptation initiative were invited to take part. Upon agreeing to participate a date and location was organised. Face to face interviews were requested but this was not always possible. A telephone interview was offered as an alternative – this was the case for 14/30 interviews.

A consent form was issued to all participants (Appendix 2) before the start of the interview. Participants were informed of their right to terminate the interview at any point. Participants were also informed that their participation would be individually anonymised and should they not want certain comments to be transcribed they need only specify. All participants were aged over 18 years.

All interviews conducted with stakeholders taking part in the research followed the same format. Questions were grouped into sections regarding a particular line of enquiry. Due to the semi-structured nature of the interview not all questions were standardised from interview to interview as some stakeholders wished to expand on certain topics more than others.

At the start of the interview, participants were invited to elaborate on topics or introduce ideas and issues that have not been covered by the interview questions should they have information and/or views that they deemed relevant.

The first section of the interview schedule did not relate to the topics being explored but was a ‘warm up period’ in which participants were asked questions about themselves and whether they had any questions about the research as a whole. The ‘warm up’ section of the interview, although not directly relevant to the results, is important in making the participant feel comfortable and develops a rapport between the researcher and the participant (Longhurst 2003). The interview schedule was not necessarily followed in order, allowing the discussion to unfold in a conversational manner and permitting participants to raise issues they felt most important (Longhurst 2003). Interviews lasted approximately an hour with some interviews extending to two hours. To ensure that the research incorporated the maximum number of suitable participants the snowballing technique was applied (Goodman 1961), at the end of each interview participants were asked if there was anything else that they would like to add. They were also asked if they would be available to answer any follow up questions in the near future, and crucially in accordance with the snowballing technique, whether there was anyone else that they think should be contacted and invited to take part in the research. By this means the iterative rounds of semi-structured interviews were able to incorporate the network of stakeholders engaged in adaptation initiatives in the nuclear neighbourhood.

5.3 Qualitative data analysis

As prescribed by the GTM, data collection and data analysis were conducted simultaneously one informing the other. Figure 3.4 illustrates this process. As discussed in the proceeding section, semi-structured stakeholder interviews were conducted using an interview schedule (Appendix 3). Transcripts and field notes were then entered into computer assisted qualitative analysis software (CAQDAS) Nvivo 10 (2012) and emerging themes coded. The emergence of these key themes then informed the update of the interview schedule. This process was continuous throughout the data collection period. The remainder of this chapter discusses the processes and techniques adopted to analyse the data in accordance with the GTM approach.

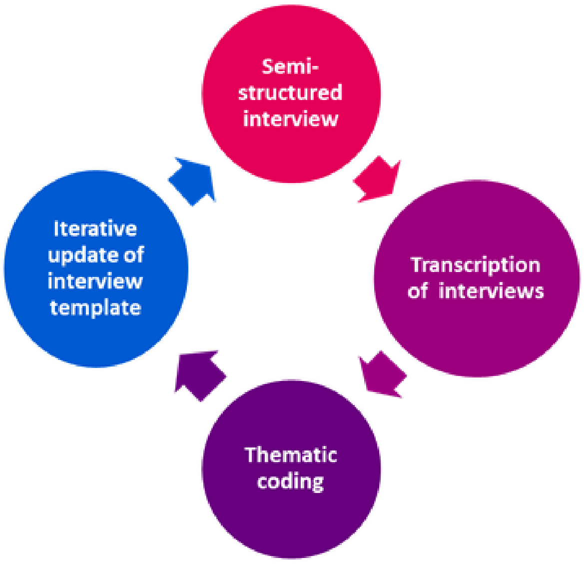


Figure 5.2. The Grounded Theory Methodology (GTM) data collection and analysis process.

5.3.1 *Transcription of interviews*

Interviews conducted during the data collection phase of the research were recorded using a Dictaphone and transcribed by hand into Microsoft Word (2010) by the researcher. In two cases, recording interviews was not possible as these interviews were conducted on site at nuclear power stations. For security reasons, a Dictaphone was not permitted. In these cases the interview schedule was followed and stakeholder responses were recorded via extensive field notes. Field notes were typed up in the same format as interview transcripts.

It is noted here that transcribing interviews by hand is laborious and time-consuming. Some may argue that outsourcing transcribing would enable more extensive data collection (Burke et al 2010). For example, Smith (2006) considers the values of outsourcing transcription paramount to reducing expenditure in the healthcare industry. However, due to the iterative approach employed by the GTM it is imperative that the researcher is familiar with the data and has an in depth understanding of key themes emerging in order to inform the proceeding phase of data collection (Figure 3.4). During the transcription process, the researcher tentatively coded the data reflecting key themes emerging from the stakeholder interview process. Transcripts were then imported in the CAQDAS NVivo10 (QSR 2012) for further analysis.

As the interview recordings were transcribed, repeated comments and nuances were noted manually before the transcript documents were imported into NVivo 10. These nuances formed the basis of the development of the six key themes (Section 5.6)

5.3.2 *Utilising NVivo 10*

CAQDAS has been aiding researchers for over 25 years (Barry 1998). Early CAQDAS programmes such as Atlas/ti and Nudist were met with trepidation by researchers. Initial concerns centred around the use of such computer software distancing researchers from their data, essentially leading to qualitative data being analysed in a quantitative way (Seidel 1991). These concerns stemmed from the complex nature of the coding processes in early CAQDAS developments (Weaver and Atkinson 1994). On the other hand, it was hoped that developments of such technology would help automate, speed up and thus ‘liven up’ the coding process, enabling the researcher to become more engaged with the data. Such technical developments provided a more complex way of looking at relationships in data hence aiding more conceptual and theoretical thinking. In addition, CAQDAS had the potential to provide a formal structure for writing and storing memos to develop the analysis of data (Barry 1998).

Early concerns surrounding the complexity of organising and coding data have now been overcome and recent updates in CAQDAS have provided the qualitative researcher in professional communications, with powerful tools to assist in the research process (Hoover and Koerber 2011). The latest CAQDAS, NVivo10 (QSR 2012) is regarded as a forerunner in qualitative data-analysis software and has been used in numerous environmental studies addressing topics surrounding the social implications of climate change. For example, Whitmarsh (2008; 2009) used NVivo in multiple studies to explore the behavioural responses of the public to climate change threats, investigating the relationship between intentions and actions as well as exploring disparities in public understanding of climate change. Similarly, Measham et al (2011) explore barriers and challenges experienced by community-based environmental planners when implementing climate change adaptation initiatives in Sydney, Australia. They employed NVivo to group the responses of participants of interviews into themes. In this study, multiple researchers conducted interviews and coded their transcripts individually. NVivo then enabled themes between researchers to be compared instantaneously. CAQDAS has also been employed in studies relating to nuclear power, climate change and radioactive waste. For example, Bickerstaff et al (2008) used NVivo to code transcripts from focus groups exploring how UK citizens interpret the reframing of nuclear power as part of the solution to mitigate GHGs whilst maintaining energy supply for an ever increasing demand.

Background research into the preceding applications of NVivo CAQDAS software deemed NVivo10 (QSR 2012) an indispensable analysis tool. Hoover and Koerber (2011) assert that analysing qualitative data using NVivo10 enhances the efficiency, transferability and transparency of research. These qualities are very much necessary when investigating the complexities of a 'wicked' problem such as climate change adaptation. As such, NVivo 10 has been used throughout this study to enhance analysis of interview transcripts aiding the development of key themes emerging from the data collection.

Interview transcripts were imported into the NVivo 10 programme. Each interview file was labelled by organisation in the chronological order the interviews took place. This is important to note as key themes that emerged as the interviewing process advanced, informed the update of the interview template. Hence, interviews taking place later in the data collection process faced a more developed and specific interview template.

Initial records of the emergence of themes within the data were noted when the researcher transcribed. This was an important step in the data analysis as it enabled the researcher to fully engage with the collected data. It is deemed necessary that the researcher is familiar with the content of their data to fully utilise the tools of CAQDAS in further analysing key themes and relationships (Barry 1998).

Key themes found within the data collected are represented in NVivo 10 as 'Nodes'. Nodes can be created and colour coded for each emergent theme. Key themes contributing to or inhibiting the 'successes' of adaptation initiatives were highlighted in the transcripts. The development of said 'nodes' were then used to inform and update subsequent interview templates. The key themes are as follows: i) decision timescales, ii) perceived responsibility, iii) units of governance, iv) response to climate shocks, v) knowledge flows and vi) evolution of partnership working. Each of these themes will be further elaborated in the results sections 5.6.3 - 5.6.8 and then discussed in section 5.7.

As the data collection/analysis phase of the research progressed, the complexity of key themes increased due to the data collected becoming more diverse, encompassing more stakeholder organisations and perspectives. To reflect this complexity 'sub-nodes' were created under key themes. To illustrate this, the key theme *decision timescales* a 'parent node' has multiple aspects by which stakeholder organisation relate and interact with the theme. For example, whether an organisations decision are made on a 'visionary' basis of the future or determined by 'operational' practices. In this case 'visionary' and 'operational' comprise sub-nodes within the parent theme of *decision timescales* (Figure 5.3).

5.3.3 *Thematic coding*

Following the GTM, thematic coding of interview transcripts took place as the data was collected creating an iterative coding process. During the transcription, of stakeholder interviews initial observations were noted. Once the data had been imported into Nvivo 10 these observations were coded. It is recognised that there are various types of coding: descriptive (which denotes attributes of the source), thematic (which outlines key topics within the data) and analytic (which attempts to define patterns and determines how they could be interpreted) (Edhlund and McDougall 2012). However, there is no standard process for coding and extracting themes (Dixon 2014).

Figure 5.3 illustrates the coding matrix that was produced from the iterative GTM process of simultaneous data collection and analysis. The six key themes are displayed as 'parent nodes' with a variety of subsequent 'child nodes' associated with the key theme. The 'child' nodes either refer to the range of stakeholder responses or the factors influencing such responses. There are an additional 10 nodes that were created in the coding analysis process (Figure 5.3). These nodes represent additional factors that affect a stakeholder organisations position on the six key themes. It is recognised that the matrix for the coding system is chaotic. This is a result of the iterative process of the GTM employed for the research, as analysis iterations progressed some nodes became more prominent than others.

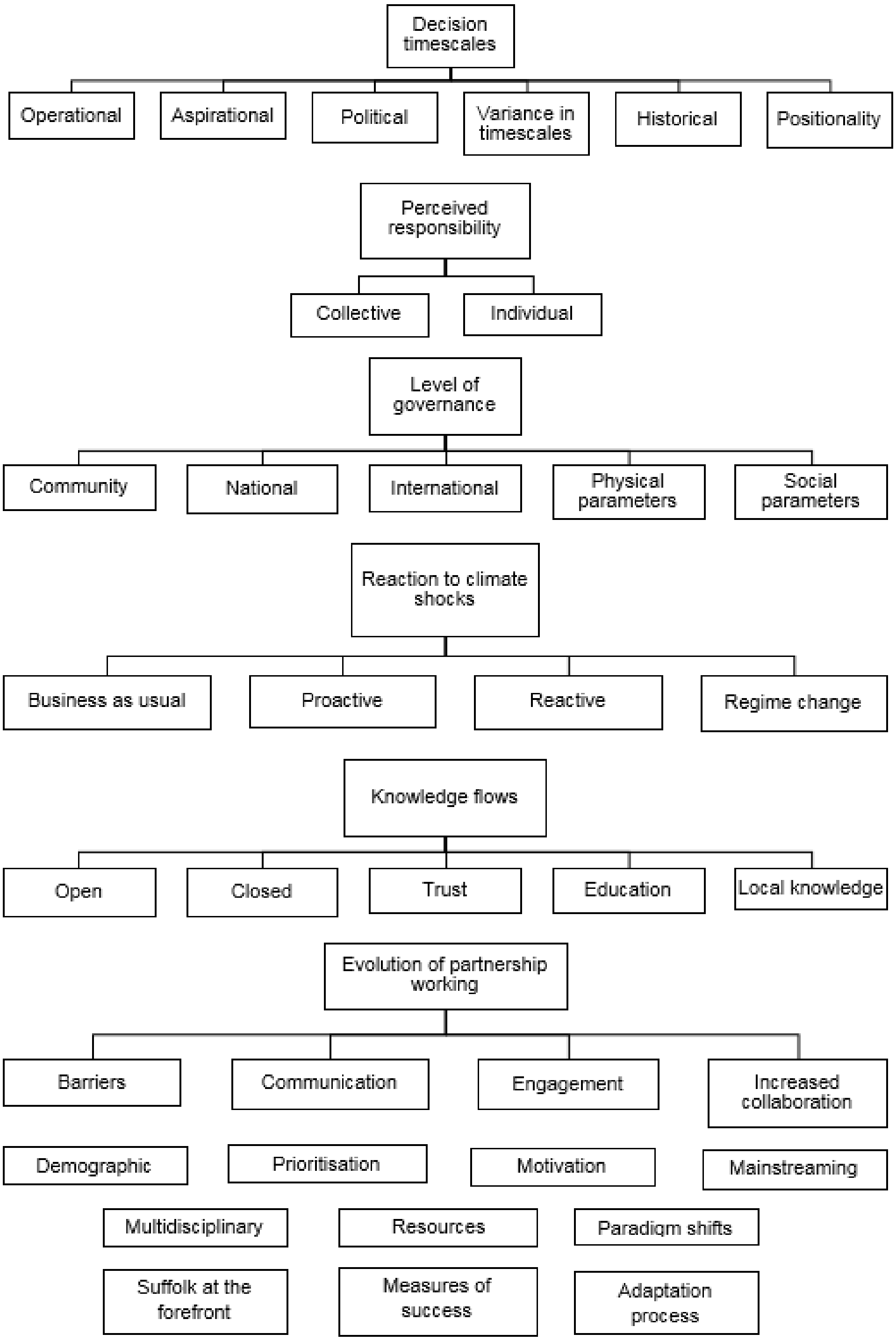


Figure 5.3 Nodes of thematic coding from stakeholder interview analysis in the Sizewell nuclear neighbourhood, Suffolk, UK.

5.4 Emergence of shared stakeholder opinions

As the interview process advanced, key themes became increasingly established with common opinions being expressed repeatedly by different groups of stakeholders. It is important to recognise such shared opinions across stakeholder organisations throughout the data collection period as they may form the basis for advice and guidance for the future multi-organisational management of the coastline With reference to the water management industry Phal-Wostl (2002) assert that recognising the value and nature of different stakeholders is becoming crucial as environmental management is becoming more polycentric incorporating the views of multiple stakeholders. Recognising and categorising stakeholders based on mutual opinion/positionality into groups is a common analysis process in qualitative research. These groups are known as stakeholder thematic networks (STN's). It is recognised here that not all stakeholder organisations hold the same opinion on certain issues. The grounds of differing opinions are explored in the discussion (Section 5.7). The term STNs is interchangeable with 'stakeholder groups'. The term stakeholder groups is used from here onwards for ease of reading.

Stakeholder groups were flagged in NVivo10. Such categorisation adds a further dimension to the research and another platform for analysis. Enabling qualitative information to be analysed through semi-quantitative mapping of relationships, allows the networks and scales of linkages to be visualised (Ziervogel and Downing 2004). Interactions between stakeholder groups and social capital with reference to facilitating climate change adaptation initiatives is increasingly being researched on an international scale (e.g. Adger 2001; Adger 2010; Bauer and Steurer 2014; Downing et al 2005). The use of stakeholder groups enables the networks of stakeholders in the coastal environment to be compared with other neighbourhoods addressing coastal management practices or the potential impacts of climate change. Enabling comparison between stakeholder groups could lead to the development of recommended 'best practice' advice when implementing climate change adaptation in coastal localities in general.

5.5 Completion of data collection

Data collection was considered completed when a ‘saturation’ point was reached. At 30 completed interviews this was the case. The saturation point can be identified as when key themes are repeated by stakeholders with no novel ones emerging (Bowen 2008; Guest et al 2006). At the end of each interview participants were asked who else, if anyone they thought should be invited to take place in the research. At saturation point the same names were repeated and had either taken part in the research or did not wish to.

All recordings and transcripts were individually anonymised to the organisational level and kept under password protection in accordance with the Data Protection Act (1998).

5.6 Results: Key attributes impacting adaptation ‘success’, in the Sizewell nuclear neighbourhood, Suffolk, UK

This results section outlines the key findings from semi-structured interviews conducted with stakeholders involved in coastal management and climate change adaptation in the Sizewell nuclear neighbourhood, Suffolk, UK.

As anticipated, the iterative approach prescribed by the GTM produced a wealth of information and knowledge, from experienced individuals, representing various stakeholder organisations. The semi-structured nature of the interviews meant that stakeholder responses were not standardised in nature and therefore not directly comparable. Stakeholder interviews produced a complex web of interlinked issues thought to influence the adaptive capacity of organisations in the Sizewell neighbourhood. It is recognised here that there are difficulties associated with presenting such non-linear concepts in a systematic way (Garner 2013).

To convey these intricate issues with clarity, the results first describe the presence of stakeholder groups present in the nuclear neighbourhood (section 5.6.1). Stakeholder organisations share the same opinions as other organisations in the same stakeholder group (Section 5.6.2).

Analysis of the interview transcripts revealed six key themes that have the potential to govern the 'successes' of climate change adaptation efforts. Before presenting the stakeholder groups, evidence of the following six themes is presented:

i) *Decision timescales* refer to the time periods on which stakeholder organisations view the future and act;

ii) *Perceived responsibility* refers to the opinions of stakeholder organisations as to who is responsible for leading, funding and implementing climate change adaptation;

iii) *Units of governance* refers to the structure governing adaptation to climate change;

iv) *Response to climate shocks* refers to the ways stakeholders may change their behaviour and adaptation actions in response to an extreme weather event;

v) *Knowledge flows* refers to the ways in which stakeholders share knowledge of the potential impacts of climate change and subsequent implications for adaptation and;

vi) *Evolution of partnership working* refers to the extent to which stakeholders in the nuclear neighbourhood work in collaboration.

The way in which a stakeholder organisation interacts with a key theme largely depends on which stakeholder group the organisation belongs to. Stakeholder standpoints and interactions with each theme appear to vary (Table 5.2). Results revealed 12 influential factors that affect such interactions and standpoints. Some of these factors have been identified by others and are outlined in the literature review (Chapter 3, section 2.9).

5.6.1 *Stakeholder groups*

During the data collection period of the research, participants' responses to questions asked in the semi-structured interviews collated into both similar and polarized viewpoints.

Common opinion, experiences and knowledge, expressed by representatives of stakeholder organisations, collated naturally into clusters regarding the key themes of enquiry. Six stakeholder groups emerged; 1) Statutory agencies (Competent authorities), 2) Non-governmental organisations (NGOs), 3) Local government, 4) National Government, 5) Commercial entity, 6) Community groups (Figure 5.4).

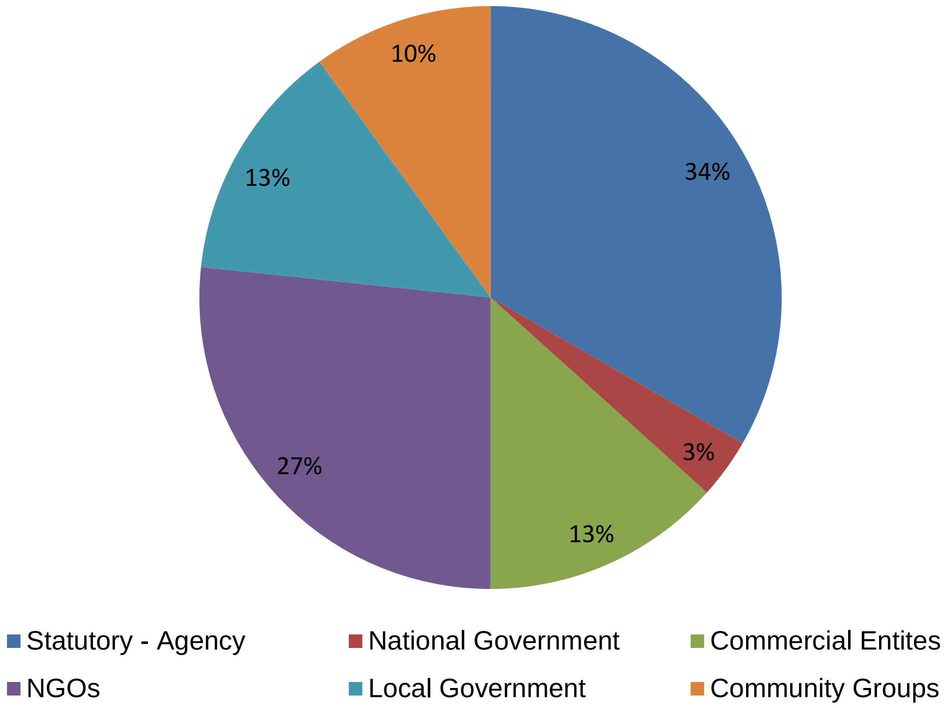


Figure 5.4 Stakeholder groups regarding climate change adaptation in the Sizewell nuclear a neighbourhood, Suffolk, UK.

The 30 semi-structured interviews included 16 stakeholder organisations all with varying priorities and remits regarding coastal management and adaptation to climate change. Figure 5.4 illustrates the six groups around which stakeholder opinions gathered (Table 5.2).

Stakeholder Groups	Stakeholder Organisations
Commercial Entities	EDF Energy (EDF)
Community Groups	Alde and Ore Estuary Partnership (AOEP), Suffolk Coast Against Retreat (SCAR). Deben Estuary Partnership (DEP), Minsmere Levels Stakeholder Group (MLSG).
Local Government	Suffolk Coastal District Council (SCDC), Suffolk County Council (SCC), Waveney District Council (WDC), Regional Flood and Coastal Committee (RFCC).
National Government	Committee on Climate Change (CCC)
NGOs	Royal Society for the Protection of Birds (RSPB), National Trust (NT), National Farmers Union (NFU), Area of Outstanding Natural Beauty (AONB), Suffolk Wildlife Trust (SWT).
Statutory – Agency	Environment Agency (EA), Natural England (NE).

Table 5.2 Stakeholder organisations categorised by stakeholder group

5.6.2 *Range of stakeholder standpoints regarding the six key themes governing pathways to 'successful' climate change adaptation*

Upon analysis of the interview transcripts, results illustrated that the opinions and experiences of different stakeholder groups either collated or became polarized resulting in a range of standpoints.

Table 5.3 demonstrates the differing ranges of standpoints regarding the six key themes recognised to affect the 'successes' of climate change adaptation efforts.

	Key themes	Range of stakeholder standpoints
I.	**Decision timescales**	Operational to aspirational
II.	**Perceived responsibility**	Ownership of the issue (Collective to Individual)
III.	**Units of governance**	Social vs physical including appropriate spatial scale
IV.	**Response to climate shocks**	Business as usual to transformational change
V.	**Knowledge flows**	Open/permeable – closed
VI.	**Evolution of partnership working**	Silo to collaboration

Table 5.3 Range of stakeholder interaction to the key themes governing 'successful' adaptation in the Sizewell nuclear neighbourhood

The range regarding i) *Decision timescales* centres on the type of timescales over which stakeholders make decisions and whether they are instigated from an aspirational or operational viewpoint. Regarding ii) *Perceived responsibility*, the scale refers to the degree to which stakeholders take ownership of the need to address climate change by implementing adaptation initiatives. The scale relating to iii) *Units of governance* refers to the means by which coastal management and adaptation is bounded either socially or physically, ranges from the coastal cell to national and international governance systems. Regarding iv) *Responses to climate shocks* the scales of stakeholder reactions range from a business as usual – where no changes in the operations or functions of the organisation is observed to total transformational change where the mandates of an organisation and operations significantly change. The scale related to v) *Knowledge flows*, refers to the transparency and openness of stakeholder organisations, the extent to which they are willing to share knowledge that may aid adaptation with other stakeholder organisations in the nuclear neighbourhood. Finally, vi) *Evolution of partnership working*, refers to the extent that a stakeholder organisation works with others in their efforts to implement climate change adaptation.

For each of the key themes presented (Section 5.6.3 to 5.6.8), a diagram outlining the concept of the theme is provided. Each diagram presents the key theme, outlines the range of stakeholder interaction below and then influencing factors the influencing factors affecting the standpoints of each stakeholder group.

5.6.3 *Decision timescales (Operational to aspirational)*

The first of the six key themes that stakeholders expressed had an influence on the success of climate change adaptation efforts, are the timescales over which stakeholder organisations make decisions (Figure 5.5) (Research question 6).

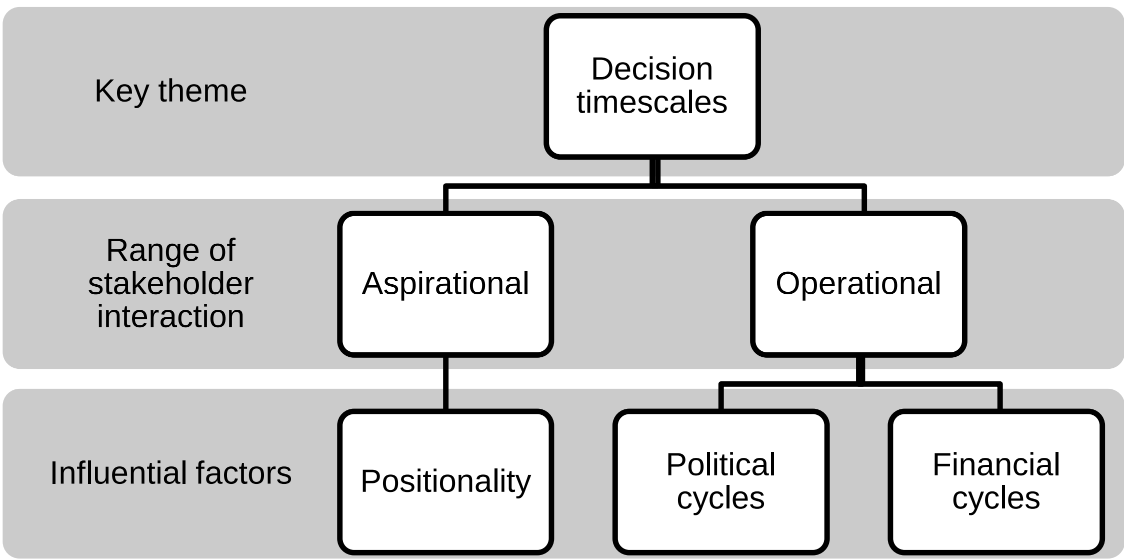


Figure 5.5 Concept outlining the theme of decision timescales

Results from the semi-structured interviews indicate that there are multiple dimensions to decision timescales. The range of stakeholder responses varied along two conceptual functions of time; *aspirational* and *operational* (Figure 5.5). Aspirational decision timescales refer to the farthest time horizon (years from present) a given stakeholder organisation considers. These timescales represent the agenda and capabilities of stakeholder organisations when considering the potential impacts of climate change. Operational decision timescales refer to the practical time horizons that reflect the functioning of a given stakeholder organisation. Operational timescales therefore define the timeline by which practical day-to-day adaptation occurs (Figure 5.5).

All six stakeholder groups expressed that coastal management decisions and adaptation initiatives are made with both aspirational and operational time horizons in mind. Results illustrate that both the operational and aspirational decision timescales of stakeholders collate into groups (Figure 5.6). Note, there are only 12 stakeholder organisations present in Figure 5.6. This is because four stakeholder organisations did not speak sufficiently about decision timescales.

Results from semi-structured interviews indicate that stakeholders exhibit different aspirational time horizons (ATHs) (Figure 5.6). Statutory agencies, national government and commercial entities exhibit the most far-reaching ATHs; these three stakeholder groups exhibit aspirational timescales of 80 to 100 years into the future. Results illustrate that the ATH of NGOs and local governmental are less far-reaching typically on a 40 to 60 year timescale. Community groups represent the shortest ATH however, the ATH of these groups feature the greatest range, from ~5 to 35 years into the future (Research question 5).

When examining the operational time horizons (OTH) of stakeholders organisations results indicate that unlike the ATH all stakeholder organisations operate on similar timescales (Figure 5.6). OTH for all stakeholder groups are limited to ~5 years into the future.

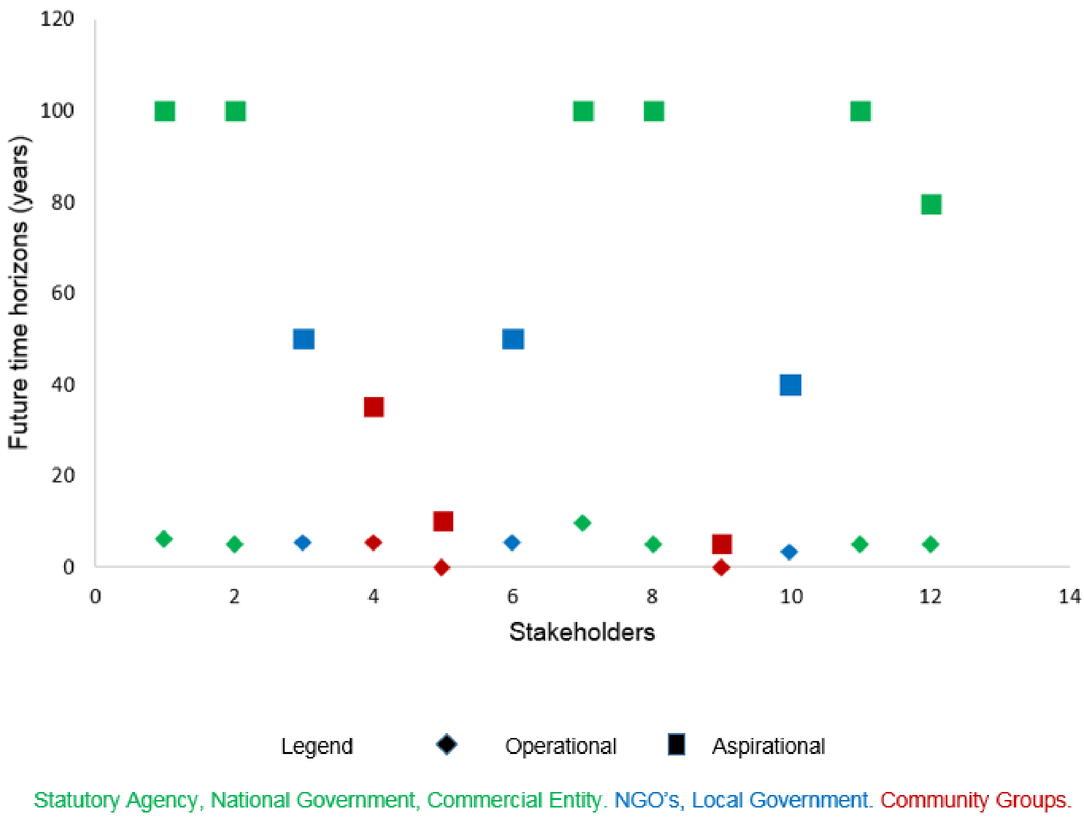


Figure 5.6 Aspirational and operational decision timescales of stakeholder organisations in the Sizewell nuclear neighbourhood

Analysis of the interview transcripts revealed that the functioning of financial and political administration systems can inhibit the adaptive capacities of stakeholder groups by limiting their OTH when addressing climate change adaptation. Some stakeholder organisations expressed that short OTH focused and sharpened organisational objectives. A representative from one local government organisation asserted:

'There are no guarantees of funding but it sets out an objective to how that part of the coast should be managed'. SCDC

Similarly, a representative from a statutory agency revealed:

'We are given money and they [government] try to give us a three year financial planning horizon and they will say okay, for the next comprehensive spending review you are going to get this much money to spend doing these kind of things and there is no negotiation'. EA

The preceding assertions point to financial cycles as inflexible, constraining stakeholder organisations when attempting to implement adaptation initiatives. A representative from an NGO expressed concern that such short-term inflexibility could lead to maladaptation:

‘you end up with some stupid investments coming towards the end of the year because if you don’t spend your money you have to give it back which doesn’t make people use their money in the wisest ways’. RFCC

In addition, a representative from a statutory agency asserted that short OTHs inhibit ATHs to a maximum of 10 years:

‘We use different timescales for different things. Our long-term investment strategy is over five years but we are also trying to do scenario planning… so we have done a whole load of work on coastal management plans with local authorities using three epochs, up to 40, up to 100 and up to 200 years. So we are familiar with the territory, we are familiar with all that stuff but I think if you actually look we are mostly working in a maximum of a five to 10 year horizon’. EA

Interviews revealed that it is not just financial systems that inhibit climate change adaptation. Political timescales also affect the OTHs of stakeholders. For example, both statutory agencies, operating on a national scale and NGOs, working at a local scale, expressed the following:

‘Most people don’t think beyond 5 years really, they work in election timescales and people just think in terms of political timescales, immediate timescales. In terms of adaptation it is an issue, the DEFRA pathfinder has found through investigation that people don’t necessarily consider themselves at risk until it is really staring them in the face’. EA

‘More nationally we have the political four to five year timescales which can mean it is difficult. We would hope that we would have a statutory remit and we are in place for that but there is always a challenge working with these things [adaptation] working on political cycles’ NE

'Without wanting to get too philosophical you know politicians, because of the structure of democracy, frankly politicians naturally think short-term. You know that climate change is a long-term thing, so there is the real issue there'. RSBP

The same concerns regarding the influence of political timescales are also present at the local level. Representatives from both NGOs and community groups in the Sizewell neighbourhood expressed:

'…the other thing is that the locally appointed officials, most of them are happy to stay here but the local MPs are looking for a promotion somewhere else and this is just a 5 year cover'. MLSG

'I fear we get the politician we deserve. I do not think that politicians think beyond the next election overall. Certainly the ones with any power don't'. AONB

As established in the literature review (Chapter 2, Section 2.9), climate change adaptation is a complex and multidisciplinary societal issue. Results from the semi-structured interviews support this notion, highlighting that financial and political cycles are inherently linked and simultaneously influence the OTHs of stakeholder organisations. Representatives from the environmental sector find financial and political cycles particularly restrictive of their mandates. Environmental organisations from both NGOs and statutory agency stakeholder groups expressed the following:

'Funding has to work on political cycles and that has an influence on the way we work year to year' NE

'I think the short-term bottom line is always seen by politicians and business people and the long-term benefits are not being realised' RSPB

Although viewed as limiting, financial and political systems standardise the OTHs between stakeholders (Figure 5.6). A stakeholder representing a NGO asserts the following regarding OTHs:

'*It is a good period of time because as long as goals are set up to be achievable it is seen to be the first phase of a longer plan. I think people can accept that, they can see that 5 years is just down the road and can say that is where we want to be then'* NT

Interview analysis revealed that the ATHs are largely subjective and influenced by positionality of stakeholders. Results indicate three components that contribute to the overall positionality of a stakeholder organisation: i) comprehension ii) world views and iii) awareness of others. The following quotations illustrate that there is a realisation amongst stakeholder groups that extreme long-term ATHs are difficult to comprehend:

'If you are looking at 80 – 100 year that is sort of achievable in your mind. I think that this is some of the argument for longer-term plans. I think that people find it very difficult if you are talking in 500 years'. NT

'It is too bigger picture for people to grasp and for society to manage, especially politicians who have a five year window or so, so what do they know and what do they care? Even if they care it is very difficult to understand' Consultant to Sizewell B

'I think that 100 year plans and a 500 year plan are a good things but we have to accept that what you are planning might be utter rubbish by the time we get to 100 years' NT

World views also contribute positionality. Results indicate that there is a perception between stakeholders in the Sizewell neighbourhood, that world views limit ATH to the length of a lifetime. A representative from a statutory agency asserted the following:

'I have been in meetings and discussions where communities have openly said we are only interested in the next 40 – 50 years as we won't be here beyond that and that is their prerogative really'. NE

Interviews revealed that stakeholders' world views directly affect the success of adaptation schemes in the Sizewell nuclear neighbourhood. Referring to a relocation scheme on the Suffolk coast, an interviewee reported that only 50% of the vulnerable population decided to take part in the scheme. The scheme enables residents whose houses are at risk of falling off the cliff top, as a result of erosion, are offered a piece of land inland as compensation:

'Some of the reasoning behind that was to do with people ages because if you were in your 70s you'd probably think that the house is going to be good for another 20

years and I wouldn't be here after that so I won't do it… there is still quite a lot of resistance to the idea that we won't defend at all costs'. NT

This world view is then explained by a representative from a community stakeholder group:

'It depends how old you are and it depends on what kind of personality you are...we will range from people who are exactly the same age but who take completely polarised views about the future… I have got grandchildren and so it is easy for me I can see 50 years hence easily because I look at the girls and I can see that they will be 60 in a jiffy. 50 years from now I will be long dead but they will only be 60, younger than me now and yet some people think that 50 years is a long time '. SCAR

Another fundamental factor affecting the ability of stakeholders to successfully manage a changing coastline is an awareness and appreciation of the timescales over which others operate. Results indicate stakeholder have a varied awareness of others. For example, stakeholders from both statutory agencies and NGOs expressed awareness stating:

'I think you have to be patient with different scenarios and different groups and different timescales I suppose' EA

'Everyone is working flat out doing what they are doing but no one is stepping back and having a look from afar if you like' SWT

However, other NGOs and commercial entities expressed a lower level of awareness of others:

'*I think that the AONB certainly aspires to think long-term, I think the NGOs are better at thinking long term. I think that with the local government it is more difficult'*. AONB

'The RSPB have long-term ambitions for the site, they think in terms of 50, 70, 100 or more years. The only other organisation to think in these timescales is us'. EDF

Figure 5.6 shows that the local government and NGOs work on the same timescales regarding climate change adaptation and that in addition to commercial entities both national government and statutory agencies think of ATH in the region of 100 years.

Finally, interview analysis has revealed that the possibility of a NNB at Sizewell has increased awareness of the need to plan for the long-term management of the coast.

'*One of the things that Sizewell C has done is inadvertently triggered a conversation about the long-term future of the Minsmere valley'*. NE

5.6.4 *Perceived responsibility for climate change adaptation (Ownership of the issue. collective to individual)*

Another theme that arose from the semi-structured interviews was perceived responsibility – who do stakeholder organisations regard responsible for climate change adaptation in the nuclear neighbourhood? The range of stakeholder interaction centres on taking ownership of the issue – whether stakeholders believe that responsibility is individual to each organisation or collective, to be shared between all organisations (Research question 5). Interview analysis indicates three influential factors affect how stakeholder groups perceive responsibility for adaptation: financial capital, empowerment through decentralisation and the government's localism agenda and the degree of empathy shown towards the adaptive capacities of others (Figure 5.7).

As previously mentioned, all six themes are inherently interlinked. It must be noted here that the theme of perceived responsibility is directly interlinked with the evolution of partnership working (Section 5.6.8).

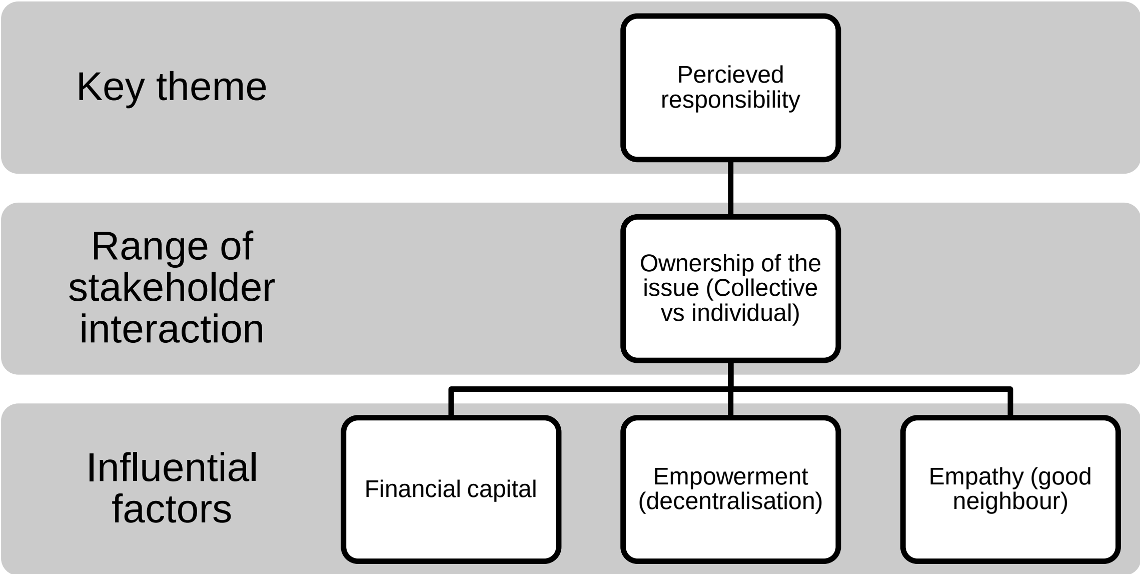


Figure 5.7 Concept outlining the theme of perceived responsibility

Results indicate that stakeholder groups operating on a local level believe that adaptation should be a collective endeavour. Representatives from statutory agencies and NGOs asserted the following regarding collective responsibility:

'I would say that it is collective; I think that we are all responsible because we all contribute to it [climate change] in one form or another and we are all affected by it' NT

'My sense is that now everyone accepts that it is a collective responsibly' NE

Interviews highlighted that an acceptance of collective responsibility insights a level of confusion between stakeholder organisations as they are not aware exactly what role they should fulfil. A representative from a community group in the Sizewell neighbourhood states:

'The EA and the landowners are responsible for a number of drains and the EA is responsible for the defences but we have meetings about who should do what and whose money we use'. MLSG

Interviews revealed that the government's decentralisation policy, coupled with decreases in central sources of financial capital, empower stakeholders in the coastal zone to take collective ownership of the need to implement adaptation. Representatives from statutory organisations, who have experienced significant funding cuts, expressed the following regarding decentralisation and increased empowerment of local stakeholder groups:

‘Yes I think there is always a bit of a tussle between the policy and the implementation of things. I think we are generally moving in the right direction towards people taking more ownership and understanding the accountability and responsibility that goes alongside empowerment’ EA

‘Local communities want to galvanise themselves as they realise that the government for whatever reason cannot and won’t pay for flood management, coastal erosion and protection or adaptation’ NE

What I would say is that it has moved with the times whereas 6 or 7 years ago the expectation was that the government should pay, full stop, no negotiation. There is now recognition and I think I would say general acceptance that this is no longer the case and if people want continue to be protected then there has to be some funding coming from those people who benefit’ EA

‘Funding of coastal management is changing whether people like it or not. It means that if local people want protection from flooding and erosion they are going to have to pay for it themselves’ NE

Semi-structured interviews have revealed that, decentralisation and the recent economic climate, has heightened the awareness of the adaptation capacity of each stakeholder group. Interview analysis revealed that stakeholder organisations vary in the degree of empathy shown to others. The following quotes illustrate that stakeholder groups that have either experienced financial cuts or do not have a guaranteed financial capital, namely statutory agencies and NGOs, accept collective responsibility for adaptation more readily, looking to stakeholder groups that are perceived to be more affluent (commercial entities), for support:

‘I think that things are going to be very tight. I cannot see the money coming from anywhere else at the moment and I think there is a big hope that EDF are going to dig deep into their pockets and do things to help like in Minsmere and things like that. They probably don’t need to as they can defend their little island and they are going to be fine so quite where that money is going to come from, I don’t know’ SWT

'A planned adaptation, you know that is a lot of work and at the moment the EA do not have the money to help us with modelling and or whatever is required. EDF certainly do but at the moment we have had no success with influencing them to help us with adaptation' RSBP

Commercial entities responsible, for developing the NNB, are perceived to have the resources to lead on efforts of collective responsibility for climate change adaptation in the nuclear neighbourhood:

'Money, I think they know that they have enough money to deal with every eventuality'. Consultant to Sizewell B

However, there is a perception that they are reluctant to show empathy to neighbouring stakeholder organisations, declining to share collective responsibility for the adaptation of the nuclear neighbourhood as a whole:

'The statutory obligation of Sizewell B – there is a 10 year review cycle of safety cases. They're not too concerned about the sluice or anything off the Sizewell B site'. Consultant to Sizewell B

'They have got to manage their own resources to adapt and how they manage those resources and at what rate, if they put more effort into Minsmere they are putting less effort in somewhere else. They have got to judge the balance of that'. EDF

Despite a reluctance to accept collective responsibility, it appears that commercial entities are unaware of how they are perceived by other stakeholder groups:

'I happen to think that we are very good neighbours we try very hard to not disturb what is going on to the north of us and we try very hard to live alongside' EDF

5.6.5 *Units of governance (Social vs physical including appropriate spatial scale)*

One of the themes deemed to affect the success of adaptation in the coastal zone centred on the most appropriate units of governance. The 'units' by which the coastal zone is governed refers to politically defined entities such as council constituencies, on the one hand, and physical boundaries such as sediment cells on the other (Research question 9). Interview analysis revealed three influential factors that shape the opinions of stakeholder groups regarding the most appropriate units of governance: the effect of political systems, intellectual capital and financial capital (Figure 5.8).

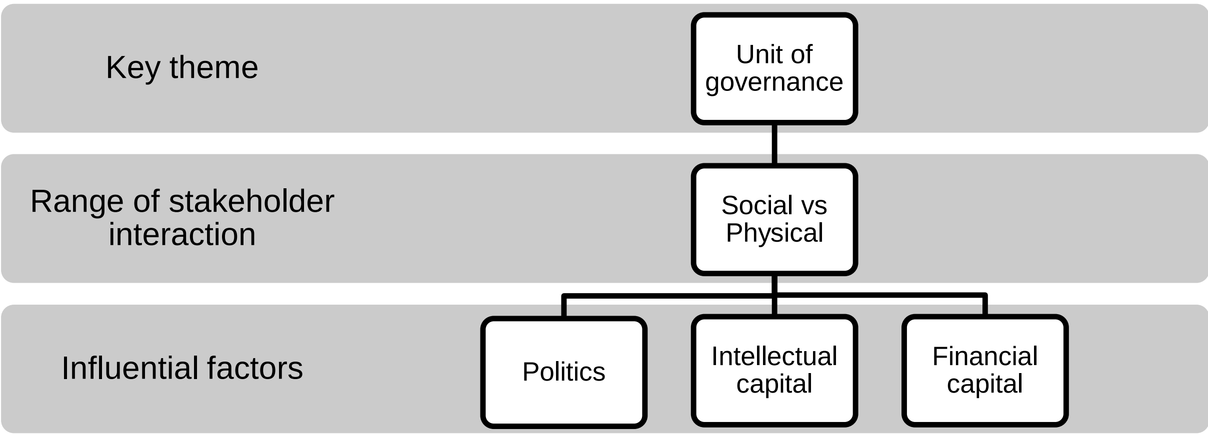


Figure 5.8 Concept outlining the theme units of governance

Interview analysis revealed a substantial awareness, across all stakeholder groups that the Suffolk coastline features complex sediment systems and a subsequent belief that the physical functioning of the coast must be incorporated into coastal management and adaptation strategies. The following quote from a statutory agency representative illustrates this:

> *'… a soft coast, which has very high energy and is a very dynamic, has exposed open coast which also has valleys attached to it, within which there are coastal wetlands. Management is about what it means to make sure that the coast can still support wildlife for as long as possible but also do that in a way that acknowledges that the coast is dynamic and we all have to plan for change'.* NE

A representative from the local government also expresses awareness and concern that physical processes are not adequately integrated into coastal management policies:

‘If you defend one section you have implications north and south and we don't think that has been taken sufficiently into account’. SCDC

Similarly, an advisor to Sizewell B explains that coastal physical systems span international boundaries and do not superimpose onto socially bounded governance systems:

There should be an international approach; I have been seeding all my working life for an international approach. For example, Holderness is a great pile of glacial sediment that is eroding into the sea and is eroding at a couple of meters a year… the Thames relies on Holderness for its mud as that is where it all comes from. It is a major source… it has to be [management] international as coastal systems don't reflect political divisions’. Consultant to Sizewell B

Supporting this assertion, a representative from a statutory agency also highlighted that socially constructed coastal management boundaries do no match the physical functioning of coastal systems:

‘The EA manages flooding, the local authorities, district authorities and unitary authorities up the coast manage coastal erosion, it is an odd and historic split and obviously it is odd as those two processes are often linked in a coastal processes sense so you often have cutting the cake in a slightly arbitrary way’. EA

Interview analysis has revealed that although there is widespread awareness of the importance of physical systems between stakeholder groups locally, this level of awareness does not extend to central authorities. Stakeholders in the Sizewell neighbourhood are concerned that central government does not consider the social or physical processes involved in coastal change in sufficient detail. A representative from an NGO expressed:

‘I think the government, by which I mean central government, irrespective of political party, the whole operation, politicians and DEFRA, I don't get the sense that they actually understand the size of the challenge and complexity of the challenge, I just

don't think that they get it and unfortunately there are no signs that they are getting it'. AONB

Stakeholder interviews revealed that there are frustrations between stakeholder groups regarding the means by which coastal management and adaptation governance is bounded. Some stakeholders believe that coastal change should be bounded purely by physical processes and administered centrally:

'I think the whole thing needs to be planned centrally. The SMP do try to get over the problem of localism but then they break it down into sub cells and management units. The management units have no respect for the sediment flow. I think that there is a mismatch between the sediment cell idea of continuity and the development and management unit side of things'. Consultant to Sizewell B

Some appreciate the social challenges associated with central management and the SMP:

'It is easier said than done because some cliffs are allowed to erode because the sediment released is then free to provide more protection somewhere else'. NE

Whereas others believe that both social and physical elements should be incorporated and financial resources dedicated equally to both units of governance:

'I have this thing that I call the 50/50 rule, which is, for all the money and resource that you might want to put into a project on the kind of the physical science side, understanding the coastal processes or understanding wave dynamics or whatever it is actually you need. You need to have a similar amount of investment put into doing the community engagement side of things'. NT

5.6.6 *Response to climate shocks (Business as usual – transformational change)*

In light of the severe winter storms experienced on the south east coast of the UK in winter 2013/2014, stakeholder organisations were asked if extreme climatic events change how their organisation operates regarding adaptation. Stakeholders were asked if their organisation had enacted any changes in the way they operate or if it was 'business as usual' (BAU) (Research question 10). Results indicated that stakeholder preparedness, positionality and the legacy of an extreme event influence how stakeholder organisations react to extreme events (Figure 5.9).

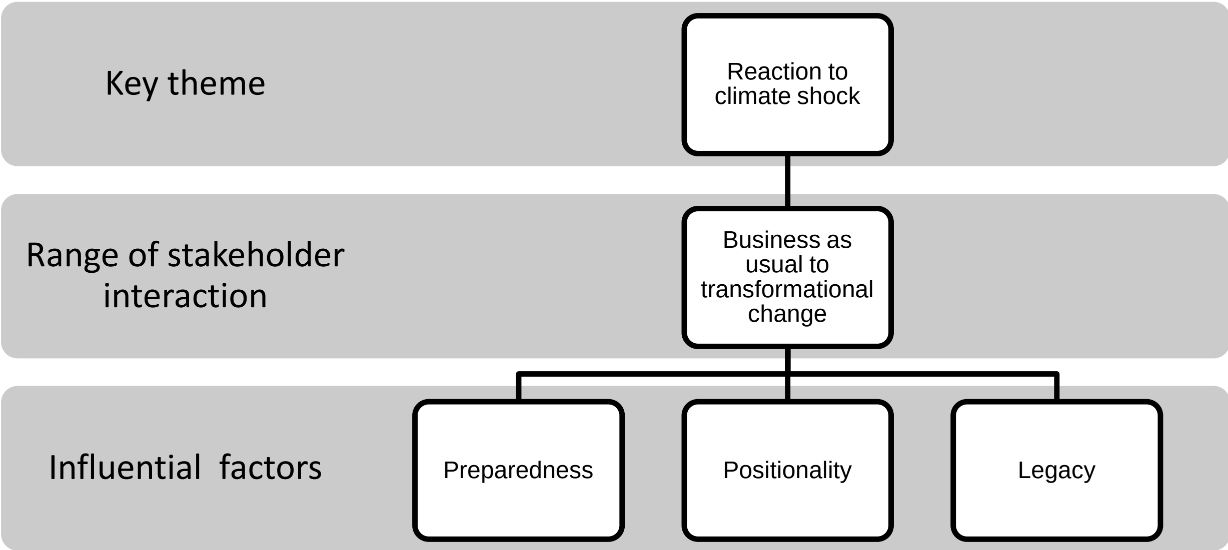


Figure 5.9 Concept outlining the theme of response to climate shocks

Semi-structured interviews revealed that formally established stakeholder organisations tend to adopt a BAU approach to adaptation after extreme events. Interviews revealed that there is little evidence of organisational transformation at this level. When asked if their organisation had changed anything about the way it operates after the winter storms of 2013/2014 stakeholders reported that an awareness of the possibility of the occurrence of extreme events meant they were prepared. Representatives from statutory agencies and NGOs expressed the following:

'I don't think there has been any substantial change. We are acutely aware of the risk in the Suffolk patch and we know where our greatest challenges are and where to expend our capital so I don't think it has caught us unaware or anything like that. I think that we knew that there was going to be a big storm at some time and it happened and we warned and responded accordingly'. EA

'No because we had already got that in our minds and we knew we were going to have an event and if you manage the site long enough it happens every nth year. 'We can usually predict the effect of the surges before we get the call from the EA as we know the way the sea behaves'. SWT

'So we have always been quite realistic about how we are going to adapt to climate change so from our point of view it probably hasn't changed much'. RSBP

However, some stakeholder interviews revealed that awareness and therefore preparedness is not equal amongst all stakeholder groups:

'Moving from the mitigation to the adaptation and there is a real cultural barrier there to overcome because it is about recognising we don't have the power to do exactly what we would like to do. People don't get it. They really, really don't like it that we are not masters of our destiny and that we cannot control nature'. AONB

Results indicate that, due to a lower level of preparedness, climate shocks can significantly affect community groups, heightening their perception of risk and resulting in a greater willingness to engage in climate change adaptation and therefore are more likely to implement transformational change. For example, local government and statutory agencies have observed the following:

'I certainly think that communities perhaps inevitably are keener to engage more urgently as they feel under imminent threat. So if there is a risk of flooding or a risk of erosion that is accelerating then inevitably people will want to talk to competent authorities quickly'. NE

'I would have said that the whole issue of the coast, the changing coast and the vulnerability of the coast is now much more at the front of people's minds. I think that their awareness has been significantly raised and I think that people now want to do more'. SCDC

A member of a community group revealed the following about fellow communities in the nuclear neighbourhood:

'I think that Snape parish council they didn't wake up until they got flooded. They didn't even want to produce a member for the partnership but now they realise that they ought to'. AOEP

Analysis of the semi-structured interviews also revealed that the legacy of climate shocks is a significant factor influencing how stakeholder organisations respond after an event. Community groups in the Sizewell neighbourhood revealed that younger people want to get involved with climate change adaptation as a direct result of the winter storms in 2013/2014:

'Young people in their 40s, the two sets of parents with younger children. They have stepped up to take over the resident's association and it is because of the surge'. SCAR

On the other hand, results have indicated that the legacies of climate shocks are often diffused at a centralised level of society due to lengthy bureaucracy. A member of and NGO operating in the Sizewell neighbourhood expressed the following:

'The climate change version means that something really, really, really bad has to happen before we will start taking it seriously and wake up. Whether that will be in time or not that is another matter because of the lags in the system'. AONB

5.6.7 *Knowledge flows (Open/permeable – closed)*

Interviews with stakeholders in the coastal zone have revealed that the means by which knowledge is shared is a key factor controlling the 'success' of adaptation initiatives in the coastal zone. The presence of existing and planned nuclear power stations seem to have an effect on the way in which knowledge is shared between stakeholder organisations (Research question 5). Not all stakeholders operate with equivalent degrees of transparency. These disparities in transparency have the potential to affect a stakeholder groups ability to implement 'successful' adaptation initiatives. Stakeholder standpoints range from open to closed knowledge flows (Figure 5.10).

The semi-structured interviews revealed that there are four influencing drivers that govern the way that stakeholder groups interact with the theme: trust, education, intellectual capital, and financial capital (Figure 5.10). As previously mentioned, all six key themes are inherently interlinked. It must be noted here that the theme of knowledge flows is directly interlinked with the evolution of partnership working (Section 5.6.8).

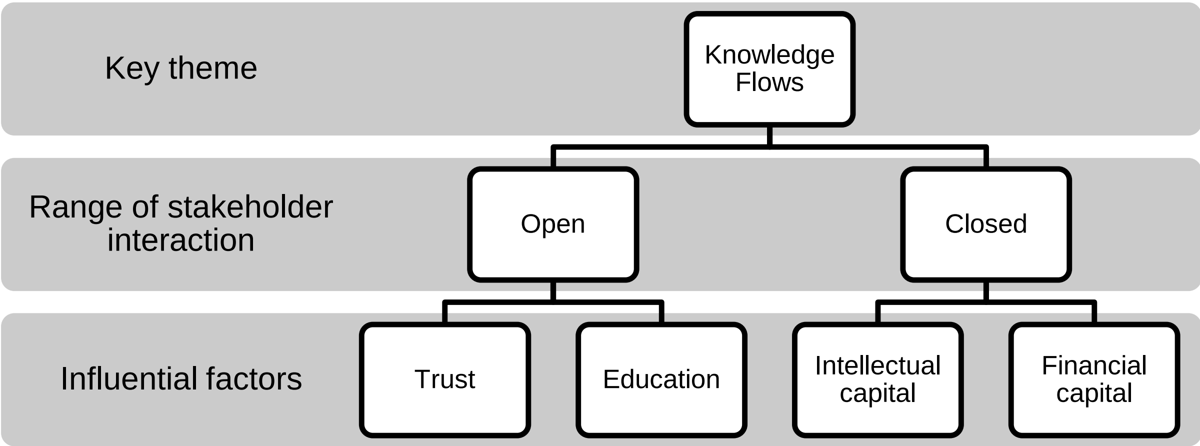


Figure 5.10 Concept outlining the theme of knowledge flows

Results indicate that the primary drivers promoting open knowledge flows are trust and education. Stakeholder groups operating locally in the nuclear neighbourhood expressed the importance of trust when sharing knowledge related to climate change. Representatives from the local government expressed the following:

‘Well it is responding to people, so trust in what you are doing and all that you are saying is absolutely critical. You have to respond to people in a way that they can engage with. If they say I’m not happy about this and what about that? You have to deal with that directly you cannot ignore it’. SCDC

‘The problem with all of these issues is engaging with communities, building trust with these communities takes a long time. When problems crop up we need people who understand the individuals and who have the trust of the individual, you cannot do that by parachuting somebody in because they have to start right at the bottom and build right back up again’. SCDC

Similarly, a representative from an NGO expressed:

‘One of the things that the AONB does well is being an honest broker and we quite often find ourselves trusted by people who don’t trust each other... Our key intangible legacy will actually be about building trust, relationships and understanding between people who started and probably will remain in a place where they don't agree with each other. From a place where you don't agree with each other to a place where you are exploring the things that you do agree about even if you disagree about other things is actually quite a journey and that is our legacy’. AONB

Corresponding, to the theme of perceived responsibility, analysis of semi-structured interviews revealed a lack of trust between commercial entities and other stakeholder groups. The following quotes from NGOs illustrate this:

'I now think that EDF are doing quite a good job trying to communicate but it seems that we don't really believe them'. AOEP

'I would say that there is a healthy scepticism'. RSPB

Elements of enmity are also expressed by the commercial entity:

'…yes it is very much a matter of trust between individuals but equally it is fundamentally a matter making sure that we don't compromise these individuals by them in any sense being seen to be too close or chummy with us. They are friendly with us but they are only friendly with us where it is working and where we are being absolutely, rigorously fair'. EDF

Stakeholders inevitably have unequal access to the resources required to gain knowledge about how the coastal zone may change due to the potential impacts of climate change. Factors surrounding the protection of intellectual capital and the associated financial costs appear to make stakeholder organisations with such knowledge wary of sharing it with other stakeholder groups. Again, similarly to the theme of perceived responsibility, stakeholders regarded as affluent (commercial entities) tend to keep knowledge 'in house' as expressed by a representative from local government:

'EDF is cautious about how it shares its information and the key body that they deal with is the EA because they are the enforcement authority' SCDC

The commercial entity explains their reasoning for being cautious about sharing their technical knowledge:

'As a developer there would be an apprehension that the likes of the RSPB could use that material to argue against the development. Of course they could do that could do that but it is more important in our mind that the key data that related to these sites is shared…let's get everyone up the point where we understand we have the right data… and try to work together to deal with them' EDF

Despite protecting their intellectual capital, the preceding quote from the commercial entity and the proceeding quotes from other stakeholder groups illustrate that all stakeholder organisations realise the importance of knowledge and understanding of both climate change and the possible impacts when attempting to negate the threats of climate change via adaptation. Statutory agencies and local government organisations realise that knowledge is unequal between stakeholders:

'I would have said there is a divergence of understanding and belief in climate change'. SCDC

'…there are some very well educated and well informed people who take an interest and these people will come from the local community and they will be absolutely on top of things but if you were trying to talk to the general populous they probably don't understand it very well' RFCC

A representative from a statutory agency expressed that enhancing the knowledge of stakeholder organisations though education must be addressed sensitively:

'I think that you have to be careful as to not to be seen as condescending to these people, I think that a lot of it does come down to education…Slowly and surely trying to get across to people how the coast functions and why it is the way it is and that sometimes it is better to work with natural processes'. NE

With this in mind, stakeholder organisations expressed the importance of platforms on which to exchange their knowledge, experiences and future adaptation plans, citing forums as a good mechanism to do so:

'I think it is essential that everyone knows what everyone else is doing'. SWT

Suffolk Coastal Forum I think is a very good place, it has created a greater understanding and there is exchanging of knowledge going on and the main thing, and I don't know if we do enough, is the spreading of knowledge back to the people that you go there to represent'. AOEP

'I now live here and I sail I have got reasonable local knowledge, yes it is local people all coming together to provide local knowledge but informed knowledge'. AOEP

Results from the semi-structured interviews have highlighted that there are different forms of knowledge: from technical knowledge of coastal dynamics gained though modelling to in depth local knowledge of the behaviours of people and wildlife gained over long periods of time spent living and working in the nuclear neighbourhood. Different stakeholder groups possess different types of knowledge. All stakeholders recognise that neutral platforms, such as the Suffolk Coastal Forum are essential for providing stakeholders with opportunities to share knowledge and build trust.

5.6.8 *Evolution of partnership working (silo to collaboration)*

The final theme describing the ability of stakeholders in the nuclear neighbourhood to implement adaptation successfully is the evolution of partnership working. Results from the semi-structures interviews reveal that that over the last decade, there has been a shift in the ways in which many stakeholders operate, moving from a silo approach to coastal management and adaptation to a much more collaborative approach. Therefore, stakeholder groups range from addressing the impacts of climate change individually as a silo to working together in collaboration.

Semi-structured interviews revealed that there are four main influential factors effecting stakeholder standpoints with the evolution of partnership working: intellectual capital, perceived responsibility, communication and empowerment through decentralisation. The results revealed that the evolution of partnership working is the most transcending of the six key themes as perceived responsibility (Section 5.6.4), a key theme in its own right, was determined to be an influencing factor (Figure 5.11).

Analyses of the semi-structured interviews indicated that the theme of perceived responsibility has the potential to influence the evolution of partnership working in the nuclear neighbourhood (Section 5.6.4). Results from this theme revealed that most stakeholder groups accept a collective responsibility for coastal management and adaptation in the nuclear neighbourhood. The recognition of a collective responsibility promotes the evolution of partnership working from silo towards collaboration. However, results highlighted that there is some confusion surrounding statutory responsibilities of stakeholders. Results illustrated that commercial entities, in charge of the nuclear infrastructure in the Sizewell area are reluctant to share collective responsibility of the adaptation of the neighbourhood instead focus solely on their own estate. Stakeholder interviews revealed that such self-inflicted isolation inhibits the evolution of partnership working.

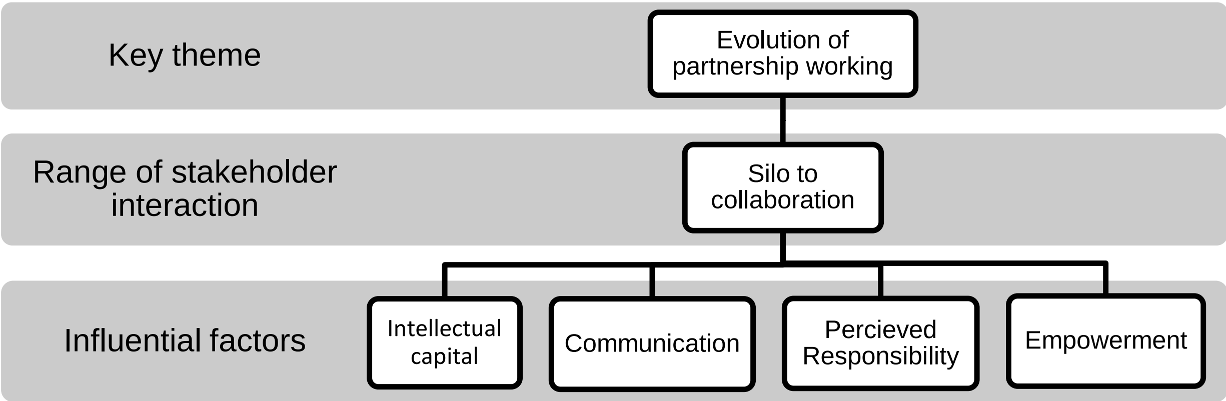


Figure 5.11 Concept outlining the theme of evolution of partnership working

In addition to the established theme of perceived responsibility, insights from stakeholders in the Sizewell nuclear neighbourhood revealed that one of the key factors affecting the evolution of partnership working is recognition of the necessity of communication. Stakeholders recognised that a lack of communication between stakeholder groups can inhibit the evolution of partnership working, particularly when intellectual capital and perceived responsibilities vary. Representatives from community groups expressed that a lack of communication can lead to feelings of animosity between stakeholder groups:

‘If you leave people completely in the dark and then suddenly do something then it always ends up about why people didn't get told rather than what the problem actually was’. AOEP

‘There is also the fact that there had been quite a lot of feeling about the behaviour of RSPB who own about half of the levels that they hadn’t engaged with the community’. MLSG

Stakeholders with statutory duties also recognise that a lack of communication inhibits stakeholder collaboration. A representative from a statutory agency expressed:

'Whenever they [the community] have a decision forced upon them they get very unhappy about that. It again comes to this psychology and people are quite emotive on this subject and get very upset'. NE

Stakeholders also highlighted that the importance of communication had been recognised and improved over recent years. A member or a community group expressed the following:

'Well communication is much better than it was in 1953 and yes even in just the last few years… before there was no dialogue and no discussion; they were equally as deaf to what the locals were saying'. MLSG

However not all stakeholder groups are equally communicative. Results revealed that there is a perception that some groups are more approachable than others. A representative from an NGO expressed the following:

'People know where to come if they want to talk about anything. It think we are probably more approachable I don't know because we are local I think like the RSPB they are a national body rather than a local one so I think that is why really'. SWT

Similarly to other themes, one of the factors favouring partnership working is empowerment of local stakeholder groups via decentralisation. Empowerment of these groups is necessary as centralised statutory agencies are increasingly struggling to lead on coastal management issues due to shortages in resources. Members of community groups recognise this:

'they are so short staffed now they essentially can't participate, they just don't have the resource anymore and it is actually one of the things that is worth mentioning is the progressive cuts in environmental bodies whether that is NE or English Heritage or even the EA. It makes it harder and harder for them to have the staff resource to invest in communities and relationships which actually the only way they are going to solve these difficult problems'. AONB

Decentralisation coupled with the recognition of the importance of communication, locally based stakeholder groups have established platforms to enhance communication and therefore promote the evolution of partnership working. A stakeholder representing community groups and the local government expressed:

‘Estuary planning partnership was set up, that was the first time we had ever got sitting in one room, every possible organisation with an interest in the estuary, both public and private you name it… it was essentially a talking shop, it meant that for once everyone in the room all got together and everyone talked about what was happening’. AOEP

‘Futurescapes is basically our strategy of engaging with external stakeholders to try and encourage them and influence them and provide the network and forum for advocacy where we can get them to start thinking about wildlife and natural systems’. RSPB

‘I think in terms of partnership working there are stresses and strains there always are I think generally through the Suffolk Coastal Forum we have a direction of travel that is pretty well shared. SCDC

Results show that statutory agencies and commercial entities also value communication. When referring to a initiative designed to raise awareness of the potential impacts of climate change and the need for adaptation a representative from a statutory agency expressed:

‘I was one of the people that was involved in the setting up of that project and the principle aim of that was that it was a communication tool so the idea was that it could be used by the agencies as a tool to get the information out to an as wide as possible audience. It also meant that that group of individuals could fire their questions through us up to the top end’. NT

‘we needed to have a mechanism of talking to local stakeholders that gave them a consistent venue for talking about issues and gave us a consistent venue for guiding their expectations in terms of this is where the marine studies are, this is where they are likely to go. EDF’

Local organisations recognise that commercial entities make efforts to communicative however much like the themes of knowledge flows and perceived responsibility local stakeholder groups do not express an affinity to commercial entities. A representative from the local government expressed:

'We can have a sensible conversation with them, sometimes robust but we can have a sensible conversation with them'. SCDC

Overall stakeholder groups consider the levels of communication between organisations sufficient in enabling the evolution of partnership working. A representative from a community group captured this view:

'I think that that is one of the ways in which Suffolk is getting on as everyone has these platforms by which to know everyone'. AOEP

Results have revealed that stakeholder groups regard the evolution of partnership working as essential to ensure the successful management and adaptation of the coastline. However, a representative from one NGO expressed considerable caution regarding partnership working at a local scale:

'I think that it would be an extremely bad thing to allow people to do their own thing on the coast. Of course every stakeholder is going to have a say about what they want from the coast but the decision about what to do must be a non-local one and it should be a top down process otherwise you will get things like that East Bavance man who dumped in all those tyres. People put their own defences up which just cause problems elsewhere and you cannot afford to act unilaterally and locally you have to have some centralisation. It has to be central, of course the stakeholders must have their say but on an international scale it is a good thing but on a local scale it is an extremely bad thing'. Consultant to Sizewell B

The preceding quote highlights that increased stakeholder collaboration and partnership working is not completely risk free. Promoting an increasingly

collaborative approach to adaptation could cause maladaptation if stakeholders are not guided in their adaptation efforts. As illustrated above misinformed or inappropriate measures are adopted by (semi) autonomous stakeholders working in the neighbourhood to protect their own interests. Therefore, it is important to have a neutral but comprehensive overview of the influential factors affecting the success of coastal management and adaptation in the nuclear neighbourhood.

A representative from a statutory organisation epitomises the importance of understanding the factors that could influence the standpoint of a stakeholder group on the key themes:

'I think that it's often perceived to be woolly minded social science nonsense and why do you need to do that because you know we have scientists telling us what is going on. Well, actually, the reason you need to do it is because you are not going to convince people to come along with you if you don't'. NT

Analysis of the key themes that emerged from the semi-structured interviews exposed 12 influential factors that have the power to impact on stakeholder organisations and therefore affect the outcomes of adaptation decisions: communication, education, empathy, empowerment, finance, intellectual capital, legacy, perceived responsibility, politics, positionality, preparedness and trust (Figure 5.12).

To illustrate how each influential factor impacts on the six key themes, Figure 5.12 was constructed. Each bar on the figure represents a key theme. The bar for each key theme is compartmentalised based on the influential factors that impact a given theme. Results illustrate that the established key themes are most frequently affected by three separate factors. Finance is the most widespread influence, affecting four of the six themes.

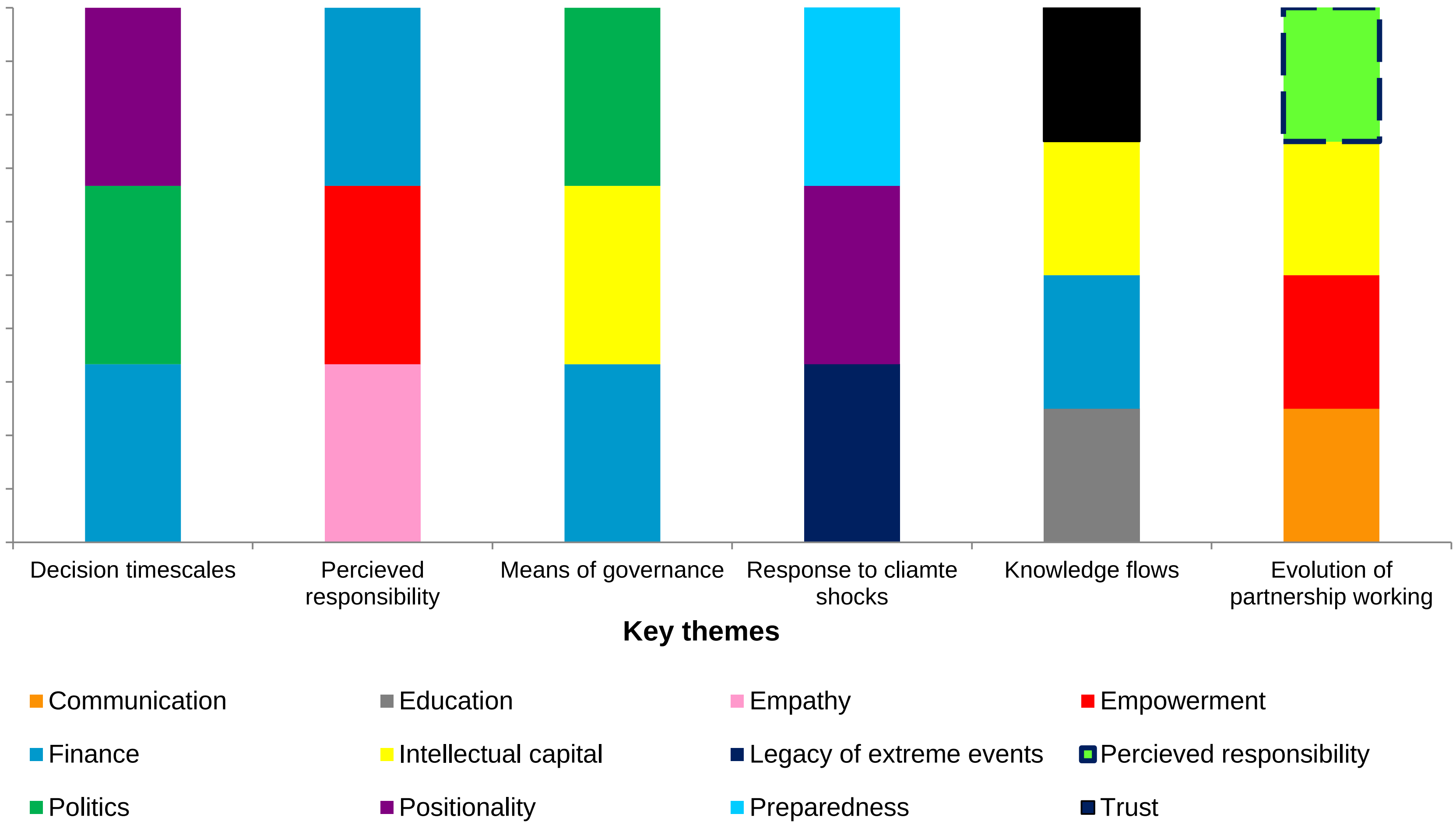


Figure 5.12 Factors influencing key themes

5.7 Discussion

This phase of the research has answered calls (Eakin and Patt 2011; Wise et al 2014) for focussed research on the adaptation process, identifying and factors enhancing or inhibiting the process. The analysis of interview transcripts highlighted six key themes that have the potential to inhibit or enhance the successes of coastal management and climate change adaptation initiatives. This section discusses the findings from the semi-structured interviews, whilst drawing on the published literature to explore the results and considering how the investigation has advanced the field of study. This discussion firstly addresses the interlinked nature of the six key themes before discussing each theme in turn.

5.7.1 *Thematic interactions*

The six themes highlight attributes of society that affect the adaptation efforts of stakeholder organisations in the nuclear neighbourhood (Table 5.3). Depending on the nature of influencing factors, the key themes have the potential to enhance or inhibit the ‘success’ of climate change adaptation efforts. Results indicate that a stakeholder organisation’s standpoint on with key themes correlate depending on which stakeholder group an organisation belongs to (Table 5.2). However, stakeholder groups alone do not fully explain the complexities of stakeholder engagement in climate change adaptation in the coastal zone surrounding long-lived infrastructure. Multiple factors affect an organisations ability and enthusiasm to implement climate change adaptation initiatives. These key themes are not linear nor are they stationary or isolated.

Figure 5.12 illustrates the interconnectedness of the key themes. As displayed, the six key themes do not exist in isolation; they are interlinked hence the graphic shows them overlapping. The funnel represents the decision-making landscape. As stakeholder organisations advance on the decision-making process, the themes interact. Results revealed 12 influential factors that have the power to impact on stakeholder organisations and therefore affect the outcomes of adaptation decisions. The 12 factors are displayed in the chevrons underneath the funnel: communication, education, empathy, empowerment, knowledge flows, legacy, perceived responsibility, politics, positionality, preparedness and trust.

One of the 12 influencing factors – perceived responsibility – is a key theme in its own right. Perceived responsibility was also found to be an influencing factor in the evolution of partnership working. This interconnected nature of the 6 key attributes of the adaptation process further highlights the complexities of the factors affecting the successes of climate change adaptation in nuclear neighbourhood (Figure 5.13).

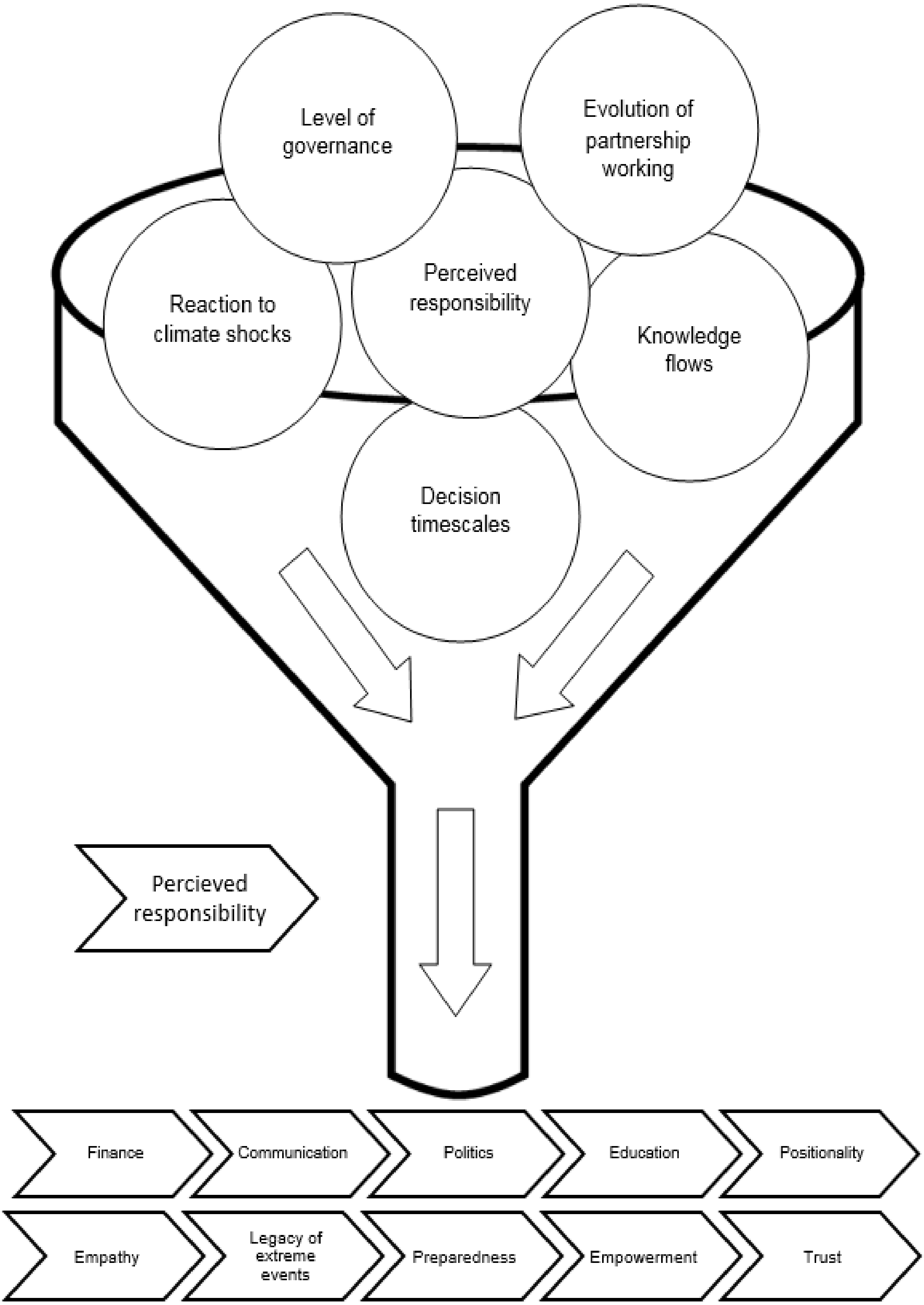


Figure 5.13 A conceptual model of the six themes and decision-making landscape

5.7.2 *Decision timescales*

Stakeholder organisations in the Sizewell nuclear neighbourhood believe that the timescales on which decisions are made have an effect on the success of climate change adaptation efforts (Research question 6). The literature refers various timescales when considering the potential impacts of climate change (de Elia et al 2014), there is an increasing awareness of the importance of considering the timescales on which adaptation decisions should be made to enable the timely implementation of adaptation actions (Chapman et al 2014; Eisenack et al 2014; Measham et al 2011). Biesbroek et al (2011), found that stakeholders deemed conflicting timescales the most important barrier hampering the development and implementation of adaptation strategies in the Netherlands. With this in mind, further attention must be paid to both the timescales incorporated into adaptation initiatives and the timeframes on which decisions are made especially as there is increasing concern that world systems are approaching irreversible tipping points (Chapter 2, Section 2.2.2).

Results uncovered that stakeholder groups in the nuclear neighbourhood consider the timescales relating to climate change adaptation in two different dimensions: one from an aspirational perspective and the other from an operational perspective. Understanding these two different dimensions to decision timescales and how timescales vary between stakeholder organisations in the nuclear neighbourhood helps to answer research question 5: To what extent does the presence of nationally significant, long-lived coastal infrastructure, affect stakeholders engaging in climate change adaptation? Operational decision timescales refer to the timescales on which an organisation functions whereas aspirational timescales refer to the farthest future point a stakeholder organisation considers in their mandate. Results revealed three influential factors that may influence a stakeholder organisation regarding their stance on decision timescales: positionality, political cycles and financial cycles (Figure 5.12).

5.7.2.1 *Operational decision timescales*

Results highlighted that the OTHs on which decisions are made are consistent between all stakeholder groups ~ 5 - 10 years into the future. Stakeholders express that OTH are bounded by financial and political administration systems. These systems typically cycle every five years mirroring political terms in office and financial investment plans. The most affected stakeholder groups are those with statutory remits and mandates (national government and statutory agencies) as these are issues from centralised government. The effects of which cascade down to stakeholder groups operating locally (local government, NGOs) often determining the extent of their resources for the following OTH. Stakeholder groups not constrained by national statutory remits, namely community groups and commercial entities, are less bound by OTHs. However, they experience the diffused effects from other stakeholder groups operating in the nuclear neighbourhood.

As ATHs vary so greatly (Section 5.7.2.2), better aligned OTHs may prove valuable when attempting to implement climate change adaptation in a neighbourhoods with multiple stakeholder groups. OTHs provide a shared timescale over which adaptation efforts may be planned and implemented.

5.7.2.2 *Aspirational decision timescales* Unlike OTHs, results illustrate that the range of ATHs vary significantly between stakeholder groups. Results suggest that the positionality of stakeholder organisations governs their ATH. Positionality is defined as ‘the occupation or adoption of a particular position in relation to others’ (Oxford Dictionary, 2016). A previous study also found that positionality can affect how stakeholders engage with climate change. They found that the geographic positionality of US cities affect the timescales on which governing authorities refer to climate change, coastal and states focused on specific harms that they faced from climate change, while interior states "scaled up" to focus on climate change as a global problem occurring over extensive timescales (Osofsky and Lecvit 2007). Analysis of stakeholder interviews indicated that there are three factors that determine the positionality of a stakeholder organisation in relation to adaptation in the nuclear neighbourhood; i) comprehension of the issue ii) world views and iii) awareness of others.

Comprehension of climate change refers to understanding and ability to process and include long-time horizons associated with both climate change and nuclear infrastructure into coastal management and adaptation. Results revealed that all stakeholder groups find the comprehension of long-timescales difficult and therefore struggle to make decisions beyond more than 100 years into the future. There are multiple studies that cite the theory of cognitive dissonance (Festinger 1957) to explain the limited comprehension of the distant time horizons associated with climate change. Climate change is often perceived as a global, distant problem and often does not resonate with the everyday values of stakeholders (Adger et al 2013; Ross et al 2016; Pinto 2015; Scruggs and Benegal 2012). Stakeholder organisations’ inability to comprehend time horizons that are in line with the lifetime of the nuclear infrastructure is a factor that may impact their adaptation success. However, as all stakeholder groups struggle with the comprehension of distant time horizons, it is not considered trait that contributes the varied ATHs observed in the nuclear neighbourhood. Results revealed that the world-views of stakeholder organisations vary, directly affecting ATHs. It appears that stakeholder organisations representing community groups exhibit the greatest range in their ATHs however, they extent the shortest distance into the future. The farthest-reaching ATHs are that of centralised stakeholder groups (statutory agencies, national government and commercial entities) whereas more local stakeholder groups, (NGOs and local government) exhibit ATHs that are mid-range (Figure 5.6).

One theory relating to world-views that may explain the differences in ATHs is emotional motivation. Van der Linden et al (2015) explain that emotional motivation occurs when the brain considers experience over analysis when making decisions. There are two systems of brain function involved in decision making: one is intuitive, experiential, automatic, emotional, and fast; the other is deliberate, analytical, effortful, rational, and slow (Kahneman 2012). It is important to note the role of the individual here as experience is unique to the person. Semi-structured interviews uncovered that community groups, who have no statutory remits, are frequently established because individuals in the nuclear neighbourhood feel emotionally compelled to initiate adaptation to climate change (for instance, due to apprehension about the loss of their home or the wellbeing of their descendants). Therefore, the ATHs of these stakeholder groups reflect the emotions of individuals and are limited to extent of their world-views.

At the other end of the range (statutory agencies, national government and commercial entities), the remit of some stakeholder groups requires a more extensive ATHs. The mandates of these groups are objectively developed, often in response to policy and legislation. ATHs of these groups are prescriptive and not influenced by emotion, as evidenced by the safety case requirements issued by the Office for Nuclear Regulation (2014), which requires the commercial entities responsible for nuclear infrastructure to ensure it can safely withstand a 1 in 10,000 natural hazard event.

Stakeholder organisations exhibiting mid-range ATHs consist of local government and NGOs. Stakeholder interviews revealed that these organisations have policy led remits and also employ individuals that may be emotionally motivated to implement adaptation. Many live in the nuclear neighbourhood or have an affinity to the area. The combination of objective remits and a personal affinity could therefore be a contributing factor to the exhibited mid-range ATHs.

The final trait of positionality refers to the awareness stakeholders organisations have of each other. Interview analysis indicates that stakeholders organisation think that they have a good awareness of the ATHs of others. However, this is not the case. A false sense of awareness may result in unidentifiable barriers between stakeholders when attempting to collaborate on adaptation efforts. Serrao-Neumann et al (2014) share this concern stating that greater levels of planning and policy integration across sectors and scales will be required to improve the adaptation potential of highly vulnerable coastal communities.

To date, research efforts have focused on factors constraining and enabling long-term climate in decision-making. The literature focused on factors constraining long-term decision-making centre on: social issues of cognitive dissonance, limitations of reliable climate information, and financial and technical constraints (Jones et al 2016). The same factors were also found to affect stakeholders in the Sizewell nuclear neighbourhood. Conversely, Jones et al (2016) cite enabling factors as collaboration and bridgework between stakeholders, increased accessibility of climate information, improved underlying science, institutional reform and windows of opportunity for building trust. Although productive, the listed factors all require action before the benefits are realised. Communicating the discovery that all stakeholder groups operate on very similar OTHs may encourage stakeholders to collaborate on common grounds.

5.7.2.3 *Application of findings*

This section of research has determined that stakeholder groups think in two time dimensions when considering future climate change adaptation (i.e. ATHs and OTHs). Influenced by elements of positionality, ATHs vary depending on stakeholder group whereas OTHs, influenced by political and financial systems remain constant regardless.

An appreciation of the two dimensions of future time horizons may aid stakeholder organisations in defining successful strategies to implement adaptation. An appreciation of varying ATHs could help to overcome conceptual barriers inhibiting collaboration and adaptation implementation. The realisation that all stakeholder groups operate on the same 5 to 10 year timescale provides a practical and neutral platform on which all stakeholder groups could collaborate and strategically plan the long-term adaptation of the nuclear neighbourhood.

5.7.3 *Perceived responsibility*

Stakeholder organisations in the Sizewell nuclear neighbourhood believe that the perceived responsibility for the management and adaptation of the coastline has an effect on success of climate change adaptation efforts. Results have indicated that there is a lack of agreement about who is and who should be responsible for climate change adaptation. This is not unique to nuclear neighbourhoods. For example, Adger et al (2009) found through policy document and household surveys that after the 2009 flood events in Northern Ireland and northwest England, there were significant differences in individuals' perceptions of responsibility for flood protection. Apparently, o*mission bias* is a factor affecting perceived responsibility for adaptation - people will decline to take responsibility for an action to avoid taking personal responsibility for a potential loss even if such loss is as severe as doing nothing (Patt and Schröter 2008; Shackleton et al 2015).

Huntjens et al (2012) stresses the importance of defining boundaries of responsibility before addressing climate change adaptation. Regarding the water sector, they report that ultimate responsibility lies with the government. However, results from interviews with stakeholders in the nuclear neighbourhood indicate that bounding responsibility is not a straightforward endeavour in situations involving long-lived infrastructure. Lack of clear boundaries for responsibility of adaptation in the nuclear neighbourhood, means that the duty of responsibility becomes somewhat subjective, hence perceived responsibility ranges from collective to individual. Results from the semi-structured interviews revealed three influential factors: empathy, financial capital and empowerment (Figure 5.12).

5.7.3.1 *Collective responsibility* The economic recession of 2008 led to decreases in public sources of financial capital for the coastal zone. Results highlighted that the funding system for coastal management and adaptation has been in a state of flux since the onset of the recession. Porter et al (2015) found that despite considerable efforts to ensure that local authorities have access to climate information, adaptation implementation in the UK has been severely hampered by budget cuts and lack of political support. Result from this study echoed the findings of Porter et al (2015). However, the observed decrease in public funding has led to an increase in private investment funded by other stakeholder groups in the coastal zone, and this in turn has increased the perception of collective responsibility for the management and adaptation of the nuclear neighbourhood.

It must be noted here that perceived responsibility is strongly linked with the key theme of evolution of partnership working (Section 5.7.9). Driven by the necessity to pool financial capital, local and informal stakeholder groups increasingly work together in partnership to secure capital from sources such as grant in aids. Results from the semi-structured interviews have revealed that the increase in partnership working and access to financial grants has empowered local stakeholder groups to adopt an increased level of responsibility for the management and adaptation of the nuclear neighbourhood. This is consistent with Becker et al (2013) who assert that public and private sectors will need to combine and create new financing mechanisms to implement climate change adaptation. They express that this is particularly true for long-lived infrastructure that may face radically different climate regimes to the one in which it was constructed.

Interviewees from the nuclear neighbourhood gave many examples of joint initiatives they have been involved in to secure the funds to implement. Examples include permitting development outside of the footprint of a village and imposing a coastal maintenance tax on holiday properties in the area.

Schmidt et al (2013a) recognise that whilst the costs of coastal defences increase, there is a gap of knowledge on the possible future financing arrangements. Results from the Sizewell nuclear neighbourhood indicate that local stakeholder groups such as community groups, NGOs and local governments are willing and able to take responsibility for adaptation in the coastal zone

5.7.3.2 *Individual responsibility* Results indicate that not all stakeholder groups are affected by the economic climate in the same way, so empathy for the financial constraints to adaptation is not universal amongst stakeholder organisations in the coastal zone. This supports assertions by Fankhauser (2013) and Weitzman (2009) who express there has been an inability to meaningfully evaluate the economic impacts of climate change. Commercial entities in the coastal zone do not engage in joint funding initiatives nor do they take collective responsibility for the management and adaptation of the coastline. Interviews revealed that they perceive adaptation to climate change as an individual endeavour and taking sole ownership for the responsibility for the adaptation of their estate but exhibiting limited involvement of adaptation efforts elsewhere in the nuclear neighbourhood.

Semi-structured interviews uncovered that the degree of empathy displayed for others may be driven by different motivation to engage in climate change adaptation (Research question 5 and 8). Local groups (community groups and local government) are largely driven by emotional and personal attachment to aspects of the nuclear neighbourhood. The motivation of centralised groups (commercial entities, national government) is largely shaped by statutory responsibilities. For example, adaptation from the commercial entity, responsible for the nuclear infrastructure, is prompted by mandatory reviews of safety cases. Whereas adaptation by community groups occurs voluntarily such as the conception of the Alde and Ore Estuary Partnership and the Deben Estuary Partnership and the instigation of the East Lane Enabling Development initiative (Table 4.2a). These groups have been established by the residents of the nuclear neighbourhood in response to a heightened sense the potential risks of climate variability and change. They aim to raise funds to maintain ageing and degraded flood defences and contribute to the collaborative management of the coastline with other stakeholder groups. In addition, local government, NGOs and community groups have come together to find a solution for the adaptation of the Minsmere gravitational sluice. This sluice may lose gravitational properties as sea level rises leading to increased erosion and saline inundation of the Minsmere levels. However, commercial entities in the neighbourhood are reluctant to engage in the management and adaptation of this infrastructure as they have the resources and confidence that they can maintain their estates regardless of the fate of the sluice. Similarly to the themes of knowledge flows and evolution of partnership working, commercial entities are frequently regarded as 'the other'.

5.7.3.3 *Application of findings*

The chapter has established that perceived responsibility for climate change adaptation varies between stakeholder groups. Perceptions range from considering the adaptation of the coastline to be the responsibility of individual organisations on the one hand and a collective endeavour to be shared between all stakeholders on the other. Results highlighted that the statutory divisions of responsibility in the coastal zone are regarded confusing and arbitrary therefore more emphasis is placed on perceived responsibility. Influenced by factors of empathy, financial capital, empowerment and politics, stakeholders varied in their level of perceived responsibility.

Stakeholder groups that have experienced recent financial cuts were more likely to express a collective perception for adaptation responsibility than those who are more financially secure. As evidenced by the establishment of the EA grant-in-aid funding mechanism (Environment Agency 2014). Set up in 2007, this scheme promotes collaboration and shared responsibility for adaptation, at risk communities can apply for funding to support adaptation initiatives in partnership with the EA. Stakeholder groups perceived to be financially secure, namely commercial entities, exhibit lower levels of empathy towards others adopting individual responsibility for the adaptation of their own estates. However, results detected feelings of animosity towards commercial entities, not because of their different stance on perceived responsibility but due to their lack of empathy towards others. Such insights into the drivers of relationships between different stakeholder groups could be valuable to all organisations in the nuclear neighbourhood when attempting to implement successful climate change adaptation.

5.7.4 *Units of governance*

Stakeholder organisations in the Sizewell nuclear neighbourhood expressed that the units by which the coastline is governed has the potential to affect success of adaptation efforts. The range of stakeholder interaction with this theme centres on whether the coast should be managed according to physical units such as sediment cells or whether governance should be defined by political boundaries such as council constituencies. stakeholder groups in the nuclear neighbourhood revealed that the geographical scale on which the coast should be governed was also a topic for discussion (Research question 9).

The recognition that the governance of the coastal zone should incorporate physical processes has been established since DEFRA established the UK Shoreline Management Plans (SMPs) in 1999. The coast of England and Wales was broken down into 11 primary coastal cells and a series of 39 sub-cells that reflect the physical processes of the coastline. The SMPs form the basis of contemporary coastal management practices by considering how the coastline is likely to change over the next 100 years and recommending how the coastline should be managed via one of four approaches. These are: hold the line, advance the line, managed realignment and no active intervention (Environment Agency 2015). Although widely employed by coastal stakeholders, SMPs are not statutory in the sense that the recommended management practises are not universally accepted and implemented. Results from the semi-structured interviews in the Sizewell nuclear neighbourhood indicate that the debates still remains over the best units of governing and adapting the coastline to the potential impacts of climate change.

Results revealed that the units by which climate change adaptation is governed has the potential to either enable or inhibit the climate change adaptation efforts of stakeholders in the nuclear neighbourhood. Results revealed three influential factors that affect standpoints of stakeholder groups on the units of adaptation governance: politics, intellectual capital and financial capital.

Despite presence of the SMP, local stakeholder groups in the coastal zone do not think that the physical processes of the coastline have been incorporated sufficiently into management practices. These groups have an in depth local knowledge about how the coastline behaves and are in touch with the day to day geomorphological changes of the coastline. There appears to be frustration amongst these stakeholder groups as they sense that such in depth knowledge is not utilised and incorporated into coastal management practices. Clark et al (2013) also detect frustrations in coastal management strategies citing the need for increased collaboration between stakeholders (Section 5.7.7) and incorporation of different knowledge into the coastal governance system. A study of the management of the Quebec coastline, Canada highlighted that incorporating different types of knowledge into coastal management practices can be beneficial to the overall management and adaptation of the coastline (Bernatchez et al 2011).

There is recognition within the Sizewell nuclear neighbourhood and the published literature that there are multiple sources of knowledge regarding coastal dynamics. However not all knowledge is incorporated into coastal management and adaptation. This raises questions about the most appropriate units and scales of coastal governance and who currently defines said boundaries. Dronkers and Stojanovic (2016) recognise the difficulties in managing coastal zones in an integrated manner. They highlighting the failure of the European Commission (2014) to include ICZM into a binding directive requiring all member states to employ the principle to develop special marine plans. Calling for a better coordinated, consistent approach to marine monitoring across nations bordering the North Sea, they assert that a consistent inclusive coastal management approach is necessary for informing policy, the general public and for developing the adaptive capacity of wider society.

The quandary relating to the units and scale of coastal governance is also linked to issues of perceived responsibility (Section 5.7.3). Stakeholders expressed that the physical functioning of the coast does not map onto constituency boundaries of local governance. Consequently, there appears to be confusion in the Sizewell nuclear neighbourhood as to where the spatial boundaries of governance are. This documented confusion surrounding governance boundaries sparks a debate on what the spatial scales of coastal governance should be to ensure that a given coastline could successfully adapt to the potential impacts of climate change.

5.7.4.1 *Application of findings* This section has highlighted that the debate surrounding the most appropriate units by which to govern the coastline is ongoing. Results from the semi-structured interviews indicate that all stakeholder groups recognise the importance of incorporating the physical processes of the coastline into management practices. Results have highlighted that the social boundaries by which the coast is governed do not necessarily superimpose onto the physical functioning of the coastline. Results from the semi-structured interviews and the published literature both highlight the importance of joint learning and knowledge sharing between stakeholders in the coastal zone when attempting to manage the coastline and ensure successful adaptation to climate change in the future.

5.7.5 *Response to climate shocks*

The Suffolk coast is one of the most rapidly eroding coastlines in Europe. Coastal communities have experienced climatic extremes following both historic and recent events such as the winter storms of 1953 and 2013/2014. In light of the severe winter storms 2013/2014 and predicted increases in more to frequent and severe storm events (Murray and Ebi 2012; Wuebbles et al 2014), stakeholder organisations in the Sizewell nuclear neighbourhood were deliberately asked about the impact of extreme events to determine if and to what extent seasonal climate shocks had changed their approach to climate change adaptation. Stakeholder interactions ranged from business as usual to transformational change (Research question 10). Results revealed three influential factors: legacy of extreme events, positionality and preparedness (Figure 5.12).

In the presence of climate change uncertainty it is impossible to denote whether climate change adaptation efforts are addressing the threats posed by anthropogenic climate change or climate shocks and change deriving from climate variability (Deser et al 2012). We may never understand the precise contribution made by anthropogenic climate changes to individual extreme events and climate variability (Pelling 2010). Nonetheless, it is important to understand how climate shocks might affect the adaptation actions of vulnerable communities.

Results revealed little evidence of transformational change in the formalised stakeholder groups (commercial entities, national government and statutory agencies). Similarly, to themes of decision timescales and knowledge flows, stakeholder groups with extensive ATHs and in depth technical knowledge expressed the lowest level of disruption by the winter storms of 2013/2014. These organisations adopted a ‘business as usual’ response to adaptation despite the climate shock. Access to technical climate information and employing extensive ATHs, enabled adaptation efforts to be proactive in nature, increased the preparedness therefore reducing the level of disruption caused by the winter storms. The work of Berrang-ford et al (2011) supports these findings, they reported that proactive adaptation planning is more likely to be undertaken by national governments who have greater resources. Therefore these stakeholders tend to exhibit greater adaptive capacities.

On the other hand, results revealed that stakeholder groups without extensive ATHs or in depth technical knowledge were more likely to undergo transformational change after experiencing climate shocks. Lack of in depth technical knowledge, less resources and shorter ATHs meant these groups were less prepared for climate shocks. Their adaptation efforts were reactive in nature. The work of Eisenack and Stecker (2012) support these findings, when referring to the dimensions of adaptation they found that the availability of different types of knowledge can determine whether an adaptation initiative is reactive of proactive. They assert that a reactive adaptation is based on knowledge of the past and present whereas proactive adaptation is based on knowledge of future climate projections or scenarios. The number of adaptation initiatives designed and implemented by local authorities and community groups, such as the *Alde and Ore and Deben estuary partnerships* demonstrate that there is an appreciation of the severity of risk and a desire to implement proactive adaptation responses.

Proactive adaptation is desirable as it is the first opportunity to prevent any detrimental effects of climate variability and change, the proactive adaptation process assumes relatively logical and sequential processes of human decision-making and behaviour whereas reactive adaptation takes place once a critical event has occurred (Grothmann and Patt 2005). Although proactive adaptation is seen as desirable in the first instance, Hielsecher et al (2008) highlights that reactive adaptation can be valuable when used as an indicator to monitor the successes of proactive adaptation efforts. The need for reactive adaptation highlights areas of preparedness that could be improved.

The role of climate shocks is closely linked to the theme of perceived responsibility. Through personal experience of extreme events, community groups in the nuclear neighbourhood recognise the threat that extremes in climate variability pose to coastal assets. They are taking responsibility to implement adaptation initiatives for example, by enabling development outside of the footprint of their village to generate capital for coastal defence initiatives (*East Lane Enabling Development*, Table 4.2a). In the absence of certainty regarding the impacts of anthropogenic climate change adaptation initiatives are currently addressing impacts of coastal change as evidenced by the *Deben and the Alde and Ore estuary partnerships* (Appenidx 1a), both of these initiatives have a strong focus on building resilience to climate variability by promoting the maintenance and repair of flood defence walls. Similarly, the *East Lane enabling development initiative*, is centred on preventing increased erosion from extremes in climate variability such as storm surges. Adaptation projects are therefore reactive to both shocks induced from climate variability and coastal change but proactive in response to anthropogenic climate change and may help lessen the impacts of possible impacts.

5.7.5.1 *Legacy of extreme events* Results highlighted that the legacy of extreme shocks are more extensive amongst localised stakeholder groups than centralised groups. Community groups expressed that younger members of the community have volunteered to help run such groups. Similarly to the other themes discussed, evidence of transformational change at the local level is primarily driven by positionality. The winter storms of 2013/2014 prompted an emotionally driven response by parents living in exposed locations of the nuclear neighbourhood to actively get involved with the future management and adaptation of the coastline as they desire to ensure prosperous futures for their descendants.

On the other hand, stakeholders expressed that it would require a more severe climate than the winter storms of 2013/2014 for the legacy of an event to significantly change the operations of centralised stakeholder groups. Due to lag times in the operations of centralised groups, the legacies of climate shocks tend to become diffused before any changes can be implemented. This observed diffusion can be explained by the theory of the 'dictatorship of the present' (Caplin and Leahy 2000) whereby centralised governance prioritises current issues over those that are deemed uncertain and distant. To overcome such issues of centralised, cognitive dissonance, Mazmanian et al (2013) recommend that government frameworks must allow jurisdictions to take action to increase their climate resilience including to climate shocks.

5.7.5.2 *Application of findings* Localised stakeholder groups are more likely to enact transformational change in response to extreme events as they are emotionally motivated to implement measures to reduce the impacts of future climate extremes. Therefore, localised adaptations to climate shocks are largely reactive. On the other hand, centralised stakeholder groups expect climate shocks so adaptation is more proactive, reducing physical and emotional impact of climate shocks and therefore resulting in a business as usual response.

One meta-analysis of the literature found that reactive adaptation is more prolific than proactive adaptation: 409 to 342 papers respectively (Ford et al 2015). This section has identified possible sources of the difference in the ways in which stakeholders implement adaptation. The discussion has provided an insight as to how influential factors shape responses to climate shocks. On a local level this insight could be valuable for stakeholders when attempting to collaborate to successfully manage and adapt the coastline surrounding static long-lived infrastructure. On a higher level these insights could help develop reactive adaptation responses into proactive initiatives therefore decreasing the negative impacts of climate change on vulnerable coastal communities.

5.7.6 *Knowledge flows*

Stakeholder organisations in the Sizewell nuclear neighbourhood expressed that the presence of long-lived infrastructure affects ways in which knowledge flows between stakeholder groups has the potential to affect success of adaptation (Research question 5). These results support the findings of Chapter 4, the variable framework approaches to adaptation established in Chapter 4 provides evidence of the presence of differing types of knowledge and resource availability. For example, elements of the SL framework can be employed only when stakeholders have in depth technical knowledge or access to climate modelling results. On the other hand, if organisations have an in depth knowledge of the coping capacities and adaptation strategies of stakeholders in the nuclear neighbourhood, then elements of the VL approach may be deployed. Differing types of knowledge can be valuable in to others in the adaptation decision making landscape. The results from the semi structured interviews indicate that each organisation has its own perspective and knowledge base that may be incorporated to improve adaptation of in the nuclear neighbourhood (Research question 7). There is an extensive literature documenting the existence of knowledge gaps between sectors in relation to climate change adaptation. Research has identified knowledge gaps at international (Biesbroek et al 2013; Swart et al 2009), national (Lemmen et al 2008) and local scales (Wilson et al 2010) of society.

The way in which knowledge flows between stakeholder organisations is less established. One recent study focussing on climate change adaptation in the agricultural sector found the knowledge brokering to be dynamic and messy (Adelle 2015). With increasing numbers of organisations implementing adaptation initiatives, it is important that mechanisms to share knowledge are efficient so that lessons learnt and methods of best practice can be shared (Fünfgeld 2015). Clar et al (2013) asserted that most adaptation guidelines focus on subjective experiences of good practice rather than empirical results therefore missing opportunities of knowledge brokering. This research provides a valuable insight into the factors that enhance and inhibit the flow of knowledge between stakeholders in the nuclear neighbourhood.

Results from the semi-structured interviews in the Sizewell neighbourhood revealed four factors influencing the ways knowledge flows between stakeholder organisations: education, trust, intellectual capital and finance (Figure 5.12).

5.7.6.1 *Inhibiting open knowledge flows* Results revealed two factors that have the potential to inhibit knowledge flows between stakeholders: Intellectual capital and financial capital. Semi-structured interviews revealed that knowledge between stakeholder organisations varies. Different stakeholder groups possess different types of knowledge. Organisations that operate locally (community groups, NGOs and local government) possess in depth local knowledge of the nuclear neighbourhood; whereas more centralised organisations (commercial entities, national government and statutory agencies) possess advanced technical knowledge and hold more data regarding the physical functioning of the coast. Hiwasaki et al (2014) emphasised the value of combining technical knowledge and indigenous knowledge in adaptation efforts, highlighting that since the 2004 Indian Ocean tsunami, disaster risk reduction specialists have acknowledged the importance of local knowledge. However, such knowledge is yet to be incorporated into the decisions made by communities, scientists and policy makers.

When considering the value of different types of knowledge present around a NNB, Freeman's (1994) theory of 'who and what really counts' comes into play. Commercial entities, responsible for existing nuclear infrastructure and the development of the NNB, are less willing to share their data with other stakeholder groups, protecting their intellectual capital and financial investment. Hegger et al (2012) explain that for knowledge to be produced and shared successfully, thresholds of credibility and legitimacy of knowledge must be met. This suggests that elements of stakeholder salience exist between groups in the nuclear neighbourhood, with technical knowledge prized above local knowledge. The costs required to gain such knowledge can explain the observed dynamics of knowledge sharing. Stakeholders possessing an in depth local knowledge have generally gained such knowledge from a lifetime of living in the nuclear neighbourhood and observing the behaviour of the coastline. On the other hand, stakeholders with advanced technical knowledge of coastal behaviour gained such knowledge through significant financial investment. These stakeholder organisations seek to protect their financial capital and are therefore reluctant to share their information with stakeholder groups perusing different agendas for the future management of the coast (Section 5.6.7). Evidently, stakeholder groups have different levels of financial resources to aid adaptation and the economic climate has the capacity to significantly alter financial resources exacerbating gaps between stakeholder organisations. For example, interviews revealed that the 2008 financial crisis led to a decrease in the availability of public money for financing coastal management and adaptation. This stemming of financial capital affects stakeholder groups disproportionately. Those relying on public investment have experienced cuts (statutory agencies, local and national government), those relying on public/private investment partnerships (community groups and statutory agencies) are now more reliant on private investment. Commercial entities, responsible for the existing nuclear infrastructure and then development of the NNB operate in isolation from public funding. However, these groups are exposed to different economic challenges such as raising capital for new developments and agreeing guaranteed electricity prices. The economic challenges faced by the commercial entities are of a different order or magnitude to that of any other stakeholder groups in the nuclear neighbourhood as evidenced by the Hinkley Point C NNB which is expected to cost EDF £16 billion to construct (EDF 2012).

Chow and Chang (2008) found, that organisations are more willing to share knowledge with others who face similar challenge and have similar goals. However, as explained, by their very nature, not all stakeholder groups share the same vision for the future management of the nuclear neighbourhood. Therefore, it is important to consider factors enabling ‘open’ knowledge flows

5.7.6.2 *Enabling open knowledge flows* As discussed, there is an element of stakeholder salience surrounding intellectual capital in the nuclear neighbourhood. Semi–structured interviews revealed that increased trust and education are two factors that may decrease the fragmentation in knowledge flows, enabling 'successful' climate change adaptation. The importance of climate change education is documented widely throughout the literature. For example, Deressa et al (2009) found that education and access to climate change information were two of the main factors affecting the adaptation capacities of farmers in the Nile basin citing the main barriers as lack of adaptation information and financial capital. Bennet et al (2014) uncovered that communities on the northern Andaman coast of Thailand are experiencing and reacting to the impacts of climate change with very little knowledge of climate change *per se*. They assert that climate change education would greatly improve the adaptive capacity. In addition, Spalding et al (2014) assert that increased knowledge sharing will a critical part of coastal adaptation planning, likely reducing the need for expensive engineering options.

Results from the nuclear neighbourhood reflect the current literature - all participants acknowledged the importance of knowledge sharing and promoting education between stakeholder groups. Building on the current literature and the recognition that there are different types of knowledge, stakeholders in the nuclear neighbourhood expressed the importance of creating environments by which knowledge can be shared. Considering the impending impacts of a climate change, Castree et al (2014) argue that the fruits of multidisciplinary knowledge sharing are more valuable to adaptation implementation than the advancement of 'hard' science. There is evidence of such cross-sectorial knowledge exchange in the Sizewell nuclear neighbourhood such as the Suffolk Coastal Forum.

Results revealed that trust is a key factor affecting how willing a stakeholder group to share knowledge. The importance of trust between stakeholders in the coastal zone is documented in the literature. For instance, Schmidt et al (2013b) asserts that trust-building between stakeholders on the Portuguese coastline is essential to improving adaptation success. In this study, trust was deemed important when sharing *and* receiving climate information.

Within the nuclear neighbourhood there appears to be a lower level of trust between commercial entities, responsible for the nuclear infrastructure, and the rest of the stakeholder groups. It is perceived that commercial entities are reluctant to share their technical information with others. This again may be due to issues of stakeholder salience. Zhao et al (2012) suggest that the perceived importance of information may be shaped by the perceived risks of an organisation. Commercial entities do not experience the same level of risk as other stakeholders. In the case of Sizewell, their frontage is defended to a 1 in 10,000-year event whereas the Minsmere frontage, which belongs to RSBP, is defended to a 1 in 100-year event. As such, commercial entities may be unaware of the value of the knowledge they hold, and may not recognise the importance of sharing such knowledge with other stakeholder groups.

He et al (2009) found that people share climate information because they enjoy helping others and wish to maintain trusting relationships. As previously discussed in decision timescales (section 5.7.2), the operations of commercial entities are not driven by emotion – their remits are shaped by legislation and policy. For this reason, they may be less inclined to voluntarily share knowledge with their neighbours. On the other hand, stakeholder groups with an emotional affinity to the area may be more inclined to share their knowledge so to maintain constructive and harmonious relationships with their neighbours. A lack of appreciation for such social dynamics may results in feelings of animosity between groups, leading to distrust and therefore inhibiting successful climate change adaptation. Hence, promoting more open knowledge flows through education and trust could not only reduce the chance of maladaptation, it could enhance relationships between stakeholder groups in the coastal zone which in turn, may increase the adaptive capacity of the nuclear neighbourhood as a whole.

5.7.6.3 *Application of findings*: This section of research has determined that the presence of long-lived nuclear infrastructure in the coastal zone affects the means by which knowledge flows between stakeholder organisations. The degree to which knowledge flows between stakeholder organisations ranges from open and transparent to closed and impermeable. The interaction of stakeholders and the range of knowledge flows was influenced by four factors: intellectual capital, financial capital, trust and education.

Results indicated that the stakeholders exhibiting closed, impermeable knowledge flows are those with in-depth technical knowledge who seek to protected their financial capital invested to such knowledge. Local stakeholder groups (community groups, NGOs and local government) exhibited in depth local knowledge. Trust-building and educational opportunities were found to promote open and transparent knowledge flows. The research uncovered that promoting open knowledge flows and acknowledging the value of different types of knowledge has the potential to enhance the success of adaptation efforts in areas where there is secular divide between stakeholder groups.

5.7.7 *Evolution of partnership working*

Stakeholder organisations in the Sizewell nuclear neighbourhood expressed that the extent of partnership working between groups has the potential to affect success of adaptation. Results indicate that the evolution of partnership working is the most noteworthy theme affecting adaptation success. As illustrated by Figure 5.12 the theme of perceived responsibility (a key theme in its own right) acts as an influential driver affecting the evolution of partnership working.

Since Arnstein's ladder of participation (1969), there has been a rise in studies focussing on stakeholder engagement (Hurlbert and Gupta 2015). There is now widespread recognition that collaboration between stakeholders at all scales, from the international efforts of the IPCC to the local stakeholder neighbourhoods, can increase adaptation implementation rates. Leck and Simon (2013) stress the value of multi-scalar collaborative relationships between national regional and local stakeholders, in the coastal zone; Becker et al (2013) express the importance of encouraging new collaborations between stakeholders. Progressing from Arnstien's ladder, Collins and Ison (2009) explain that multi agency collaboration is necessary as no single stakeholder has clear access to understanding all of the issues or the solutions; adaptation is fundamentally dependent on new forms of learning facilitated by collaboration. With this in mind Holm et al (2013) express the need for new epistemological frameworks and adaptation practices that exceed the boundaries of single disciplines.

Although there is widespread recognition of the importance of stakeholder collaboration, the social dynamics that influence how and to what extent stakeholders collaborate are less well defined (Wise et al 2014). Semi-structured interviews with stakeholders in the nuclear neighbourhood revealed some of the social dynamics influencing the success of adaptation collaboration. Results revealed four influential factors: communication, empowerment, intellectual capital and perceived responsibility. As perceived responsibility is a key theme in its own right, the influencing factors acting on the theme of perceived responsibility also influence the evolution of partnership working.

5.7.7.1 *Encouraging stakeholder collaboration:* Results indicate that strengthened communication, feelings of empowerment and a collective sense of responsibility for the adaptation of the nuclear neighbourhood drive the evolution of partnership working. Insights from the semi-structured interviews revealed that there has been an increase in communications between stakeholder groups in recent years. Organisations belonging to the statutory agency stakeholder group have altered their approach to adaptation from a ‘decide, announce, defend’ approach (Twigger-Ross and Colbourne 2009), with very little communication or consultation with other stakeholders the nuclear neighbourhood, to a ‘yes, if at all possible’ approach to requests from other stakeholders. Stakeholders attribute this to increased empowerment of more localised through the government’s localism agenda and a decrease in centralised funding. The current economic climate means that much funding is a result of public – private partnerships such as grant in aids.

Results indicate that stakeholders within the same stakeholder group work together more extensively than other networks. As discussed (Section 5.7.3.1), increased localism promotes the perception of a collective responsibility for adaptation between stakeholder groups operating locally.

5.7.7.2 *Inhibiting stakeholder collaboration* Results have indicated that stakeholder groups do not value partnership working equally. Similarly to previous themes, stakeholder groups have varied standpoints regarding the key themes. The observed evolution in partnership working has not developed at an equal rate. Partnership working seems less urgent to those groups with greater resources and intellectual capital. Similarly to other themes, organisations that do not actively participate in the evolution of partnership working tend to be centralised (national government) or privatised commercial entities. Due to greater resources, these organisations perceive the risks posed by climate change less problematic as in many cases they are able to implement adaptation initiatives superior to others. For example, EDF have defended the frontage in front of Sizewell B to a 1 in 10,000-year event in accordance with the required safety cases (EDF 2011) and are therefore less likely to accept collective responsibility for the adaptation of the neighbourhood as they are more confident that they have sufficient 'in house' adaptive capacity. Whereas the frontage of the Minsmere RSPB reserve is likely to experience significant breaches in the next 20 years if action is not taken (Environment Agency 2009), as evidenced by the semi-structured interviews the RSPB is actively seeking the aid of EDF in collective adaptation efforts.

5.7.7.3 *Application of findings* When referring to the implementation of cross-sectorial climate change adaptation policies and plans in vulnerable coastal zones, Serrao-Neumann et al (2014) assert that there is very little evidence of how this can be achieved in practice. This section of the research has provided insights as to how the development of stakeholder collaboration can help and hinder climate change adaptation efforts. Results suggest that awareness of the benefits of stakeholder collaboration is increasing in the nuclear neighbourhood of Sizewell. This research has discovered that empowerment, increased communication between stakeholder groups and a greater sense of collective responsibility are all factors that enhance stakeholder collaboration. However, the protection of intellectual capital was deemed to inhibit adaptation collaboration between stakeholder groups.

The findings from this research offer valuable insights into the social dynamics affecting those involved in coastal adaptation in the nuclear neighbourhood. Such insights may be used to inform and develop pragmatic guidance for the future development of climate change adaptation efforts. These considerations are discussed in the concluding section of this chapter.

5.8 Conclusion

There is now widespread appreciation throughout society that the potential impacts of climate change on coastal zones may be significant. However, the implementation and success of adaptation actions are subject to uncertainties surrounding factors relating to future geomorphological processes and socio-economic responses. This section of the research answers calls by Nicholls and Cazenave (2010) who call for more assessment of the mechanisms by which adaptation is planned and implemented. This section of the research has provided a detailed insight into the coastal management and adaptation decision-making landscape in the coastal neighbourhood surrounding long-lived infrastructure using Sizewell as a case study.

The chapter first established that a diverse set of stakeholder organisations are involved in coastal management and adaptation in the nuclear neighbourhood and that their priorities vary depending on their individual remits. Results revealed that stakeholder organisations naturally fell into six groups: commercial entities, community groups, local government, national government, NGOs and statutory agencies. By possessing similar standpoints on the key attributes of the climate change adaptation process Organisations within each groups exhibit affinity to one other.

Semi-structured interviews with stakeholder organisations in the Sizewell nuclear neighbourhood revealed six key themes that have the potential to impact upon the successes of climate change adaptation initiatives: i) decision timescales, ii) perceived responsibility, iii) units of governance, iv) response to climate shocks, v) knowledge flows and vi) evolution of partnership working. As discussed, semi-structured interviews revealed 12 factors that affect the standpoint and opinions of each stakeholder group. These are: communication, education, empathy, empowerment, finance, intellectual capital, legacy of extreme events, perceived responsibility, politics, positionality, preparedness and trust. The following equation can be used to summarise the relationships between the key findings:

(12 Influential factors X 6 Key themes) 6 Stakeholder groups = Stakeholder standpoint

Results revealed that intellectual capital and finance are the most influential factors, interacting with four and three themes respectively. Positionality, empowerment and politics also influence the way stakeholder organisations interactions with multiple themes. Results also discovered that the theme of perceived responsibility, a theme in its own right, plays a key role in the evolution of partnership working (Figure 5.12)

This research provides insights into the complex nature of the decision-making landscape and key factors affecting the success of climate change adaptation. Increasing the awareness of these factors with stakeholder organisations in the nuclear neighbourhood may prove to be valuable in adaptation success.

In addition to highlighting the prominence of the six key themes that govern the success of adaptation efforts, the research has also provided an insight to how other factors affect the standpoints of in relation to the key themes. These standpoints varied depending on which group a stakeholder organisation belonged to and are shaped by the complex interaction of the 12 influential factors (Figure 5.12).

Overall, this section of the research has uncovered fundamental variations in standpoints of different stakeholder groups. Generally, more centralised and/or financially secure groups (national government and commercial entities) adopt a more clinical objective approaches to adaptation. This contrasts with groups situated and operating locally (community groups and local government). These stakeholder organisations hold more subjective and emotionally motivated standpoints. The standpoints of NGOs and statutory agencies form the middle ground. The standpoints of these groups are shaped by prescribed remits. However, in many cases individuals working locally in these organisations have an affinity to the area so there is a degree of subjective, emotional motivation when making decisions about the adaptation of the nuclear neighbourhood.

This section of the research has also uncovered differences in the ways in which stakeholder organisations engage with each other. The findings from this section of the research have enhanced the understandings of varied stakeholder standpoints present in the adaptation process, complementing the work of others attempting to advance Arnstein's Ladder of participation (1969) (Collins and Ison 2009; Tritter and McCallum 2006). For example, Hurlbert and Gupta (2015), suggest a 'split ladder' of participation that differentiates between technical and non-technical decision-making and encouraging a deep and collaborative learning. The insights into social dynamics associated with climate change adaptation and decision-making in the Sizewell nuclear neighbourhood may be used to aid such learning about different types of participation and in turn the development of pragmatic advice and guidance for enabling the implementation of successful adaptation initiatives.

5.8.1 *Enabling adaptation implementation*

Over the last 20 years, the international community has attempted to set nations on a pathway to ensure that humanity limits global warming to 2 °C. However, these efforts are unlikely to be successful; many are now predicting that the interim 2020 mitigation targets will not be reached (BBC News 2016). Failing to achieve mitigation targets points to the need to take adaptation efforts much more seriously.

An improved understanding of the architecture and attributes of adaptation may support and promote successful implementation. This section considers the findings and suggests some practical ways to strengthen implementation and increase the likelihood of successful adaptation, moving towards shared vision of coastal zone management.

5.8.1.1 *Gaps and valleys in the adaptation decision making landscape:* Gaps between stakeholders in the adaptation decision-making landscape can inhibit the 'successful' implementation of climate change adaptation (Pelling 2010, Thomas and Twyman 2005). To date, the adaptation literature has focused on producing tools to identify and categorise gaps and associated barriers to successful climate change adaptation (Chapter 2, section 2.9). The most frequently cited 'gaps' in the literature centre around: differences in the conceptual interpretation of climate change and adaptation (Biesbroek et al 2013); variance in the ways that different sectors address climate change and adaptation (Dany et al 2016; Moser and Boykoff 2013; Nisbet et al 2010); differing levels of knowledge (Moss et al 2013); and discrepancies in resources and access to climate change information (Gerlitz et al 2015). Currently there is limited research beyond case-studies and theory (Lesnikowski et al 2015), recently there have been calls to focus on the mechanisms enabling adaptation implementation and to establish pragmatic guidance for decision makers (e.g. Dupuis and Knoepfel 2013; Wilby et al 2010; Johnson and Wilby 2015). Mastering 'successful' adaptation implementation is particularly urgent when considering climatically induced environmental tipping points. Figueres (2013) fears that crossing such thresholds could catapult society into uncharted territory, without tangible implementation strategies, much of the body of adaptation research could become immaterial.

This section of the research acknowledges the calls above and proposes that labelling the imbalances and differences between stakeholder organisations involved in climate change adaptation as 'gaps' can be counterproductive. The language implies that the parties on either side are irreconcilably separated. Instead, the empirical results from this research suggest that it would be more appropriate to refer to gaps in the adaptation decision-making landscape as 'valleys' as although stakeholders exhibit different standpoints, all parties in the nuclear neighbourhood are faced with the same potential threats from climate change and are therefore inherently linked. The term 'valleys' is regarded as more constructive terminology here - stakeholder groups may stand on opposite sides of the valley but the valley is shaped by the same forces and connected by the river running through it.

The ways in which societal factors can influence adaptive capacities has been documented extensively (e.g. Adger et al 2009; Grothman and Patt 2005; Shakleton et al 2015). For instance, Adger et al (2009) assert that the overall limits to adaptation are ultimately determined by the goals of the adaptation, which are underpinned by diverse social issues. They claim that it is possible to overcome social limitations to adaptation. Shackleton et al (2015) argues that more attention is needed on societal gaps, to establish how these barriers occur, how they interact to shape adaptation processes, who they affect most, and what is needed to overcome them. With this in mind, the key findings from Chapter 5 can be used to explain the 'valleys' between stakeholders engaged in adaptation in the Sizewell nuclear neighbourhood. The presence of six different groups which denote the various standpoints of stakeholder organisations, six key themes, each an attribute of successful climate change adaptation and 12 influential factors that shape the standpoints of stakeholders with regards to the key themes simplify and bound the complexities of the adaptation decision making landscape. These attributes of the adaptation process can be arranged into an equation expressing a matrix of possibilities (Section 5.7.7.3). The matrix of possibilities denotes a vast number of permutations therefore the possibilities of stakeholder standpoints are almost infinite. Some stakeholder standpoints may be polarized others may be similar with subtle differences.

The findings of this section of the research addresses the call by Shackleton et al (2015) and provides evidence of how societal factors interact to shape the adaptation process. The increased understanding of the architecture and attributes controlling successful climate adaptation, gained throughout this research, can be used to promote social capital enabling 'valleys' in the adaptation decision-making landscape to be bridged. The following sections explain how the research insights might translate into practice.

5.8.1.2 *Commonly aligning different sectors of society:* The results showed the range of stakeholder organisations engaged in the management and adaptation of the coastal neighbourhood surrounding long-lived infrastructure. This leads to a host of stakeholder standpoints regarding the implementation of adaptation. One way to progress towards successful implementation of climate change adaptation and simultaneously bridge the valleys between different stakeholder standpoints is to strategically target the reduction in societal segmentation.

Previous research suggests that education and promotion of joint knowledge production between societal sectors can decrease the gaps between those engaged in climate change adaptation (Hegger et al 2012; Moss et al 2013). Although productive for adaptation efforts moving forward, consideration must also be given to the brokerage of existing knowledge. Some have expressed that opportunities to broker knowledge across societal sectors have previously been missed (Clar et al 2013). For example, in a systematic review of 64 online adaptation tools, Mitchell et al (2016) concluded that the majority were unfit for purpose, lacking structure and key information that are essential for planning and implementing adaptation initiatives.

Lemos (2015) calls for the active management of the boundary between knowledge production and use in adaptation efforts. To manage this interface effectively it is essential to understand how the process works. Bidwell et al (2013) recognise that knowledge sharing is not a linear process but rather takes place within networks. For example, one study of the Great Lakes region in the USA, found that adaptation knowledge is disseminated centrally to specialized local networks; in this way information is tailored to meet particular applications (Kalifatis et al 2015). The nature of this dissemination approach means that knowledge is not readily accessible to all stakeholders. Similarly, the semi-structured interviews in the Sizewell nuclear neighbourhood revealed that knowledge is unevenly distributed between stakeholder organisations leading to issues of stakeholder salience and protection of intellectual capital further segmenting societal sectors involved in adaptation.

Identifying the existence of different types of knowledge and variations in stakeholder salience adds to the understanding of the root causes behind societal segmentation and informs efforts to bridge gaps between stakeholder organisations. Sheate and

Partidário (2010) stress the importance of sharing knowledge above information. The presence of a positivist assumption – the opinion that access to information will lead to improved adaptation decision-making – may hinder the reduction of societal segmentation. For example, the semi-structured interviews revealed that information rich organisation such as the commercial entities, responsible for the development of the NNB, are reluctant to share unprocessed information with other stakeholder groups. They deem it risky as information and raw data may be interpreted and used in ways that are detrimental to the development of the NNB.

Insights from the interviews revealed that stakeholders are more willing to share their knowledge, information that has been processed through learning, as opposed to raw data. For example, commercial entities share their knowledge through formal consultation processes where their knowledge has been framed for the benefit of their intentions. With this in mind, Sheate and Partidário (2010) found that sharing knowledge rather than information sharing is more likely to influence decision-making. As established, different types of knowledge are present within the nuclear neighbourhood, hence, it is important to provide neutral platforms and environments for knowledge sharing. Semi-structured interviews revealed that there are already environments to facilitate such knowledge sharing in the Sizewell nuclear neighbourhood. For example, events such as the Suffolk Coastal Forum enable sharing. Even so, organisations sharing knowledge have control as to what they choose to disseminate to the organisations requesting knowledge. Co-producing questions at such events, provides a neutral platform from which various stakeholder organisations can collaborate and constructively share knowledge. In this way, gaps between stakeholders may be bridged and organisations better aligned in their efforts to implementation successful climate change adaptation.

5.8.1.3 *Positively framing adaptation:* Semi-structured interviews with stakeholders in the Sizewell nuclear neighbourhood indicated that stakeholder organisations typically regard adaptation to climate change as a duty set by statutory obligations rather than an endeavour that could yield rewards. Theories around cognitive dissonance denote that stakeholders regard climate change as a distant threat that does not impact on day to day operations as prominently as other social factors such as health and finance, hence the threat is mentally downplayed and adaptation action is less likely (Adger et al 2013; Moser 2010; Whitmarsh 2008; Wolf et al 2010). Similarly, the theory of normative social influence denotes that stakeholders are likely to mirror the behaviour of others. In a study investigating perceived risk and flood insurance purchase Lo (2013) concluded that adaptive behaviour is not necessarily driven by the perception of risk but by the ways in which the individuals situate themselves in their social circles or society. To overcome the discussed social barriers, bridge the valleys between differing stakeholder standpoints and aid stakeholders with in adaptation implementation, adaptation should be framed and promoted as a beneficial endeavour with contemporary, tangible co-benefits.

5.8.1.4 *Making adaptation appealing:* The semi-structured interviews revealed that finance, together with intellectual capital, are the most influential drivers affecting how stakeholder organisations engage with climate change adaptation. The 2008 economic recession has resulted in significant cuts in public funding for coastal management and adaptation. Therefore, it is reasonable to assume that framing adaptation as an appealing endeavour might incentivise stakeholders to engage, collaborate and implement adaptation more readily. There are a range of ways of framing adaptation as appealing, some regard the loss of damages appealing (Roberts and Pelling 2016) whereas others view the benefits of adaptation in monetary terms or increases in security such as sustainable food supplies (Caballero-Anthony et al 2015). Work by Hudson et al (2016) supports this notion. They found that insurance-based measures are able to incentivise adaptation. They measured how households adaptation behaviours changed under insurance based incentives compares with households that act on their own subjective risk beliefs. Their results suggest that financial incentives could reduce residential flood risk in Germany by 12 % and 24 % in France by 2040. This suggests that creating investment opportunities for the private sector could help generate capital for the implementation of climate change adaptation. Increased private investment in adaptation would enable stakeholders in the Sizewell nuclear neighbourhood to overcome barrier associated with the lack of financial resources. For example, many of the individuals involved in community groups do so on a voluntary bases, as such their time and efforts are limited and often on an ad hoc bases. Increased private investment would improve the capabilities of these groups, capitalising on enthusiastic and knowledgeable human resource.

Interviews with stakeholders revealed that community groups are already leading initiatives to generate financial capital. For example, the Enabling Development initiative (Table 4.2a) raised capital to support the protection of a hamlet and listed Martello Tower. Interviewees from community groups also divulged plans to impose a coastal protection tax on all holiday lets in the coastal zone to generate capital for coastal management and adaptation. The interviews also showed that financial capital is an influential factor in the adaptation process and the adaptation literature asserts that making adaptation profitable could increase investment. However, not all stakeholder groups expressed an interest in investing in adaptation. This may be because investment opportunities have not yet been identified but it also poses the question, what could spark enthusiasm to invest in adaptation?

5.8.1.5 *Recognising the value of the 'sizzle' factor:*When considering how to bridge the valleys, align stakeholder standpoints and subsequently increase adaptation implementation rates, the mantra of Elmer Wheeler, a famous 20th century American salesman, can be applied. Wheeler (1938) believed that in order to sell the sausage you need to sell the sizzle. It is not the item or idea being sold that necessarily secures a purchase; the emotions associated with the item or idea is more influential. Wheeler recognised that these feelings can be influenced by a sales pitch. The same logic can be applied to climate change. To date, climate change has tended to been framed in a negative way. For example, films such as *The Day After Tomorrow* and media have often portrayed climate change as an uncontrollable, undesirable vision of the future (Hulme 2009, Leiserowitz 2004; Painter 2013). Futerra Sustainability Communications (2015) claim that to achieve climate change goals, the issue must be rebranded as a positive, 'sizzling' vision. They assert that it is the 'vision' of the future that people buy into and purchase.

Simply making adaptation financially appealing to stakeholders is not sufficient to ensure success, as a profitable opportunity does not necessarily engage the emotions relating to the issue of climate change *per se*. Futerra Sustainability Communications (2015) claim that the psychological theory involved in converting climate change from a negative to a positive vision of the future is also essential. They draw on the psychological theory of 'availability heuristic' developed by Tversky and Kahneman (1973): when a person is faced with a decision under uncertainty they rely on a simplified vision of the future rather than an extensive calculation of possible futures (Kahneman and Tversky 1982). In this way, negative visions of climate change have dominated our subconscious and therefore adaptation is often regarded a duty.

The results from this thesis provide an insight into what could be a more constructive vision of the future, seen through the eyes of the diverse stakeholders in the Sizewell nuclear neighbourhood. The establishment of the stakeholder groups, key themes and influencing social factors, provide a starting point from which stakeholders can develop their understandings of the adaptation process and realise a positive vision of the future adaptation of the nuclear neighbourhood.

Due to the diverse nature of stakeholder organisations in the Sizewell nuclear neighbourhood it is unrealistic to expect stakeholders to reconcile the same vision(s) for the future management of the coastline, as illustrated by the matrix of possibilities (Section 6.3.1) there are vast number of different standpoints stakeholders may adopt. However, embracing the insights into the architecture and attributes of adaptation, could aid stakeholders in their collective endeavour to successfully manage and adapt the coastline. In the first instance, this could be achieved by bridging the valleys between stakeholder groups and overcoming barriers inhibiting adaptation. When framed by the attributes of adaptation, these actions have tangible benefits with measurable outcomes such as accepting a collective responsibility for the adaptation of the coastline and sharing knowledge more freely. The following section considers how the findings from this research may be generalised and utilised by stakeholders in other vulnerable coastal locations.

The following chapter concludes the thesis. It will first situate the research within the adaptation knowledge base then revisit the aims and objectives. The key innovations of the methodology will be highlighted. The chapter will summarise the key findings and consider their wider implications. Finally, the Conclusion will acknowledge the main caveats of the research, how these might be addressed, and consider opportunities for further work.

Chapter 6: Conclusions

6.1 The importance of successfully adapting to anthropogenic climate change in coastal zones

Coastal zones globally are experiencing rapid development, including siting of nationally significant long-lived infrastructure. At the same time, these zones are expected to be at the forefront of climate change impacts. In accordance with the IPCC (2014, pp 80), successful adaptation is defined by *measurably increasing the adaptive capacity of human and natural systems*. Successful adaptation of the UK's coastal zones is becoming ever more pertinent as the UK government has pledged to increase national nuclear energy generating capacity by eight NNB in coastal zones of England and Wales. The centennial life span of such infrastructure development requires well-informed, integrated approaches to adaptation to protect long-term operations and ensure safety.

The multifaceted, unbounded, fuzzy nature of climate change adaptation means that it can be difficult to study holistically. Hence, methods of best practice are difficult to synthesise (Ford et al 2013). To date, research has tended to centre on theories of adaptation, the development of analytical tools and identification of barriers (Biesbroek et al 2013). Meanwhile, practitioners are struggling to find pragmatic guidance to implement successful climate change adaptation (Moser and Boykoff 2015; Serrao-Neumann et al 2014; Wise at al 2014).

By examining the decision-making landscape as a whole, this PhD contributes to the adaptation discipline by defining the architecture and attributes governing the success of adaptation processes in the neighbourhood of long-lived coastal infrastructure. Insights gained from this research can help stakeholder organisations to implement adaptation initiatives to address the potential threats of climate variability and change.

This final chapter first revisits the aims and objectives of the research before recapping the methodological approaches used to address the research questions. Next, the chapter outlines the key findings and identifies the most innovative contributions of the research to adaptation knowledge. The last section reflects on the limitations of the research before proposing opportunities for further research.

6.2 Resolving the research questions

This research resolved the questions outlined in Section 1.5 by focussing on UK coastal case study areas featuring long-lived infrastructure. By employing a mixed methodology approach the research captured the perspectives of a wide range of stakeholder organisations engaged in the adaptation of the coastal zone. By examining the adaptation decision-making landscape as a whole, the research defined the architecture and attributes governing the overall efficacy of the adaptation process.

To investigate the research questions four groups of questions were compiled:

(1) Regarding the context of adaptation (Research questions 1 – 2), asked about the key stakeholders operating in the coastal neighbourhoods of long-lived infrastructure and about the main threats they face from climate change.

(2) Regarding the architecture of adaptation (Research questions 3 - 4), questions asked about the nature of the adaptation framework used by stakeholders, in order to establish how framework adaptation approaches differ amongst stakeholder organisations, whether there are preferred adaptation frameworks and to what extent the frameworks employed might affect the success of adaptation initiatives as a whole.

(3) Regarding the attributes of adaptation (Research questions 5 - 9), questions asked about how stakeholders were involved in adaptation and what motivates them to engage with the issue. This set of questions also addresses the timescales over which adaptation decisions are made, how the presence of the nuclear infrastructure and perturbations in national administrative systems might shape local adaptation efforts and also within what domains stakeholders thought coastal management and adaptation are most appropriately bounded.

(4) Regarding the role of climate shocks (Research question 10), investigated the legacy of climate shocks, asking about the main lessons learnt and whether there have been any subsequent changes to adaptation strategies.

To address these four themes, research progressed in two distinct phases. First, to define the architecture of adaptation, an investigation into the adaptation frameworks used by stakeholder organisations in the neighbourhood of long-lived infrastructure was conducted (Chapter 4). Second, to establish key attributes of adaptation, an extensive exploration into the factors influencing the adaptive capacities of stakeholder organisations was undertaken via an iterative semi-structured interview process with stakeholder organisations in the Sizewell nuclear neighbourhood, Suffolk, UK (Chapter 5). Chapter 5 then evaluated some practical ways by which the challenges associated with achieving successful adaptation implementation might be overcome. Each step is recapped below.

6.2.1 *Investigating the architecture of adaptation through adaptation framework analysis*

Four coastal neighbourhoods with long-lived infrastructure were identified: Hinkley Point in Somerset, Sizewell in Suffolk, Wylfa on Anglesey and Portsmouth Harbour in Hampshire respectively. These four neighbourhoods were selected for their spatial distribution and varied exposures to the potential impacts of climate variability and change (Chapter 3).

Surveys were undertaken to identify climate change adaptation initiatives in the four study neighbourhoods. Adaptation documents with an online presence were compiled into an inventory. The frameworks stakeholders use when planning and implementing adaptation initiatives were categorised using a criterion tool.

The criterion tool for identifying and categorising climate change adaptation initiatives was based on a broader synthesis of adaptation frameworks evident in the peer reviewed literature (Armstrong et al 2015, Appendix 4). The tool applies six criteria (or characteristic hallmarks) (see Table 4.1). In summary, these are:

i) *Use of climate model information* refers to the extent by which adaptation initiatives incorporate outputs from GCMs and climate scenarios such as UKCP09;

ii) *Analysis indicators* refer to the metrics for determining the level of risk or severity of potential impacts posed by climate change. These may be environmental (e.g. temperature, precipitation or erosion rates) or social vulnerability (e.g. health, GDP or literacy rates) indicators;

iii) *Level of socio-economic knowledge* refers to the extent to which local demographic factors, that may affect adaptive capacity, are considered and incorporated;

iv) *Degree of stakeholder engagement* refers to the extent and at what stages in the adaptation process stakeholders are involved and consulted (which may vary between extensive consultation from the inception of an initiative to zero consultation);

v) *Adaptation implementation mechanisms* refer to the means by which initiatives are implemented. These may include the commissioning of 'hard' adaptations such as flood defence and alleviation schemes or 'softer' social adaptations such as behaviour changes;

vi) *Scale of implementation* refers to the domain within which the adaptation initiative is implemented. This could range from site-level (such as a flood wall) through to national-level policy reforms.

The above hallmarks are used to denote three adaptation frameworks: Scenario-Led, Vulnerability-Led and Decision Centric. Adaptation initiatives from the nuclear neighbourhood were compiled and categorised using the criterion tool. The use of a standardised tool enables cross comparisons of framework approaches used for adaptation initiatives in different coastal zones surrounding long-lived infrastructure.

6.2.2 *Investigating the attributes of the adaptation process in the coastal neighbourhood surrounding NNB*

To investigate the attributes affecting the process leading to successful adaptation, the second phase of the research focussed solely on the stakeholder organisations in the Sizewell nuclear neighbourhood on the Suffolk coast, UK. This site was selected, from the four used to investigate the architecture of adaptation, as the Suffolk coastline is one of the most vulnerable parts of the UK coastline. Furthermore, the development of the NNB is at the public consultation stage, so there is a diverse set of stakeholders who are actively engaged in coastal management and adaptation. Using the adaptation inventory from the first phase of the research as a starting point, stakeholders at the organisational level were identified and invited to contribute to the research by taking part in a semi-structured interview.

The Grounded Theory Methodology (GTM) was employed to establish factors that affect the ability of stakeholders to 'successfully' implement adaptation to climate change. This research approach requires that data collection and analysis are undertaken simultaneously, one informing the other. As this methodology is iterative in nature and participant led, it was deemed the most appropriate means of researching the contentious and unbounded topics of climate change, coastal management and nuclear power.

The one to one, face to face, semi-structured interview format ensures that the effects of stakeholder salience and normative social influences are reduced as there are no external influences from other stakeholders. The semi-structured interview technique helped to build a rapport between the researcher and the participant, thereby encouraging the participant to speak extensively and openly about their knowledge, experiences and views about the factors contributing to successful adaptation. The semi–structured format also enabled the researcher to guide the direction of interview. In the first instance interview questions centred on the factors deemed to affect climate change adaptation efforts voiced by the academic literature (Section 2.9). The interview schedule was pilot tested before being used for data collection. This was achieved by interviewing the principle investigators of the coastal research projects ARCoES and iCOASST.

As prescribed by the GTM, data analysis was undertaken in parallel with data collection. Interview recordings were transcribed, analysed and coded using the CAQAS software NVivo 10. Analysis and coding were carried out at each iteration of the data collection which consisted of a batch of approximately five interviews. Emerging nodes and themes, such as the differences in decision timescales and reactions to climate shocks (Figure 5.3), were used to update the interview template informing subsequent interviews. The data collection phase of the research was deemed complete once a saturation point was reached. This was judged to be when all relevant stakeholder representatives had either taken part in the research or were unwilling/unable to do so. Relevant representatives were identified using the snowball technique (Goodman 1961) by asking participants if there was anyone else they deemed suitable to take part in the research.

6.2.3 *Enabling adaptation implementation - realising future vision(s) for coastal management and adaptation surrounding long-lived infrastructure*

The academic literature was consulted to determine how a greater understanding of the architecture and attributes of adaptation can ensure the successful future management of the nuclear neighbourhood. This stage of the research considered how to practically strengthen adaptation initiatives and realise the future visions of stakeholder organisations.

‘Gaps’ emerged in the ways in which different stakeholder organisations approached adaptation. Practical ways in which the defined architecture and attributes of adaptation can help to overcome the challenges associated with such gaps were then considered and discussed with the support of the published literature.

It is recognised that stakeholder groups in the nuclear neighbourhood exhibit fundamental differences in their nature and the ways in which they comprehend the risks posed by climate variability and change. With this in mind, it may be unrealistic to try to achieve one vision of future coastal management and adaptation. Instead, by utilising the defined architecture and attributes of adaptation, as established in this thesis, stakeholders may move forward with a greater appreciation of the process of adaptation and the factors that mould the means by which stakeholder organisations engage with the issue. Armed with this knowledge stakeholders may increase their appreciation of others operating in the nuclear neighbourhood and navigate a productive pathway towards their future vision(s) of coastal management and adaptation.

6.3 Key findings

In line with the aims of the thesis, the research questions were addressed by two empirical phases, which, with the aid of the published literature considered future visions for the management of coastal neighbourhoods near long-lived infrastructure. This research has defined the architecture and attributes of the adaptation process outlining how these elements may enhance or inhibit efforts to implement climate change adaptation. The following sections summarise the key findings of the research, and point to the innovation and practical value of the results.

6.3.1 *Architecture of adaptation success*

The four adaptation inventories confirmed that the management and adaptation of the coastal zone is fundamentally a multidisciplinary endeavour. Multiple sectors of society are involved in adaptation initiatives in each of the study areas. In all four neighbourhoods, the environmental sector either regulatory (EA and NE) or conservationist (NT, SWT, RSPB, AONB, SWT) led on more than half of the documented adaptation initiatives (Figure 4.5). Document analysis also revealed that the initiatives were most frequently overseen from a local administrative level such as a local council (Research question 2).

Inventories highlighted that the three theoretical adaptation frameworks (SL, VL and DC), do not readily map onto 'real world' practice. Instead, coastal managers and decision makers adopt a hybrid framework approach to adaptation (Section 4.3.5). The DC framework was most prominent and was utilised in partnership with elements of either the VL or SL framework approaches. No evidence was found of VL and SL framework approaches being used in combination (Research questions 3 and 4).

When comparing the composition of hybrid frameworks and the physical environs of each study site (Chapter 3), the site least vulnerable to climate (Wylfa) employed more SL elements than those deemed more vulnerable (Hinkley, Sizewell and Portsmouth). Adaptation documents exhibiting with elements of the SL framework were primarily advice notes and scoping exercises resulting in little on-the-ground adaptation. For example, The AONB's Vision for Anglesey (Table 4.2e) aims to understand the potential impacts of climate change and draft a strategic adaptation response.

When applied to the four inventories, the criterion tool was able to categorise the hallmarks of adaptation into one of the three framework approaches 86% of the time. Using the criterion as a standardised tool enables decision-makers to compare the adaptation and management framework architecture in different locations. It is recognised here that only a modest number of adaptation documents were available. Further application as mentioned above would establish the potential transferability of the tool. If robust, the criterion tool could provide an innovative platform on which to develop methods of best practice for the future management and adaptation of coastal neighbourhoods surrounding long-lived infrastructure. The tool would enable stakeholders to directly compare their approaches to adaptation and, based on their experiences, review the strengths and weaknesses of different frameworks.

The three theoretical framework approaches to adaptation did not map seamlessly to on-the-ground adaptation efforts of practitioners. This highlights opportunities to further align academic and practitioner approaches. Alignment could promote greater collaboration between stakeholders and refine the architecture of adaptation, advancing adaptation frameworks to aid the success of climate change adaptation efforts. In practice, this could be achieved by holding workshops with stakeholders, teaching them how to use the criterion tool to analyse their framework approaches and facilitating conversations between different organisations.

6.3.2 *Attributes of adaptation success*

The semi-structured interviews with stakeholders in the Sizewell nuclear neighbourhood uncovered many factors that have the potential to both enhance and inhibit climate change adaptation efforts (Research questions 5 -9).

First, this phase of the research highlighted the diverse profile of stakeholders organisation involved in coastal management and climate change adaptation in the nuclear neighbourhood (Research question 2). Interview analysis uncovered similarities and differences between the ways in which stakeholder organisations engage in climate change adaptation. Opinions of stakeholder organisations varied regarding the attributes of the adaptation process. Results revealed that these standpoints depended on the type of stakeholder organisation. Six stakeholder groups were established based on the collation of standpoints and opinions; i) commercial entities, ii) community groups, iii) local government, iv) national government, v) NGO's and vi) statutory agencies.

Second, the participant-led iterative approach of the GTM, pointed to six key themes deemed by all stakeholder groups as central to the success of adaptation. These were:

i) *Decision timescales* which refer to the type and scale of timescales over which stakeholders make decisions.

ii) *Perceived responsibility* refers to the degree to which stakeholders take ownership of the adaptation initiative(s).

iii) *Units of governance* refers to the boundaries by which coastal management and adaptation is framed either socially or physically.

iv) *Response to climate shocks* refers to stakeholder reactions in the wake of an extreme weather event (ranging from no changes to operations through to transformational change where the mandate of an organisation or operations step-change).

v) *Knowledge flows* refer to the transparency and openness of stakeholder organisations, including the extent to which they are willing to share knowledge and information with other stakeholder organisations in the nuclear neighbourhood.

vi) *Evolution of partnership working* refers to the diversity of the networks within which an organisation works with others to implement adaptation.

Third, stakeholder standpoints on the six key themes varied depending on which stakeholder group an organisation belonged to. The standpoints adopted by these groups were shaped by 12 social influences:

i) levels of *communication* between stakeholders, *ii)* availability of *education* opportunities by which stakeholders can learn and share knowledge about the potential impacts of climate change, adaptation and the management of the coastline,

iii) empathy refers to the awareness and affinity stakeholders display towards one another,

iv) empowerment refers to the reasons motivating stakeholders to engage with coastal management and adaptation,

v) finance refers to monetary cycles and economic resources available to stakeholders to fund adaptation,

vi) intellectual capital refers to the individual knowledge bases of stakeholder organisations,

vii) legacy of extreme events refers to the ways in which extreme events change the operations of stakeholder organisations,

viii) perceived responsibility refers to the level or responsibility a given organisation accepts for the adaptation of the nuclear neighbourhood,

ix) politics refers to means by which political cycles impact adaptation efforts,

x) positionality refers to the adoption of a particular position in relation to other stakeholder with based on the comprehension of climate change, world views and an awareness of others,

xi) preparedness refers to differences in the state of readiness for the potential impacts of climate change and variability and

xii) the levels of *trust* displayed between stakeholder organisations.

Understanding the relationships between the attributes of adaptation (Chapter 5) simplifies the complex adaptation decision-making landscape by compartmentalising the topic, enabling stakeholders to understand how each other currently address the potential impacts of climate variability and change. Such simplification provides a means to answer challenging questions about achieving the successful adaptation of the nuclear neighbourhood. Answering these challenging questions about the adaptation process could further align stakeholders and increase their shared understanding of the adaptation process.

With regards to the specific research questions, this thesis has determined that the timescales over which stakeholders make adaptation decisions are both aspirational and operational (Research question 6) . Operational timescales are typically ~ 5 year into the future whereas aspirational time horizons vary depending on stakeholder group and influencing social factors (Sections 5.6.3 and 5.7.2). Stakeholder collaboration has increased amongst some stakeholder groups as evidenced by the collaborative involvement of multiple stakeholders in the inception of both the Deben and Alde and Ore Estuary management plans and increases in applications for grant in aid funding. Stakeholder groups that are less tied to national politics and finance (commercial entities) are less likely to seek collaborative working (Sections 5.6.8 and 5.7.7).

With regards to research question 7, the findings uncovered that there are different types of knowledge present in the nuclear neighbourhood. Some stakeholder groups possess in depth technical knowledge of the physical functioning of the coast (e.g. bathymetry modelling of off shore sediment transport and thermal plums). Others have deeper local knowledge of stakeholder networks (e.g. skills, experiences and contacts of individuals and stakeholder organisations).

All knowledge types are valuable when considering the successful adaptation of the coastline. This was evidenced by the response to the winter storms of 2013/14, local stakeholder groups were asked to help the Army in reporting damages to flood defences. Their in-depth, high resolution knowledge of the nuclear neighbourhood supported the swift completion of the task, enabling repairs to be completed in a timely manner. Commercial entities, with in depth technical knowledge, recorded the event and changes to the off shore bathymetry with instruments on the sea bed. They presented the results at an the annual Suffolk Coastal Forum conference increasing the knowledge of stakeholders organisations engaged in the management and adaptation of the nuclear neighbourhood. Similar to stakeholder collaboration, not all stakeholder groups are equally willing to share their intellectual capital during peace time. For example, commercial entities are wary of sharing their advanced technical information for fear of data being manipulated in ways that does not coincide with their interests. On the other hand, those stakeholder groups with in depth social knowledge are more willing to share. Trust between stakeholder organisations and educational opportunities such as coastal workshops, annual conferences and monthly stakeholder forums promote open knowledge flows; conversely the protection of intellectual and financial capital inhibit the flow of knowledge (Sections 5.6.7 and 5.7.6).

With regards to research question 8 the motivation of stakeholders when implementing adaptation is strongly linked to their sense of perceived responsibility (Sections 5.6.4 and 5.7.3). Stakeholders are either motivated by statutory duties or emotions due to their positionality. The research revealed that there is some debate between stakeholders in the nuclear neighbourhood regarding the most appropriate units of governance. However, there is recognition that both physical and social dimensions need to be incorporated into coastal management but as of yet no formulation has been established. Some stakeholders believe that the bounds of governance should reflect sediment flows whereas others believe there should be both physical and social units of governance (Sections 5.6.5 and 5.7.4).

When considering research question 10, it is evident that stakeholder organisations respond differently to climate shocks. Local, self-motivated groups (such as community groups and NGOs) were more likely to adopt transformational change than formalised stakeholder groups (statutory agencies, government and commercial entities). Results revealed that discrepancies in levels of preparedness, as indicated by the level of disruption caused by the winter storms of 2013/14, contributed to the different reactions to climate shocks (Sections 5.6.6 and 5.7.5).

As outlined above, effective dissemination of the findings could enlighten stakeholder organisations engaged in adaptation in the neighbourhood of long-live infrastructure by helping them to understand the dynamic, social nuances between organisations and aid future adaptation. This could be facilitated by revisiting stakeholders in the nuclear neighbourhood individually or designing an event to communicate the architecture and attributes of the adaptation to all stakeholders in the nuclear neighbourhood,

6.3.3 *Future visions of adaptation success*

As the stakeholder organisations operating in the Sizewell nuclear neighbourhood are diverse, 'valleys' nee 'gaps' between stakeholder organisations are expected, as in many cases organisations are fundamentally different. It is acknowledged that the standpoints of stakeholders are shaped by a complex array of social factors as established in Chapter 5. Therefore, different stakeholder organisations may remain on opposite sides of the 'valley'. Instead of breaking down and overcoming barriers associated with the differences in stakeholder standpoints, efforts should be made to bridge and align the adaptation efforts of stakeholder organisations. The conclusion of chapter 5 considers ways in which opposing standpoints could be connected by i) reducing divisions between sectors of society and ii) positively framing and incentivising adaptation.

Improved understanding of the architecture of adaptation might enable stakeholders to (re)consider how the adaptation process is approached both collectively and individually. Using the criterion tool, stakeholders could make more informed choices, by objectively identifying which framework(s) approach(es) are most applicable for each element of their adaptation initiatives. The criterion tool would also enable stakeholders to compare their adaptation efforts with the framework approaches of others. The ability to directly compare frameworks and objectively discuss the advantages and disadvantages of different approaches will further enable methods of best practice to emerge.

The establishment of the criterion tool and hybrid approach to adaptation as well as; the six stakeholder groups outlining different stakeholder standpoints, the six key themes governing the success of the adaptation process, and the 12 factors influencing stakeholder interactions with the key themes, will enable stakeholders to appreciate the standpoints of others in the nuclear neighbourhood. These attributes could be used to strengthen existing efforts in the Sizewell nuclear neighbourhood as well as those seeking to adapt other vulnerable coastal zones. However, it is recognised that the shape of both the architecture and attributes may vary depending on cultural setting, scale and environs, and mix of stakeholder groups. Nonetheless, the key themes and influencing social factors could be used by others, to understand the adaptation process and promote the implementation of adaptation initiatives, lowering overall levels of vulnerability.

6.4 Transferability of the research

When considering the transferability of the research, the fundamental findings from the adaptation framework analysis could be applied to climate change adaptation initiatives in other sectors and localities. The hybrid approach to adaptation challenges the literature, illustrating that no standardised framework that can currently ensure successful adaptation whilst satisfy the needs of all stakeholders. The criterion tool, used to distinguish the framework approach of stakeholders, proved 86% applicable to the four UK case study areas. It is recognised that the sample sizes in this part of the research were small (Section 6.5.1), therefore, it is difficult to determine the transferability of the findings.

It is reasonable to assume that a comparable stakeholder group would be engaged in the management and adaptation of the coastline because the overall governance system and socio-economic factors are comparable. The additional three case study areas (Hinkley Point, Portsmouth Harbour and Wylfa) are also exposed to similar socio-economic environments such as the economic recession, the government's localism agenda and the exit from the European Union. As such, similar key themes and influencing social factors could be transferred to these neighbourhoods. However, as the physical environments and demographics vary between these study areas (Table 3.2) the standpoints of stakeholder organisations might be different.

Generalisation of the attributes of adaptation to other cultural settings is less straightforward. Governance systems and coastal management strategies vary from county to county. For example, coastal management in Morocco and Tunisia is described by Caffyn and Jobbins (2003) as more centralised and deficient in local democracy. Similarly, in China, coastal management is a government-led, top-down endeavour (Ye et al 2015). For these reasons, it would not be possible to superimpose the attributes of adaptation, established in the Sizewell nuclear neighbourhood, directly to coastal neighbourhoods internationally. In countries where coastal management and adaptation is centralised, it would be expected that the portfolio of stakeholder groups would be much smaller. Similarly, the established six key themes and social factors may not be directly relevant in different cultural contexts.

However, applying the overall methodology to identify stakeholder groups, key themes and social factors to coastal zones internationally may assist decision makers in other regions with long-lived coastal infrastructure. Considering the core principles of the attributes could develop the understanding of the complex social factors at play in the coastal zone, establish to what degree the infrastructure impacts the management of the coastal neighbourhood, and aid them when attempting to implement successful adaptation initiatives.

6.5 Limitations

This research project is not without caveats. On reflection, the principal limitations centre on aspects of the research methods. The following sections identify the most important limitations, then suggests ways in which they might be overcome.

6.5.1 *Sample size*

When compiling the inventories of adaptation documents, imbalances in the total number of adaptation initiatives present in each neighbourhood acted as a limitation when analysing the results. The total number of adaptation initiatives ranged from 14, in the Sizewell neighbourhood (2013), to four in the Wlyfa neighbourhood (2016). These differences may reflect variations in the actual or perceived risk and vulnerability of each neighbourhood. However, these imbalances made it difficult to determine framework utilisation in the Wylfa neighbourhood and to draw comparisons between all study sites. One way to overcome this would be to increase the number of neighbourhoods surveyed. This would help to determine whether the Wylfa or Sizewell neighbourhoods are representative of others, and thereby assess the transferability of the criterion tool and generality of the findings of hybrid approaches to adaptation, in practice.

The sample size for the semi-structured interviews was deemed sufficient as a saturation point was reached meaning that all perspective participants had been invited to take part in the research. The validity and transferability of the results could be increased by interviewing stakeholders from the neighbourhoods included in the framework analysis section of the research. However, this was not feasible within the time-constraints of the research project. Beyond the UK, possible considerations of neighbourhoods featuring long-lived infrastructure include; the coastal nuclear developments in China such as Ling'ao II, Ningde or Qinshan II, Rotterdam and Amsterdam, the Panama Canal and the artificial islands off the coast of Dubai. Sampling coastal zones with and without the presence of long-lived infrastructure would also add an extra dimension to the framework analysis. This could determine whether the presence of such infrastructure is a controlling factor on the type of adaptation framework adopted by stakeholders.

6.5.2 *Criterion tool*

During the analysis of the adaptation inventories there were occasions when the criterion tool was unable to categorise the adaptation initiative. This may be because the information needed to categorise was not present in the document and/or, the information in document did not sit within the hallmarks of the tool. In the latter case, it is difficult to determine whether the non-applicability is reflecting the valley between academic theory and real world practice or deficiencies of the criterion. One way to overcome this uncertainty would be to increase the number of adaptation initiatives categorised. This would enable further refinement of the criterion tool and help pin point any reason(s) for non-applicability.

6.5.3 *Methodology and role of the individual*

Adopting the GTM ensured that the data collected was participant-led and limited confounding factors such as interviewer bias and stakeholder salience. Based on an extensive evaluation of qualitative research techniques, the GTM was deemed fit for purpose. However, there were aspects of the GTM that were not accounted for at the outset of the data collection.

For instance, when interviewing representatives from various stakeholder organisations, the GTM cannot differentiate between the personal views held by the individual and the official views of the organisation that they represent. Hence, when interviewing stakeholders with a personal affinity to the area it was difficult to determine whether they spoke from a personal or professional viewpoint. This makes it difficult to evaluate to what extent the established influencing societal indicators impact an organisation as a whole. To overcome this limitation, future interview questions could be designed to investigate how the personal standpoints and beliefs of individuals influence them in their role within the organisation. Simply being aware of the role of the individual could help to tease out when participants are speaking from personal or professional viewpoints.

6.6 Reflections and opportunities for further research

One element of the methodology which was not fully recognised at the start of data collection was the diversity of insights provided by interviewees. As the GTM prescribes the simultaneous undertaking of data collection and analysis, it was a challenge to incorporate all aspects of the findings into the bounds of this study. For example, the demographic of stakeholders involved in adaptation could be investigated further to determine how the Suffolk coastline may compare to other study areas. As mentioned (Section 6.5.3), future research could further determine the transferability of the architecture and attributes of adaptation by applying the methodological approach to other coastal neighbourhood featuring long-lived infrastructure.

Investigating the architecture and attributes of adaptation of coastal zone featuring long-lived infrastructure at different scales and cultural settings would further establish the validity and transferability of the findings. Dissemination of the key messages through publications, presentations and follow up workshops with participant stakeholders organisations would establish the degree to which the findings may resonate in other cultural settings. Planned dissemination events include a presentations at the Suffolk Coastal Forum, Environment Agency and assisting in the dissemination of the EPSRC, ARCoES project as a whole.

The existing architecture and attributes of adaptation provide a barometer of the decision-making landscape in the Sizewell nuclear neighbourhood. Future research could revisit the case study area post Brexit to determine the extent to which shifts in international geopolitics affect the management and adaptation of vulnerable coastal zones in the UK.

The insights and knowledge gained throughout this PhD research have highlighted a need to develop understanding of the social architecture and attributes of adaptation processes in tandem with technical developments of the field. Understanding the social complexities of the decision-making landscape will enable those engaged in adaptation to develop methods of best practise, to utilise technological advancements in climate modelling and infrastructure design, and empower all stakeholders to realise their shared visions for the future of the coastal zone.

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Appendices

Appendix 1:

Invitation to participate in research (Email)

Dear [INSERT STAKHOLDER REPRESENTTIVE],

I wanted to email to introduce myself and my project and extend an invitation to you to take part in the research. I attended the Suffolk Coastal Forum last month and your contact details were passed on to me and it was recommended that I get in touch with you and that you might be interested in taking part.

My PhD project is part of a multi-million pound project; Adaptation and Resilience of the Coastal Energy supply (ARCoES) which is run by Liverpool University and funded by EPSRC through the ARCC programme. ARCoES is a multi-faceted, 5 year project which aims to develop a decision-support tool that will enable sustainable coastal energy http://www.liv.ac.uk/earth-ocean-and-ecological-sciences/research/adaptation-and-resilience-of-coastal-energy-supply/about/.

The PhD is socially orientated. I'm focussing on coastal management and stakeholder engagement, surrounding infrastructure with centennial lifespans, with regards to adaptation to climate change. The study site I'm using to investigate this is the Sizewell nuclear power plant and the proposed Sizewell C development. I'm really interested in how decisions are made regarding adaptation to climate change and how different organisations in the area interact on this issue.

I'm now into the data collection stage of my research. I'm collecting data by talking to organisations in the area engaged with climate change adaptation. I'm fully aware that this is a very busy time for all organisations especially in the wake of the storms we had last winter. I'm hoping that the extreme weather conditions may encourage enthusiasm for climate change adaptation and in turn my project. I have had a really positive response from stakeholders in the area thus far; my hope, over the next couple of months, is to talk to as many representatives from relevant organisations operating in the Sizewell area as possible in order to build a complete picture of climate change adaptation issues and interactions in the Sizewell neighbourhood.

I have attached a document giving you a more detailed overview of the project and what your involvement would require.

I would really value the opportunity to talk to you about your experiences with climate change adaptation and issues arising from coastal change on the Suffolk coastline. I would especially value your insight from the wealth of knowledge and experience you have as [INSERT POSTION AND ORGANISATION HERE]. I would be really grateful for any help that you might be able to offer me.

I'm currently organising a visit to Suffolk to hold meetings with various stakeholders the week commencing the [INSERT DATE AND TIME HERE], it would be brilliant if I could come and meet with you should you wish to participate. If this is not an appropriate time a telecom meeting could be organised. Alternatively, I shall be making another trip to the area at [INSERT DATE AND TIME HERE] so maybe we could arrange a meeting then.

If you have anyone else in mind that you think might be interested in the project and/or would like to take part that would also be very valuable to me

Thank you for taking the time to read this email. If you have any questions at all please don't hesitate to contact me.

I shall look forward to hearing from you soon.

Kind Regards,

Jenny Armstrong

Appendix 2:

Participant Consent Form

Consent Form – Jennifer Armstrong PhD Interviews

Study Title: Defining a 'successful' pathway to climate change adaptation in the neighbourhood of long-lived coastal infrastructure.

Name:

- I'm aware that the interview may be recorded in order to aid the researcher.
- I'm aware that the interview recordings and transcripts with be individually anonymous and will be destroyed 12 months after the completing on the PhD.
- I'm aware that I may pull out of the interview at any stage without explanation.

Data Protection

I understand that information collected during my participation in this study will be stored on a password protected computer and that this information will only be used for the purpose of this study. All files containing any personal data will be made anonymous.

Signed:

Date:

Appendix 3:

Draft Interview Schedule

1) *How long have you worked for X?*

2) *Please could you tell me about your role, what does it entail on a day to day basis?*

3) *How does X operate in the Sizewell area?*

4) *What were the main motivations that inspired the inception of the project?*

5) *Please could you tell me a bit about your role in the adaptation project?*

6) *How do you currently determine the success projects?*

7) *Please could you outline the different stages that your project featured? Please expand.*

8) *Which aspect of the project is the most significant to the overall success of the project? [Relative importance, time dependant, resource dependant]*

9) *What factors contributed to the success of the primary stage of your adaptation project?*

9a) What obstacles hampered the success of the primary stage?

10) *What factors contributed to the success of the secondary stage of your project?*

10a) What factors, if any, inhibited the success of the secondary stage?

11) *What factors contributed to the success of the final stage of your project?*

11a) What factors, if any, inhibited the success of the final stage of your project?

12) *To what extent are the different stages of your project linked? How does one affect the other?*

13) *How did the affected population/neighbourhood react to your adaptation project at the various stages?*

14) *Do the project/operations of X collaborate with any other stakeholders in the neighbourhood surrounding the nuclear power station?*

15) *What are your experiences with stakeholder collaborations when dealing with the threats of possible climate change impacts?*

16) *Do you think that stakeholder collaborations are a successful approach when dealing with the threats of climate change?*

17) *Do you think that there is a difference when implementing climate change adaptation project between organisations with adopted vs appointed positions responsible for action undertaken?*

18) *How important do you think the role of the individual is when dealing with climate change adaptation plans?*

19) *What if any feedback did you receive about your project?*

20) *Did the nature of the feedback change throughout the project? Why?*

21) *What if any challenges have you faced?*

22) *How do you think the stakeholders in the neighbourhood of the nuclear power plant perceive the responsibility to adapt to the threats of climate change?*

Examples if possible

23) *In your experience are there any issues surrounding the timescales that stakeholders work to?*

Examples if possible

24) *In your experience in the Sizewell neighbourhood. Has there been any recent change to the composition of funding when it comes to coastal defence. Public vs private?*

25) *How will the project be reviewed once it has been completed?*

26) *Do you have any formal actions regarding reviewing and updating the project into the future?*

If so, what periods of time do you operate in?

27) *How did the winter storms of 2013/2014 affect X?*

28) *If any what were the lessons learnt from the winter storms of 2013/2014?*

29) *Have the operations of X changed at all since the winter storms?*

30) *How do you see the future evolving, more devolved responsibility?*

31) *How do you think the decision making process could be improved if at all?*

Questions for the individual:

Appendix 4:

Published paper: Armstrong, J., Wilby, R. and Nicholls, R. (2015). Climate change adaptation frameworks: an evaluation of plans for coastal Suffolk, UK. Natural Hazards and Earth System Science, 15, 2511-2524.

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Natural Hazards and Earth System Sciences
EGU

Climate change adaptation frameworks: an evaluation of plans for coastal Suffolk, UK

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Abstract. This paper asserts that three principal frameworks for climate change adaptation can be recognised in the literature: scenario-led (SL), vulnerability-led (VL) and decision-centric (DC) frameworks. A criterion is developed to differentiate these frameworks in recent adaptation projects. The criterion features six key hallmarks as follows: (1) use of climate model information; (2) analysis of metrics/units; (3) socio-economic knowledge; (4) stakeholder engagement; (5) adaptation of implementation mechanisms; (6) tier of adaptation implementation. The paper then tests the validity of this approach using adaptation projects on the Suffolk coast, UK. Fourteen adaptation plans were identified in an online survey. They were analysed in relation to the hallmarks outlined above and assigned to an adaptation framework.

The results show that while some adaptation plans are primarily SL, VL or DC, the majority are hybrid, showing a mixture of DC/VL and DC/SL characteristics. Interestingly, the SL/VL combination is not observed, perhaps because the DC framework is intermediate and attempts to overcome weaknesses of both SL and VL approaches. The majority (57 %) of adaptation projects generated a risk assessment or advice notes. Further development of this type of framework analysis would allow better guidance on approaches for organisations when implementing climate change adaptation initiatives, and other similar proactive long-term planning.

1 Introduction

There is increasing agreement between scientific and political spheres of society that the potential impacts of anthropogenic climate change need addressing via both mitigation and adaptation as a twin-tracked approach (Dang et al., 2003; Kleina et al., 2005; Pielke Jr., 2009). The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) states that there are significant co-benefits, synergies and trade-offs between mitigation and adaptation efforts. However, tools to understand and manage these interactions remain limited (IPCC, 2013). The necessity of adopting the twin-tracked approach is increasingly being acknowledged across a range of sectors (Craig, 2010; Delgado et al., 2011; Semenza et al., 2011; Wong et al., 2014) and is particularly appropriate for regions already experiencing stress from impacts of climate variability and change (Solomon et al., 2008). However, there is growing concern that examples of theoretical best practice for implementing adaptation, within the academic literature, may not translate efficiently to facilitate, deploy and monitor real-world adaptation actions (Eisenack and Stecker, 2012).

It is important to note that the process of climate change adaptation is not a new phenomenon. Human activity along with the autonomous behaviour of flora and fauna have always adapted to the natural variability in the long-term climate. Burton et al. (2004) assert that the innovative aspect is in fact incorporating future climate risk into policy making therefore making adaptation mandatory. They affirm that although our understanding of climate change and its potential impacts has become clearer, the availability of practical guidance on implementing adaptation has not kept pace.

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