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Assessing Adaptation Knowledge in Europe: Vulnerability to Climate Change

Final Report

European Commission
DG CLIMA

Assessing Adaptation Knowledge in Europe: Vulnerability to Climate Change

Final Report

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List of acronyms

AR3	Third Assessment Report (from the IPCC)
AR4	Fourth Assessment Report (from the IPCC)
AR5	Fifth Assessment Report (from the IPCC)
AST	Adaptation Support Tool
BALTADAPT	Development of a Baltic Sea Region-wide Climate Change Adaptation Strategy
BASE	Bottom-Up Climate Adaptation Strategies Towards a Sustainable Europe
BSR	Baltic Sea Region
CARAVAN	Climate change: a Regional Assessment of Vulnerability and Adaptive Capacity for the Nordic countries
CCRA	Climate Change Risk Assessment
CECILIA	Central and Eastern Europe Climate Change Impact and Vulnerability Assessment
CIV	Climate, impacts and vulnerability
CLAVIER	Climate Change and Variability: Impact on Central and Eastern Europe
Climate-ADAPT	European Climate Adaptation Platform
CLIMSAVE	Climate Change Integrated Assessment Methodology for Cross-Sectoral Adaptation and Vulnerability in Europe
CLISP	Climate Change Adaptation by Spatial Planning in the Alpine Space
CMCC	Centro Euro-Mediterraneo sui Cambiamenti Climatici (Italy)
CMIP	Coupled Model Intercomparison Project
Defra	Department for Environment, Food and Rural Affairs (United Kingdom)
DG CLIMA	Directorate-General for Climate Action (European Commission)
DIFD	Department for International Development (United Kingdom)
DRR	Disaster Risk Reduction
EC	European Commission
EEA	European Environment Agency
ENSEMBLES	Ensemble-based predictions of climate changes and their impacts
ERDF	European Regional Development Fund
ESPON Climate	Climate Change and Territorial Effects on Regions and Local Economies
EU	European Union
FP7	Seventh Framework Programme for Research and Technological Development
GCM	General Circulation Model
GDP	Gross Domestic Product
IMELS	Italian Ministry for Environment, Land and Sea
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
MATRIX	New Multi-hazard and Multi-Risk Assessment Methods for Europe
MEDIATION	Methodology for Effective Decision-making on Impacts and Adaptation
MEDPRO	Mediterranean Prospects
MOVE	Methods for the Improvement of Vulnerability Assessments in Europe
MRE	Monitoring, Reporting and Evaluation

MS	Member States
NAP	National Adaptation Plan/Programme
NAS	National Adaptation Strategy
NUTS	Nomenclature of Territorial Units for Statistics
PCET	Climate Plan on Energy and Territory
PESETA I and II	Projections of economic impacts of climate change in sectors of the European Union based on bottom-up analysis
PLU	Local Urbanization Plans
PROVIA	Global Programme of Research on Climate Change Vulnerability, Impacts and Adaptation
PRUDENCE	Prediction of Regional Scenarios and Uncertainties for Defining European Climate change risks and Effects
RAMSES	Reconciling Adaptation, Mitigation and Sustainable Development for Cities
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
SLF	Sustainable Livelihood Framework'
SRCAE	Regional Scheme on Climate, Air and Energy
SRES	Special Report on Emissions Scenarios (from the IPCC)
SREX	Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (from the IPCC)
SWD	Staff Working Document (European Commission)
UKCIP	UK Climate Impacts Programme
UKCP09	UK Climate Projections 2009
UNISDR	United Nations Office for Disaster Risk Reduction
VAF	Vulnerability Assessment Framework

Executive Summary

There is extensive interest in assessing risks and vulnerabilities to climate change because observed climate change has already led to a wide range of impacts on environmental systems and society, and damage costs from natural disasters have increased. Increases in climate change impacts and damage costs are also projected for the future. In addition, there is evidence that climate change can increase existing vulnerabilities and deepen socio-economic imbalances in Europe (EEA, 2012).

The knowledge assessment study

This project is a knowledge assessment study designed to synthesise the frameworks, processes and methods being used to assess vulnerability in Europe. It describes the concepts and definitions covering impacts, vulnerability, risk, resilience, adaptive capacity. A selection of European research projects focusing on national and transnational level assessments were reviewed. The current status of European Member States' risk and vulnerability assessments were analysed initially through the country information pages on Climate-ADAPT. The study then synthesised the information from EU research projects and EU MS to provide a reference framework that can be shared with those who are considering developing risk and vulnerability assessments. Finally lessons learned, gaps, challenges and recommendations are provided. The primary focus for the task is on vulnerability assessment methods (and related concepts of impact, risk and adaptive capacity) that have been undertaken at the national level (characterised by a method applied to multiple sectors). Individual sector or, city level assessments are not part of this study. The European Environment Agency (EEA) is currently developing a report on national climate change impact, vulnerability and risk assessments in Europe to be published in 2018, extending the findings of this study, which is based on a desk review, complemented by in-depth interviews with a limited number of countries.

It forms part of a broader project that analysed the current state of knowledge available to support adaptation decision making in Europe in three areas. Task 1 considered ecosystem-based adaptation (EbA) measures across a number of sectors, Task 2 considered the infrastructure sector comprising of the transport, energy and construction sectors and Task 3 considered national vulnerability assessments and methods.

What is a vulnerability assessment?

A vulnerability assessment is an evidence gathering activity to assess who (or what) is vulnerable, to what, and under what circumstances. For example, elderly people – the 'who' – are more susceptible to high temperatures – the 'what' – hence in the event of a heatwave – the 'circumstance' – they will be more vulnerable. An assessment can also be applied to systems, for example buildings, roads and habitats as well as people. (Section 1.3)

The overarching purpose of a risk and vulnerability assessment is to inform decision-makers about the potential risks and opportunities presented by climate change. It provides a means to evaluate the impacts associated with different scales of climate change, along with evidence to compare different adaptation response strategies and policy options (Moss, et al., 2010). A risk and vulnerability assessment may form part of a wider adaptation policy cycle that is used to support policy-makers. (Section 1.3) Vulnerability assessment considers both *social* vulnerabilities (determined by factors such as economic diversity, demographic, income, education, critical thresholds, social cohesion/capital, equity, governance, policy priorities) and *biophysical* vulnerabilities (determined by factors such as climate change and variability, including extremes, land use, habitat quality, water availability, critical thresholds, frequency, duration and magnitude). Vulnerability assessments typically explore current vulnerability, or future vulnerability or some combination of the two (e.g. future biophysical determinants acting upon current social determinants).

Evolution, framing and definitions of the term 'Vulnerability'

The evolution of the term 'vulnerability' in the context of climate change can be traced through both the academic literature and the IPCC Assessment reports. In 2001 vulnerability was defined by the Intergovernmental Panel on Climate Change (IPCC) as:

"The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes**"** (IPCC, 2001)

and is presented as a function of three interacting components: exposure, sensitivity and adaptive capacity (the terms are defined in section 1.4). The IPCC Special Report on Extremes (IPCC, 2012) focuses on the concept of vulnerability as understood by the disaster risk community, vulnerability is defined generically as:

'The propensity or predisposition to be adversely affected'.

The shift in framing means that information can be translated more easily into a risk management approach that facilitates policy making.

Section 1.5 describes 7 different frameworks for vulnerability assessments or, which incorporate vulnerability within a broader conceptualisation of the adaptation cycle. The analysis of these frameworks indicates a number of similar features such as; they are all composed of a series of steps and they are generally nested within the adaptation planning cycle or risk disaster management process. There are some differences such as; they occupy a continuum between climate impacts (top-down and science-first) and risk management (bottom-up, decision-first and participatory).

Approaches for assessing vulnerability within European research projects

A selection of European research projects focusing on methodologies for national and transnational level assessments were reviewed based on inclusion and exclusion criteria. The frameworks and methodologies used in the EU research projects were analysed and summarised as lessons learned, gaps and challenges (Section 2).

We have used the criteria to select 8 research projects (Baltic, BASE, CLIMSAVE, ESPON, MATRIX, MEDIATION, PESETA I and II and RAMSES) that were the most relevant based on the criteria, and availability of resources and time to conduct the analysis. As such, the analysis undertaken highlights some of the EU research on vulnerability assessment (frameworks and methodologies), but also provides further information on the methodologies used in some countries' national assessments.

The results show that the frameworks used in the research projects fit within the continuum between climate impacts and risk management. Analysis of the characteristics within the different frameworks provide a range of characteristics such as geographic focus from national to household, which field of literature it originates from e.g. DRR or adaptation and whether it assesses present climate variability or future climate change. The characteristics at either end of the continuum are provided in Table 2. Most projects and national assessments cover features within both perspectives and are positioned somewhere between the two ends. This probably reflects the shift in framing and sharing of concepts over the past 20 years, and the influence of the IPCC assessment reports and guidance. It also reflects the purpose of the project in that some projects are aiming to have a European overview of e.g. economic impacts with no expectation that this will be used for national policy planning. Whereas, some assessments are locally specific and designed to a feed into development of adaptation options for e.g. a city hence, it would be expected that the methods and framings for these two different purposes would be different.

Section 2.2 describes the methodology (stages or process steps) used in the research project. It also describes the methods being used to gather information. The results show that there is a wide range of methods that have been used for data collection and analysis such as climate projections, impact modelling, economic assessment, stakeholder workshops, surveys or panels, social and institutional assessment and expert elicitation. All the projects use a range of projects that are both quantitative and qualitative. The majority of these projects use mainly quantitative methods e.g. modelling rather than qualitative methods e.g. participatory. The two projects that use mainly qualitative and participatory methods are BALTIC and MATRIX. In some cases stakeholders are a fundamental part of the project and are involved as equal partners and there is co-creation of outputs with the researchers. In other projects stakeholder have more of a consultation role where top-down information is developed, then 'sanity checked' by stakeholders.

Measuring vulnerability and the use of Indicators

Measurement of vulnerability is an important aspect of vulnerability assessment. Issues of accountability, and a need to understand the effectiveness and efficiency of plans have driven interest in M&E. An additional driver for measurement has been the recent implementation of international policy frameworks including the Paris Agreement, Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction, all of which have reporting requirements and for which vulnerability is a critical concept. There is no agreed integrated metric for vulnerability to climate change as vulnerability is a theoretical concept thus it cannot be measured directly. This is also true of adaptation. This lack of a single measure means that a combination or set of indicators is required to provide an accurate picture of both adaptation and vulnerability. Thus vulnerability indicators tend to be used in tandem with indicators of related terms such as impacts, resilience, sensitivity, exposure and adaptive capacity.

Measures of vulnerability (V) usually comprise three components: exposure to climate change (E), sensitivity to its effects (S) and adaptive capacity for coping with the effects (AC), such that:

V = f (E, S, AC) (Carter & Mäkinen, 2011)

For indices, attempts are made to quantify each component through the development of indicators that can then be combined into an integrated index of vulnerability. In the context of vulnerability assessment, (Carter & Mäkinen, 2011) suggest that indicators are commonly drawn from a combination of the biophysical realm (primarily of exposure and sensitivity) and from socio-economic statistical sources (mainly describing adaptive capacity). (Carter & Mäkinen, 2011) highlight that more stakeholder-driven approaches can be used as alternative or complementary approaches to quantitative indicator studies whereby stakeholders agree upon the main issues and responses of importance for assessing vulnerability to climate change.

Approaches and progress on assessing vulnerability within EU Member States

Section 3 covers Vulnerability Assessment approaches being used at national level by EU Member States. Information was collected about both the frameworks and methods being used at national level for the 28 EU countries. The information was collected by using a two stage evidence gathering process.

Stage 1 gathered evidence that was available on the 28 country information pages on Climate-ADAPT (Summary and Assessments pages). This evidence was used to provide an overview of both the stage of the assessment process for each country and analyse what methods and techniques were used within this process. There were some challenges in using this data in that it is provided by the countries and at times it does not provide much detail, may not be fully up to date or, may be in-complete.

Stage 2 has gathered evidence from publically available information, mainly on national websites and reports and verified this information through direct contact with the experts and policy-makers in each country (by email and interviews). The countries were selected for a Stage 2 analysis by using inclusion and exclusion criteria (see section 3.2).

The results were analysed against the framework set out in the EU Strategy Guidance. It shows that 21 out of 28 countries have indicated that they have 'completed ' a vulnerability assessment. Some of the steps within an assessment are also analysed such as, 24 out of 28 countries have completed assessments of future climate variables and expected impacts. Only very few (4) countries have provided information in Climate-ADAPT about

developing socio-economic projections and the four countries are Germany, the Netherlands, Portugal and the UK. Finally 11 countries have mentioned stakeholder involvement in their assessments.

The methods that countries have used for doing national vulnerability assessments in Europe (Section 3.1.3) were drawn from the National adaptation policy processes in European countries report (EEA, 2014) and the Climate ADAPT country information pages (accessed June 2016). The evidence for which methods countries have used is provided in Annex 6.3.

The evidence shows that countries have used a range of methods to assess vulnerability. This can vary from 2 methods up to 17 methods. In countries that have used a small number of methods, typically they have used expert appraisal and literature review. Figure 6 summarises the different methods used and how many countries are using each method. It shows that the most common methods for vulnerability assessment in Europe are expert judgement/appraisal, use of climate scenarios, literature review or analysis of existing information, modelling, engaging stakeholders and the development of indicators (12 countries) have developed, or are developing indicators. This has increased from the self-assessment survey results when only 4 countries reported having developed indicators (EEA, 2014).

Countries have used EU funded activities in a range of ways to support their vulnerability assessments. Six countries have used data from an EU research project and the projects most often referenced are ENSEMBLES, PESETA I, PESETA II and ESPON Climate. Five have received funding for a research project, 3 countries have received funding for a NAS and 1 country has received funding for cross-border work.

Detailed examples have been developed to provide greater insight into the methods used for vulnerability assessment within Europe. The countries selected for a Stage 2 analysis were Bulgaria, Finland, France, Germany, Portugal, Sweden and UK. The countries were analysed according to the topics such as framework, knowledge gaps, transboundary issues, dealing with uncertainties, measuring vulnerability and methods for adaptive capacity. For each topic, examples from some of the countries are selected to illustrate the methods that country has used to address the topic.

Lessons learned from this analysis include:

1. There has been a significant increase in the knowledge base for vulnerability assessments since 2014, with 21 out of 28 countries having completed a vulnerability assessment. However, the assessments vary significantly in their level of detail. The knowledge base has also been boosted by a number of EU-funded research projects such as, ESPON and PESETA. This has helped countries with no national level assessment to prioritise their risks supported by a stronger evidence base.

2. A number of countries are either in the process of, or have completed a second assessment. Typically the first assessment focuses on biophysical factors (Figure 3 boxes 1 and 3). Subsequent assessments aim to fill any gaps, for example, incorporating data on social factors (Figure 3 boxes 2 and 4), greater coverage of sectors or impacts, involving more stakeholders, further research and the creation of data at smaller scales/finer resolution e.g. city level.

3. When measuring vulnerability using indicators, countries have used blended or 'mixed-methods'. This involves multiple sources of information and combining quantitative and qualitative methods e.g. using a range of indicators (process, output and outcome), alongside stakeholder perspectives gained through self-assessments or surveys and consultations with experts.

4. The countries have used a number of different techniques to account for uncertainty such as
    - Estimating uncertainty within the climate projections: using multiple runs of climate models, using multiple storylines or scenarios for emissions and socio-economic projections and considering the outputs from many GCMs/RCMs models
    - Indicating the robustness of the evidence by: calculating confidence levels from low to high, use of probabilistic (10^{th}/90^{th} percentiles), or ranges (min/max) in data outputs and use of uncertainty methods, for example, sensitivity analysis, fuzzy multi-criteria decision-making

- Exchanging knowledge with stakeholders: both gathering evidence to address uncertainties and communicating the uncertainty e.g. visualisations, to those that need to use it.
  However, most assessments would benefit from more comprehensively addressing uncertainty. Providing guidance on how to address uncertainty would be one way of supporting improvements in vulnerability assessments.

5. Most countries have used the IPCC definitions (AR4, AR5) of vulnerability and related concepts highlighting the influence of a trusted, international source of knowledge and the benefits of a common understanding of terms. This is particularly important when different arenas – economic, DRR, climate science communities – use the same terms but with different meanings. The team involved in a vulnerability assessment should aim have an agreed understanding of the terms related to vulnerability at the start of the process.

6. Highly vulnerable groups that are actively engaged in the process generate broader insights which are more likely to guide decision-makers into developing policy (and supporting guidance) that will increase the equity and resilience of vulnerable groups. In addition, countries that have allowed time for consensus building have considered it to be well worth the effort as the decisions made from the evidence are more robust.

7. National vulnerability assessments of climate change benefit from using a consistent (i.e. the same climate projections), integrated methodology that allows comparison between, and across sectors and risks. National vulnerability assessments also benefit from using a wide range of methods to gather evidence from primary and proxy sources including quantitative e.g. modelling, and qualitative e.g. stakeholder opinions. The choice of methods and framework (Figures 2a & 2b) should remain flexible and determined by the purpose and resources available for the assessment in each country.

Recommendations and gaps

It is recommended that the following elements should form part of a vulnerability assessment:

1. Emissions scenarios
2. Climate scenarios and Projections variability and change
3. Potential Impacts (current and future)
4. Sensitivities physical and social
5. Adaptive capacity physical and social
6. Exposure climate and non-climate
7. Vulnerability (social and biophysical)
8. Socio-economic scenarios and projections
9. Economic appraisal
10. Uncertainties are acknowledged and addressed
11. Use of qualitative evidence to supplement quantitative knowledge gaps
12. Risks and opportunities
13. Participation of Stakeholders

These elements are shown graphically in the reference framework diagram (Figure 8) below:

This reference framework is provided to help countries understand the framing of their vulnerability assessments and the implications of this, and provide a check-list for countries to consider when developing their vulnerability assessments (section 4.1).

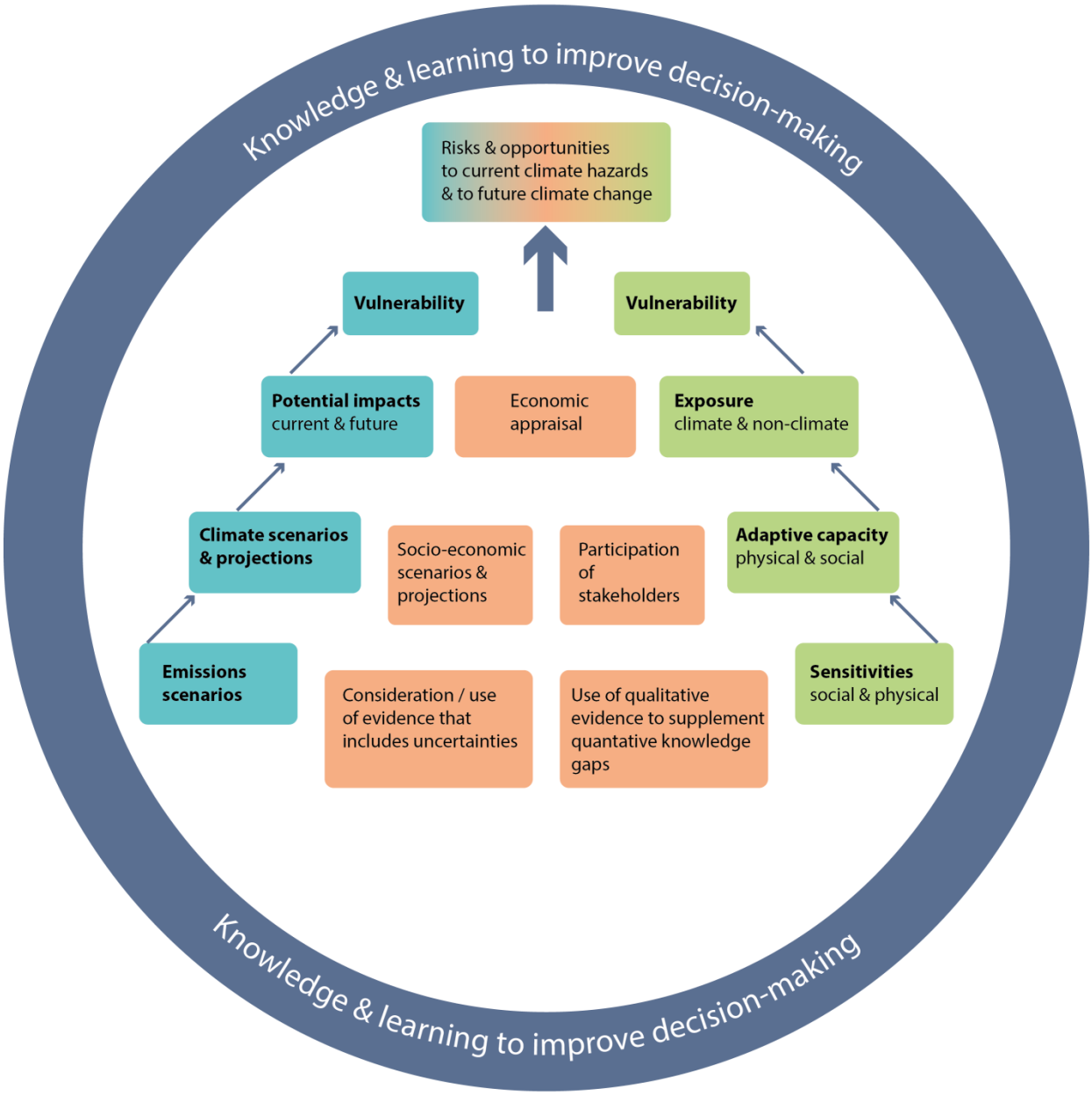


Figure 8. Reference Framework for vulnerability assessment.

The purpose and the framing of an assessment, as well as the knowledge and science capacity available, will determine which methods are chosen for the assessment. It should be noted that a vulnerability assessment undertaken under one framing will give different results to an assessment undertaken with another. Understanding these differences (the strengths and limitations) will help identify an appropriate framing and methods for the intended purpose. This understanding is important, as the results of the vulnerability assessment will greatly affect the selection of adaptation options and ultimately the success, or failure of the policies to reduce vulnerability, or exploit opportunities to climate change.

Recommendations for Future Research			
Type	**Evidence for gap or challenge**	**Recommendations research needs**	**Suggested organisation to implement**
Ways of addressing uncertainty	Most countries have not dealt comprehensively with uncertainties within the evidence in some parts of the assessment e.g. national socio-economic scenarios.	• Information about uncertainty within the evidence, is needed to inform the assessment e.g. **how to deal with uncertainties in the evidence related to future socio-economic scenarios** and projections at a detailed spatial resolution (NUTS 3 level). • Identification **of 'good' practices on the use of evidence that includes uncertainty**. This research should also lead to demonstration projects and guidance at the national and transnational levels.	DG R&I (Framework Programmes), JRC, JPI-Climate (and its members)
Application	**Measuring and monitoring information:** many of the available indicators to measure vulnerability are dependent on access to existing data. There is limited information about the implications of trying to measure vulnerability from multiple perspectives (national, local, sectoral, research framing, socio-demographic). There are challenges of developing indicators by linking quantitative and qualitative information.	• To understand the **implications of assessing vulnerability from different perspectives** in that it will result in different outcomes and indicators. • To understand the **process of constructing vulnerability indicator sets** given the different approaches taken. The need for linking of information from different levels (national to household) and different types (quant. and qual.). We need to learn lessons about how quantitative and qualitative information can be integrated e.g. combining impact modelling outputs with socio-economic data. • Both of the above should lead to demonstration and case studies and the learning from these should be turned into **guidance**. • To **synthesise existing practices and indicators** to enhance the knowledge of what is already available (There is a EEA project looking at creating a database of indicators of vulnerability, adaptation and resilience currently in use at national level planned for 2017)	EEA and ETC DG R&I (Framework Programme) and JRC, with DG CLIMA, EEA

Recommendations for Future Research			
Methods	**Information on *future* socio-economic scenarios is limited** since only 2 of the research projects and less than a quarter of countries have analysed future socio-economic scenarios.	• Research and knowledge exchange to **demonstrate the value of using nationally specific, socio-economic scenarios** within the assessment process (moving beyond biophysical and including socio-economic future vulnerability). Use existing European scenarios (ESPON, IMPRESSIONS, ENHANCE) as a basis to build nationally specific ones. • This should include demonstration projects at the national and transnational levels.	JRC and European Regional Development Fund (ESPON Programme)
Methods	The majority of countries have not assessed ***current* social vulnerabilities** in detail. It is crucial that vulnerable groups (affected by impacts or policy) are involved in developing and making decisions about assessing vulnerability and selecting adaptation measures.	• Support (funding and capacity building) to provide **information on current social vulnerabilities at national and local level**. Methods for assessing social vulnerability including participatory methods exist, e.g. PROVIA guidance, but many of these have not yet been used in national assessments. (There is a EEA project doing a stock-take of social vulnerability, justice and climate adaptation in 2017) • To understand and **demonstrate the** various approaches that are being used in terms of **added value to the assessment process**. This includes developing the capacity to select and use appropriate methodologies. • Demonstration and case studies on the different approaches should be undertaken and the learning disseminated through **guidance** documents	DG CLIMA
Trans-national	The focus on national assessments has meant that most countries have **not included transnational issues** as part of their assessment	• To **assess vulnerability across-national borders** (e.g. catchment assessments) and encourage the joining up of national and EU Transnational regional funds and knowledge. • This should include understanding the implications for national vulnerabilities as a result of consideration of transnational issues. • **Transnational demonstration and case (learning) studies** should be undertaken and disseminated	DG CLIMA

Recommendations for Future Research			
Recommendations for Knowledge Transfer			
Type	**Evidence for gap or challenge**	**Recommendations research needs**	**Suggested organisation to implement**

Sharing knowledge, building capacity and informing those undertaking assessments	The knowledge and evidence that comes from European research project results has less added value (research impact) because typically communication stops at the end of the project.
	
	As a result, the availability of, and access to, the resulting knowledge by those undertaking national assessments is reduced.
		• **Supporting a long-term knowledge sharing network** including using and linking to existing networks e.g. EIONET, Climate-KIC, Climate-ADAPT, Climate Disclosure Project, and reaching out to non-climate networks e.g. ICLEI, Industry Associations and trade bodies - drawing on learning from Milieu. For more details see section 2.4.
		• The KE network could do the following activities:
		  • mapping to synthesise tools and methods,
		  • summarising information from research projects for different audiences,
		  • targeting dissemination and knowledge exchange to user-defined organisations (their trusted sources), e.g. EEA could write and promote their reports jointly with a sector. thematic or regional body to reach a new audience.
		  • translation of guidance and summaries into many EU languages.
			DG CLIMA/EEA

1 Introduction

1.1 Background

There is extensive interest in assessing risks and vulnerabilities to climate change because observed climate change has already led to a wide range of impacts on environmental systems and society, and damage costs from natural disasters have increased. Increases in climate change impacts and damage costs are also projected for the future. In addition, there is evidence that climate change can increase existing vulnerabilities and deepen socio-economic imbalances in Europe (EEA, 2012).

The character and severity of impacts from climate change depend not only on the changes in climate but also on the vulnerability (exposure, sensitivity and adaptive capacity) (IPCC, 2007) of the person or, system that is affected by the change. The consequences of these changes can cause alterations in the normal function of communities and societies, and depending on the severity, can result in the loss of function and/or widespread damage. Climate change and vulnerability are influenced by a wide range of factors, including anthropogenic climate change, natural climate variability, and socio-economic development. Adaptation to climate change (and disaster risk management) focuses on reducing vulnerability and increasing resilience to the potential adverse impacts of climate change, including extremes. Even though associated risks cannot be fully eliminated, they can be managed through a variety of approaches such as reducing the exposure (e.g. flood defences), increasing adaptive capacity (e.g. educating society) or sharing the risk (e.g. insurance).

Climate change will have very different implications for each country due to the variations in climate, different sensitivities for each country and sector and a differentiated capacity to adapt to climate changes. A solid evidence base for assessments is needed to be able to deal with these spatially-specific challenges in order to develop appropriate strategies and plans that have political support at various governance levels from national to local.

Governments and public institutions have a responsibility to create 'enabling conditions' for private adaptation to occur. The European Union (EU) has recognised this need to create 'enabling conditions' and has developed the EU Adaptation Strategy to strengthen Europe's resilience to the impacts of climate change. One of the three objectives of the strategy is to promote action by Member States (MS) by encouraging all Member States to adopt comprehensive adaptation strategies. The EU has provided guidance and funding to help Member States to build up their adaptation capacities and take action. The majority of MS Governments within Europe have now developed National Adaptation Strategies (NAS) that include risk and vulnerability assessments.

The Guidance for the EU Adaptation Strategy (EC, 2013) identified that one of the limiting factors for the development of successful adaption was that there was a further need for climate change risks and vulnerability assessments and that at the time (2013) only a few MS had engaged in the preparation of detailed risk and vulnerability assessments. In addition, the issue of uncertainty and the lack of dedicated research were further barriers. Since that time, EU research has advanced and more countries have prepared vulnerability assessments (EEA, 2014) both at the national, sectoral and subnational (regional or city level).

1.2 Introduction to the project

This project is a knowledge assessment study designed to synthesise the frameworks, processes and methods being used to assess vulnerability in Europe. It describes the concepts and definitions covering impacts, vulnerability, risk, resilience, adaptive capacity. A selection of European research projects focusing on national and transnational level assessments were reviewed. The current status of European Member States' risk and vulnerability assessments were analysed initially through the country information pages on Climate-ADAPT. The study then synthesised the information from EU research projects and EU MS to provide a reference framework that can be shared with those who are considering developing risk and vulnerability assessments. Finally lessons learned, gaps, challenges and recommendations are provided.

The primary focus for the task is on vulnerability assessment methods (and related concepts of impact, risk and adaptive capacity) that have been undertaken at the national level (characterised by a method applied to multiple sectors). Individual sector or, city level assessments are not part of this study.

It forms part of a broader project that analysed the current state of knowledge available to support adaptation decision making in Europe in three areas. Task 1 considered ecosystem-based adaptation (EbA) measures across a number of sectors, Task 2 considered the infrastructure sector comprising of the transport, energy and construction sectors and Task 3 considered national vulnerability assessments.

Task 3 aimed to analyse the following research questions:

- **What information is available on methods to assess vulnerability (and/or related concepts) in the EU?**
  The primary focus for the task is on vulnerability assessment methods that have been undertaken at the national level, characterised by a method applied to multiple sectors. City level assessment methods are not part of this task to avoid duplication with work undertaken for Mayors Adapt/the Covenant of Mayors for Climate & Energy. Analysis of adaptation assessment methods to identify and prioritise adaptation options are not part of this task.

- **What are the main concepts (impacts, vulnerability, risk, resilience, adaptive capacity etc.) that are used when describing 'vulnerability assessments'?**
  Clarify these terms and provide recommendations for the most appropriate use from the policy-makers perspective.

- **What approaches/methods are being used to measure vulnerability in Europe?**
  Compare and contrast the assumptions, factors considered as influencing it, data and models used, and the outcomes.

- **Recommendations and guidance on how to describe vulnerability at different scales or across regions, including an analysis of challenges and gaps (e.g. in data, factors, assumptions), aiming at developing a robust reference framework for vulnerability (adaptation capacity, resilience) assessment.**

- **Recommendations for future research and for knowledge transfer.**

The European Environment Agency (EEA) is currently developing a report on national climate change impact, vulnerability and risk assessments in Europe to be published in 2018. This EEA report will provide a systematic review of national climate change impact, vulnerability and risk assessments and their use for policy-making across Europe, based on information and reflections reported directly by EEA member countries. The EEA report extends the findings of this study, which is based on a desk review, complemented by in-depth interviews with a limited number of countries.

1.3 What is a Vulnerability Assessment?

A vulnerability assessment is an evidence gathering activity to assess who is vulnerable, to what, and under what circumstances. For example, elderly people – the 'who' – are more susceptible to high temperatures – the 'what' – hence in the event of a heatwave – the 'circumstance' – they will be more vulnerable. An assessment can also be applied to systems, for example buildings, roads and habitats as well as people.

The overarching purpose of a risk and vulnerability assessment is to inform decision-makers about the potential risks and opportunities presented by climate change. It provides a means to evaluate the impacts associated with different scales of climate change, along with evidence to compare different response strategies and policy options (Moss, et al., 2010). Within this overarching purpose four purposes are identified by Patt et al. (2009) for undertaking a vulnerability assessment:

i. to improve adaptation planning,
ii. to frame climate change mitigation as an urgent problem(by contrasting impacts of unmitigated and mitigated climate change)
iii. to address social injustice, by exposing the differential burden of vulnerability borne by the socially disadvantaged, or
iv. to improve basic scientific understanding of vulnerability and improve the methods and tools used in its evaluation.

Vulnerability assessment is a well-established and critical part of adaptation planning that is embedded within the policy cycle (see the next section 1.3.1) and also within conceptualisations of the adaptation planning process.

1.3.1 Vulnerability assessment within the policy cycle

A risk and vulnerability assessment may form part of a wider adaptation policy cycle that is used to support policy-makers. Figure 1 shows where the vulnerability assessment sits conceptually in a generic adaptation policy process. The approach, in common with many processes for policy making and also for adaptation, is circular and iterative.

The concept of a continuous and evolving process is particularly important for adaptation, since adaptation itself is by nature a continuous learning and improvement process. Other key features are that it requires simultaneous input from several sectors, and that it requires stakeholder input at various stages in its application.

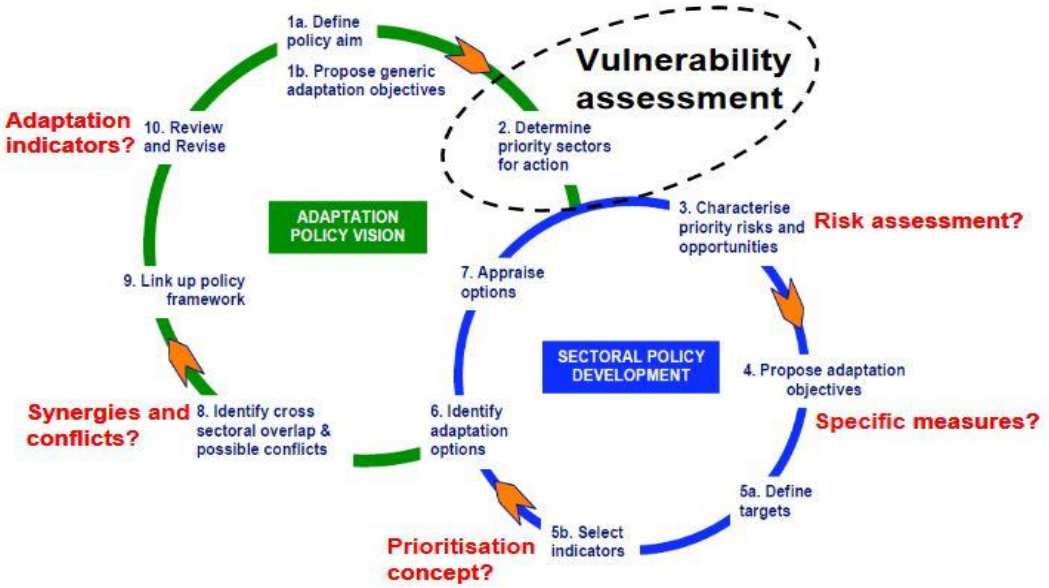


Figure 1. Vulnerability assessment located in a modified and annotated generic method or adaptation policy setting

(Coll & Sweeney, 2013) modified from **(Defra, 2005)**

It should be noted that while theoretical definitions of vulnerability are diverse and to some degree remain vague (Wolf, et al., 2013), the methodologies for assessing vulnerability are less so. Assuming the above understanding of vulnerability, focusing on the determinants of vulnerability can provide the backbone of vulnerability assessments. Vulnerability assessment considers both *social* vulnerabilities (determined by factors such as economic diversity, poverty and wealth, education, critical thresholds, social cohesion/capital, equity,

governance, policy priorities) and *biophysical* vulnerabilities (determined by factors such as climate change and variability, including extremes, land use, habitat quality, water availability, critical thresholds, frequency, duration and magnitude).

Vulnerability assessments typically explore current vulnerability, or future vulnerability or some combination of the two (e.g. future biophysical determinants acting upon current social determinants). This latter is justified primarily to ensure that adaptation actions designed in the present are robust for future changes, whereas if the focus is on future socio-economic conditions it raises the concern that identified adaptation may not necessarily address current vulnerabilities (Preston & Stafford-Smith, 2009). The need for a vulnerability assessment that addresses both current and future socio-economic conditions could arguably be seen as being more supportive of a pathway approach to adaptation planning.

This also links to the differences between contextual vulnerability ('a present inability to cope with external pressures or changes, such as changing climate conditions') and outcome vulnerability (the residual consequences that remain after adaptation has taken place). If a country chooses to look at current vulnerability they will effectively be assessing contextual vulnerability and will choose different methods to asses this compared to the methods that would be chosen if the vulnerability assessment was considering a combination of current and future vulnerability.

The focus on vulnerability assessment within this study recognises that such assessments (along with related concepts of impacts, risks, resilience and adaptive capacity assessments) are one of the key components of the adaptation process. A vulnerability assessment also provides a basis for identifying vulnerabilities of current climate variability and future climate change on human wellbeing and the environment.

1.4 Definitions of vulnerability and vulnerability assessment

There are many definitions of 'vulnerability' resulting in conceptual confusion around the term (Wolf, et al., 2013) and its application, but also around related concepts such as resilience, risks and adaptive capacity. The term has both a common use (the state, or appearance of, being open to attack or injury) and a scientific use stemming from geography and natural hazards research. The scientific use of 'vulnerability' has its roots in geography but is now applied in a multitude of disciplines including climate change assessment, natural hazards (disaster risk) research, ecology, public health, poverty and development, and sustainability science.

The evolution of the term 'vulnerability' in the context of climate change can be traced through both the academic literature and the IPCC Assessment reports. In 2001 vulnerability was defined by the Intergovernmental Panel on Climate Change (IPCC) as:

"The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes**"** (IPCC, 2001)

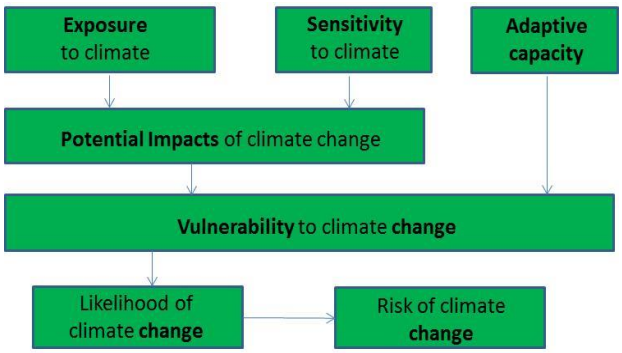
and is presented as a function of three interacting components: exposure, sensitivity and adaptive capacity (defined below). This definition is further refined in the IPCC AR4 as being the final outcome of an assessment of the exposure to climate change, the sensitivity of the system, subsequent impacts and the capacity of the system to adapt to these impacts. It considers both bio-geophysical as well as socio-economic factors.

It has been argued that the indicators used for determining 'vulnerability' in the disaster risk context are often in practice quite similar to those describing the 'sensitivity' of the system's components to 'climate' in the climate change community. Also that 'vulnerability' in the climate change community is sometimes used similar to 'risk' in the disaster risk community (see Figure 2). The main difference is that the DRR community are considering climate *variability* and the climate science community are considering climate *change*.

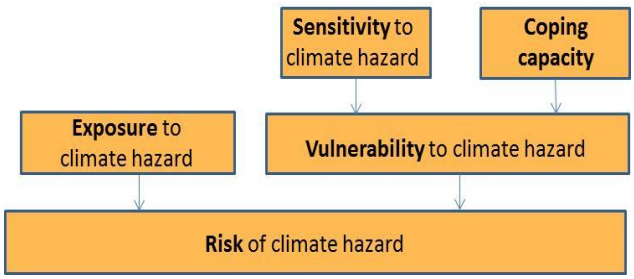
In practice there appear to be few systematic differences between national-level climate change assessments denoted as vulnerability and risk assessments, such as those in Germany and the United Kingdom.

The IPCC Special Report on Extremes (IPCC, 2012) focuses on the interconnections between extreme weather events, climate change and disasters. This report no longer uses the vulnerability definition of the IPCC AR4 but

follows largely the concept of vulnerability as understood by the disaster risk community: 'Vulnerability is defined generically as the propensity or predisposition to be adversely affected'.



2a. Framing of vulnerability assessment from a natural science/climate impacts viewpoint (subset of diagram from EEA (EEA, 2012)



2b. Framing of vulnerability assessment from a risk management, DRR and international development viewpoint – changes in terminology

Figure 2. Framing of vulnerability assessments from climate impacts and risk management viewpoints

In the field of disaster risk, this includes the characteristics of a person or group and their situation (sensitivity/susceptibility) that influences their capacity to anticipate, cope with, resist, and recover from the adverse effects of physical events.'' (IPCC, 2012). The shift in framing means that information can be translated more easily into a risk management approach that facilitates policy making.

The IPCC AR5 (IPCC, 2014) retains this disaster risk focused definition as defined in the IPCC SREX Report (IPCC, 2012) and recognised that "vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt". A distinction is also drawn between contextual vulnerability ("a present inability to cope with external pressures or changes, such as changing climate conditions") and outcome vulnerability (the residual consequences that remain after adaptation has taken place).

To support understanding of the concepts and elements within this definition the terms are provided here (IPCC, 2014):

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected. The exposure of various elements can be expressed as part of the vulnerability but the exposure assessment may also be regarded as separate from vulnerability assessment.

Sensitivity: The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise).

Adaptive Capacity: The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to response to consequences. A broad set of factors such as wealth, social status, knowledge capital determine adaptive capacity.

The IPCC (IPCC, 2001) identifies eight broad classes of determinants of adaptive capacity:

i. available technological options,
ii. resources,
iii. the structure of critical institution and decision-making authorities,
iv. the stock of human capital,
v. the stock of social capital including the definition of property rights,
vi. the system's access to risk-spreading processes,
vii. information management and the credibility of information supplied by decision makers, and
viii. the public's perceptions of risks and exposure.

(see also the Sustainable Livelihoods Framework 5 capitals in section 1.5)

As with many widely applied concepts, interpretations and definitions of vulnerability vary, albeit centred on a broadly agreed set of principles. O'Brien et al. (O'Brien, Eriksen, Nygaard, & Schjolden, 2007) make the case that these interpretations do matter and they contrast two dominant definitions, outcome vulnerability and contextual vulnerability, to illustrate this. They argue that these definitions stem from two distinct framings of the climate change issue ('outcome vulnerability' as a scientific framing and 'contextual vulnerability' as a human-security framing) with each prioritising the production of different types of knowledge, and emphasising different types of policy responses to climate change. Critically for this study, they recognise the utility of approaching vulnerability from different perspectives but that this also affects vulnerability assessment processes and outcomes.

1.4.1 Defining terms associated with vulnerability

Understanding vulnerability also requires an understanding of the other concepts associated with vulnerability (IPCC, 2014):

Impacts (Consequences, Outcomes): Effects on natural and human systems. The term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts. (in a risk disaster framing this could be termed **Hazard =** qualified by intensity and probability*)*

Resilience: The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk = (Probability of Events or Trends) × Consequences. Risk results from the interaction of vulnerability, exposure, and hazard.

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.

1.5 Frameworks for Vulnerability Assessments

There are a number of different frameworks for assessing risks and vulnerabilities to climate change or which incorporate vulnerability within a broader conceptualisation of the adaptation cycle. The following frameworks have been drawn from the literature and are described in this section:

- IPCC Technical Guidelines for Assessing Climate Change impacts and Adaptation 1998
- UKCIP Risk, Uncertainty and Decision-making Framework
- UKCIP Wizard
- Climate-ADAPT Adaptation Support Tool
- PROVIA Guidance on Assessing Vulnerability, Impacts and Adaptation to Climate Change
- EU Adaptation Strategy Guidance
- Sustainable Livelihoods Framework (SLF)

A number of these frameworks build upon one another, thus an evolution in framing and concepts is evident. For example, the key principles in the UKCIP Risk, Uncertainty and Decision-making Framework have gone on to inform the Adaptation Wizard and strongly influence the Climate-ADAPT Adaptation Support Tool and also the EU Adaptation Strategy Guidance.

IPCC Technical Guidelines for Assessing Climate Change impacts and Adaptation, 1998

A set of technical guidelines for the scientist that does not seek to prescribe a single preferred method but rather a range of methods, some of which may be more suitable than others to particular tasks, but which yield comparable results across regions and sectors. The guidelines aid users in assessing the impacts of potential climate change and in evaluating appropriate adaptations. The Guidelines outline a seven-step process and a range of methods is identified at each step. These steps are:

- Definition of the problem;
- Selection of the methods;
- Testing of the methods;
- Selection of the scenarios;
- Assessment of biophysical and socioeconomic impacts;
- Assessment of autonomous adjustments;
- Evaluation of adaptation strategies.

This has been the dominant way of assessing impacts and adaptation for the past 2 decades (Carter & Mäkinen, 2011).

The UKCIP Risk, Uncertainty and Decision-making Framework

The Risk, uncertainty and decision-making framework is a step-by-step process to help you assess what adaptation measures are most appropriate for your organisation or business. It is based on standard decision-making and risk principles, and will help you answer the questions: What climate change risks could affect my decision? What adaptation measures are required, and when should they be implemented? This is a structured framework with guidance. Uncertainty analysis is a key feature of this risk assessment. Stages 3, 4, and 5 are tiered, allowing the decision-maker to identify, screen, prioritise and evaluate climate and non-climate risks and options before deciding whether more detailed risk assessments and options appraisals are required.

The Guidelines outline a seven-step process. The key stages of the process are 1) Identify the problem and objectives; 2) Establish your risk tolerance level and decision-making criteria; 3) Identify and assess your risks; 4) Identify a range of adaptation options; 5) Appraise your adaptation options; 6) Make a decision; Implement the decision; and 7) Monitor the decision and evaluate any new information.

UKCIP Wizard

The UKCIP Wizard is a 5-step process to help users assess their organisation's vulnerability to current climate and future climate change, identify options to address your organisation's key climate risks, and help you develop and implement a climate change adaptation strategy. The Wizard is also a guide to information, tools and resources. It is based on the UKCIP Risk, Uncertainty and Decision-Making Framework. The Wizard is an online tool that supports those making adaptation decisions through the following steps: 1- Getting started; 2- Current climate vulnerability; 3- Future climate vulnerability; 4-Adaptation options; and 5-Monitoring and Review

Step 2, assessing how vulnerable your organisation is to the current climate, provides background knowledge and the building blocks from which to help can think about how future climate change might affect them. Step 2 also identifies organisational responses to previous weather events and how these could inform adaptation planning. Step 3 contains information on how the climate is expected to change, and helps users to assess how those climatic changes may affect their organisation.

Climate-ADAPT Adaptation Support Tool

The aim of the Adaptation Support Tool (AST) is to assist users in developing climate change adaptation strategies and plans by providing guidance, links to relevant sources and dedicated tools. The European Commission has issued EU guidelines on developing adaptation strategies as a component of the EU strategy on adaptation to climate change, with the aim to support EU Member States in the process of developing, implementing and reviewing their adaptation strategies. They provide a common understanding of key features relevant to adaptation processes, building on the experience available in the EU. The steps and recommendations of the AST are aligned with the contents of these guidelines.

The steps of the AST are: 1. Getting started, preparing the ground for adaptation, 2. Assessing risks and vulnerability to climate change, 3. Identifying adaptation options, 4. assessing adaptation options, 5. implementation and 6. monitoring and evaluation. Under assessing risks and vulnerabilities to climate change the AST suggests: analyse how past weather events have affected your area of concern, undertake a climate change risk and vulnerability assessment, take transboundary issues into account, develop an approach for addressing knowledge gaps and for dealing with uncertainties, and select your area's main concerns and set your strategic direction.

As a first step in undertaking a risk and vulnerability assessment, users consider available information for their country's future threats (e.g. sectoral vulnerability assessments) and opportunities should be collected and analysed. Several sources of information exist including assessments carried out at national level and within several research projects.

PROVIA Guidance

An innovative aspect of the PROVIA Guidance is its reliance on the use of decision trees. Decision trees guide the user through various choices that are made when conducting an assessment, based on criteria specific to each stage of the adaptation learning cycle. The conceptual basis, the decision trees and the methods and tools included in the PROVIA Guidance build on research conducted within the project MEDIATION: Methodology for Effective Decision-making on Impacts and Adaptation (funded by the EC, FP7).

The PROVIA Guidance is structured along a five-stage iterative adaptation learning cycle, which comprises the following tasks:

- Identifying adaptation needs (impacts and vulnerability)
- Identifying adaptation options;
- Appraising adaptation options;
- Planning and Implementing adaptation actions;
- Monitoring and evaluating adaptation action and learning.

The first stage of this process includes assessment of impacts and vulnerability and the guidance sets out the methods that could be used. Within the description of the methods they discuss the framing of vulnerability and this is shown in Figure 3 below. It shows how biophysical and social determinants combine to shape vulnerability. It distinguishes between 'current' and 'future'. An assessment of *current* determinants would provide vulnerability to climate *variability* and an assessment of *future change* determinants would provide vulnerability to *climate change.* This avoids using the term *present vulnerability*, given that vulnerability refers to potential harm in the future, but still recognises that there are two different time horizons of interest in framing vulnerability.

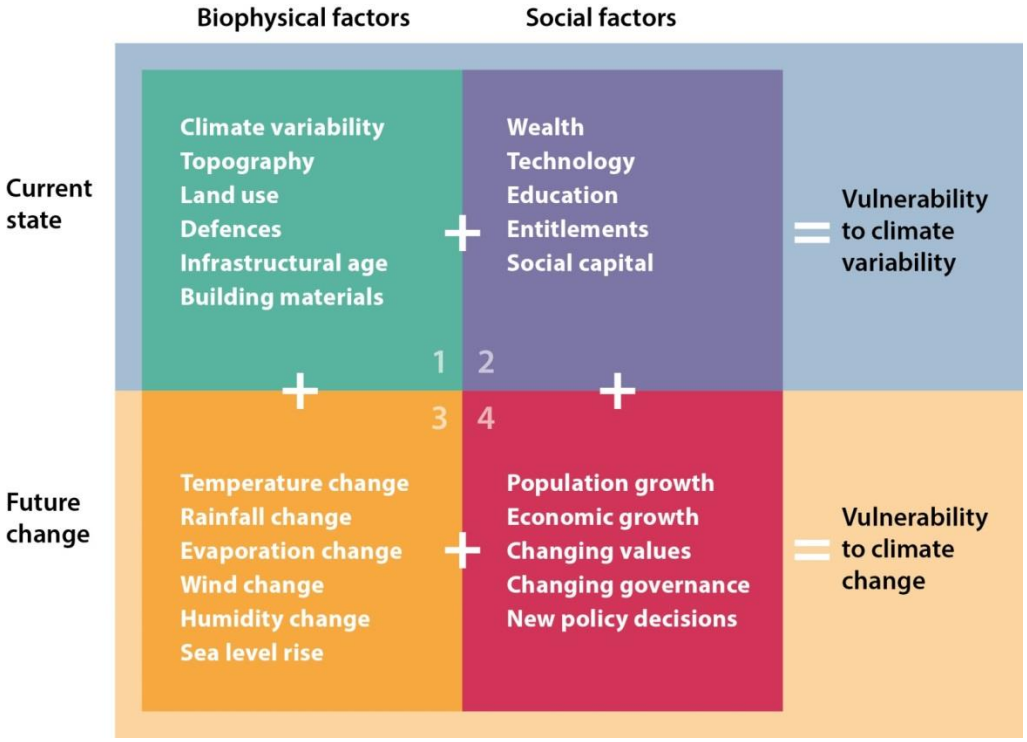


Figure 3. Current and future determinants of vulnerability to climate variability and climate change. Modified from (Preston & Stafford-Smith, 2009), (PROVIA, 2013)

Sustainable Livelihoods Framework (SLF)

The UK Department for International Development (DFID) developed a 'Sustainable Livelihood Framework' (SLF) which is one of the most widely used livelihoods frameworks in international development practice (DFID, 2000)

The SLF views vulnerability as the context that frames the external environment in which people exist. Critical trends as well as shocks and seasonality, over which people have limited or no control, have a great influence on people's livelihoods and on the wider availability of assets. Not all of the trends and seasonality must be considered as negative. Vulnerability emerges when human beings have to face harmful threats or shocks within adequate capacity to respond effectively. The difference between risk and vulnerability is of crucial relevance for assessing causes of poverty. Risk is defined as the likelihood of occurrence of (external) shocks and stresses plus their potential severity, whereas vulnerability is the degree of exposure to risk (hazard, shock) and uncertainty, and the capacity of households or individuals to prevent, mitigate or cope with risk (see Figure 2b).

SLF focuses on people, it seeks to gain an accurate and realistic understanding of people's strengths or "capitals" and identifies five types of assets or capitals upon which livelihoods are built, namely

i. human capital,
ii. social capital,
iii. natural capital,
iv. physical (infrastructure and economic) capital and
v. financial capital

EU Adaptation Strategy Guidance

The EU Adaptation Strategy Guidance provides one of these frameworks in the form of four steps to ensure that a comprehensive picture of current and future risks and vulnerabilities is obtained. This covers the following:

1. Analyse how past weather events have affected your country e.g. national risk assessment using observations.
2. Undertake a climate change risks and vulnerability assessment. If the available information base is not sufficient further work may be needed covering:
    a. Future trend (projection) of various climate variables based on ideally more than 1 climate scenarios e.g. IPCC Special Report on Emissions Scenarios (SRES) or Representative Concentration Pathways (RCPs).
    b. Expected impacts (both hazards) and population distribution, vulnerable population, economic activities and economic value.
    c. Timescale: climate variables, impacts and vulnerability differentiated over short (2020s), medium (2050s) and long (2080s) term.
    d. An indication of the level of confidence (high, medium or low) using statistics, probabilities or statements.
    e. Assessment of socio-economic development and other non-climatic factors e.g. megatrends in population growth, resource use, markets, economic growth.
    f. Tailored so that the outcomes are policy relevant and have had end-user involvement.
3. Take trans-boundary issues into account – the cross-border nature of climate impacts (see Transnational pages on Climate-ADAPT for regional strategy priorities, existing projects and funding opportunities)
4. Develop an approach for addressing knowledge gaps and for dealing with uncertainties. It is important to identify, prepare and practice actions under several future scenarios – there can be scenarios for climate, impacts and socio-economic developments.

Similarities and differences in the features of frameworks

There are many features that these frameworks have in common with each other. Some of the reason for this is the fact that they have built on one another over time. For example, key principles of the UKCIP Risk and Uncertainty Framework have gone on to inform the Adaptation Wizard and this has strongly influenced the structure and content of the Adaptation Support Tool and the EU Adaptation Strategy Guidance.

The similar features include:

- They are all composed of a series of steps (some are more disaggregated than others)
- They are generally nested within the adaptation planning cycle or risk disaster management process e.g. ISO 31000
- The assessment stage typically sits in the early stages of the process e.g. stage 1, 2 or 3 as would be expected for the evidence base for supporting decision-making on identification and selection of adaptation options. Analysis of adaptation assessment methods to identify and prioritise adaptation options are not part of this task.

The frameworks are different in their approach because:

- They range from more to less prescriptive
- They occupy a continuum between climate impacts (top-down and science-first) and risk management (bottom-up, decision-first and participatory).

As part of the MEDIATION project the framings of vulnerability assessments was reviewed and summarised (Carter & Mäkinen, 2011) in the following way.

The seven-step IPCC framework is sometimes cited as the 'standard' or 'first generation' approach to climate impact assessment (UNFCCC, 2005). Its analytical focus is on the identification and quantification of impacts of climate change, often on a particular sector or a region. It places a large reliance on the scenarios of future climate i.e. a long term rather than near term outlook. It is characterised as a "top-down" approach because it proceeds from global climate projections that are subsequently downscaled and applied to assess regional impacts.

It has been criticised for treating adaptation as a residual at the end of the analysis, and for over-simplifying the role of adaptation in responding to multiple stresses. For example, many studies ignore adaptation altogether. Hence results may exaggerate the impacts of climate change. The approach tends to concentrate on biophysical effects of climate change that can be readily quantified, and treats higher-order socio-economic impacts only if quantitative models are available to link to the biophysical effects. Therefore, the main output from such studies that can be used to inform policy is an assessment of physical vulnerability for a time period in the future. This is visualised in the right-hand side of Figure 4.

An alternative approach that focuses on social vulnerability is characterised by Dessai and Hulme (Dessai & Hulme, 2004) as a "bottom-up" approach and is visualised on the left hand side of Figure 4. Here the unit of study is local, commonly households or communities, and the temporal scale tends to be more immediate and near term than in top-down approaches as decision-making on adaptation must address both current and future vulnerabilities and actions. Vulnerability to climate is addressed largely as a problem of climate variability now and focuses on social vulnerability.

The great majority of assessments that follow this approach are found in developing countries, where vulnerability research tends to be focussed on the short to medium term, often in response to immediate risks presented by current climate variability in the context of existing vulnerabilities. In contrast, developed countries are often regarded as resilient to variability, and vulnerability studies of this type have tended to be ignored until recently (e.g. (O'Brien, Eriksen, Nygaard, & Schjolden, 2007). Bottom-up approaches are closely connected with other frameworks dealing with resource management, disaster management and sustainable development, which offer opportunities for integrating climate change considerations into existing decision-making and management contexts.

Figure 4 reinforces the summary of features above. However, another approach to framing distinguishes *three* "framings" of vulnerability assessment (Malone & Engle, 2011):

- As an extension of research on impacts of climate change focusing mainly on physical risks of climate change (e.g. studies of numbers of people at risk from climate change)
- As an offshoot of sustainable development research, focusing on social aspects of vulnerability to climate change, determined by factors such as governance and human capital
- As a development of hazards and disasters research and newer research related to resilience, which focuses on flexible responses that integrate both physical and societal capacities to cope in the short term and adapt in the longer term.

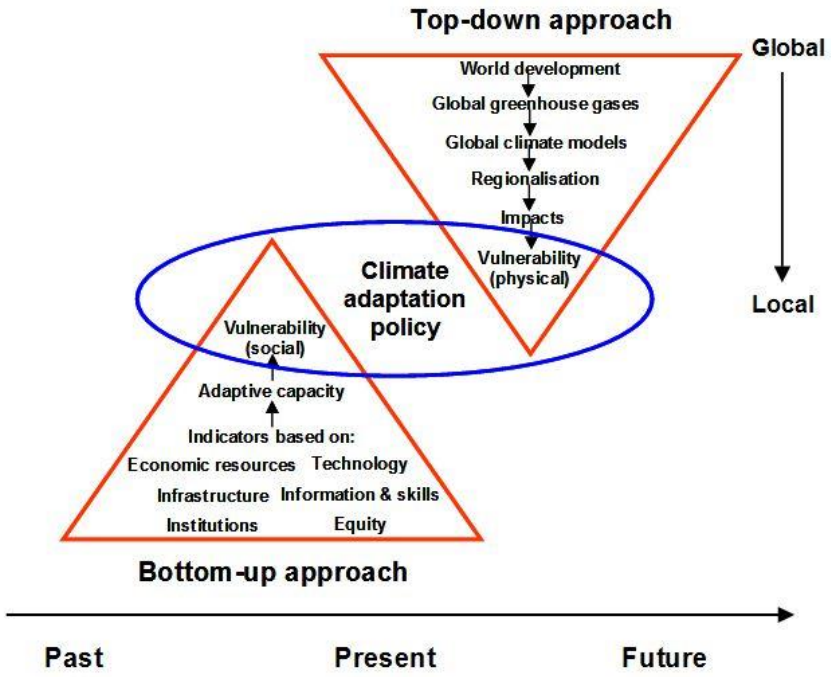


Figure 4. Top-down and bottom-up approaches for addressing climate change policy

(adapted from **(Dessai & Hulme, 2004) (Carter & Mäkinen, 2011)**

Resilience frameworks

Resilience frameworks provide an additional angle to assessing adaptation. Their origins lie in research traditions on population, landscape ecology and resource management and consequently their methodological foundation is strongly mathematical and modelling-based. Key elements that set resilience frameworks apart from the mainstream adaptation literature include:

- a systems-oriented rather than agent-based view in examining adaptation (It focuses on the relationships between system elements, context and feedbacks rather than individual elements of a system) and

- the fundamental assumption that the natural state of a system is one of change rather than equilibrium. (Hence adaptation assessments should not aim at reducing vulnerability in relation to static risks at a given point in time but focus on maintaining system flexibility).

2 Approaches used for assessing and measuring vulnerability in Europe

A selection of European research projects focusing on methodologies for national and transnational level assessments were reviewed based on inclusion and exclusion criteria. The frameworks and methodologies used in the EU research projects were analysed and summarised as lessons learned, gaps and challenges. The results from EU research projects were merged with the results from the EU MS analysis (Section 3) to provide a reference framework (Section 4.1) that can be shared with those who are considering developing risk and vulnerability assessments. Finally, recommendations are provided. The primary focus for the study is on vulnerability assessment methods (and related concepts of impact, risk and adaptive capacity) that have been undertaken at the national or transnational level (characterised by a method applied to multiple sectors). Individual sector or, city level assessments are not part of this study.

The research projects were selected for further analysis by using the following inclusion and exclusion criteria:

Criteria 1 – Research project focus was at the European or national level and not at the local level

Criteria 2 – Focus of research project (or a work package) was on the methodology for vulnerability assessment, rather than individual elements of an assessment such as climate scenarios or impacts assessment

Criteria 3 – Research project was completed with final deliverables available online as of August 2016

Criteria 4 – Research project was seen as influencing future research related to vulnerability assessment (based on expert judgement)

Criteria 5 – Research project results had been used in national MS vulnerability assessments

Criteria 6 – Multiple projects using the same methodology. If the research project led to a follow-on project that used the same methodology only one of the projects was selected.

We have used these criteria to select 8 research projects that were the most relevant based on the criteria and availability of resources and time to conduct the analysis. As such, the analysis undertaken highlights some of the EU research on vulnerability assessment (frameworks and methodologies), but also provides further information on the methodologies used in some countries' national assessments.

There are additional research projects that are ongoing or that dealt with aspects of a vulnerability assessment (e.g., IMPRESSIONS, ClimateCost, ENHANCE. Helix and Rise-AM, PESETA-GAP, PESETA III), including a number of research projects with a focus at the local level. Although potentially useful projects these were not included on the basis of the inclusion and exclusion criteria.

2.1 Summary of findings from research projects

Eight research projects were analysed in section 2 and these include:

1. Baltic Challenges and Chances for Local and Regional Development
2. BASE - Bottom-Up Climate Adaptation Strategies Towards a Sustainable Europe
3. CLIMSAVE - Climate Change Integrated Assessment Methodology for Cross-Sectoral Adaptation and Vulnerability in Europe
4. ESPON Climate - Climate Change and Territorial Effects on Regions and Local Economies.
5. MATRIX - New Multi-hazard and Multi-Risk Assessment Methods for Europe
6. MEDIATION - Methodology for Effective Decision-making on Impacts and Adaptation

7. PESETA I and II - Projections of economic impacts of climate change in sectors of the European Union based on bottom-up analysis
8. RAMSES - Reconciling Adaptation, Mitigation and Sustainable Development for citiES.

The information for this section comes from the eight research project summaries in Annex 6.1. Section 2.1 describes the overview and frameworks of the research projects. Section 2.2 describes the methods used in each research project. The approaches used for measuring (and indicators) of vulnerability are discussed in section 2.3 and the lessons learned, gaps and challenges are in section 2.4.

2.1.1 Overview of research projects

An overview of the eight research projects in terms of project length, funding source, website and short description are provided in Table 1:

Table 1. Overview of the eight research projects

Title	Project length, funding source, website	Description
Baltic Challenges and Chances for Local and Regional Development	2007-2013 European Regional Development Fund and the Baltic Sea Region Programme http://www.balticclimate.org/en/project/main-outputs/supporting-material-for-impacts-and-vulnerability-assessment	The Baltic Climate Vulnerability Assessment Framework (VAF) was developed within the Baltic Challenges and Chances for Local and Regional Development project and is intended for assessments of challenges and chances at local level in the Baltic Sea Region (BSR). The Framework was based on a participatory process and a series of exercises where the stakeholders considered the evidence compiled during the inventory phase and used their respective knowledge.
BASE Bottom up Adaptation Strategies for a Sustainable Europe	2012-2016 FP7	BASE compiled and analysed data and information on adaptation measures and their effectiveness towards a publicly available comprehensive, integrated knowledge base. BASE focused on questions related to local level action by exploring 23 case studies across Europe with an emphasis on analysis of social and economic benefits, sectoral adaptation costs, and policy coherence and implications, implementation and stakeholder participation.
CLIMSAVE Climate Change Integrated Assessment Methodology for Cross-Sectoral Adaptation and Vulnerability in Europe	2010 – 2013 FP7 website and IAP tool: www.climsave.eu/	CLIMSAVE developed an integrated assessment online tool to enable stakeholders to understand and explore cross-sectoral benefits and conflicts of different impacts, vulnerabilities and adaptation options to better inform robust policy responses. Two important aspects included were advancing the treatment of cross-sectoral interactions and including the implications of continuing socio-economic changes.
MATRIX Multi-hazard and Multi-risk Assessment Methods for Europe	2010-2013 FP7 All reports from the MATRIX project are available at: http://matrix.gpi.kit.edu/Deliverables.php	MATRIX developed a new multi-hazard, multi-risk assessment framework (online simulation tool) that focussed on natural hazards of relevance to Europe (earthquakes, volcanic eruptions, landslides, tsunamis, wildfires, winter storms, and coastal and inland flooding) and possible combinations of these events and their implications to help inform decision makers in national civil protection and disaster management authorities.

Title	Project length, funding source, website	Description
MEDIATION Methodology for Effective Decision-making on Impacts and Adaptation	2010-2013 FP7 http://www.mediation-project.eu/	MEDIATION analysed the available methods, metrics and tools for assessing impacts, vulnerability and adaptation options (CCIVA), synthesised the knowledge to develop an overarching integrated methodology and put all the results on a common platform to share the knowledge that has been gained. It aimed to provide decision makers with a set of tools and metrics that can be used to meet the field's many challenges.
ESPON Climate Climate Change and Territorial Effects on Regions and Local Economies	2007-2013 Partly financed by European RDF. ESPON Programme www.espon.eu Final report https://www.espon.eu/export/.../CLIMATE/ESPON_Climate_ScientificReport_DFR.pdf	ESPON Climate was one of the projects within the wider ESPON 2013 Programme. It was a pan-European vulnerability assessment providing the basis for identifying regional typologies of climate change exposure, sensitivity, impact and vulnerability. Tailor-made adaptation options can be derived which are able to cope with regionally specific patterns of climate change. It responded to the needs identified in the EU Territorial Agenda (Priority 5).
PESETA I and II Projections of Economic impacts of climate change in sectors of the EU based on bottom-up analysis	PESETA I 2006-2009 http://peseta.jrc.ec.europa.eu/ PESETA II 2010-2014 https://ec.europa.eu/jrc/en/peseta PESETA I & II – funded by JRC	PESETA I & II was designed to make a consistent multi-sectoral assessment of the economic impacts of climate change in Europe for the 2071-2100 time horizon. PESETA I considered the impacts in five areas and looked at four climate runs. PESETA II extended the coverage to nine areas and up to 15 climate runs were modelled by some of the sectoral teams.
RAMSES Reconciling Adaptation, Mitigation and Sustainable Development for Cities	2012-2017 FP7 http://www.ramses-cities.eu/	To produce quantified evidence of the impacts of climate change and the costs and benefits of a wide range of adaptation measures, focusing on cities. The project focuses on Antwerp, Bilbao and London, with Rio de Janeiro, Bogota, Skopje, Hyderabad and New York involved as supporting cities. Work Package 3 aims to support the design of adaptation strategies in cities by providing a set of tools to assess city-scale vulnerability and evaluate climate risks on key sectors.

2.1.2 Frameworks used in the research projects

The frameworks that were used in each research project are described in this section and reviewed against the frameworks described in section 1.5.

The *Baltic Climate Vulnerability Assessment Framework* consists of eight exercises each emphasising a specific element concerning vulnerability to climate change and climate adaptation, including exposure to climatic and non-climatic risks, sensitivity and adaptive capacity. Together these exercises facilitate a robust assessment of the challenges and changes related to of climate change.
These exercises include:

- How might future society be?
- Climatic Stressor Mapping;
- Socio-economic Stressor Mapping;
- Analysing socio-economic sensitivity;
- Identifying and ranking Adaptive Capacity;
- Identification of Key Actors and Mapping;
- Limits of adaptation measures;
- Integrated Vulnerability Analysis.

The critical aspect of the approach taken in the *BASE* project is that it assumes there is no single framework or systematic approach to assessing vulnerability. This can be viewed as both a strength and weakness; the projects' bottom-up nature means that the project focuses on decision-relevant information and methods tailored to a given context but this makes in more difficult to draw transferable conclusions. Quite correctly, BASE is unapologetic in this emphasis that 'diversity rules'. The empirical evidence is that vulnerability takes different forms and shapes in different contexts (the BASE case studies). In the case studies some effort was made to extract common features, but then different aspects were used in the modelling work that was undertaken both from a macro-economic modelling perspective and sector specific models. Consequently, we can conclude that vulnerability assessment is examined within the BASE project from a 'decision-first' perspective.

The *CLIMSAVE* project developed an integrated assessment approach to enable stakeholders to understand and explore cross-sectoral benefits and conflicts of different adaptation options to better inform robust policy responses. It devised a new integrated impact, vulnerability and adaptation assessment framework taking account of multi- and cross-sectoral change, climate change and socio-economic change. This work built on a comprehensive assessment of current scientific literature and existing sectoral tools supplemented by expert knowledge and on-going research. Using the steps within the Integrated Assessment Platform (online tool), stakeholders can explore potential adaptation strategies for reducing climate change vulnerability, discovering where, when and under what circumstances actions may help:

- Impacts - investigate how different amounts of future climate and socio-economic change may affect urban, rural and coastal areas, agriculture, forestry, water and biodiversity;
- Adaptation - take scenarios from the impacts analysis and investigate how adaptation can reduce the impacts of climate change;
- Vulnerability - investigate which areas or 'hot spots' in Europe may be vulnerable to climate change in your scenario, before and after adaptation; and
- Costs - identify the relative cost of adaptation measures to reduce the impacts of climate change.

The *ESPON* project's vulnerability assessment methodology consisted of an exposure analysis making use of existing projections on climate change and climate variability A sensitivity analysis developed by creating indicators for each sensitivity dimension (physical, environmental, social, economic and cultural). Exposure and sensitivity were then combined to determine the potential impacts of climate change for each dimension. The impact values of the five sensitivity dimensions were finally combined to one overall sensitivity value. Adaptive capacity was derived by developing several indicators for each of the five major determinants of adaptive capacity and finally aggregated to an overall adaptive capacity. To determine the overall vulnerability of regions

to climate change the impacts and the adaptive capacity to climate change were combined for each region. The analysis thus focused on what would be the result if climate change took place unrestrictedly and impacted on the regions without further preparation.

The vulnerability framework within the *MATRIX* project was a staged process and allows for the identification of vulnerability hot spots. It assumes that vulnerability to pressures, such as climate change, depends on the capacity to cope and that this is determined by the amount of capital that can be used to deal with the pressures. Five types of capital were defined and interlinked: natural, manufactured, social, human and financial. It focussed on natural hazards of relevance to Europe (earthquakes, volcanic eruptions, landslides, tsunamis, wildfires, winter storms, and coastal and inland flooding) and possible combinations of these events and their implications. As the focus was on short-term extreme events and their implications, climate and climate change scenarios were not explicitly incorporated. A strong emphasis was placed on assessing socio-economic consequences (direct and indirect, time-dependent) of multi-hazard events focussed on the consideration of human and social capital, natural capital and financial and economic capital.

The MEDIATION project analysed the available methods, metrics and tools for assessing impacts, vulnerability and adaptation options (CCIVA), synthesised the knowledge to develop an overarching integrated methodology and put all the results on a common platform to share the knowledge that has been gained. The platform is intended to be used by scientists, policy advisors or practitioners with a technical or scientific background. It was not built for untrained decision-makers or the general public. It aimed to provide decision makers with a set of tools and metrics that can be used to meet the field's many challenges.

The project has developed a diagnostic framework with multiple entry points that helps users select appropriate methods and tasks for a given adaptation situation. It comprises a sequence of decision trees that map types of adaptation situations onto appropriate research approaches or onto practices in those cases in which research is not applicable. The interlinked framework encompasses generic methodologies, natural science–based models, socio economic evaluation methods, and social and institutional analytical frameworks.

PESETA I and PESETA II is based on bottom-up biophysical impact models that consider the relationship between climate change and biophysical impacts in a structured way. It used the FP7 Climate Cost project outputs and impacts are valued and integrated in economic terms within a multi-sectoral computable general equilibrium economic model to estimate the effects of climate change impacts on the overall economy. All the biophysical impact models in the study used input data from the same climate scenarios.

The *RAMSES* project has developed a climate risk analysis methodology that can be applied to all EU cities to identify priorities for national and EU adaptation investments, in this sense the approach could be framed as ‘decision first’. The analysis methodology combines hazard, exposure and vulnerability information and thus could also be framed as ‘science led’, albeit not driven purely by climate science. Conceptually, the RAMSES approach to risk analysis is consistent with the conceptual framework proposed by the IPCC on the WGII AR5 (IPCC, 2014) which identifies the three interacting components of climate change risks; hazard, exposure and vulnerability. An objective of this methodology is that it can be used to assess the relative priorities for cities through the identification of significant risks for each city, and the relative contribution of hazard or vulnerability to that risk.

Analysis of frameworks used in research projects

A number of frameworks were described in section 1.5 and there was an analysis of the similar and different features. In this section the analysis is taken further. The analysis in section 1.5 concluded with ‘The frameworks occupy a continuum between climate impacts (top-down and science-first and more data/modelling oriented) and risk management (bottom-up, decision-first and participatory)’ and this is shown visually in Figure 5.

Risk Management perspective Climate Impacts perspective

Figure 5. Visual of the continuum of the vulnerability assessment frameworks between climate impacts perspective and risk management perspective

Further analysis of the characteristics within the different frameworks provides a range of characteristics such as geographic focus from national to household, which field of literature it originates from e.g. DRR or adaptation and whether it assesses present climate variability or future climate change. The characteristics at either end of the continuum are provided in Table 2. As would be expected, in reality most projects and national assessments cover features within both perspectives and are positioned somewhere between the two ends.

Table 2. Main characteristics of vulnerability frameworks that describe either end of the continuum

Characteristics of the frameworks	A: Risk management	B: Climate impacts
Purpose of the assessment	Decision –first	Science-first
Climate assessment	Present climate variability	Future climate change
Driver of the assessment	Bottom-up – locally driven, co-production	Top-down – globally or nationally driven
Geographic focus	Community or household focused	Nationally or regionally focused
Type of methods used	Participatory or qualitative methods	Modelling or quantitative methods
Primary subject of interest	People centred/socio-economic (based on 5 capitals), governance	Biophysical impacts (flood, heat)
Origin of field of literature	DRR and international development field	Climate science field

The eight research projects were analysed against the characteristics in Table 2 and the characteristics that are in the continuum that are represented in each project are listed in Table 3.

Table 3. Results of analysis of each research project against characteristics of the vulnerability frameworks continuum

Baltic	Bottom-up, participatory, social and biophysical
BASE	Participatory, modelling, decision-first, future climate change
CLIMSAVE	Modelling, participatory, climate impacts, top-down, socio-economic scenarios, future climate change
ESPON	Top-down, climate impacts, 5 capitals
MATRIX	Present climate variability, 5 capitals, socio-economic, top-down
MEDIATION	Participatory, modelling, biophysical, social, decision first
PESETA	Modelling, future climate change, climate impacts (economic), top-down
RAMSES	Decision-first, top-down (data driven), modelling, cities

Table 3 shows that no projects are primarily one framing, they sit somewhere in the middle demonstrating that most projects show a mix of the two framings and borrow characteristics from both. This probably reflects the shift in framing and sharing of concepts over the past 20 years, and the influence of the IPCC assessment reports and guidance. It also reflects the purpose of the project in that some projects are aiming to have a European overview of e.g. economic impacts with no expectation that this will be used for national policy planning.

Whereas, some assessments are locally specific and designed to a feed into development of adaptation options for e.g. a city hence, it would be expected that the methods and framings for these two different purposes would be different.

2.2 Methods used in the research projects

This section describes the methodology (stages or process steps) used in the research project. It also describes the methods being used to gather information, such as climate or socio-economic scenarios, modelling, stakeholder engagement through face-to-face workshops or email surveys for each of the 8 research projects.

BALTIC

The Baltic Climate Vulnerability Assessment Framework (VAF) is intended for assessments of challenges and chances at local level in the Baltic Sea Region (BSR). The Framework is based on a participatory process and a series of exercises where the stakeholders consider the evidence compiled during the inventory phase and input their respective knowledge (solicited through questionnaires and workshop consistent with delivering the required exercise outputs).

The inventory phase recognizes that assessing the local challenges and chances generated by global climate change requires data and information at the appropriate scales in order to facilitate an integrated assessment of the challenges and chances. Three main elements of data and information support have been identified: statistical inventory at the appropriate scale; climate change related data; and policies and measures inventory. When all the necessary data is collected, the local challenges and chances generated by climate change can be assessed, together with relevant stakeholders.

The stakeholder mapping aims to identify the key stakeholders to be engaged and how and for what purpose they are to be engaged in the different exercises comprising the vulnerability assessment process. Guidelines are available to support this mapping. The types of stakeholders to be involved and nature of their engagement is informed by the roles they would be undertaking in the climate stressor mapping exercise (most critical climate stressors and chances that affect vulnerability and adaptation) and in the socio-economic stressor mapping exercise (most critical socio-economic stressors and chances).

The exercises and the process were developed and then modified from other projects carried out at the Centre for Climate Science and Policy Research (CSPR) and applied in seven Baltic Climate Target Areas (TAs). Based on the experiences of the Baltic Climate project participants, the exercises and process were further revised. This revision through consideration of use in practice lead to the development of a set of guidelines consisting of three sections and one appendix, following the logical steps of the assessment.

Section 1 The *"Introduction"* presents the VAF and in brief the typical questions that the vulnerability assessment should be able to answer (concerns, goals and objectives).

Section 2 *"Preparing the Process"* describes the role of the process leader, preparations, documentation/output, and evaluation as well as how to prepare for the exercises.

Section 3 *"The Vulnerability Assessment Framework Practical Exercises*" contains the main issues addressed in three blocks: (1) introduction (stakeholder mapping, challenges and chances), (2) exposure and sensitivity (future scenarios, climate stressors, socio-economic stressors, local sensitivity), and (3) response action (adaptive capacity, responsibilities of key actors, integrated vulnerability assessment and action plan).

BASE

A multitude of methods are used in the project but the broad focus tends to be on analysis, showcasing examples and developing tools and methods. Synthesis and is also an important aspect for example drawing together, then building upon, economic evaluation methods to develop new tools. A further example of the types of methods and tools developed for specific sectoral needs is the adaptive capacity index (ACI) developed to define the extent to which the impacts of climate change and their interactions with social systems increase levels of vulnerability of agricultural systems.

The application of terms and development of products to support the assessment of risks and vulnerability are driven by bottom up needs and to address specific subject areas (e.g. vulnerability of ecosystems), sectors or groups.

One of the outputs from the BASE project was a Policy Brief that demonstrates the process of co-creation with stakeholders. The BASE project has produced ten recommendations for improving the practical implementation of the three overarching objectives of the EU Adaptation Strategy. The BASE recommendations emerged from general modelling approaches combined with careful analyses of individual case studies across Europe. The recommendations were developed in a co-creation workshop with representatives of local cases, national policy makers, representatives of DG Clima, DG Research and OECD as well as researchers.

CLIMSAVE

The project developed an integrated assessment approach to enable stakeholders to understand and explore cross-sectoral benefits and conflicts of different adaptation options to better inform robust policy responses. Two important aspects within the project were advancing the treatment of cross-sectoral interactions and including the implications of continuing socio-economic changes.

A range of climate change scenarios were incorporated. For Europe, four emissions scenario were used (SRES A1b, A2, B1 or B2), three climate sensitivity levels (low, medium or high) and the choice of five GCMs (MPEH5, CSMK3, HADGEM, GFCM21 and IPCM4). For Scotland, the climate change scenarios were based on the UK Climate Projections (UKCP09) and emissions scenarios chosen to be equivalent to SRES B1, A1B and A1F1.

A set of four plausible socio-economic futures for both Europe and Scotland was developed with stakeholders through a series of five workshops (around 20 stakeholders at each). Qualitative storyline scenarios where then quantified by the stakeholders for inclusion in the IAP, further strengthening expert input into the project.

CLIMSAVE incorporated an economic assessment of adaptation options. The costs of 'hard' adaptation options were characterised drawing on an extensive literature search. The costs of 'soft' adaptation options were identified using expert judgement, as was the potential for each hard and soft option to contribute to overall adaptation in a sector, information on cross-sectoral impacts (both direction and intensity) and the cross-sectoral effects of proposed adaptation options. However, given the lack of knowledge on costs, monetary measures for the cost-effectiveness of adaptation options were not derived; a qualitative description was included to help users think about various adaptation options.

Reviews of scientific literature, an understanding of existing models and databases, expert judgement, and stakeholder engagement, consultation and feedback through discussions and workshops were all methods used to contribute to the research and to analyse the outputs. The final IAP assessment tool includes linked sectoral models and databases allowing for both qualitative and quantitative scenario analysis and a degree of economic analysis.

IMPRESSIONS has taken the CLIMSAVE methodology further but the work is ongoing so have not been reviewed for this study.

ESPON

The *exposure analysis* made use of existing projections on climate change and climate variability (one GCM (ECHAM5/MPI-OM) and one regional circulation model (CCLM) and one IPCC climate scenario, A1B) the ESPON Climate project aggregated data for two time periods (1961-1990 and 2071-2100) for eight climate stimuli. River flooding and sea level rise were added as two immediate 'triggered effects' of these climate stimuli.

Each region was then assessed in regard to its climate change *sensitivity*. The report looked at the sensitivity of economic sectors (calculated based on the regional dependency of different economic sectors, and on assumptions about sensitivity to climate change in a given economic sector based on a literature review. This was then used to establish the potential economic impacts of climate change for each of the sectors considered. Several sensitivity indicators were developed for each sensitivity dimension (physical, environmental, social, economic and cultural). Each indicator was calculated based on consideration of the literature in absolute and relative terms and then combined.

An example of a sensitivity indicator was determined for settlements particularly sensitive to sea level rise. It was assumed that every coastal settlement is prepared for one metre above mean sea level (which is the projected level of sea level rise for Europe). Instead it was decided to consider what effect this one metre sea level rise would have in the event of a major costal storm e.g. surge using the DIVA model and the HYDRO1K digital elevation model. Subsequently these areas were overlaid with the CORINE Land Cover data in order to determine the settlement areas located in these inundated areas. Finally, both the total size of these settlement areas and their ratio in relation to the total settlement area of each NUTS 3 region were calculated and then combined to reach the final coastal flooding settlement sensitivity indicator. Exposure and sensitivity were then combined to determine the potential *impacts* of climate change. After determining the individual impacts, all impacts of one dimension were aggregated. The impact values of the five sensitivity dimensions were finally combined to one overall sensitivity value. This combination was calculated on the basis of relative weights, which were determined through a Delphi survey[1] among the members of the ESPON Monitoring Committee.

Adaptive capacity (i.e. the economic, knowledge and awareness, institutional, infrastructure and technological ability of a region to adapt to the impacts of a changing regional climate) was derived by developing several indicators for each of the five major determinants of adaptive capacity. The individual indicators were subsequently combined for each determinant and finally aggregated to an overall adaptive capacity. This aggregation was again conducted on the basis of the Delphi survey results. To determine the overall *vulnerability* of regions to climate change the impacts and the adaptive capacity to climate change were combined for each region. The analysis thus focused on what would be the result if climate change took place unrestrictedly and impacted on the regions without further preparation.

The limited number of climate models and scenarios to develop the climate projections were chosen due to time and financial constraints and the fact that these cover almost the entire ESPON space. The ESPON Climate project was the first attempt for a pan-European cross-sectoral climate change vulnerability assessment. The project succeeded in developing and implementing a comprehensive methodology that integrates data and interrelations across a vast range of relevant fields. Nevertheless, for each indicator a detailed methodology had to be developed that built on existing research findings, established causal relations to other indicators and utilised the most appropriate and up-to-date data. The project developed several advanced methods for assessing climate change impacts for the pan- European study on a very fine-grained scale.

[1] The Delphi Method is an expert survey in two or more 'rounds' in which, in the second and later rounds of the survey the results of the previous round are given as feedback (Cuhls 1998). It is a relatively strongly structured group communication process, in subjects, on which naturally unsure and incomplete knowledge is available, are judged upon by experts. It is conducted anonymously in order not to let anyone lose face in the event of a change of opinion. The methodology is designed to avoid domination by particular individuals. What differentiates Delphi from ordinary opinion surveys is that the experts' answers after the first round are influenced by their colleagues' opinions and that the respondents can learn from the views of others. The Delphi method is designed to build consensus and stresses the psychological processes involved in communication rather than mathematical models.

For example, the assessment of many indicators was performed on a 100 x 100 metre grid cell basis, e.g. to identify exactly those parts of a region's population which are sensitive to river flooding inundation or which live in urban heat islands and are especially sensitive to heat events in the summer.

MATRIX

The focus was on developing a framework to assess the risks from multiple natural hazards and the impacts of interactions between hazards. Hazards sometimes occur in combination with each other, either occurring independently but at the same time, or when one event is triggered by another. The new risk framework developed in the project provides a means of assessing the interactions between hazards and their implications, including risk comparability, cascade effects and the time–dependence of social and infrastructure vulnerability (where one event changes vulnerability to future events).

The research built on knowledge of single natural hazard risk assessment approaches and early approaches to multi-hazard assessment but is not explicitly linked to climate change assessments. The aim was to provide a first basic and rigorous methodology providing guidelines for multi-hazard risk assessments.

Comprehensive reviews of existing literature informed the MATRIX research. The project also included strong links throughout the research with experts from National Platforms for Disaster Reduction, government representatives, related international organisations (e.g. UNISDR) and with some input from the private sector (e.g. insurance). Stakeholder engagement and consultation via interviews and workshops throughout the project was designed to elicit expert knowledge and judgement to inform the development of the risk assessment framework and to advise on its usefulness. Information from 36 semi-structured interviews, 3 workshops with over 70 participants from 11 different countries, feedback with questionnaires and focus group discussions was used.

A detailed scenario-based analysis incorporating a matrix system for describing relationships between hazards was developed. The multi-risk assessment framework consists of three levels designed to lead the user though qualitative (flow chart), semi-quantitative and finally quantitative analysis (based on Bayesian networks) of the interactions between hazards, time-dependent vulnerability and accompanying uncertainties. Within the tool, where decision makers from different technical and administrative areas are involved, the weighting of the damage categories (e.g., human, economy, ecology, and infrastructure) are defined and the risk ranking is obtained through consensus. Assessment of economic losses was considered, generally concentrating on direct losses arising from direct damage to residential buildings over annual time scales and urban spatial scales.

MEDIATION

The project analysed the available methods, metrics and tools for assessing impacts, vulnerability and adaptation options (CCIVA), synthesised the knowledge to develop an overarching integrated methodology and put all the results on a common platform to share the knowledge that has been gained. The platform is intended to be used by scientists, policy advisors or practitioners with a technical or scientific background. It was not built for untrained decision-makers or the general public. It aimed to provide decision makers with a set of tools and metrics that can be used to meet the field's many challenges. As there is no single method to make policy on adaptation, MEDIATION developed guidance on several methods and offered a number of options based on different cases. They recommend that methods should be selected according to the policy decision context, the available data, the conditions of applicability, and the objectives of the users. The results should be made available through a common platform, which should be linked with Climate-ADAPT.

The main results of the MEDIATION project are provided in the interactive MEDIATION Adaptation Platform which comprises:

- The MEDIATION Adaptation Pathfinder, which guides users who want to support their decisions about particular adaptation challenges with the most appropriate methods and tools.
- The MEDIATION Toolbox, which provides detailed information on around 40 methods and tools.
- The MEDIATION Case Study Navigator, which provides case studies that were used to build the two tools above. In addition a synthesis brochure, several policy technical briefing notes and other training products have been developed to enable an easy uptake of the methods and tools. The MEDIATION

framework was used as the conceptual basis for the UNEP/WMO/UNESCO PROVIA´s Guidance for the Assessment of Impacts, Vulnerability and Adaptation.

The project developed a diagnostic framework with multiple entry points that helps users select appropriate methods and tasks for a given adaptation situation. It comprises a sequence of decision trees that map types of adaptation situations onto appropriate research approaches or onto practices in those cases in which research is not applicable. The interlinked framework encompasses generic methodologies, natural science–based models, socio-economic evaluation methods, and social and institutional analytical frameworks. The diagnostic framework recognises that the purpose of an assessment largely determines its emphasis and hence the type of approach(es) most suitable for addressing the purpose. The pursuit of particular approach will involve the deployment of one or more specific methods, and associated with each method could be a suite of tools, either models or procedures already available from earlier work, or developed as part of the assessment itself. Some tools are specific to a single method (e.g. specific impact indices); others may embrace multiple methods and approaches.

PESETA I and II

The methodology of the JRC PESETA I and II projects had three steps. In the first stage the climate runs are selected and used as input to all the biophysical models. In a second stage, the biophysical impact models are run to compute the biophysical impacts. In a third step, the impacts are valued and integrated in economic terms using a general equilibrium economic model.

JRC PESETA II project goes beyond PESETA as it considers more impact categories and more climate runs. PESETA considered the impacts in five areas: agriculture, coastal systems, river floods, tourism and human health. PESETA II extends the coverage to nine areas, adding energy, transport infrastructure, forest fires, and habitat suitability. Furthermore, PESETA looked at four climate scenarios, in PESETA II looked at up to 15 climate scenarios have been modelled by some of the sectoral teams.

Both PESETA and PESETA II projects have largely benefited from past DG Research projects that have developed impact modelling capabilities (e.g. the FP7 ClimateCost project) and high-resolution climate scenarios for Europe (the FP6 ENSEMBLES project). In particular, the economic assessment of PESETA II uses impact evidence on coastal impacts and agriculture in the 2080s from the FP7 ClimateCost project. The project methodology has two distinctive features. Firstly, it is based on the results of many bottom-up biophysical impact models. Bottom-up models take into account the relationship between climate change and biophysical impacts in a structured way, modelling all the relevant interactions and mechanisms. Secondly, the assessment is made in a consistent way, where all biophysical impact models use the same climate data, and take into account other horizontal issues. This allows the various sectoral biophysical impacts to be compared under a consistent and harmonised economic setup. This is a major advantage as it enables comparison of otherwise very heterogeneous climate impact indicators. Furthermore, the comparison allows a first assessment of where impacts could be severe providing insights into where adaptation funds could be prioritised.

The economic analysis considers a hypothetical situation, where the climate of the future is assumed to occur in the economy of today. The advantage of this perspective is that the modelling effort can be focused on the impacts of climate change rather than the wider question of how Europe's economy might develop to the period 2070-2100 (2080s). The disadvantage is that the interactions between climate change and economic and population growth are not considered, since climate change is the only shock imposed on the EU economy.

In PESETA II a number of constraints are provided in that the study underestimates the climate damages in Europe because of a number of reasons. Firstly, the coverage of the effects due to climate extremes is limited in the sectoral models used in the project. Secondly, key impacts without market prices, such as losses of ecosystem services or damages to biodiversity, are not considered. Thirdly, abrupt climate change or the effects of passing climate tipping points are not integrated in the analysis. Finally, the study does not consider how Europe would be affected indirectly through the impacts of climate change in the rest of the world. Therefore the project cannot fully capture the overall scale of the risks due to climate change in Europe in a long-term context.

A computable general equilibrium model can be representative for large scale i.e. the 5 multi-country regions for PESETA I and country level for PESETA II, but this method not suitable for detailed national planning (Carter and Mäkinen 2011, Table 5. p24).

RAMSES

The main aim of RAMSES is to produce quantified evidence of the impacts of climate change and the costs and benefits of a wide range of adaptation measures, focusing on cities. Work Package 3 aims to support the design of adaptation strategies in cities by providing a set of tools to assess city-scale vulnerability and evaluate climate risks on key sectors. A climate risk analysis methodology has been developed for urban areas providing a top-down, and broad, view of climate risks to cities across Europe which can be used as a baseline.

A high level indicator-based vulnerability assessment methodology was used based on a sequential implementation of a number of analytical steps. It started with the development of a casual model linking hazards and elements at risk. A literature review was then used to scope potential indicators.

Drawing upon Downing's 'causal chain of hazard development' (Downing, 1990) and Wisner and Blaikie's 'Pressure and Release model' (Wisner et al.,1994), these explanatory factors were then organised in different categories and represented in a series of schematic figures that aim to represent the causal structure of vulnerability and risk within each impact chain.

Exposure indicators have been developed to reveal the degree to which cities' population and assets could be directly affected by climate change-driven threats. In some cases these provide estimates for the proportion of a city exposed to given hazards while in other cases it is assumed that a given city is equally exposed. Vulnerability indicators have been classified into two distinct groups a) sensitivity indicators referring to those factors that increase vulnerability and b) adaptive capacity referring factors that reduce vulnerability. The majority of these vulnerability indicators have been obtained from the Urban Audit Database, with some new adaptive capacity indicators produced based on internet searches and other relevant sources.

A database including comparable indicators was then developed and data are subsequently classified and pre-processed for statistical soundness. Weighting factors were applied and a sensitivity assessment was performed on vulnerability scores. For the analysis the cities were clustered to aid the interpretation of results. Vulnerability scores were then combined with hazard and exposure data, delivering a risk index for all cities under each impact chain.

This approach was applied to 571 cities in the GISCO Urban Audit 2004 Database for heatwaves, droughts and pluvial floods. Coastal flooding was assessed on the 92 coastal cities and in the case of fluvial flooding the assessment was performed for the 365 Urban Audit cities with water courses with at least 500km2 catchment area.

The methods that have been used within the research projects are summarised in Table 4.

Table 4. Summary of the methods used in the projects

Review of literature/existing databases	BALTIC BASE CLIMSAVE, ESPON MATRIX MEDIATION PESETA RAMSES
Expert Judgement/appraisal	BALTIC BASE CLIMSAVE ESPON MEDIATION PESETA RAMSES
Interviews/surveys (remote)	MATRIX
Stakeholder/engagement/consultation/advisory committee	BALTIC BASE CLIMSAVE, MATRIX MEDIATION
workshops/seminars (face-to-face)	BALTIC CLIMSAVE MATRIX MEDIATION
qualitative assessment	BALTIC BASE CLIMSAVE ESPON MATRIX MEDIATION
quantitative assessment	CLIMSAVE BASE ESPON MATRIX PESETA MEDIATION
Climate modelling (global)	CLIMSAVE ESPON PESETA
Climate modelling (downscaled to regional- NUTS2 level?)	ESPON

Uncertainty considered	CLIMSAVE, ESPON (Delphi) MATRIX MEDIATION PESETA
scenario analysis (climate)	BALTIC CLIMSAVE ESPON PESETA
scenario analysis (socio-economic)	BALTIC CLIMSAVE
scenario analysis (impact)	CLIMSAVE PESETA MEDIATION
Economic analysis	BASE CLIMSAVE ESPON MATRIX MEDIATION PESETA
indicators/indexes/metrics	ESPON PESETA RAMSES
Monetisation exercise	
multi-criteria scoring system	
application/ further development of existing frameworks and/or tools	BALTIC BASE CLIMSAVE ESPON MATRIX MEDIATION
Identification of knowledge gaps	BALTIC BASE CLIMSAVE MEDIATION
Socio-economic evaluation	MEDIATION
Social and Institutional assessment	BALTIC MEDIATION

All of the research projects have used a large number of methods to gather information. As would be expected this typically starts with a literature review then a series of data collection steps. These may be either quantitative or qualitative or a combination of both. The information is then appraised by experts (and sometimes stakeholders) and the final step is the development of frameworks or tools and identification of knowledge gaps. There is more homogeneity within the research projects in terms of steps within the project compared to the country assessments which are more varied in their structure.

There is a wide range of methods that have been used for data collection and analysis such as climate projections, impact modelling, economic assessment, stakeholder workshops, surveys or panels, social and institutional assessment and expert elicitation. All the projects use both quantitative and qualitative methods. The majority of these projects use mainly quantitative methods e.g. modelling rather than qualitative methods e.g. participatory. The two projects that use mainly qualitative and participatory methods are BALTIC and MATRIX. In some cases stakeholders are a fundamental part of the project and are involved as equal partners and there is co-creation of outputs with the researchers. In other projects stakeholder have more of a consultation role where top-down information is developed, then 'sanity checked' by stakeholders.

2.3 Approaches used for measuring (and indicators) of vulnerability

Measurement of vulnerability is an important aspect of risk and vulnerability assessment. The emphasis on the quantification of vulnerability and related concepts has grown as the climate change adaptation community has moved from a focus primarily on impacts to more risk-based approaches and responses. Inevitably the latter leads us to questions such as "how big is the problem and for whom?" and "how substantial are the risks?" The engagement of policy and decision-makers in discussions of how best to respond to climate impacts has further driven the need for quantitative and qualitative evidence to justify investments aimed at reducing vulnerability. As (Harley, Horrocks, Hodgson, & van Minnen, 2008) note "indicators of vulnerability promise to provide a credible and transparent means by which decision-makers can identify priority needs and so justify certain types of action." The growing number of national adaptation plans and programmes, alongside increasing investments in adaptation, has fostered an active community of practice working on monitoring and evaluation (M&E). Issues of accountability, and a need to understand the effectiveness and efficiency of plans have driven interest in M&E. An additional driver for measurement has been the recent implementation of international policy frameworks including the Paris Agreement, Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction, all of which have reporting requirements and for which vulnerability is a critical concept. The EU adaptation preparedness scoreboard does not require reporting per se. But, the Commission collects data from various sources (e.g. reporting by Member States against the MMR regulation that includes assessing vulnerability) and completes country fiches and the scoreboard from this data. All of the above factors have combined to further increase interest and the relevance of vulnerability measurement.

2.3.1 Vulnerability indices and indicators

The various drivers of vulnerability measurement outlined above has resulted the development of a variety of adaptation indicators at a range of spatial scales. As observed by (Schauser, et al., 2010) there is no agreed integrated metric for vulnerability to climate change as vulnerability is a theoretical concept thus it cannot be measured directly. This is also true of adaptation. This lack of a single measure means that a combination or set of indicators is required to provide an accurate picture of both adaptation and vulnerability. Thus vulnerability indicators tend to be used in tandem with indicators of related terms such as impacts, resilience, sensitivity, exposure and adaptive capacity. In some cases vulnerability in used as an overarching concept to be measured rather than subordinate to adaptation. For example, in the development of evaluation criteria for adaptation (Weiland & Tröltzsch, 2016) frame the effectiveness of adaptation measures as "outcome vulnerability" i.e. the vulnerability which is left after the adaptation measures have been implemented, thus placing vulnerability at the core of evaluation objectives.

Approaches to the measurement of vulnerability are as broad as the term itself. Indicators and measures may focus on a given subject of vulnerability (e.g. sector, group, theme) or span multiple sectors and variety of scales (e.g. understand the vulnerability of a habitat in a given location or of a whole country). They may form part of a wider monitoring or evaluation effort or may be part of a discrete index or system for a specific theme or purpose. Vulnerability indicators can also be combined with impact, risk adaptation and resilience indicators and can relate to inputs, outputs or outcomes. They may be situated within a 'Theory of Change' (and approach which seeks to set out a systematic description and illustration of how and why a desired change is expected to happen in a particular context) or as part of a broader assessment process.

Measures of vulnerability (V) usually comprise three components: exposure to climate change (E), sensitivity to its effects (S) and adaptive capacity for coping with the effects (AC), such that:

V = f (E, S, AC) (Carter & Mäkinen, 2011)

For indices, attempts are made to quantify each component through the development of indicators that can then be combined into an integrated index of vulnerability. Indicators play an essential role in the monitoring, reporting and evaluation of policies, programmes and projects (EEA, 2015) and, 'providing clues and direction on how change is occurring and if outcomes are being achieved' (Climate-Eval Community of Practice, 2015). In the context of vulnerability assessment, (Carter & Mäkinen, 2011) suggest that indicators are commonly drawn from a combination of the biophysical realm (primarily of exposure and sensitivity) and from socio-economic statistical sources (mainly describing adaptive capacity).

(Carter & Mäkinen, 2011) highlight that more stakeholder-driven approaches can be used as alternative or complementary approaches to quantitative indicator studies whereby stakeholders agree upon the main issues and responses of importance for assessing vulnerability to climate change (Malone & Engle, 2011). These stakeholders may be experts or vulnerable groups and can provide a valuable alterative perspective to quantified indicators as well as being valuable information sources where data limitation exist.

2.4 Lessons learned and identification of gaps and challenges

This section provides the lessons learned and identifies the gaps and challenges. In each of these sections the items are categorised into five areas covering: frameworks, concepts, application, ways of addressing uncertainty measuring vulnerability, knowledge transfer and methods. Where the category is missing, there are no items for that category.

2.4.1 Lessons learned from the research projects

Frameworks

- There is a continuum in the current framing of vulnerability assessments between a risk management approach and a climate impacts approach. The research projects that have been analysed are spread across the continuum because they tend to display characteristics of both framings.

- The frameworks should be seen as a useful way of visualising the structure of the ideas and how they fit together. It is not important to 'fit' a vulnerability assessment into a particular framing, it should be purely used as a means of understanding the perspective from which the evidence has been gathered.

Concepts

- It is important to understand the concepts and their evolution because the same words are used to describe different ideas.

Application

- Some of the research projects have NOT been used by countries in their national assessments. This is partly because their results were published fairly recently (many are 2013) and the assessment was done before this date. This is also due to the fact that the tools that are produced within research projects tend to be designed for experts to use, which makes them not user-friendly for policy-makers. The majority of research project outputs need to be 'translated' into a more user-friendly format that provides just the highlights. The results also need to be communicated for many years beyond the end of the project.

Ways of addressing uncertainty

- All of the research projects address uncertainty to some extent and all of them recognise the need to address uncertainty.

Methods

- In all research projects a wide range of methods are used to gather evidence from a range of sources. They tend to be both quantitative and qualitative.

2.4.2 Gaps identified from the research projects

Frameworks

- There is a gap in the framing of vulnerability assessments related to a 'resilience' approach that is i) systems-oriented (it focuses on the relationships between system elements rather than individual elements themselves) and ii) the fundamental assumption that the natural state of a system is one of change rather than static (hence aiming to reduce vulnerability by maintaining system flexibility).

Application

- There is a gap in that the information and tools developed in the research projects need to be better communicated to end-users. Typically the communication of the results stops at the end of the project. The results may have been shared/co-created with stakeholders from case studies during the project, disseminated at a conference, published as an academic paper and displayed on a website but these are unlikely to have been scaled-up to reach a critical mass of end-users such that it taken up and shared peer-to-peer. In addition, the tools that are produced within research projects tend to be designed for experts to use, which makes them not user-friendly for policy-makers. This is a barrier to the pick-up of research and the knowledge and evidence generated, including decision-support tools. The result is that the potential value of that research is not realised, but also that the research is not being integrated into the national assessment
- The majority of research project outputs need to be 'translated' into a more user-friendly format that summarises just the highlights. They also need to be translated into multiple European languages. The results also need to be communicated for many years beyond the end of the project using a variety of channels. Climate-ADAPT should be part of these channels, but other methods like social media, webinars, long-term capacity building, training on particular topics, knowledge sharing workshops and continuous online forums should be utilised too.

Knowledge Transfer

- There is a gap in terms of knowledge transfer and mobilisation. This could be addressed by supporting an effective knowledge sharing network that facilitates sharing knowledge to inform national assessments. This should include:
    - Use of the EIONET to facilitate the translation (of both research into policy relevant guidance and guidance into many different European languages to facilitate action at local level) and transfer of research results to those conducting vulnerability assessments at the national and transnational levels. The EIONET could also be used to better understand knowledge and evidence gaps
    - Use of Climate-ADAPT to include case (learning) studies on the use of research results within vulnerability assessments at the national and transnational levels. This provides a place for those undertaking national and transnational vulnerability assessments to gain awareness of the research results and learn how they can be used
    - In the context of reaching out and informing vulnerability assessments at other levels (local, sectoral, organisational), there is a need to use existing trade and sector bodies. These are the trusted sources of information and where those having to conduct such assessments will go to seek advice. This could be done through Climate-ADAPT reaching out and linking with the respective bodies (e.g., linking with their media, including their existing information sharing websites).
    - For SMEs, there are advantages to working with Climate-KIC in terms of reaching out and informing this community regarding vulnerability assessments.

Methods

- Two of the research projects (BALTIC & CLIMSAVE (IMPRESSIONS - not finalised) have looked at future socio-economic scenarios and projections and this is a research gap.

Measuring vulnerability

- There is a need to measure vulnerability that is driven by the need for accountability, understanding efficiency and effectiveness of plans and international policy frameworks (Paris Agreement, Sustainable Development Goals, Sendai Framework for DRR). Since there is no agreed metric for vulnerability to climate change as it is a theoretical concept, a group of indicators is needed to provide an accurate picture of vulnerability. Further work is needed to quantify each component of vulnerability with indicators and then integrate these. The indicators need to cover both biophysical and socio-economic development factors and combine quantitative and qualitative information.

2.4.3 Challenges from research projects

Frameworks

- The ideas attached to the frameworks have shifted over time and the frameworks are not static theories. The ideas merge with elements of one taken up by another hence the frameworks are not stand-alone i.e. they do not fit neatly into boxes there is a flow of ideas form one to another. Hence we have chosen a continuum to visualise the framings.

Measuring vulnerability

- There is no agreed metric for vulnerability to climate change as it is a theoretical concept. There is a similar challenge for adaptation unlike for mitigation. Hence there is a tendency to use groups of indicators for related concepts e.g. exposure, impacts, sensitivity and adaptive capacity. It is a challenge to quantify each component with indicators and then integrate into indices. Indicators cover both biophysical and socio-economic development factors.

3 Vulnerability assessment approaches being used at national level by EU Member States

Information was collected covering vulnerability assessment approaches, both frameworks and methods being used at national level for the 28 EU countries. The information was collected by using a two stage evidence gathering process as described below.

Stage 1 gathered evidence that was available on the 28 country information pages on Climate-ADAPT (Summary and Assessments pages). This evidence was used to provide an overview of both the stage of the assessment process for each country and analyse what methods and techniques were used within this process. There were some challenges in using this data in that it is provided by the countries and at times it does not provide much detail, may not be fully up to date or, may be in-complete. It also focuses on providing the results and outcomes of the assessments as opposed to the details of the methods and assessment process that are needed for this study. This is also true of the IPCC National Communications that were also mined for information.

Stage 2 has gathered evidence from publically available information, mainly on national websites and reports and verified this information through direct contact with the experts and policy-makers in each country (by email and interviews). The countries were selected for a Stage 2 analysis by using inclusion and exclusion criteria and more detail is provided in section 3.2.

3.1 Findings from analysis of information on Climate-Adapt for 28 European countries

The findings from analysis of the 28 EU countries (Stage 1 assessment) are provided in this section.

The first part of this analysis will focus on the process the countries have undertaken and the information is provided for each country in Annex 6.2. The second part will focus on the methods they have used to complete this process and the analysis spreadsheet is provided in Annex 6.3.

3.1.1 Process used for the analysis of national vulnerability assessments in Europe

The process that has been used by UKCIP to analyse the evidence is derived from the framework set out in the EU Adaptation Strategy Guidance. This framework has much in common with many of the other frameworks described in section 1.3 in that a) It provides guiding principles rather than dictating which methods to use, b) It is based on a number of steps c) It is nested within the framework of the adaptation policy cycle, in particular the Adaptation Support Tool (AST), Step 2 Assessing risks and vulnerability to climate change, but also step 3 Identify and assess your risks of the UKCIP Risk and Uncertainty Framework and step 2 Current climate vulnerability and step 3 future climate vulnerability of the UKCIP Wizard.

As is described in Section 1.3 the framework uses four steps to ensure that a comprehensive picture of current and future risks and vulnerabilities is obtained:

1. Analysis of past weather events
2. Undertake a climate change risks and vulnerability assessment.
   a. Future trend (projection) of climate variables based on more than 1 climate scenario
   b. Expected impacts biophysical and socio-economic.
   c. Multiple timescales (short to long) for climate, impacts and vulnerability.
   d. An indication of the level of confidence (high, medium or low)
   e. Socio-economic development and other non-climatic factors (current and future)
   f. Policy relevant outcomes and end-user (stakeholder) involvement.

3. Take trans-boundary/cross-border issues into account
4. An approach for addressing
    a. knowledge gaps and
    b. dealing with uncertainties.

The Climate-ADAPT summary table for each country provides the 'Status of Impacts, vulnerability and adaptation assessments' and the results are provided in Table 5.

It shows that 21 out of 28 countries have indicated that they have 'completed' a vulnerability assessment.

No countries have mentioned Step 1 (analysis of past weather) in Climate-ADAPT.

Table 5 also shows the results for Step 2 of the framework.

- 24 out of 28 countries have completed assessments of future climate variables and expected impacts - Steps 2a future climate projections and 2b expected impacts
- 21 out of 28 countries have used at least 2 different timescales (short/long) for their climate projections - Step 2c multiple timescales
- Only 3 countries (Austria, Germany and UK) have mentioned that they are using confidence levels - Step 2d
- Very few (4) countries have provided information in Climate-ADAPT about developing socio-economic projections - Step 2e. The countries that have developed socio-economic projections are Germany, the Netherlands, Portugal and the UK.
- 11 countries have mentioned stakeholder involvement in their assessments - Step 2f.

Although the majority of countries have limited information about the methods they have used, a few countries have provided greater insight into their methods.

For example: Cyprus has used a three stage process to assess future vulnerability to climate changes in Cyprus for the 11 selected policy areas. Taking into consideration (i) the current vulnerability assessment, (ii) the magnitude of the projected future changes in the climatic parameters considered to affect each impact and (iii) other socio-economic projections for the period 2021-2050 relative to the impact.

Caution should be used when interpreting the results since the information on Climate-ADAPT is based on the reporting from the countries, which is rapidly evolving. The details may be minimal, not fully up to date or may be incomplete. Where there is very little information the content of Table 5 is left blank.

Table 5. Analysis of countries against Step 2 of the EU Adaptation Strategy Guidance framework

28 EU Countries	Status of Impacts, vulnerability and adaptation assessments	2a. Future climate projections	2b.Impacts biophysical and socio-economic	2c. Short/medium/ long timescales for climate, impacts and vulnerability	2d. Confidence level	2e. Future socio-economic projections	2f. Policy-relevant outcomes and end-user involvement in process
Austria	Complete, being updated						
Belgium	Complete						
Bulgaria	Currently being undertaken						
Croatia	Currently being undertaken						
Republic of Cyprus	Complete						
Czech Republic	Complete						
Denmark	Complete						
Estonia	Complete						
Finland	Complete						
France	Complete						
Germany	Complete						
Greece	Currently being undertaken						
Hungary	Currently being undertaken						
Ireland	Complete						
Italy	Complete						
Latvia	Complete						

28 EU Countries	Status of Impacts, vulnerability and adaptation assessments	2a. Future climate projections	2b.Impacts biophysical and socio-economic	2c. Short/medium/ long timescales for climate, impacts and vulnerability	2d. Confidence level	2e. Future socio-economic projections	2f. Policy-relevant outcomes and end-user involvement in process
Lithuania	Complete, being updated						
Luxembourg	Complete, being updated						
Malta	Complete - flood risk assmt only						
Netherlands	Complete, being updated						
Poland	Currently being undertaken						
Portugal	Complete, being updated						
Romania	Currently being undertaken						
Slovakia	Complete						
Slovenia	Currently being undertaken						
Spain	Complete, being updated						
Sweden	Complete						
United Kingdom	Complete, being updated						

Status of Impacts, vulnerability and adaptation assessments - from Climate-ADAPT country/summary table

Table 6 shows the results for steps 3 transboundary issues , 4a - assessing knowledge gaps and 4b - addressing uncertainties of the framework. It shows that

- Very few countries (6 Finland, Hungary, Italy, Lithuania, Romania and Slovakia) have considered trans-boundary issues within their assessments – Step 3. One example of where trans-boundary issues have been considered is Hungary, Slovakia and Romania have developed a vulnerability assessment of the Tisza river valley and another is the countries in the Baltic Sea region strategy (mentioned in Lithuania's information)
- A small number of countries (8) are addressing knowledge gaps within their assessments –Step 4a (Austria, Finland, Germany, the Netherlands, Portugal, Spain, Sweden and the UK)
- Most countries (22) are taking account of uncertainties to some extent. There is further explanation of accounting for uncertainty within vulnerability assessments and the methods countries are using in the following section.

Table 6. Analysis of countries against Steps 3 and 4 of the EU Adaptation Strategy Guidance framework

EU Countries – 28		3. Account for trans-boundary issues	4a. Addressing knowledge gaps	4b. Dealing with uncertainties
Austria	AT			
Belgium	BE			
Bulgaria	BG			
Croatia	HR			
Republic of Cyprus	CY			
Czech Republic	CZ			
Denmark	DK			
Estonia	EE			
Finland	FI			
France	FR			
Germany	DE			
Greece	GR			
Hungary	HU			
Ireland	IE			
Italy	IT			
Latvia	LV			
Lithuania	LT			
Luxembourg	LU			

EU Countries – 28		3. Account for trans-boundary issues	4a. Addressing knowledge gaps	4b. Dealing with uncertainties
Malta	MT			
Netherlands	NL			
Poland	PL			
Portugal	PT			
Romania	RO			
Slovakia	SK			
Slovenia	SI			
Spain	ES			
Sweden	SE			
United Kingdom	UK			

3.1.2 Taking account of uncertainty within vulnerability assessments

The term 'uncertainty' is used by scientists 'A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable' (IPCC, 2014). Thus, the direction or even the approximate magnitude of a phenomenon may be known, although the exact magnitude is not known. For example, a scientific projection of global mean temperature for a given emissions scenario may report a best estimate of 3°C, with an uncertainty range of 2–4.5°C. The uncertainty interval reflects the impossibility to forecast *exactly* what will happen. There is also uncertainty related to non-climatic drivers such as social and economic factors, like population. Some sources of uncertainty can be quantified whereas others cannot. Furthermore, some of them can in principle be reduced by further research whereas others cannot.

There have been many instances that have been reported (Capela Lourenço, et al., 2014)http://link.springer.com/search?facet-creator=%22Tiago+Capela+Louren%C3%A7o%22 where scientists and decision-makers have found it difficult to incorporate uncertainties within their decision-making process and also to communicate these uncertainties to those that need to use them. It is important to take uncertainty into account because it strengthens the adaptation decisions and their relevance. If uncertainty is not accounted for it would mean that not all the evidence had been considered and there may be a risk that there could be unexpected consequences from the decisions made. There is increased likelihood that the action will be inadequate, inappropriate or may increase vulnerability. In some cases the concern over how to account for uncertainty is used as a reason for inaction and this should be avoided.

In some cases there is concern that expert elicitation and stakeholder review are rather subjective ways of accounting for uncertainty. However, it needs to be acknowledged that decisions taken under uncertainty will *always* include subjective evaluations of the available knowledge base. Hence, expert elicitation and stakeholder review are considered to be valid methods for accounting for uncertainty particularly because they can reflect on the context in which the decision is being made and peoples responses. Whereas quantitative methods can provide very objective insights, they cannot give an insight into human behaviour. Typically therefore a combination of methods is used to account for uncertainties.

Most countries (21 out of 28) have considered uncertainty to some extent in their assessments generally within the areas of future climate projections, climate downscaling and global emissions and socio-economic scenarios (e.g. IPCC SRES, (IPCC, 2000)). This has increased from the self-assessment survey results where 18 countries had considered uncertainty (EEA, 2014). Countries have done this using the following methods:

- Calculation of ensembles (many runs) of climate data for both GCMs and RCMs (or the use of data from a research project that has an ensemble dataset);
- Use of multiple storylines (scenarios) for emissions and socio-economic projections e.g. SRES A1B or nationally developed;
- Use of many models e.g. GCMs, RCMs; and
- Expert elicitation and stakeholder/peer review.

The development of multiple storylines for socio-economic projections can be illustrated with an example from Germany (EEA, 2014) where a range of trends in future socio-economic development was taken into account with the use of two different scenarios covering economic, demographic and spatial change.

The majority of countries have addressed vulnerability assessments from a 'science-first' perspective where quantitative evidence about climate and impacts is considered before qualitative information about how vulnerable e.g. people are and how they would cope. Although it is a core part of the frameworks reviewed in section 1.3 the assessment of the concept of adaptive capacity is relatively rare, with about 20% of countries having completed this type of assessment. The assessment of socio-economic scenarios/development and/or economic appraisal of the impacts of climate change is also fairly rare, with approximately 20% of countries having completed this type of assessment. This indicates that less than a quarter of countries have completed step 2.e.

Interpretations of frameworks and terms by countries

Section 1 covered the different definitions of terms associated with vulnerability and the various frameworks that can be used for vulnerability assessment. This section draws from those descriptions and has assessed how these have been used and interpreted by different countries. Examples have been extracted from the Climate-ADAPT country information pages/assessments sheet are provided to illustrate the variety of interpretations and uses.

- The transnational region of the Pyrenees has used the definitions from AR4 to provide an explanation of what vulnerability is, and this is illustrated with a clear and simple graphic on page 7 of the PYRENEES CLIMATE Change Observatory Phase 1 Report. http://www.opcc-ctp.org/images/espacedocumentaire/publications/ADAPTATION/PLAQ-ANG-OBSER-2011_BD.pdf

- Luxembourg's description of its work on human health provides an example of how countries have interpreted the term 'vulnerability'. This example demonstrates that vulnerability is interpreted as synonymous with impacts/hazards/risk. The example shows a link from 'hazard' = temperature to 'impact' = dry period to 'risk' = heat wave and these terms are all under the heading of vulnerability. *'Vulnerability in Human health: a projected increase in temperature in all seasons and an increase in the number of dry periods and the number of days within a dry period could increase the risk of heat waves and have an effect on air quality. Changes in the water cycle could increase public health risks related to water quality and water scarcity.*

- Latvia (CA/country/Impacts & vulnerability assessments sheet) has described how it has interpreted the terms 'risk' and 'vulnerability'.
  'Assessments of risks and vulnerability to climate change (addresses the observed and potential environmental exposures and the socio-economic context to analyse who or what – individual or system– is vulnerable and to what climatic primary or secondary parameters, to what extent) regarding situation and specific conditions in Latvia have been done at two levels. First, in the BSR Programme 2007-2013 and ERDF common project BALTADAPT. Second, at the national level with analysis of climate change impacts and vulnerability in sectors (agriculture, forestry, fishery, biodiversity,

construction, health, infrastructure, transport, coastal zone development, tourism, and energy) provided in the informative report of implementation "Environmental policy strategy 2009-2015" and evaluated all the main risks in the country.'

Adaptive capacity

As defined in section 1.3 adaptive capacity is the ability to adjust and respond. It is determined by social factors that are described in section 1.4 within the PROVIA framework as 'social determinants' and for the 'current state' could include wealth, technology, education, entitlements and social capital, and for the 'future change' could include population growth, economic growth, changing values, changing governance, new policy decisions. There is little information about this in the country pages on Climate-ADAPT, however in Latvia's assessment there is information about how it is considering indicators for vulnerability. Although still in its development phase and not yet implemented, Latvia is proposing to use a number of social determinants such as GDP, population density, institutional capacity and technical capacity showing that it is considering how to assess adaptive capacity within its assessment.

3.1.3 Methods used for national vulnerability assessments in Europe

The methods that countries have used for doing national vulnerability assessments in Europe were drawn from the National adaptation policy processes in European countries report (EEA, 2014) and the Climate ADAPT country information pages (accessed June 2016). The evidence for which methods countries have used is provided in Annex 6.3.

The evidence shows that countries have used a range of methods to assess vulnerability. This can vary from 2 methods up to 17 methods. In countries that have used a small number of methods, typically they have used expert appraisal and literature review. For example in Italy the knowledge base produced through literature review was further enhanced by an ongoing dialogue on climate change adaptation among national, regional and local institutions. Two panels were established for this purpose. An 'institutional panel' coordinated by IMELS, involving representatives of relevant institutions (e.g. Ministry of Economic Development, Ministry of Agricultural and Forestry Policies, Ministry of Health) and other institutional stakeholders (e.g. Department of Civil Protection, State-Regions Conference, National Association of Italian Municipalities), and a 'technical panel of experts' coordinated by CMCC, involving about 100 members of the national scientific community (EEA, 2014).

Figure 6 shows the different possible methods that have used by the countries (EU28) in their vulnerability assessments, and how many countries are using each option.

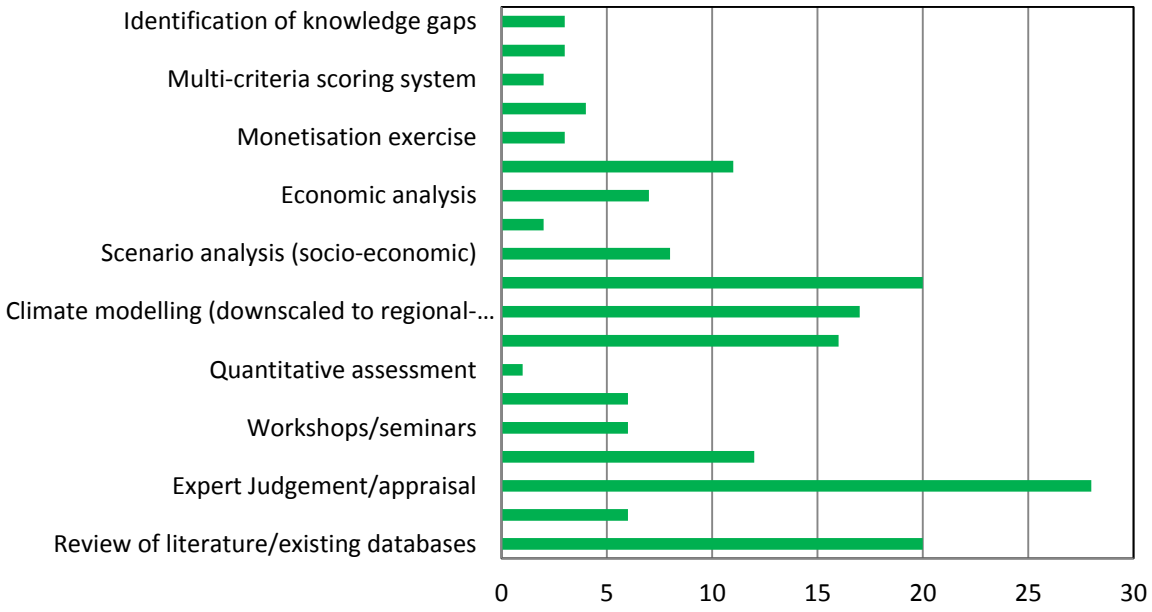


Figure 6. Methods used by EU28 countries for vulnerability assessments

- Expert judgement or appraisal is the method used by all 28 countries. Expert appraisal usually involves bringing together a panel of experts and policy-makers across a range of disciplines and sectors, for example, national government ministries, local government municipalities, researchers and sector representatives (such as health or infrastructure).
- A literature review, or analysis of existing information is the second most popular option. It is being used by 20 countries
- Developing future climate projections using global emissions and socio-economic scenarios are other popular options. The majority of countries use the IPCC Special Report on Emissions Scenarios (SRES) (IPCC, 2000[2]) e.g. A1B, for their climate scenario analysis. However, a number of countries that have completed or updated their vulnerability assessments more recently have used the updated emissions scenarios – Representative Concentration Pathways (RCPs) (AR5, 2014), or, in a very small number of cases used both types of scenarios.
- Modelling is the fourth most common method and is being used by 16 countries. Modelling usually refers to climate modelling and downscaling of global climate projections. It can also include impact models, integrated assessment models and sector-specific impact models.
- Engagement with stakeholders is the fifth most popular option, and 12 countries (35%) are using this method in their assessments
- Twelve countries (35%) have development (or are in the process of developing) indicators. This has increased sharply from only four countries who were developing indicators in 2014 (EEA 2014). Further information on indicators using the more detailed examples is provided in section 3.

[2] IPCC. *Special Report on Emissions Scenarios.* Geneva : Intergovernmental Panel on Climate Change, 2000.

Types of EU-Funded activity used by countries

Countries have used EU funded activities in a range of ways to support their vulnerability assessments and the details are shown in Table 7. Typically there are three mechanisms, 1. countries have used data from an EU research project e.g. PESETA, 2. they have received funding for a research project linked to part of their assessment and 3. they have received funding to develop their National Adaptation Strategy (NAS) or other strategic project of which a vulnerability assessment is a part. Table 3 shows that the most common use of EU funded activities (6 countries) is data from an EU research project and the projects most often referenced are ENSEMBLES, PESETA I, PESETA II and ESPON Climate. Five have received funding for a research project, 3 countries have received funding for a NAS and the least common type of funding (1 countries) is for cross-border work.

This shows that EU funded activities are an important source of added value as they:

1. Increases the knowledge base
2. Provides evidence that is comparable between countries and sectors using harmonised datasets
3. Supports cross-border work such as CARAVAN in the Baltic Sea Region and coordinated efforts in the Alps, Pyrenees and Danube that would not be possible without EU funding.

Table 7. Types of EU-funded activities used by countries

Country	Type of funding from EU
Croatia	Used data from ENSEMBLES
Bulgaria	Used data from PESETA I & II, ESPON, CLAVIER and CECILIA
Estonia	Funding for NAS
Cyprus	Funding for NAS, Used data from ENSEMBLES
Finland	Funding for research projects
Greece	Used data from ENSEMBLES and PRUDENCE
Hungary	Funding from ESPON for cross-border work
Ireland	Funding for research (Contributed to CMIP5)
Italy	Funding for research projects (Contributed to CMIP5)
Latvia	Funding for NAS, (European Economic Area) Used data from BALTADAPT
Netherlands	Funding for research projects
Portugal	Used data from PESETA II
Slovakia	Funding for research projects (CC-TAME participant)
Slovenia	Used data from EU CLISP and ENSEMBLES

3.2 Detailed examples from 7 countries

Detailed examples have been developed to provide greater insight into the methods used for vulnerability assessment within Europe (Table 8). This Stage 2 assessment has gathered evidence from publically available information, mainly on national websites and reports and verified this information through direct contact with the experts and policy-makers in each country (by email and interviews).

The countries were selected for a Stage 2 analysis by using inclusion and exclusion criteria and these are described below:

Criteria 1 – Countries were chosen where documents were available online.

Criteria 2 – Countries were chosen that had a range of different approaches. All countries have used expert appraisal and most have used literature reviews and climate scenarios, hence the countries chosen have significantly more than these standard 3 approaches. In addition, these countries have also used different combinations of approaches.

Criteria 3 – Countries chosen had a range of maturity levels in terms of the adaptation policy process.

Criteria 4 – Countries that both have and do not have plans for a subsequent assessment. It is noted that the selection of countries that are either doing or have completed a second or third assessment often also provide an evaluation of the previous assessment methodology and insights into what could be improved which will be useful in terms of guidance for other countries.

Criteria 5 – Countries were chosen that have assessments of adaptive capacity and some countries who have not. Criteria 6 – DG Clima expressed an interest in the sub-national level assessments and 4 of the selected countries have completed assessments at this level.

Criteria 7 – The countries represent all geographic areas of Europe.

It should be noted that conclusions drawn from this small number of countries will need to be used with caution

Table 8. Selection of countries according to the inclusion/exclusion

Country	Sufficient information publically available in appropriate language	Number of different approaches used	Level of Maturity	Future assessment process	Related concept (adaptive capacity)	Sub-national assessments available	Geographic location within Europe
Germany	X	17	Mature	X	X	X	Central
France	X	12	Mature	X			Central
Finland	X	9	Mature	X	X		North
Bulgaria	X	9	Early		X		East
Sweden	X	8	Intermediate			X	North
Portugal	X	11	Mature	X			South
UK	X	14	Mature	X	X	X	North

Detailed reviews for 7 countries[3] Bulgaria, Finland, France, Germany, Portugal, Sweden and UK are provided in Annex 6.4.

The analysis of the approaches used for the seven countries will continue to use the framework of the EU Strategy Guidance to illustrate 'how' countries have undertaken their assessments. The main elements of the framework are repeated below and the full framework is in section 1.5.

2. Undertake a climate change risks and vulnerability assessment containing:

   a. Future trend (projection) of climate variables based on more than 1 climate scenario
   b. Expected impacts
   c. Multiple timescales
   d. An indication of the level of confidence (high, medium or low)
   e. Socio-economic development and other non-climatic factors (current and future)
   f. Policy relevant outcomes and end-user (stakeholder) involvement

3. Transboundary issues

4a. Knowledge gaps

4b. Addressing uncertainty

This analysis will also consider some additional issues that are key elements in a countries knowledge base and capacity to use the information generated within a vulnerability assessment to make appropriate adaptation decisions that are both flexible and robust into the future. We have called these element 'enabling factors', in that they assist in the choice of methods, the way that the results are communicated to those that need to use them and the implementation of the actions. These factors include:

- Institutional capacity, coordination and governance processes;
- Interdependencies between sectors and impacts;
- Selection of assessment methods;
- Methods for understanding adaptive capacity; and
- Development of indicators.

The intention is to provide countries that have yet to undertake certain steps with ideas and inspiration to encourage them to look at how these enabling factors can support their own assessments.

3.2.1 Benefits of frameworks based on a series of steps

The use of a framework can help countries to take a systematic view, to structure the process so that it is easier to undertake and to understand the implications of doing the assessment in a certain way. Where countries have specified their own framework this is reported. In addition, we have also analysed the approaches of countries and illustrate where these could reflect certain frameworks. We have also used the EU Strategy framework so that we can compare and contrast the different approaches that have been used across Europe. We showed in section 3.1 that the majority of countries had completed steps 2a, 2b, and 2c (climate projections, impacts and consideration of more than one timescale). This section aims to show what frameworks and methods countries have used to achieve their assessments.

[3] Contributions were provided by Bulgaria - Boryana Kabzimalska and Diana Todorova, Finland - Kirsi Makinen and Tim Carter, France - Sylvain Mondon and Céline Phillips, Germany - Susanne Hempen and Inke Schauser, Portugal - José Paulino, Sweden - Åsa Sjöström and Lotta Andersson, and the UK - Rosalind West.

Germany has used the IPCC Conceptual approach based on AR4 to asign vulnerability to each of the action fields it has chosen. Vulnerability has been described qualitatively for each action field based on the significance of its climate impacts in the specific action field and the sectoral adaptive capacities just for the near future. The Vulnerability Network (see Annex 3.2 for Germany) defined "impact chains" for each of the 15 action fields of the German Adaptation Strategy to visualise the cause-effect relationships between climate signals and potential climate impacts. They clarify which climate signal influences which potential climate impacts and provide indications about interrelationships to other action fields. The key sensitivities for these selected climate impacts were discussed and selected in expert workshops. An assessment methodology (impact models, proxy indicators or expert survey) was identified with network partners, which constituted the basis for further assessment steps.

In addition, the impact chains served as a basis for the analysis of the interrelationships between the individual action fields. The focus of the impact chains is on the present and near future (2021-2050).

France has used the following stepped approach: (i) review of historical data and past climate events, (ii) modelling, (iii) extrapolation of empirical formulas between a sector and climate followed by (iv) ad-hoc projections and scenarios. In addition, the approach of France reflects some of the principles of the PROVIA framework where it has differentiate between vulnerability to climate variability and vulnerability to climate change. The French assessment looks at vulnerability to climate variability and aims to address the issues arising from this. It does not consider future vulnerability due to climate change since the view is that the climate models cannot provide reliable projections on extreme events. Hence France deals with the exposure of the population due to current risks and are waiting until the models improve before including data on future risk, except in the case of sea level rise. The Ministry of Environment, Division on Prevention of Natural Risk, produces maps of areas at risk and indicators developed using only historical data except for sea level rise (which includes a projection into the future).

The Bulgarian approach has been assessed against the EU Strategy Framework and shows the following characteristics. Bulgaria has carried out Step 1 by assessing the effects of past events through a 'disaster' perspective 'Economic losses from natural disasters' i.e. number of events and cost of damages, including floods, fires, landslides and earthquakes. Bulgaria has recognised that the vulnerability of Bulgaria's population and businesses is accelerated by a relatively high degree of poverty in the areas that are typically most impacted. In addition, the transition from a state-controlled economy to a free-market economy, the lack of/or insufficient maintenance of infrastructure and the public sector budget cuts as a results of the economic crisis has further increased their vulnerability.

Bulgaria has carried out Steps 2a. and 2b. (climate projections and impacts) of their vulnerability assessment by using PESETA and PESETA II (funded by JRC) to gain insights into the sectoral and regional patterns of climate change impacts by the end of this century in Bulgaria. These studies used large sets of climate model runs and impact categories (sectors) and integrated biophysical direct climate impacts into a macroeconomic model, which enabled the comparison of the different impacts based on common metrics (household welfare and economic activity). The Bulgarian assessment also drew on the results of ESPON Climate vulnerability assessment methodology (spatial mapping to NUTS level 3), and the results of MEDPRO to look at extreme events and natural disasters linked to climate change. The method used was based on 'Pressure, State, Impact, Response/Drivers' and allowed integrated risk assessment of climate change on various economic sectors and regions of the country with a common framework. Bulgaria used CLIMSAVE (2013) to look at the degree of vulnerability of the system (function of adaptive capacity and the degree of impacts) with a four point scale. It also used EEA Report 12 Climate change, impacts and vulnerability (2012) to identify possible impacts of climate change on socio-economic systems and human health, as well as for indicators of the sensitivity of economic sectors to climate change.

The UK used a method based on the UKCIP RUD Framework (see section 1.5) for the first Climate Change Risk Assessment, which is a 7 step process that covers the policy planning cycle, has iterative steps to help identify the most urgent risks and explicitly deals with uncertainties.

3.2.2 End-user (stakeholder) involvement

It is recognised within many of the framings for vulnerability assessment e.g. 2.f. EU Strategy Guidance, the value of stakeholder involvement especially within the framings that are more towards the 'decision-first' end of the spectrum that use participatory methods. This is reiterated theoretically within some of the research projects, for example MEDIATION that describes 'the value of participatory research methods for ensuring saliency, legitimacy and credibility of CCIVA assessments is repeatedly stressed in the published literature. Hence the active involvement of stakeholders needs to be recorded, along with the groups that have been involved and the format of their involvement.'

The benefits of involving stakeholders is also demonstrated in practice in Germanys assessment approach. Germany established a Vulnerability Network in 2011 that was composed of 16 Federal agencies and institutes. A scientific consortium (including consultants) supported the Network and was responsible for the coordination. The Vulnerability Network created a consistent, cross-sectoral methodology based on a joint understanding of' vulnerability' and other related terms adapted from the concept of vulnerability as set out in the IPCC's Fourth Assessment Report (AR4 2007).The collaboration between the network partners and the Consortium followed a pattern of "co-production of knowledge". A co-production process was chosen because experience from past projects has shown that results, achieved in cooperation with the authorities responsible for adaptation, are better understood, better accepted and more likely to be integrated in the further adaptation process than outcomes from work solely carried out by scientists. In addition, consensus building was seen as a methodological concept for tackling uncertainty.

The benefits of involving stakeholders can also be demonstrated in practice by Finland who used a questionnaire to discover the stakeholders' general perceptions about climate change, their opinions about the credibility of climate scenarios for Finland, their climate information needs, potential impacts of climate change and their significance, their current preparedness to climate change and its impacts, coverage of climate change issues in current plans, and the need to respond and the needed measures to be taken. Stakeholders in the study were considered to be: those who have interests in a particular decision, either as individuals or as representatives of a group. They are people who influence a decision, or can influence it, as well as those affected by it. Stakeholders were defined as: 1) those affected by climate change, 2) those positioned most effectively to advance adaptation. The target sectors of the study were the sectors that climate change was assumed to have the largest impact on, and/or those sectors that would be potential actors in adaptation. The National Adaptation Strategy and international adaptation assessments and strategies were also used as sources in identification of the target sectors. The questionnaire was sent to 1133 persons representing about 15 different sectors. There were 532 respondents indicating a response rate of 47%. At the end of the questionnaire the respondents were invited to comment the questionnaire. The reasons some respondents found the questionnaire difficult to answer, were the following:

- The questions were difficult to answer from the point of view of their sector (climate change issues were not discussed within the sector or they were not considered important to the sector)
- The respondents did not have enough knowledge of the subject
- The stakeholders felt the questions were not targeted to their area of work (administration
- The questions were not commensurate and unequivocal
- The impacts given were not clearly either positive or negative for the sector
- Climate change can have both positive and negative impacts to the sectors
- It was hard to answer the questions as there are so many uncertainties concerning climate change and its impacts, the rate and magnitude of changes.
- Some of the respondents were not convinced that climate change is happening or they thought that it is part of natural variability
- The questionnaire was too long and the time to complete the questionnaire given in the covering letter (10-15 minutes) was too optimistic.

These examples demonstrate some of the challenges that need to be addressed when involving stakeholders:

- There is a need to provide very clear guidance when communicating complicated concepts to non-experts i.e. about what the impacts are and make sure that these are understood. This is easier to do in a workshop setting than in an email survey using a questionnaire.
- There is a need for adequate time to prepare information for stakeholders, for stakeholders to respond and to follow up on the results.
- There is a need to be aware of stakeholders current state of knowledge and to make allowances of time and effort for consensus building.
- There is a need to explain uncertainties and how they can be explicitly addressed.

3.2.3 Trans-boundary issues

Trans-boundary issues were rarely considered (6 countries out of 28) within a national assessment from the analysis in section 3.1.1. Trans-boundary issues were mentioned in 2 of the 7 countries that were analysed in depth. Finland and the UK have considered trans-boundary issues. Finland was a partner in the CARAVAN project "Climate change: a regional assessment of vulnerability and adaptive capacity for the Nordic countries". The UK's second climate change risk assessment (CCRA2) Evidence report (CCC, 2016) considered the international dimensions of risks and opportunities, including international dimensions of food security, imported food safety risks, global food production, human displacements (migration), international conflicts, international law and governance, and international trade routes.

However, there are a number of trans-boundary EU programmes that cover elements of vulnerability assessments such as the Alpine region, Baltic Sea region Pyrenees and the Danube. There are also a number of research projects e.g. JRC PESETA that are pan-European assessments, however it is not clear how much this information is used to make decisions about adaptation action that crosses borders.

3.2.4 Addressing Knowledge gaps

Table 2 showed that only a small number of countries (8) are addressing knowledge gaps within their assessments (Austria, Finland, Germany, the Netherlands, Portugal, Spain, Sweden and the UK). Here we describe how some of the stage 2 countries that are addressing knowledge gaps are achieving this.

Sweden published its first risk and vulnerability assessment in 2007. In 2014, as part of the evidence to be considered for the new strategy, the Government commissioned SMHI to undertake a systematic update of the assessment of risks, impacts and vulnerability associated with climate change. This included stakeholder consultation during an interactive workshop in April 2014 to identify new knowledge, gaps and challenges that had become available since the 2007 risk and vulnerability assessment. The results were published as part of the "Checkpoint 2015" report.

3.2.5 Dealing with uncertainties

To assist other countries in making provision for Step 4b dealing with uncertainties, we have summarised here the techniques that the 7 countries (stage 2 analysis) have used to account for uncertainty within their assessments:

- Calculation of confidence levels 'limited/low' to 'robust/high'. For example comparing 'level of agreement' with other studies, data or scenarios with 'level of evidence' based on statistic robustness of models or quality of observed data
- Calibration of models
- Use of probabilistic (e.g. 10^{th}, 50^{th} and 90^{th} percentiles) and/or ranges (minimum, average, maximum) in data outputs e.g. for expressing the population trend or river volume
- Use of uncertainty methods e.g. Sensitivity analysis, fuzzy multi-criteria decision-making
- Expert elicitation and stakeholder or peer review

- Workshops and visualisations for communicating the uncertainty to those that need to use it so that it can be utilised as a key part of the evidence base.

Some of these techniques are illustrated with the example from the UK in Box 1.

BOX 1: Example of how uncertainty has been accounted for in the UK.

The UK carried out the first Climate Change Risk Assessment (CCRA) in 2012 Assessment (Defra, 2012) and it provides a probabilistic climate change framework with differing degrees of confidence over various outcomes to facilitate the decision-making process.

Uncertainties were taken account of in the following way: Out of 700 impacts identified, about 100 were selected as priorities and risk metrics identified for each one. The metrics provided measures of the consequences of climate change, relative to specific climate variables. The next step developed response functions, which was the relationship between the risk metric (e.g. crop yield) and one or more climate variables (e.g. temperature or precipitation). Response functions were derived through sensitivity analysis of detailed models, historical data to produce a simple statistical relationship and expert elicitation where models or data were not available. Uncertainties associated with these approaches were taken into consideration as part of the overall confidence scoring for each risk metric. The magnitude of climate risks were then analysed using climate projections for 3 time slices and 3 emission scenarios (2020s, 2050s, 2080s – low medium and high scenarios).

Uncertainties were considered in the climate system, future emissions, current level of risk faced, the relationship of the risks to climate variables, planned or autonomous adaptation and changes in society and financial consequences of impacts estimated in a monetisation exercise. These uncertainties were handled by:

- Emission scenario analysis – within each projection a probabilistic range was used (10^{th} to 90^{th} percentiles probability range).
- Population projections (low, principle and high) were also applied to provide results combining both climate and population changes.
- Expert elicitation and peer-review were used to substantiate whether the assumptions adopted were reasonable;
- Stakeholder involvement was used to ensure that uncertainties presented in reports were understandable to the reader.

The risk metrics considered in the first CCRA varied in character in that some were quantified, some relied on expert elicitation and some on narratives from the literature. To allow comparison of these different risks they were categorised with either 'high, medium or low' magnitude consequences and either 'high, medium or low' confidence. An example score card for Health and Wellbeing is shown in Figure 5. This shows the lower (l), central (c) and upper (u) estimates of magnitude of the consequences (based on the range of emission scenarios analysed and associated probability levels) for the three time slices considered (e.g. 2020s, 2050s, and 2080s) and the overall level of confidence in these estimates (L, M, H). The score card shows both positive and negative consequences. The score card helps the decision-makers to prioritise area of action by comparing the relative magnitude of risks and indicating how soon action should be taken to mitigate or adapt to that risk.

Metric code	Potential risks for health and wellbeing	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
HE5	Decline in winter mortality due to higher temperatures	M	3	3	3	3	3	3	3	3	3
HE6	Decline in winter morbidity due to higher temperatures	M	3	3	3	3	3	3	3	3	3
BE9	Reduction in energy demand for heating	L	1	2	3	2	3	3	2	3	3
HE10	Effects of floods/storms on mental health	M	3	3	3	3	3	3	3	3	3
FL12a/b	Hospitals and schools at significant risk of flooding	M	2	3	3	3	3	3	3	3	3
HE1	Summer mortality due to higher temperatures	H	2	2	3	2	3	3	3	3	3
HE2	Summer morbidity due to higher temperatures	H	1	2	3	2	3	3	3	3	3
WA3	Reduction in water available for public supply	M	1	2	3	2	3	3	2	3	3
FL2	Vulnerable people at significant risk of flooding	M	2	2	2	2	2	3	2	3	3
BE3	Overheating of buildings	H	1	2	2	2	2	3	2	3	3
MA2a	Decline in marine water quality due to sewer overflows	M	1	2	2	1	2	3	2	3	3
WA5	Public water supply-demand deficits	M	1	1	2	1	3	3	2	3	3
FL1	Number of people at significant risk of flooding	H	2	2	2	2	2	2	2	2	3
WA6	Population affected by water supply-demand pressures	M	1	2	2	1	2	2	2	2	3
HE3	Extreme weather event (flooding and storms) mortality	M	1	2	2	2	2	2	2	2	2
BE5	Effectiveness of green space for cooling	M	1	1	2	1	2	3	2	3	3
WA10	Combined Sewer Overflow spill frequency	L	1	1	1	2	2	2	3	3	3
BD12	Wildfires due to warmer and drier conditions	M	1	1	2	1	2	3	2	2	3
HE9	Sunlight/UV exposure	L	1	1	1	2	2	2	2	2	2
HE7	Extreme weather event (flooding and storms) injuries	M	1	1	1	1	2	2	1	2	2
WA4	Change in household water demand	M	1	1	1	1	1	2	1	1	2
HE4a	Mortality due to summer air pollution (ozone)	M	~	~	~	~	~	~	3	3	3
HE4b	Morbidity due to summer air pollution (ozone)	M	~	~	~	~	~	~	3	3	3
BE1	Urban Heat Island effect	H	Too uncertain*								
MA2b	Risks of human illness due to marine pathogens	L	Too uncertain								
MA1	Risk of Harmful Algal Blooms due to changes in ocean stratification	L	Too uncertain								

**This is because magnitude is site specific*

M	Confidence assessment from low to high
3	High consequences (positive)
2	Medium consequences (positive)
1	Low consequences (positive)
1	Low consequences (negative)
2	Medium consequences (negative)
3	High consequences (negative)
~	No data

Figure 7. An example score card for Health and Wellbeing
(Sources: (Defra, 2012) (CCC, 2016) (Capela Lourenço, et al., 2014))

3.2.6 Analysis and illustration of 'Enabling factors'

Institutional capacity, coordination and governance processes

It has been recognised that governance structures that combine both top-down (policy from national government) and bottom-up (community and locally driven) governance are effective at assessing risks, developing new policy and implementing the decisions made.

This can be illustrated with an example of a process in France where adaptation measures are undertaken at two levels and combine both top-down and bottom-up governance: (i) state and institutional level, from which laws and environmental policies are released, (ii) citizen level where there is knowledge and information on climatic changes. The subnational adaptation planning policies, called 'Regional Scheme on Climate, Air and Energy' (SRCAE), include adaption measures. There are 26 schemes (one per region). These SRCAE are translated into approximately 400 local plans 'Climate Plan on Energy and Territory' (PCET) and urban plans 'Local Urbanization Plans' (PLU). PCET have been mandatory since 2010 for communities of more than 50,000 inhabitants.

An elected representative, either the mayor/president of a community/town is responsible for the PCET and its complementarity and coherence with the national adaptation strategy. The latter is the spokesperson of the community in the national arena. The elaboration of the PCET, which generally takes up to 2 years, entails:

- Prefiguration: internal organisational structure, planning, geographical scope;
- Diagnosis and mobilisation: GHG emissions, impacts and vulnerability assessments of the region, training, awareness campaigns, knowledge sharing, action plans, participatory process;
- Elaboration: definition, analysis and selection of actions, long-term action plan for the region, coherence/integration with the national plan;
- Operation: implementation of measures;
- Communication, monitoring and evaluation conducted in parallel and continuously.

Cross-cutting, transversal, coordinated adaptation action is included. Coordination actions, climate services, websites, capacity building and other actions are effectively implemented to date. However the assessment reports do not consider impacts spreading across borders and exclude 'Outre-mer' areas.

In Sweden the governance process is also a combination of top-down and bottom-up although the latest strategy document was created by combining all the regional reports, thus demonstrating a strong participatory approach and decision-making that is driven from the local level.

All 21 counties in Sweden have two regional reports, one is a regional action plans for climate adaptation and emanates from the Governmental missions given to all county boards in 2013 (and completed before July 2014). These reports included vulnerability assessments that were developed in different ways by the county boards. Most county boards had access to studies, analyses, method reports, guidelines, visits and dialogues with various stakeholders at the local, municipality level. Together, these different sources of information and expert advice provided information about the respective county vulnerabilities. The information included climate projections that were based on SRES scenarios that had been commissioned by each of the county boards using consultants or SMHI.

The second regional reports were completed in November 2014 and are based on RCP 4.5 and RCP 8.5. This set of climate indices were calculated by SMHI (commissioned by the Government) working in close cooperation and through dialogues with the county boards to identify the indices to be included and how to present the results.

In 2014 the Government undertook a systematic update of assessment of the risks, impacts and vulnerability associated with climate change and also synthesized the 21 county reports to feed into the "Checkpoint 2015". There was a concern from the county boards that such a synthesis would mask regional problems by providing one, synthesized message. However, after a joint process between SMHI and the chairing committee of the national coordination of the county boards, a report (provided as an annex to the main report) was compiled and agreed on by the county boards (who collected comments from all county boards).

Interdependencies and cross-cutting issues between sectors and impacts

Effective adaptation cannot be undertaken without careful consideration of the cross-cutting nature of risks and synergies between adaptation activities. Unless cross-cutting issues are considered, actions could be ineffective, sub-optimal in terms of their costs and benefits, or worse lead to unintended consequences.

In its first CCRA (Defra, 2012) the UK covered 'cross-cutting risks' that included consideration of the interaction between sectors, market responses, societal perceptions and the associated adaptive capacity.

In its second CCRA (CCC, 2016) the UK again covered 'cross-cutting risks' including

- Interactions among risks: climate change risks act together to impact upon natural capital, water security, food security, wellbeing, economic prosperity and ultimately global security.
- Indirect and macroeconomic impacts: the evidence suggests that indirect economic losses to the UK from climate risks are likely to be at least of the same order of magnitude as the identified direct losses. To date there has been little assessment of the potential macroeconomic impact of climate change for the UK.
- Distributional impacts: climate change will affect different people differently, depending on their social, economic and cultural background, and local environment. Low income households are particularly susceptible to climate change impacts, as impacts would disproportionately affect their disposable income. These groups also have lower capacity and resources to adapt.

As can be seen in the French example above, cross-cutting actions are included in the assessment at the community level.

Selection of assessment methods

The choice of assessment method can depend on many things such as availability of data, what knowledge is needed and who is involved in the assessment. Most countries have selected a range of different types of methods to assess the variety of risks and opportunities elaborated. The selection of assessment methods can depend on many things such as availability of data, what is being assessed and the purpose for assessing it.

This can be illustrated with an example from Germany where scientific impact models were used, but in the cases where the models were not available in the necessary spatial resolution and for the whole of Germany, the climate impacts were assessed using proxy indicators. The Indicators were identified by experts for a climate signal and sensitivity and were blended - primarily at district level. If climate impacts could not be quantified using impact models or indicators, expert surveys were conducted. The experts were asked to estimate currently existing and possible future climate impacts (near future) based on 2 climate and socio-economic scenarios.

Methods for understanding adaptive capacity

In order to determine adaptive capacity to climate change there are a number of socio-economic factors that can include economic development, technology and infrastructure, information, knowledge and skills, institutions, equity and social capital.

An example to illustrate how these factors can be determined is provided by Germany where the sector-specific adaptive capacity was assessed through interviews with network partners and external experts for all fields of action of the German adaptation strategy with the exception of the cross-sectoral areas "spatial planning" and "civil protection". The sector-specific adaptive capacity included the resources available for adaptation in the respective field of activity e.g. finance or technical options and potentially supportive and hindering factors such as lack of knowledge or awareness of the impacts of climate change. The information obtained was narratively integrated into the final report.

Bulgaria has used a three-level approach to categorise each sectors' adaptive capacity:

> 1 - High adaptation capacity: Directives are implemented, strategies and adaptation and analysis of risk from climate change in the sector;
> 2 – Enough adaptation capacity: partially implemented directives strategies and programs for adaptation and mitigation of climate changes in the sector;
> 3 - Insufficient adaptation capacity: no action is taken to address the risk of climate change in the sector.

Only a few countries have assessed adaptive capacity nationally. However, within the project MEDIATION (Hinkel, Bisaro, Pat, & Taylor, 2012) there are a number of methods being used for national adaptive capacity assessments and these are available within the outputs of the MEDIATION project - TOOLBOX/capacity analysis (http://www.mediation-project.eu/platform/tbox/capacity_analysis.html). It consists of 3 sub-sections containing information and methods for assessment, Indicators of adaptive capacity, Guidance and toolkits for Participatory Vulnerability and Capacity and Characteristics of organisational adaptive capacity.

There are four methods described for national adaptive capacity assessments and these are:

> 1 - National Adaptive Capacity Framework, World Resources Institute,
> 2 - PACT: Performance Acceleration through Capacity Transformations, Alexander Ballard Ltd
> This method was used to review the Dutch Government's National Adaptation Strategy.
> 3 - Rethinking support for adaptive capacity to climate change: The role of development interventions.
> 4 - Climate Learning Ladder
> This method was used in the Guadiana transnational river basin between Spain and Portugal as a case study within the ADAM project (2009). (Adaptation and Mitigation Strategies; http://climate-adapt.eea.europa.eu/metadata/projects/adaptation-and-mitigation-strategies-supporting-european-climate-policy).

3.2.7 Approaches to measuring vulnerability at national level

A useful starting place to understand how vulnerability is being measured at national level in Europe is to examine Monitoring, Reporting and Evaluation (MRE) frameworks that have been developed or which are currently under development. A recent report by the European Environment Agency (EEA, 2015) provides useful insights into the use of vulnerability indicators. The report highlights that countries are at different stages in establishing MRE approaches but that many are going beyond simply considering whether adaptation plans have been delivered, to track changes in vulnerability and resilience over time in key sectors and locations. This has required the development of national level indicators. An overview of the status and types of indicators being developed at national level is shown in Table 9. It should be noted that the EEA will be undertaking more detailed work on national-level adaptation indicators in 2017, including establishing a database of indicators currently in use.

Table 9. Indicator development within national-level MRE systems in Europe (EEA, 2015)

Country	Status of indicator sets and types of indicators being developed (*)
Austria	An indicator system for monitoring and reporting on adaptation for 14 sectors, outlined in the Austrian Adaptation Strategy, has been developed. It includes 45 qualitative and quantitative indicators to monitor the processes, outputs or outcomes of adaptation interventions.
Belgium	The measures in the approved Flemish Adaptation plan (part of the Flemish Climate Plan 2013–2020) are evaluated annually in a progress report. A scale of progress is established for each measure. The future NAP will take a similar approach, with each action linked to qualitative or quantitative indicators. Other more specific plans have an in-built monitoring system in which weather events will trigger adaptation measures (e.g. the heat wave and ozone peak plan).
Finland	Evaluations of the NAS (2009, 2013) applied a five-step scale to indicate the level of adaptation in different sectors (see Box 2.10). Efforts to develop suitable adaptation indicators were initiated in 2015 to support the monitoring and evaluation of the NAP 2022.
France	Annual monitoring of progress is undertaken for 19 areas and one cross-sectoral theme outlined in the NAP (2011–2015). For each area and theme, an action sheet outlines one to six actions, each comprising several components that must be undertaken in that area, totalling 84 actions and 230 measures. These actions can be broadly categorised as (1) production and dissemination of information, (2) adjustment of standards and regulations, (3) institutional adaptation and (4) direct investment (from OECD, 2015).
Germany	Indicator system for reporting on climate change impacts and adaptation areas outlined (in the NAS). 102 indicators: 97 for impacts and adaptation and 5 overarching indicators (e.g. awareness of the public, research funding, international funding, funding for municipalities).
Ireland	Ireland is in the process of developing adaptation indicators.
Lithuania	The planned MRE systems will be indicator-based and linked to NAP (3-year cycle). It will focus on six main sectors. Indicators are likely to be qualitative.
Malta	No information specifically available on indicators. Monitoring of the NAS (2012) is conducted through the screening of Malta's National Environment Policy (NEP) under the sections related to climate change.
Netherlands	In total, 41 adaptation indicators (qualitative + quantitative) are under development/consideration, but not all will necessarily be used in the end.
Slovakia	Slovakia is in the process of developing adaptation indicators.
Spain	Spain is in the process of developing an impact, vulnerability and adaptation indicator system.
Switzerland	Switzerland is not planning to develop any new indicators, but is planning to use existing data sets that provide information on adaptation and/or the development of climate-related risks or vulnerabilities. The status of indicators varies between sectors in the adaptation strategy (some are completed, some are in development, some have not started to determine indicators).
United Kingdom	As part of its statutory role to evaluate the progress of the National Adaptation Programme, the UK Committee on Climate Change (CCC) has developed a set of 33 indicators aligned to the themes and adaptation priorities identified in the NAP. These indicators are complemented by research and analysis undertaken by the ASC and presented in the evaluation report and previous non-statutory progress reports.

Vulnerability indicators can be process-based (recording a process that could realistically be expected to contribute to reduced vulnerability), output-based (recording the delivery of a specific output) outcome-based (a metric relating to the direct results of a policy or action).

A key finding from the EEA report (EEA, 2015) was the importance of blended or 'mixed-methods' approaches that use multiple sources of information and combine the quantitative and qualitative methods (e.g. using a range of indicators, alongside stakeholder perspectives gained through self-assessments, surveys and consultations with experts). This allows for more effective triangulation of information and sets vulnerability indicators within a broader portfolio of tools that can help establish a coherent picture of vulnerability and/or resilience.

The authors of the report illustrate a number of examples of mix-method approaches being applied including in Belgium, where vulnerability assessments are combined with a set of 'easy-to-use' indicators that focus on the implementation of adaptation measures, and in the Finland and the United Kingdom.

In the previous analysis in section 3.1, Figure 1 showed that 12 countries have developed indicators and that this has increased from 4 in the EEA report (EEA, 2014) based on the self-assessment survey results from 2013. Table 9 provides examples from a number of countries on the progress of developing indicators. The interviews and assessments within this project can provide additional details about what types of indicators are being developed and the process that is being used. Examples are shown from France and the UK.

The NAP for France is based on a set of 29 climate indicators (divided into six sections), of which the most important indicator is 'exposure of population to climate risks'. It is measured by assessing the number of climate risks identified as natural disasters (avalanche, forest fires, hurricanes, floods) per commune and correlating this with the population density. The higher the density, the higher the number of climate risks per local area ('commune'), the higher the indicator. This indicator was calculated using a land cover database and the national population census. The indicator has 4 categories (high, medium, low, none) depending on the combination of a range of number of inhabitants per km^2 and the number of expected risks. It has been calculated for 36,699 local areas (communes).

Risk metrics (quantitative, monetised and qualitative) were identified and used in the UK's first CCRA to broadly encapsulate the most important consequences of climate change. These included consideration of such things as the average number of people flooded per year, number of vulnerable people living in the 1 in 100-year floodplain, crop water demand, optimum crop yield, water availability for public water supply, ecological status (number of sites in a class), habitat loss and number of people suffering heat stress. Using the list of 'consequences', a list of possible metrics was produced and discussed with experts (expert elicitation). The practicality of each metric in terms of data availability, any data licensing issues and the complexity of the metric were also considered. Where the assessment required included large amounts of analysis it was "parked" for possible future assessments. If the metric required original research it was noted and recorded in the research gaps report. Proposed metrics were also reviewed by policy makers to incorporate a policy relevance perspective. Documentation for each of the selected metrics included: the rationale for their selection; sources of data including quality assessment; the calculation method; key assumptions and caveats; and the metric's sensitivity to climate and socio-economic variables. There are indicators of climate hazard, exposure, vulnerability, action and realised impacts. Examples are provided in Table 10.

Table 10. Examples of indicators in the UK

Type of indicator	Description of indicator (ID)	Data availability for CCRA (2012)	Update for 2015/data availability & Trend
Climate hazard	Number of hot days per year (HCR3)	high	The number of hot days per year in England has increased from approx. 10 per year in the 1960s to 25 per year in the 2000s.
Exposure	Number of new residential properties located in areas likely to flood (BE14)	high	Proportion of new residential addresses created in flood risk areas has only slightly declined, from 12% (2001-07) to 11% (2008-2014).
Vulnerability	Areas of urban greenspace (HCR5) (Reductions in urban greenspace will enhance the urban heat island effect, leading to higher temperatures and reduce the ability of the ground to soak up surface water, leading to a greater risk of flooding.)	high	The area of urban greenspace has declined by 74,000 Ha between 2001 and 2013; recent declines have slowed since 2008.

Type of indicator	Description of indicator (ID)	Data availability for CCRA (2012)	Update for 2015/data availability & Trend
Action	Proportion of Local Authorities undertaking Strategic Flood Risk Assessments (BE17)	high	Number of lead local flood authorities that have published strategies has increased, but rate of progress is slow.
Realised impact	Number of heat-related deaths (HCR15)	high	There is not yet enough data to determine a trend in excess summer mortality. Working with Public Health England to obtain data to populate this indicator.

3.3 Lessons learned and identification of gaps and challenges

3.3.1 Lesson learned

1. There has been a significant increase in the knowledge base for vulnerability assessments since 2014, with 21 out of 28 countries having completed a vulnerability assessment. However, the assessments vary significantly in their level of detail. The knowledge base has also been boosted by a number of EU-funded research projects such as, ESPON and PESETA. This has helped countries with no national level assessment to prioritise their risks supported by a stronger evidence base.
2. A number of countries are either in the process of, or have completed a second assessment. Typically the first assessment focuses on biophysical factors (Figure 3 boxes 1 and 3). Subsequent assessments aim to fill any gaps, for example, incorporating data on social factors (Figure 3 boxes 2 and 4), greater coverage of sectors or impacts, involving more stakeholders, further research and the creation of data at smaller scales/finer resolution e.g. city level.
3. When measuring vulnerability using indicators, countries have used blended or 'mixed-methods'. This involves multiple sources of information and combining quantitative and qualitative methods e.g. using a range of indicators (process, output and outcome), alongside stakeholder perspectives gained through self-assessments or surveys and consultations with experts.
4. The countries have used a number of different techniques to account for uncertainty such as
    a. Estimating uncertainty within the climate projections: using multiple runs of climate models, using multiple storylines or scenarios for emissions and socio-economic projections and considering the outputs from many GCMs/RCMs models
    b. Indicating the robustness of the evidence by: calculating confidence levels from low to high, use of probabilistic (10^{th}/90^{th} percentiles), or ranges (min/max) in data outputs and use of uncertainty methods, for example, sensitivity analysis, fuzzy multi-criteria decision-making
    c. Exchange knowledge with stakeholders: both gathering evidence to address uncertainties and communicating the uncertainty e.g. visualisations, to those that need to use it.
    However, most assessments would benefit from more comprehensively addressing uncertainty. Providing guidance on how to address uncertainty would be one way of supporting improvements in vulnerability assessments.
5. Most countries have used the IPCC definitions (AR4, AR5) of vulnerability and related concepts highlighting the influence of a trusted, international source of knowledge and the benefits of a common understanding of terms. This is particularly important when different arenas – economic, DRR, climate science communities – use the same terms but with different meanings. The team involved in a vulnerability assessment should aim have an agreed understanding of the terms related to vulnerability at the start of the process.
6. Highly vulnerable groups that are actively engaged in the process generate broader insights which are more likely to guide decision-makers into developing policy (and supporting guidance) that will increase the equity and resilience of vulnerable groups. In addition, countries that have allowed time for consensus building have considered it to be well worth the effort as the decisions made from the evidence are more robust.

7. National vulnerability assessments of climate change benefit from using a consistent (i.e. the same climate projections), integrated methodology that allows comparison between, and across sectors and risks. National vulnerability assessments also benefit from using a wide range of methods to gather evidence from primary and proxy sources including quantitative e.g. modelling, and qualitative e.g. stakeholder opinions. The choice of methods and framework (Figures 2a & 2b, & Section 1.5) should remain flexible and determined by the purpose and resources available for the assessment in each country.

3.3.2 Gaps

There are a number of knowledge gaps that have been synthesised from this study and they are:

1. Less than a quarter of countries have developed future socio-economic scenarios therefore there is a need for spatially detailed (NUTS 3 level) future socio-economic scenarios and projections, up to and including the long-term (2070-2100.
2. There is also a gap in assessment of current social vulnerabilities (factors such as economic diversity, poverty and wealth, education, social cohesion/capital, equity, governance, policy priorities).
3. The countries that have so far only used EU-wide information e.g. from FP7 research projects need support to develop sector-specific methodologies and a common national level methodology.
4. There is a need to address uncertainty in a comprehensive way within the assessment. Most countries have assessed uncertainty in climate projections through the use of more than one model and/or ensembles and/or more than one emissions scenario. However, most countries have not dealt so comprehensively with uncertainties in other parts of the assessment e.g. impacts and socio-economic scenarios.
5. There is little evidence from the countries of trans-national work, except for Finland.

Models and other tools:

6. Although there have been some advances in models, tools and other resources to support risk and vulnerability assessments, there are particular gaps that need further attention. These include the assessment of aggregate annual risks from multiple hazards and to multiple receptors; assessing the intangible impacts of climate change; macroeconomic models that can be applied at city or regional level; and tools to assess community resilience.
7. Decision-making tools: although not widely accessible or used, there are a growing number of decision-making tools to support adaptation related activity. However, many of these tools have been developed by the research community and may not meet the needs of practitioners.
8. Vulnerability measuring and monitoring tools: many of the available indicators to measure vulnerability are based on what data are available rather than what would be most useful.

3.3.3 Challenges

The following challenges were described by the countries during the development their vulnerability assessments:

1. There is often confusion and misunderstanding about the terms associated with vulnerability assessments and related concepts and the framework. There is a need to agree on common terms and a common framework that are most suitable for the purpose of the assessment at the start of the process and ensure that all parties agree.
2. There can be tension between the most appropriate methods for individual sector assessments and the benefits of using a common methodology for a national assessment. Some elements are critical, such as the use of the same climate projections as inputs to impact models and this is where agreement needs to be reached. Whereas some elements can be easily tailored to sector needs with no detriment to the national assessment.
3. There were challenges related to accessing data e.g. sensitive data from commercial companies or medical records or e.g. information that needs to be paid, for such as weather data or academic papers.

4. Challenges that need to be addressed when involving stakeholders:
    a. Communicating complicated concepts e.g. impacts or uncertainty, to non-experts can be difficult, ideally the evidence needs to be clear and easy to understand.
    b. There is a need for adequate time to prepare information for stakeholders, for stakeholders to respond and to follow up on the results ensuring that the learning is fed back into the assessment.
    c. There is a need to be aware of experts from different fields and stakeholders current state of knowledge and to make allowances of time and effort for consensus building.
    d. There is a need to explain uncertainties and how they can be explicitly addressed
    e. The integration of stakeholders and experts adds significantly to the time it takes to prepare an assessment but the effort is well worth it as the decisions are based on stronger evidence and hence will be more robust.

4 Recommendations

The analysis of the European research projects (Sections 2.1 & 2.2) found that research projects focus on the concepts and theories around vulnerability assessment aiming to advance method development and perhaps testing (normally in a limited way) the theories through a number of specific case studies. This is in contrast to the national vulnerability assessments (Section 3) which are generally not focused on developing methodologies but more on applying the methods already available to their particular country at various levels, from national to street level. Theoretically the research projects should feed their knowledge into the national level assessments but in reality this does not often happen. It is recommended that enabling and enhancing the process of using new knowledge from European research within national vulnerability assessments is a priority for the future.

4.1 Recommendations for a reference framework for vulnerability assessment

One of the challenges identified in section 2.4 was that the ideas attached to the frameworks have shifted over time and the frameworks are not static theories. The ideas have merged over time, with elements of one taken up by another. Hence the frameworks are not stand-alone, they do not fit neatly into boxes and there is a flow of ideas from one to another. Hence we have chosen a continuum to visualise the framings (Section 1.5). This continuum of vulnerability assessments sits between a risk management approach and a climate impacts approach. The research projects that have been analysed are spread across the continuum because they tend to display characteristics of both framings. The frameworks should be seen as a useful way of visualising the structure of the ideas and how they fit together. It is not important to 'fit' a vulnerability assessment into a particular framing, it should be purely used as a means of understanding the perspective from which the evidence has been gathered.

The analysis in section 1.5 concluded that 'The frameworks occupy a continuum between climate impacts (top-down and science-first and more data/modelling oriented) and risk management (bottom-up, decision-first and participatory)'

Further analysis in Section 2.1.2 has led to the creation of Table 11 that depicts this continuum visually. It contains the main characteristics at either end of the continuum for vulnerability assessment frameworks. These end point frameworks are described below:

A 'Risk Management' framing that comes from the starting point that there is a decision to be made to deal with a risk and this creates the need for knowledge of what will be affected, by what, and over what timescales. It is more practically based, favouring 'bottom-up', qualitative, participatory evidence that is more subjective. This has historically been the view of the disaster risk and international development communities.

B 'Climate Impacts' framing that comes from the starting point of a comprehensive understanding of the climate science through observations of the current climate variability and modelling the future climate change through the use of plausible storylines or 'scenarios'. It is often data-driven and favours quantitative, 'top-down' evidence that is seen as objective. This has historically been the view in the climate science community.

Table 11. Main characteristics of vulnerability frameworks that describe each end of the continuum

Characteristics of the frameworks	A: Risk management	B: Climate impacts
Purpose of the assessment	Decision –first	Science-first
Climate assessment	Present climate variability	Future climate change
Driver of the assessment	Bottom-up – locally driven, co-production	Top-down – globally or nationally driven
Geographic focus	Community or household focused	Nationally or regionally focused
Type of methods used	Participatory or qualitative methods	Modelling or quantitative methods
Primary subject of interest	People centred/socio-economic (based on 5 capitals), governance	Primarily Biophysical impacts (flood, heat)
Origin of field of literature	DRR and international development field	Climate science field

The decisions made about the purpose and the framing of an assessment, as well as the knowledge and science capacity available, will determine the methods chosen for the assessment.

It should be noted that a vulnerability assessment undertaken under one framing will give different results to an assessment undertaken with another. Understanding these differences (the strengths and limitations) will help identify an appropriate framing and methods for the intended purpose. This understanding is important, as the different vulnerabilities will greatly affect the selection of adaptation options and ultimately the success, or failure of the policy to reduce vulnerability, or exploit opportunities to climate change.

Within each framing there are key elements that need to be considered. The elements are drawn from the EU Strategy Guidance in the first instance and have been enhanced from the evidence gathered and analysis undertaken within this project. Hence with these two sources of information it is recommended that the following elements should form part of a national vulnerability assessment:

1. Emissions scenarios
2. Climate scenarios and Projections variability and change
3. Potential Impacts (current and future)
4. Sensitivities physical and social
5. Adaptive capacity physical and social
6. Exposure climate and non-climate
7. Vulnerability (social and biophysical)
8. Socio-economic scenarios and projections
9. Economic appraisal
10. Uncertainties
11. Use of qualitative evidence to supplement quantitative knowledge gaps
12. Risks and opportunities
13. Participation of Stakeholders

These elements are shown graphically in Figure 8. as a reference framework for vulnerability assessment.

The diagram shows the ‘climate impact’ perspective from left going upwards (blue boxes), and ‘risk management’ from the right going upwards (green boxes). There are a number of common elements to both framings (orange boxes) and all the knowledge feeds into improving decision-making, learning and reducing vulnerability.

Concluding comments

When providing guidance on choosing vulnerability assessment frameworks and methods it is important to recognise the need for flexibility in these choices. It is even more important to provide guidance that allows users to understand the implications of choosing the different approaches in terms of the results (e.g., the strengths and limitations of the different framings and methods, and the implications for the likely results). The guidance should be supported with case studies that demonstrate what was done, why the framework and methods were chosen and demonstrating the differences in the resulting vulnerabilities.

There is a need to support collaboration and learning among those undertaking or commissioning vulnerability (risk and adaptation) assessments. The learning, knowledge exchange and knowledge transfer is intended to improve decision making and responses to climate change. This support should be periodically evaluated by surveying the intended audience.

In addition, there is a need communicate to those undertaking assessments how and where the frameworks and methods across the continuum differ, and how these framings for vulnerability and risk assessments can work together.

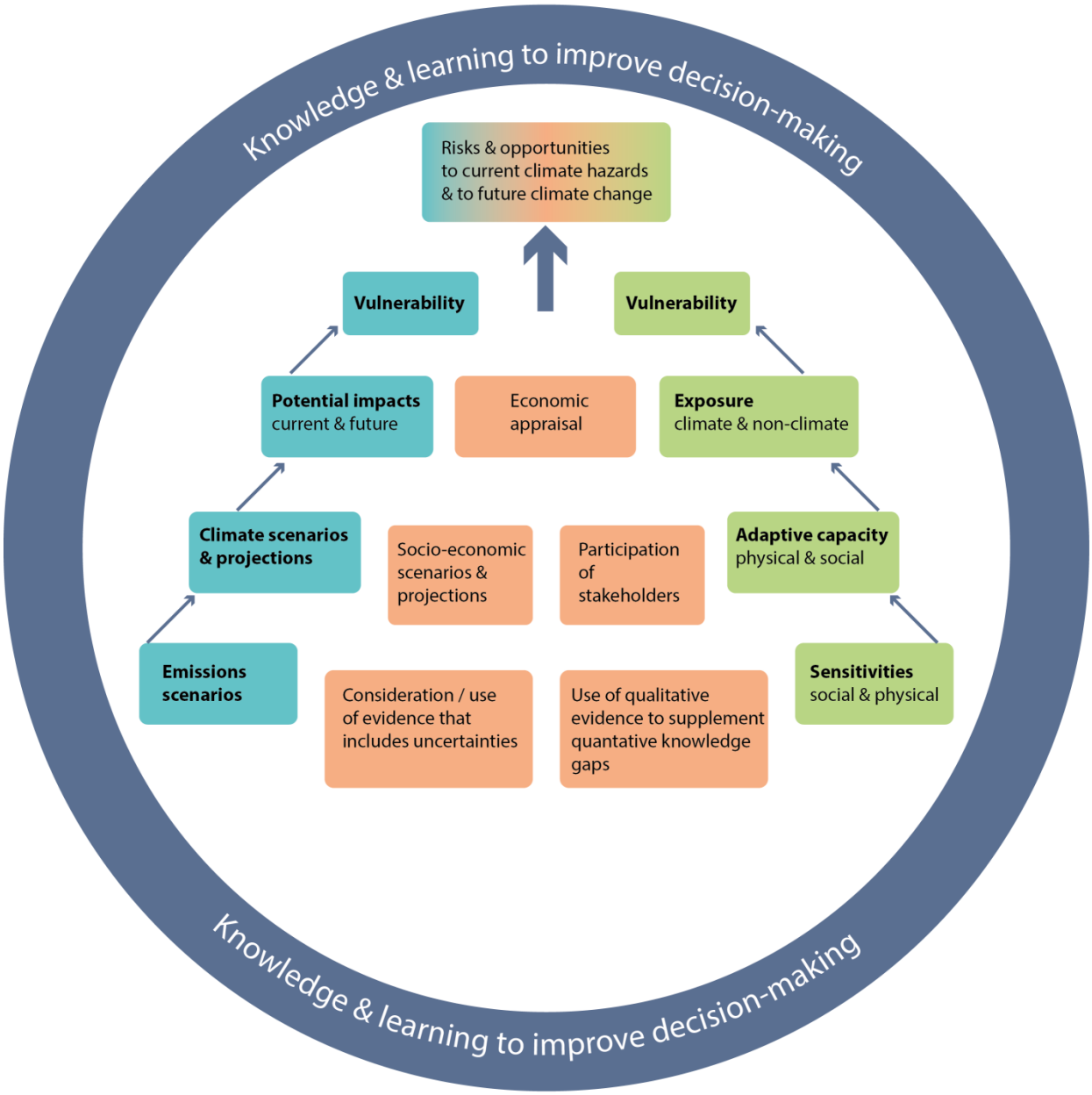


Figure 8. Reference framework for vulnerability assessment.

4.2 Recommendations for future research and knowledge transfer to address the gaps and challenges

Recommendations for Future Research			
Type	**Evidence for gap or challenge**	**Recommendations research needs**	**Suggested organisation to implement**
Ways of addressing uncertainty	Most countries have not dealt comprehensively with uncertainties within the evidence in some parts of the assessment e.g. national socio-economic scenarios.	• Information about uncertainty within the evidence, is needed to inform the assessment e.g. **how to deal with uncertainties in the evidence related to future socio-economic scenarios** and projections at a detailed spatial resolution (NUTS 3 level). • Identification of **'good' practices on the use of evidence that includes uncertainty**. This research should also lead to demonstration projects and guidance at the national and transnational levels.	DG R&I (Framework Programmes), JRC, JPI-Climate (and its members)

Recommendations for Future Research			
Application	**Measuring and monitoring information:** many of the available indicators to measure vulnerability are dependent on access to existing data. There is limited information about the implications of trying to measure vulnerability from multiple perspectives (national, local, sectoral, research framing, socio-demographic). There are challenges of developing indicators by linking quantitative and qualitative information.	• To understand the **implications of assessing vulnerability from different perspectives** in that it will result in different outcomes and indicators. • To understand the **process of constructing vulnerability indicator sets** given the different approaches taken. The need for linking of information from different levels (national to household) and different types (quant. and qual.). We need to learn lessons about how quantitative and qualitative information can be integrated e.g. combining impact modelling outputs with socio-economic data. • Both of the above should lead to demonstration and case studies and the learning from these should be turned into **guidance**. • To **synthesise existing processes and indicators** to enhance the knowledge of what is already available (There is a EEA project looking at creating a database of indicators of vulnerability, adaptation and resilience currently in use at national level planned for 2017)	EEA and ETC DG R&I (Framework Programme) and JRC, with DG CLIMA, EEA
Methods	**Information on *future* socio-economic scenarios is limited** since only 2 of the research projects and less than a quarter of countries have analysed future socio-economic scenarios.	• Research and knowledge exchange to **demonstrate the value of using nationally specific, socio-economic scenarios** within the assessment process (moving beyond biophysical and including socio-economic future vulnerability). Use existing European socio-economic scenarios (ESPON, CLIMSAVE, IMPRESSIONS, ENHANCE) as a basis to build nationally specific ones. • This should include demonstration projects at the national and transnational levels.	JRC and European Regional Development Fund (ESPON Programme)

Recommendations for Future Research			
Methods	The majority of countries have not assessed ***current* social vulnerabilities** in detail. It is crucial that vulnerable groups (affected by impacts or policy) are involved in developing and making decisions about assessing vulnerability and selecting adaptation measures.	• Support (funding and capacity building) to provide **information on current social vulnerabilities at national and local level**. Methods for assessing social vulnerability including participatory methods exist, e.g. PROVIA guidance, BALTIC; but many of these have not yet been used in national assessments. (There is a EEA project doing a stock-take of social vulnerability, justice and climate adaptation in 2017) • To understand and **demonstrate the** various approaches that are being used in terms of **added value to the assessment process**. This includes developing the capacity to select and use appropriate methodologies. • Demonstration and case studies on the different approaches should be undertaken and the learning disseminated through **guidance** documents	DG CLIMA
Trans-national	The focus on national assessments has meant that most countries have **not included transnational issues** as part of their assessment	• To **assess vulnerability across-national borders** (e.g. catchment assessments) and encourage the joining up of national and EU Transnational regional funds and knowledge. • This should include understanding the implications for national vulnerabilities as a result of consideration of transnational issues. • **Transnational demonstration and case (learning) studies** should be undertaken and disseminated	DG CLIMA

Recommendations for Future Research			
Recommendations for Knowledge Transfer			
Type	**Evidence for gap or challenge**	**Recommendations for Knowledge Transfer**	**Suggested organisation to implement**

Sharing knowledge, building capacity and informing those undertaking assessments	The knowledge and evidence that comes from European research project results have less added value (research impact) because typically communication stops at the end of the project.
	
	As a result, the availability of, and access to, the resulting knowledge by those undertaking national assessments is reduced.
		• **Supporting a long-term knowledge sharing network** including using and linking to existing networks e.g. EIONET, Climate-KIC, Climate-ADAPT, Climate Disclosure Project, and reaching out to non-climate networks e.g. ICLEI, Industry Associations and trade bodies - drawing on learning from Millieu. For more details see section 2.4.2
		• The KE network could do the following activities:
		  • mapping to synthesise tools and methods,
		  • summarising information from research projects for different audiences,
		  • targeting dissemination and knowledge exchange to user-defined organisations (their trusted sources), e.g. EEA could write and promote their reports jointly with a sector. thematic or regional body to reach a new audience.
		  • translation of guidance and summaries into many EU languages.
			DG CLIMA/EEA

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6 Annexes

6.1 Research projects and other studies

6.2 Country profiles for 28 EU countries

6.3 Methods used by 28 EU countries (Excel spreadsheet)

6.4 Detailed reviews for 7 countries: Bulgaria, Finland, France, Germany, Portugal, Sweden and UK