Generic Internal Guidance on Storyline Development

Deliverable D2.1

climatestorylines.eu
RECEIPT_eu

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

RECEIPT project information	
Project full title	Remote Climate Effects and their Impact on European sustainability, Policy and Trade
Project acronym	RECEIPT
Grant agreement number	820712
Start date and duration	01/09/2019, 48 months
Website	www.climatestorylines.eu

Deliverable information	
Work package number	WP2
Work package title	Hotspot search and Storyline development
Deliverable number	D2.1
Deliverable title	Generic internal guidance on storyline development
Description	generic internal guidance document on how to construct storylines (including avoiding biases amongst experts, ensuring causality, etc.)
Lead beneficiary	ULeeds
Author (s)	Liese Coulter, Suraje Dessai
Contributor (s)	Bart van den Hurk, Ted Shepherd, Jana Sillmann, Ümit Taner
Revision number	
Revision date	

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

DOI: 10.5281/zenodo.3663622

Dissemination level of the document

X	PU	Public
	PP	Restricted to other programme participants
	RE	Restricted to a group specified by the consortium
	CO	Confidential, only for members of the consortium

Versioning and contribution history			
Revision	Date	Modification	Author
v.0.01	15 Jan 2020	Initial version	Liese Coulter
V1.0.0	27 Feb 2020	Review	Bart van den Hurk

Approvals			
	Name	Organization	Date
Coordinator	Bart van den Hurk	Deltares	11-02-2020
WP Leaders			

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

Contents

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

Short Guide to Climate Storyline Development

A formal risk assessment of the potential impacts of remote climatic features is not straightforward. Climatic drivers, connection pathways, and impacts on economic sectors are interconnected and to some extent, mutually dependent. As demonstrated by Figure 1, such complex linkages are a barrier to calculating the probabilities of future events (Hazeleger et al., 2015) and provide the motivation for instead developing a multiple narrative format such as storylines (Shepherd et al., 2018).

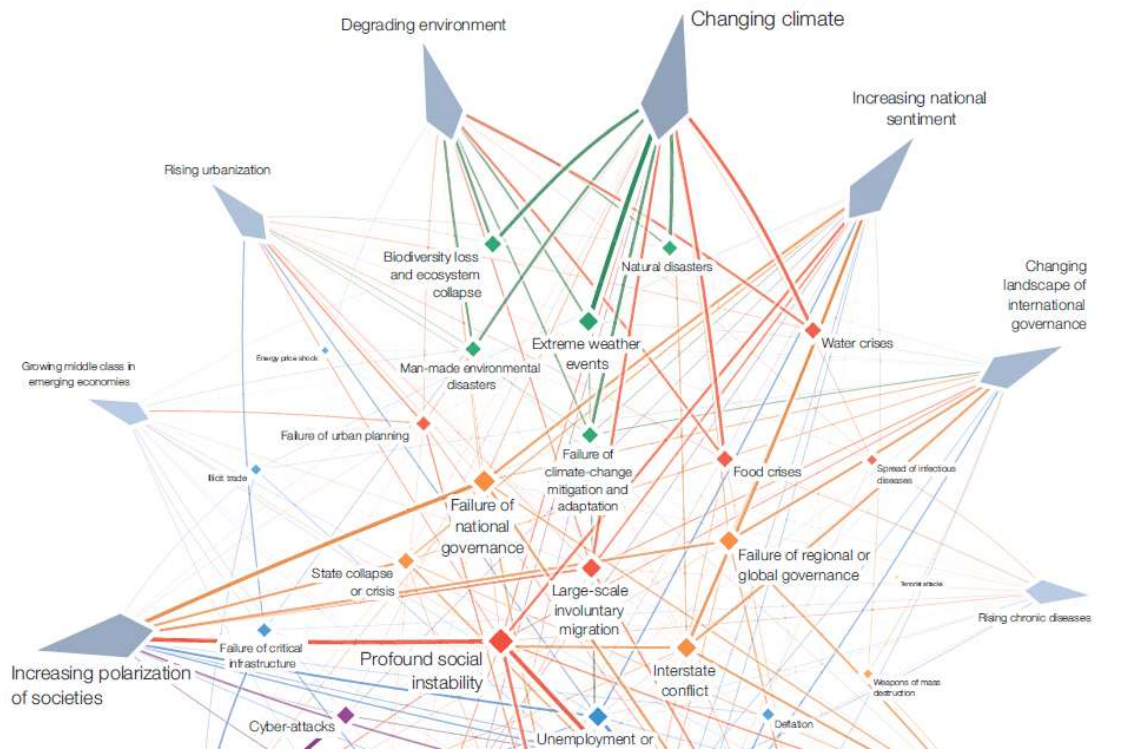

Figure 1. Excerpted from the Risks-Trends Interconnections Map 2019. World Economic Forum Global Risks Report 2019.

The climate storyline development process can be simply presented as a sequence illustrated in Figure 2 that starts by understanding climate hazards and socio-economic vulnerabilities related to sectoral concerns such as food security or the resilience of coastal infrastructure. This informs the system description and helps to identify significant causal links between climate processes and socio-economic systems to inform research

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

design. At the same time, the process will identify what scientific capacity is available to better understand climate dynamics and focus efforts where they can have the greatest benefit for science and society. Storylines can then be developed by articulating the causal links and findings, in a way that informs actors of climate risks in their sector, for example concerning food security or humanitarian aid.

Written narratives that sequence qualitative information are essential at all stages of the storyline development. Storyline narratives support research design decisions, ensure transparency and reproducibility, and communicate the climate risk storylines. High quality narratives are articulate: clear, connected and coherent.

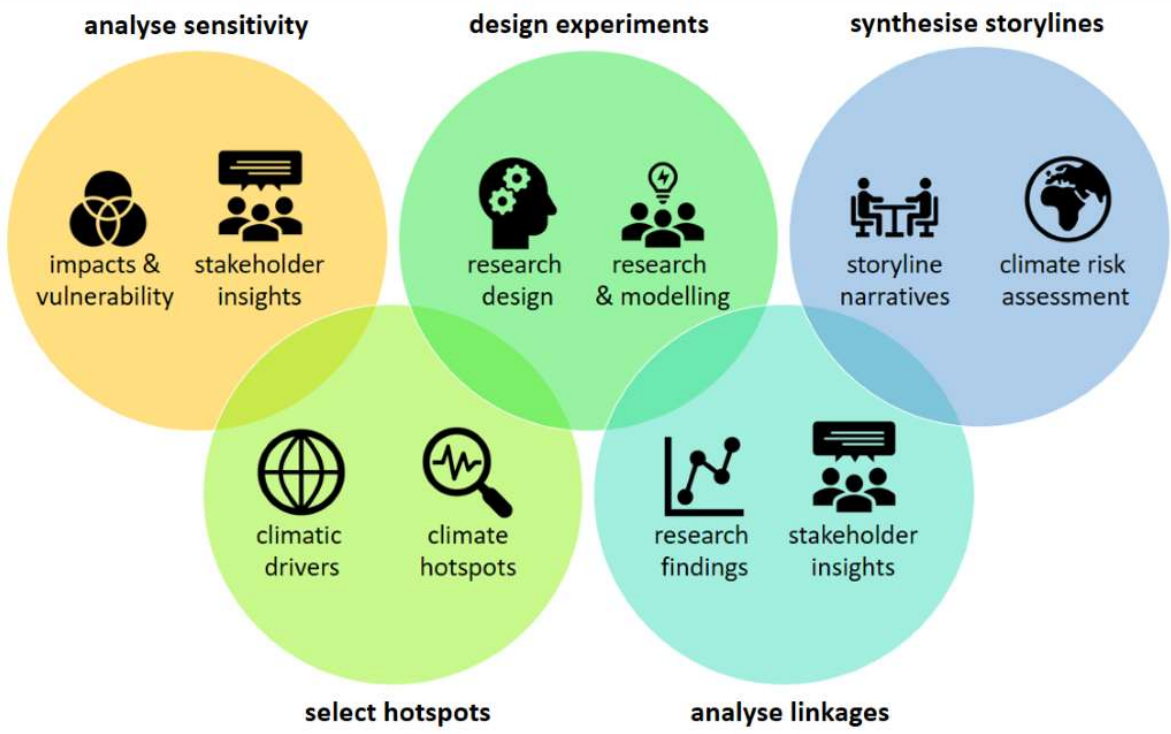

Figure 2. Simplified process for storyline development showing key elements

To verify there is robust evidence for these storylines, a whole chain of assumptions and choices, and the reasoning behind their selection, have to be well documented. First, the logic that supports prioritising a societal need or concern, and establishes the scientific value of any causal chain is articulated, clearly and distinctly. Second, models, simulations and

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

other data sources are joined and linkages explained through explicit assumptions and functional connections. Third, outputs, analysis and findings are fluently and coherently described and synthesised.

While a clear linear sequence works in theory, in practice, articulating storyline construction and narratives is an ongoing and iterative process. From initiation and research, to analysis and communication, some steps will be repeated to experiment, test assumptions and make corrections. RECEIPT has a structured program to support storyline development but the unique context of each sector and WP means a detailed 'recipe book' is neither feasible nor desirable. To gain the most benefit from stakeholder interactions, it is important to keep in mind where sector insights can help to answer guiding questions and so inform the research focus and design. This is key to the co-production process.

Table 1 sets out a simplified structure and asks questions that can guide research decisions and documentation. These probing questions can serve as a non-linear guide to developing climate risk storylines across different sectors in the project.

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

Table 1 Main steps to develop climate risk storylines.

Sectoral sensitivity analysis	
	• For each sector, what is the climate, socio-economic and research context? • What key systems within a sectoral focus area connect the world to the EU? • What are the focal points in time and space that influence climate risk? • How do selected storylines evidence and represent causal chains? • What kinds of information and metrics would be useful for stakeholders?
Hotspot selection	
	• What hazards[1] do scientists and partners see as plausible and significant risks? • What are the socio-economic implications of such risks for Europe? • What are the plausible chains of responses to climate change? • What experimental design is needed to explore these hazards? • What tools are available to provide quantification of these risks?
Experimental design	
	• What will reveal the teleconnections between climate processes? • How can sensitivities to shocks and trends be included in the research? • How can relationships between teleconnections and sensitivities be visualised? • How will the research design develop information significant for stakeholders? • How can stakeholder input inform parameter settings in experimental design?
Analyse the linkages and progression of climate risk storylines	
	• What information can be used to describe key systems and their linkages? • How do the causal chains progress under selected climate perturbations? • By what causal chains do teleconnections and sensitivities impact EU systems? • How can stakeholders clarify, expand, change & confirm these relationships? • How are climate storylines communicated to stakeholders and researchers?
Synthesis	
	• How can the sectoral climate risk storylines be synthesised to assess EU risks? • Have storylines been communicated through compelling visualisations? • What can be said about these storylines in terms of co-occurrence, positive and negative feedbacks and coincident impacts on EU systems? • How has this process contributed to EU risk assessments, progressed storyline methodology and benefited stakeholders?

[1] Hazards reflected in storylines can be short duration events, combinations of such events in time or space, or climatic trends that give rise to altered risk levels.

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

The following sections offer more detail and background on storyline development and some references to literature. A formal literature review is nearing completion and this document will be updated as the project progresses based on the literature, project experience and user feedback.

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

1. Introduction

The RECEIPT project will develop Climate Risk (CR) storylines linked to five sectors in the EU: food security, the financial sector, international development, manufacturing and European coastal infrastructure. For each sector, climate risk storylines will 1) relate to relevant climate hotspots that pose risks from climate impacts outside the EU, 2) link climate hazards to related EU systems, actors and populations, and 3) consider interconnections between the five sectors. Without assigning probabilities, storylines will draw together physical chains of high-impact weather or climate trends and events and their consequences for a sector.

Climate risk storylines are an internally consistent, detailed, plausible chain of events, stories and data that show cause-effect over a period of time. A storyline is a chain of events that can be described by narratives. Climate risk storylines are built from plausible causal chains related to climate processes. Climate narratives are developed to describe the storylines that give them structure. Storylines offer a method to represent uncertainty using physical processes as a basis for confidence in plausible future physical climates.

Once a storyline is captured in a reproducible sequential narrative, perturbations to elements in the storyline can be applied to evaluate the impact of changes somewhere in the narrative. Guidance is presented to involve stakeholder insights in storyline development and some of the advantages and limitations of the approach are explored. Examples from hydrology (Keller, Rössler, Martius, & Weingartner, 2018), flood management (de Bruijn, Lips, Gersonius, & Middelkoop, 2016) and regional climate projections (Dessai et al., 2018) demonstrate how extreme events and seasonal shifts can be communicated in storyline narratives to improve risk awareness, incorporate other relevant knowledge for decision making and represent uncertainty.

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

2. Background

In climate assessments, storylines are familiar as descriptions of the main features of future scenarios and the links connecting their driving forces (Alcamo, 2001). In relation to the IPCC, storylines are defined as "qualitative descriptions of plausible future (world) evolutions, describing the characteristics, general logic and developments underlying a particular quantitative set of scenarios" (IPCC, 2018). However, in reporting about climate change scenarios, the term "storyline" is often used interchangeably to refer to scenarios on which they are based. At its most basic, the definition that guides climate risk storyline development in RECEIPT is "a physically self-consistent unfolding of past events, or of plausible future events or pathways" (Shepherd et al., 2018).

Within the IPCC process, scenario storylines have been used to represent major uncertainties in the levels of greenhouse gas forcing of climate changes through Representative Concentration Pathways (RCP) and in alternative socio-economic futures along Shared Socioeconomic Pathways (SSP) (Girod, Wiek, Mieg, & Hulme, 2009; Kok, Pedde, Gramberger, Harrison, & Holman, 2019). Significantly, these scenarios were designed to inform assessment of climate impacts but did not reflect the consequences of climate change or adaptation development in their original construction (Girod et al., 2009). Combining scenario storylines and quantitative information is also a basis for the pathways themselves (O'Neill et al., 2013), forming an iterative foundation that supports climate risk storyline development (Kok et al., 2019).

Climate models commonly underpin efforts to develop regional climate projections in attempts to quantify some of the uncertainties (Mach & Field, 2017). This is limited when fundamental climate features such as global circulation, for example, are themselves highly variable and uncertain (Shepherd, 2019) and some processes are not well enough understood to reduce uncertainty (Risbey & O'Kane, 2011). This approach also has limited efficacy when such calculations are not possible (Hazeleger et al., 2015), or when climate impacts will result from unprecedented or low-probability events (Wright, Cairns, O'Brien, & Goodwin, 2019). Storylines can be usefully applied to moderate different sources of uncertainty found in both climate narratives and models (Pedde et al., 2018).

Analytic approaches to understand climate risk are evolving as observations of unprecedented weather events become more common (Oliver et al., 2017) and complex connections between changes in both climate and society add to deep uncertainty for

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

decision-makers (Sharmina et al., 2019). In hydrology for example, rather than following climate model-based scenarios, a scenario-neutral approach can use meteorological data over a time series to explore system sensitivities and assess impact thresholds (Keller, Rössler, Martius, & Weingartner, 2019). Rather than base impact assessments on climate scenarios, a scenario-neutral approach explores factors such as climate sensitivity of a system to consider where critical impact thresholds may be exceeded under future climate conditions (Keller et al., 2019). This approach is useful in bottom-up and vulnerability driven climate impact assessments. As attention turns to the evolution and consequences of severe weather events, it becomes increasingly important to understand how and why they unfold as they do (Trenberth, Fasullo, & Shepherd, 2015).

CR storylines are anchored to the physical expression of climate events over a nominated time and scale. The climate risk storyline method is emerging as a process that facilitates research and knowledge exchange to assess climate risk through causal links rather than focus on the probability of occurrence (de Bruijn et al., 2016; Shepherd et al., 2018). These climate risk storylines build on understanding of physical processes as the basis for confidence in plausible future climates (Dessai et al., 2018; Hazeleger et al., 2015; Shepherd et al., 2018).

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

3. Guidelines

This document began with a Short Guide to Climate Storyline Development which illustrates the sequence in five overlapping steps in Figure 2. These guidelines expand that information, illustrating in Figure 3, the centrality of the storylines to the process and in Figure 4, how storyline development aligns to the phases of Initiation, Research and Analysis.

Storyline methods offer flexibility depending on both the physical climate processes in question and the associated risks of particular interest. Key requirements common to the development of climate risk storylines are that they be based on evidence and a causal chain, include combined knowledge sources, and provide a decision-relevant narrative (Shepherd et al., 2018) that is robust, actionable, trustworthy, and reliable (Hazeleger et al., 2015). In RECEIPT, storylines are the result of co-production (Meadow et al., 2015) between researchers and stakeholders. The scientifically based and stakeholder-oriented storylines relationship is illustrated in Figure 3, where co-production of storylines links all inputs.

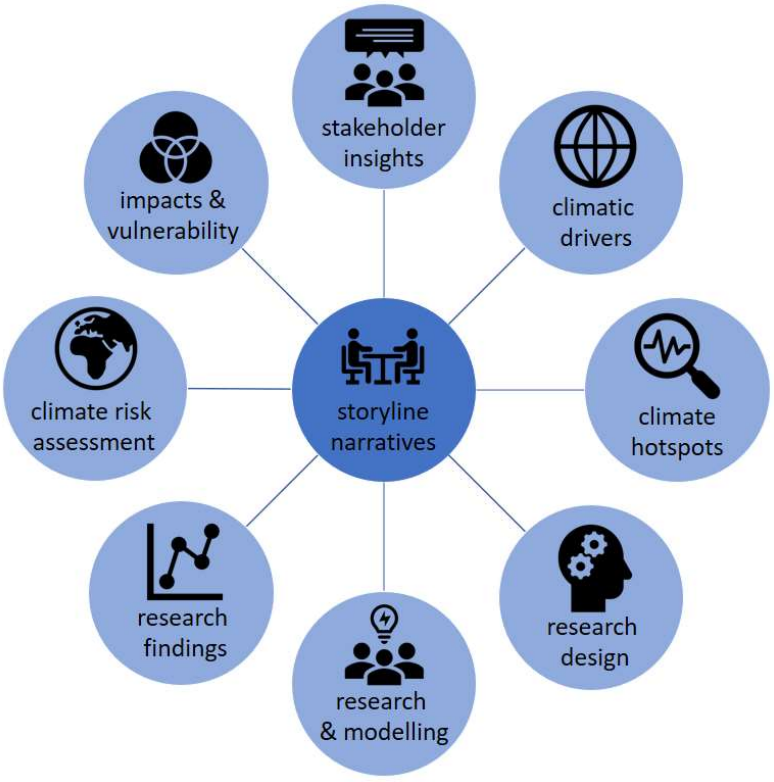

Figure 3 Illustration of storyline narratives as central to scientifically based and stakeholder-oriented development.

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

Over the lifespan of the RECEIPT project, the progress of storyline production will have different areas of focus. This is illustrated in Figure 4 through stages of Initiation, Research and Analysis. This research co-design informs the research program, resulting in climate risk storyline narratives.

- Initiation: climatic drivers are assessed to identify climate hotspots likely to affect the EU. Interviews and workshops with stakeholders indicate which impacts, vulnerabilities and non-climatic drivers are of interest to inform the research design.
- Research: the prioritized hotspots are investigated based on relevant (and varying) climate and socio-economic drivers, and outputs are contextualized considering stakeholder insights to provide a practice-oriented interpretation and better inform further research.
- Analysis: climate research and stakeholder insights inform the causal chains underpinning climate risk which are developed into storyline narratives. A synthesis of sectoral climate change impacts will take place to construct a comprehensive risk analysis.

Storylines can also contain more detailed and divergent 'micro storylines' to address uncertainty through a range of plausible (Serrao-Neumann, Schuch, Cox, & Low Choy, 2019; Shepherd et al., 2018) and counterfactual (Huybrechts, Hendriks, & Martens, 2017; Woo, Maynard, & Seria, 2017) alternatives. In addition, guiding questions such as those offered in Table 1 may be reconsidered throughout the storyline development to reflect on the process and continue to incorporate new knowledge as it is developed.

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

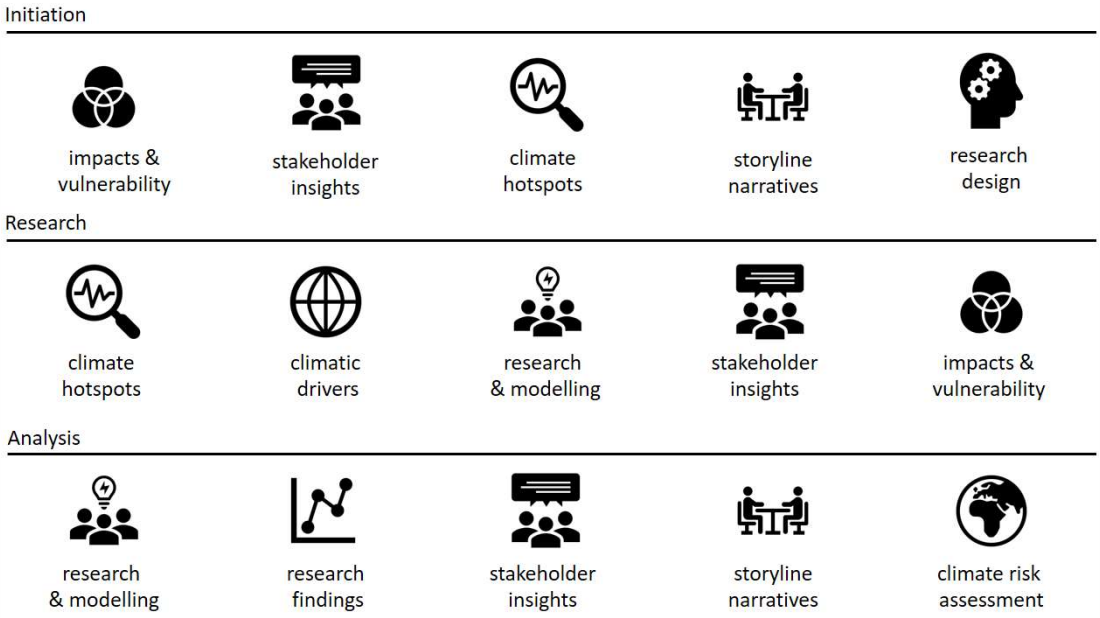

Figure 4 Illustration of the stakeholder-oriented and scientifically based storylines process as it is expected to unfold through the RECEIPT project, which involves continuous iteration between the steps in Table 1.

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

3.1. Stakeholder Engagement

Preliminary identification of some climate hotspots can be used to define focal areas for storyline development by linking research and model capacity with risks identified by stakeholders. Using these risks as a starting point, stakeholders in each of the five sectors mentioned above can be engaged with researchers and work together to understand what information can be co-created (Bremer et al., 2019) and how it might represent key factors that are not climate driven (Pereira, Sitas, Ravera, Jiménez-Aceituno, & Merrie, 2019). Care must be taken to maintain a balance in stakeholder input across the full engagement process from stakeholder selection, to developing semi-structured interview and workshop procedures, and explicitly documenting any observed biases during the elicitation process. Practice is best guided by using a recognized formal elicitation method such as Sheffield (Dessai et al., 2018), Delphi (Wright et al., 2019) or Cooke (Slottje, van der Sluijs, & Knol, 2008). A generic agenda that could be tailored to suit a one day stakeholder engagement workshop is included in the appendix. RECEIPT has an agreed Stakeholder Interaction Protocol (Coulter & Dessai, 2020)which should be referenced to guide ethical practices in recruitment, workshop participation and data storage.

3.2. Documentation

The importance of documentation cannot be overstated as a foundation to robust and reproducible storylines. The development of climate risk storylines requires a series of research design decisions and choices that must be transparent and scientifically defendable to ensure trustworthy results (Shepherd, 2019). Climate risk storylines are evidence-based, and therefore the evidence chain has to be strong and traceable. The documentation of storyline development should be focused and clear, ensuring transferability and accountability by describing the provenance of all significant arguments, assumptions and models. More detail is needed in some cases, such as what steps are taken to transition between quantified and narrative information (O'Neill et al., 2019), or to justify the choice for particular storyline elements or perturbations.

3.3. Analytic approaches

Climate risk storylines are expressions of evidence-based causal chains that include knowledge of physical climate processes. Storylines can be developed from analytic outputs in the forms of numeric and quantitative information and qualitative narrative sources,

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

including scenarios. While similar to the story and simulation (SAS) approach where scenarios underpin the storylines (Alcamo, 2001; van Vliet, Kok, & Veldkamp, 2010), climate risk storylines differ by their independence from scenarios (Shepherd, 2019), while retaining the ability to include scenarios as a potential input. To support peer review, reasoning behind choices in research design must be included in documentation to clarify connections between analytic modes. As illustrated in the cases below, analytic methods are chosen to fit information needs and research capacity to address particular scientific and adaptation challenges.

3.4. Causal chains

Many factors affect risk in the EU without forming direct cause and effect chains. Stochastic events play a role in physical and social systems where diversity in behavior and policy interventions can change outcomes (Pereira et al., 2019). In addition, the 'coevolution' of variables affecting outcomes means that deep uncertainty will remain in future risks and specific outcomes cannot be determined in advance (Sharmina et al., 2019). Therefore, storylines also include non-climatic factors and limit the length of causal chains when establishing causal roles and linking global to regional scales (Sillmann et al., 2019). Linking causal chains can help make explicit where controls for confounding factors are applied through conditioning and necessary causation (Shepherd, 2019). Carefully selected or specifically developed frameworks can facilitate selecting what simulation information to combine with sources such as expert elicitation, to develop storylines useful to inform decision-making. At the same time, storylines must be explicit about accounting for randomness in complex systems and define boundaries for what is counted as causal (Pedde et al., 2018). Documentation supporting research choices must be sufficient to enable reproducibility and inform the application of results.

3.5. Comparing different perturbations

A central element in the RECEIPT approach is the comparison of multiple parallel storylines that are mutually perturbed to express the impact of climate change features on the causal chain. Typically, a "current climate" risk storyline will map the chain of consequences resulting from a remote climatic hazard and transfer these to a European sector via the socio-economic pathways initiated from the remote domain. Storylines are assessed for three different "Paris" scenarios ranging from an ambitious Paris agreement implementation to a

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

high-end scenario with severe and continuously worsening climate effects requiring massive investment in adaptation. A perturbation of the climate feature will be applied that is related to a given alternative climate (or socio-economic) scenario (Shepherd, 2019).

A collection of these perturbations, and their comparison to the reference storyline, allows the evaluation of the scenario dependence of the sensitivity of European socio-economic sectors to remote climate hotspots. This comparison requires a setting in which the storyline is captured in a reproducible reproduction framework: a logical and scripted sequence of events, typically embedded in a model simulation. Perturbations to components of the simulations need to be applied and traced up to their European socio-economic impact.

3.6. Visualisation

Narratives aid in visualizing elements of our experience such as change and time, making risks more concrete so that decision-makers can visualize them and their implications (Wright et al., 2019). RECEIPT takes visualization a step further by developing visualization communication tools that enable stakeholders to more easily use the risk information (Bremer et al., 2019). Across RECEIPT, approaches will vary depending on thematic area data and documentation which will contribute to visualizations showing the backgrounds and impacts of the CR storylines.

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

4. Exemplar Climate Risk Storylines

The following are examples of climate risk storylines that have been published in peer reviewed journals. The examples demonstrate the process of developing storylines rather than focus on remote climate impacts on the EU. The first paper addresses linked factors that have led to past alpine flooding events through five specific storylines, based on meteorological data and observations. In the second paper, authors extend their storyline analysis to address the sequencing and consequences of low land flooding events and reflect stakeholder participation. The third example demonstrates the incorporation of expert elicitation to refine modeling requirements and improve assessments of uncertainty for decision makers.

4.1. Hydrology Example: Weather data informing Alpine flooding

Delineation of flood generating processes and their hydrological response (Keller et al., 2018)

Identified need: Flood planning **-** For decision makers to take into account likely impacts from changes in daily patterns of meteorological and catchment conditions it is useful to understand the processes that generate floods in a particular catchment.

Analytic approach: Framed in a scenario-neutral approach, a bottom-up cluster analysis based on daily data was used to identify types of processes that led to flood generation.

Climate Risk Storylines: Five physical storylines can be constructed that describe causal patterns of meteorological and catchment state conditions leading to a flood event. This information is useful to select the most appropriate downscaling methods for climate projections to account for significant combinations of variables. The event groups have distinct hydrological characteristics, largely explained by the properties of each storyline. These storylines require more context to be usefully communicated as climate narratives to non-technical decision-makers.

1. long duration, low intensity precipitation events with high catchment precipitation depths,
2. long duration precipitation events plus high precipitation depths & episodes of high intensities,
3. shorter duration events with high precipitation intensity,

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

4. shorter duration events with low precipitation intensity, and
5. rain-on-snow events.

Response actions: The analysis in this study did not extend to flood consequences and management strategies and no user participation was reported.

4.2. Flood Management Example: Sequence of events during a flood

The storyline approach: a new way to analyse and improve flood event management (de Bruijn et al., 2016)

Identified need:

The island of Dordrecht in the Netherlands sometimes experiences flooding from both high river discharges and storm surges which are projected to increase and combine with climate change. Better information about the sequence of events is needed to evaluate potential trade-offs that decision makers must consider when planning to protect critical infrastructure and human safety.

Analytic approach:

Storyline development followed four steps: system description, selection of draft storylines, developing the storylines and analysis of the storyline impacts. Physical and societal characteristics informed modelling of potential flood patterns to develop two storylines based on simulations and expert elicitation. Expertise in flood event management and the analysis of critical infrastructure vulnerability contributed to the co-production process which developed a third storyline to reflect a new flood risk management strategy.

Climate Risk Storylines:

1. A breach along the 'Kildijk' (west side), which threatens the north-west of the island
2. A breach near the 'Kop van 't Land' (east side), which results in the flooding of the whole northern part of the island.
3. The same breach location as the first storyline, but now with shelters and adequate emergency plans in place. The water system, national warnings and flood pattern are unchanged. However, authorities and other actors are better prepared and know what might happen.

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

Response actions: In this paper, the analysis extended to account for damage and fatalities consequent to the flood events. These were assessed with the Dutch Standard Damage and Fatality model to summarize the damage, number of fatalities and affected persons. This informed elements that could be included in a future flood risk management strategy, pending a full risk and cost analysis.

4.3. Regional Climate Example: Narratives to characterise uncertainty

Building narratives to characterise uncertainty in regional climate change through expert elicitation (Dessai et al., 2018)

Identified need:

Identifying the key processes controlling and influencing the Indian Summer Monsoon (ISM) in the Cauvery river basin in Karnataka (CRBK) serves as an input to climate change risk assessments informing adaptation decisions. Current practice in using climate models tends to underestimate uncertainty or provide no guidance to interpret resulting ranges of uncertainty.

Analytic approach:

Elicitation techniques provided expert knowledge from climate scientists to assess uncertainties in plausible drivers for changes in the Monsoon for CRBK. Expert knowledge of climate processes was used to construct climate risk storylines of how regional climate could change between now and the 2050s in the river basin.

Climate Risk Storylines:

In the CRBK, the most important driver of ISM precipitation was the flow of moisture over the Western Ghats. Four major storylines described future evolution of the ISM through positive or negative changes in two factors; moisture availability and strength of flow coming towards southern India. Their relative dominance will determine the amount of precipitation and for each combination, the underlying plausible processes were explored.

Response actions: Knowledge from this study was applied to improve assessments of climate uncertainty that are considered in water use planning.

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

5. References

Alcamo, J. (2001). *Scenarios as tools for international environmental assessment: Environmental Issue Report No. 24*. European Environment Agency (EEA), Copenhagen, Denmark.

Bremer, S., Wardekker, A., Dessai, S., Sobolowski, S., Slaattelid, R., & van der Sluijs, J. (2019). Toward a multi-faceted conception of co-production of climate services. *Climate Services, 13*, 42-50. doi:10.1016/j.cliser.2019.01.003

Coulter, L., & Dessai, S. (2020). *Stakeholder interaction protocol: Including consent form*. Retrieved from RECEIPT:

de Bruijn, K. M., Lips, N., Gersonius, B., & Middelkoop, H. (2016). The storyline approach: a new way to analyse and improve flood event management. *Natural Hazards, 81*(1), 99-121. doi:10.1007/s11069-015-2074-2

Dessai, S., Bhave, A., Birch, C., Conway, D., Garcia-Carreras, L., Gosling, J. P., . . . Stainforth, D. (2018). Building narratives to characterise uncertainty in regional climate change through expert elicitation. *Environmental Research Letters, 13*(7). doi:10.1088/1748-9326/aabcdd

Girod, B., Wiek, A., Mieg, H., & Hulme, M. (2009). The evolution of the IPCC's emissions scenarios. *Environmental Science & Policy, 12*(2), 103-118. doi:10.1016/j.envsci.2008.12.006

Hazeleger, W., van den Hurk, B. J. J. M., Min, E., van Oldenborgh, G. J., Petersen, A. C., Stainforth, D. A., . . . Smith, L. A. (2015). Tales of future weather. *Nature Climate Change, 5*(2), 107-113. doi:10.1038/nclimate2450

Huybrechts, L., Hendriks, N., & Martens, S. (2017). Counterfactual scripting: challenging the temporality of participation. *CoDesign, 13*(2), 96-109. doi:10.1080/15710882.2017.1309438

IPCC. (2018). *Global Warming of 1.5°C. An IPCC Special Report*. Retrieved from https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_Low_Res.pdf

Keller, L., Rössler, O., Martius, O., & Weingartner, R. (2018). Delineation of flood generating processes and their hydrological response. *Hydrological Processes, 32*(2), 228-240. doi:10.1002/hyp.11407

Keller, L., Rössler, O., Martius, O., & Weingartner, R. (2019). Comparison of scenario-neutral approaches for estimation of climate change impacts on flood characteristics. *Hydrological Processes, 33*(4), 535-550. doi:10.1002/hyp.13341

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

Kok, K., Pedde, S., Gramberger, M., Harrison, P. A., & Holman, I. P. (2019). New European socio-economic scenarios for climate change research: operationalising concepts to extend the shared socio-economic pathways. *Regional Environmental Change, 19*(3), 643-654. doi:10.1007/s10113-018-1400-0

Mach, K. J., & Field, C. B. (2017). Toward the Next Generation of Assessment. *Annual Review of Environment and Resources, 42*(1), 569-597. doi:10.1146/annurev-environ-102016-061007

Meadow, A. M., Ferguson, D. B., Guido, Z., Horangic, A., Owen, G., & Wall, T. (2015). Moving toward the Deliberate Coproduction of Climate Science Knowledge. *Weather, Climate, and Society, 7*(2), 179-191. doi:10.1175/wcas-d-14-00050.1

O'Neill, B. C., Conde, C., Ebi, K., Friedlingstein, P., Fuglestvedt, J., Hasegawa, T., . . . van Vuuren, D. (2019). *Forum on Scenarios of Climate and Societal Futures: Meeting Report. Pardee Center Working Paper 2019.10.04*. Retrieved from University of Denver, Denver, CO.: https://pardee.du.edu/forum-scenarios-climate-and-societal-futures-meeting-report

O'Neill, B. C., Kriegler, E., Riahi, K., Ebi, K. L., Hallegatte, S., Carter, T. R., . . . van Vuuren, D. P. (2013). A new scenario framework for climate change research: the concept of shared socioeconomic pathways. *Climatic Change, 122*(3), 387-400. doi:10.1007/s10584-013-0905-2

Oliver, E. C. J., Benthuysen, J. A., Bindoff, N. L., Hobday, A. J., Holbrook, N. J., Mundy, C. N., & Perkins-Kirkpatrick, S. E. (2017). The unprecedented 2015/16 Tasman Sea marine heatwave. *Nat Commun, 8*, 16101. doi:10.1038/ncomms16101

Pedde, S., Kok, K., Onigkeit, J., Brown, C., Holman, I., & Harrison, P. A. (2018). Bridging uncertainty concepts across narratives and simulations in environmental scenarios. *Regional Environmental Change, 19*(3), 655-666. doi:10.1007/s10113-018-1338-2

Pereira, L., Sitas, N., Ravera, F., Jiménez-Aceituno, A., & Merrie, A. (2019). Building capacities for transformative change towards sustainability: Imagination in Intergovernmental Science-Policy Scenario Processes. *Elementa : Science Of The Anthropocene, 7*(1). doi:10.1525/elementa.374

Risbey, J. S., & O'Kane, T. J. (2011). Sources of knowledge and ignorance in climate research. *Climatic Change, 108*(4), 755-773. doi:10.1007/s10584-011-0186-6

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

Serrao-Neumann, S., Schuch, G., Cox, M., & Low Choy, D. (2019). Scenario planning for climate change adaptation for natural resource management: Insights from the Australian East Coast Cluster. *Ecosystem Services, 38*. doi:10.1016/j.ecoser.2019.100967

Sharmina, M., Abi Ghanem, D., Browne, A. L., Hall, S. M., Mylan, J., Petrova, S., & Wood, R. (2019). Envisioning surprises: How social sciences could help models represent 'deep uncertainty' in future energy and water demand. *Energy Research & Social Science, 50*, 18-28. doi:10.1016/j.erss.2018.11.008

Shepherd, T. G. (2019). Storyline approach to the construction of regional climate change information. *Proceedings of the Royal Society a-Mathematical Physical and Engineering Sciences, 475*(2225). doi:10.1098/rspa.2019.0013

Shepherd, T. G., Boyd, E., Calel, R. A., Chapman, S. C., Dessai, S., Dima-West, I. M., . . . Zenghelis, D. A. (2018). Storylines: an alternative approach to representing uncertainty in physical aspects of climate change. *Clim Change, 151*(3), 555-571. doi:10.1007/s10584-018-2317-9

Sillmann, J., Shepherd, T., van den Hurk, B., Hazeleger, W., Martius, O., & Zscheischler, J. (2019). *Workshop Final Report: Physical modeling supporting a storyline approach*. Retrieved from Oslo, Norway https://www.cicero.oslo.no/en/publications-and-events_twex/workshop-on-physical-modelingsupporting-a-storyline-approach

Slottje, P., van der Sluijs, J., & Knol, A. B. (2008). Expert Elicitation: Methodological suggestions for its use in environmental health impact assessments. In: National Institute for Public Health and the Environment.

Trenberth, K. E., Fasullo, J. T., & Shepherd, T. G. (2015). Attribution of climate extreme events. *Nature Climate Change, 5*(8), 725-730. doi:10.1038/nclimate2657

van Vliet, M., Kok, K., & Veldkamp, T. (2010). Linking stakeholders and modellers in scenario studies: The use of Fuzzy Cognitive Maps as a communication and learning tool. *Futures, 42*(1), 1-14. doi:10.1016/j.futures.2009.08.005

Woo, G., Maynard, T., & Seria, J. (2017). *Reimagining history: counterfactual risk analysis*. London: Lloyd's.

Wright, G., Cairns, G., O'Brien, F. A., & Goodwin, P. (2019). Scenario analysis to support decision making in addressing wicked problems: Pitfalls and potential. *European Journal of Operational Research, 278*(1), 3-19. doi:10.1016/j.ejor.2018.08.035

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

Appendix: RECEIPT Stakeholder Workshop Generic Agenda

Aim: co-create climate risk storylines between societal and scientific partners

- Understand climate risk perception of sector stakeholders
- Identify significant climate vulnerabilities and risks to sector stakeholders
- Identify needs for climate data, information and analysis to respond to climate risks (explore existing and desired information systems)

Time	What	Facilitator	Facilitator notes
Morning 9:00 - 9:30	Arrival with coffee and tea Welcome and registration	All, Societal partner (SP)	Active participants are those in WP and stakeholders (other attendees-facilitators and observers-different coloured name badges?)
9:30 - 10:00	• Welcome • Expectations* • Round of Introductions (Ice breaker?)	SP	*what stakeholders get (novel assessment of sectoral climate risk) and what stakeholders give (knowledge & expertise on sectoral linkages and vulnerabilities).
10:00 - 10:30	• RECEIPT context: Scope & storyline approach • Modelling capability context: WP key issues, timescale, scenario's, averages & extremes • Climate change context: selected RCP8.5 projections to 2050 for sample hotspot	Deltares WP researcher	It would be good to keep the context setting as concise as practical to focus on stakeholder knowledge. Mention poster of RECEIPT and risk terms for reference
10:30 - 11:00	• Sectoral context: Key issues and Climate Change (7.5m) • Current understanding of Regional hotspots, crop vulnerability (7.5m) • Participant Feedback (15m)	SP WP researcher	After brief presentation (e.g. quantity of commodity, price, livelihoods, etc.), move to discussion format to identify a consensus view on workshop focus ('unit of analysis') considering remote impacts link to EU socio-economic impacts. This is important focus for remaining workshop.

Time	What	Facilitator	Facilitator notes
11:00 - 11:15	Coffee break	SP	Just time for coffees & hellos
11:15 - 11:30	Very brief re-cap of RECEIPT core concepts and agreed measures of success/risk (Volume, loss and damage cost, profitability …)	SP or WP2	Cover climate vulnerability and risk, remote climate effects, drivers of vulnerability and risk, hotspot, storyline (remind of poster reference)
11:30 - 12:30	Vulnerabilities, hotspots and climate connections (sample focus questions) 1. Overall, what creates vulnerabilities & risks to key sector in the EU? 2. Rate those risks that are weather /climate sensitive (scale 0-5; zero not sensitive; five very sensitive). 3. Highlight on a map regions that are important for sector related to the EU. 4. What weather/climate extremes and changes have already impacted key sector systems? 5. Groups: select a weather/climate event & describe how it affected the sector. 6. What vulnerabilities and risks might have the biggest impacts on key issues? 7. What regions might become more important to the sector due to climate or social change over the next 30 years ?	SP or WP2	When questions are finalized, address points 1-4 in plenary, points 5-7 in pairs or small participant groups which report back to wider group to consolidate] 20m plenary 15m pair work 15m feedback 10m consolidation This session can inform group work in the afternoon (links to part A of Systemic Risks)
12: 30 - 13:30	Lunch		

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

Time	What	Facilitator	Facilitator notes
Afternoon 13:30 - 14:00	How to construct storylines for plausible risks, linking knowledge, data, analysis and options. Sample storyline using selected hotspot projections to 2050 for climate context. Ask for stories from the audience: Trigger question - how have they experienced climate risk/impact? (15m)	WPL or WP2 WPL SP	WPL briefly shows how a storyline is constructed WPL shows a plausible storyline with a sample hotspot and event Bulk of session captures participant's first thoughts on storylines they experienced.
14:00 - 15:00	Mapping climate risk and impact on key issues: Storyline exploration Small groups develop 1-2 major storylines linking climate risks, impacts on key sector vulnerabilities, linkages and options as general cause-effect relationships	SP or WP2	Storyline exploration: small groups put together the elements discussed in the morning in cause-effect chains, focus on key issues with strong impacts linked to the EU. Max. of 1-2 main storylines per group. Use side notes from comments to develop micro storylines if there is time.
15:00 - 15:15	Coffee break		
15:15 - 15:45	Each group presents major storyline narratives • Identify similarities and differences in light of side notes for micro storylines • Group post-it votes, then discussion narrows major driving forces to 2-4 (including climate) • Discuss incorporating storyline information	SP WPL	Each group presents storylines developed. Focus on identifying similarities and differences to narrow consensus to construct a small number of storylines. Discuss modelling capability and potential evolution of driving forces
15:45 - 16.45	Systemic Risk Session - part D • Identification of data availability and uncertainty about variables/interlinkages • Future modelling opportunities; combine with expert validation.	IIASA	Formatted by WP8 to suit sector and focus
16:45 - 17:00	Next steps and expectations / Wrap up	SP	
17:00	Casual social time		

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712

Receipt

climatestorylines.eu
RECEIPT_eu

RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712