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ABSTRACT

In the face of climate change, a major challenge is to inform and guide long-term climate change adaptation planning under deep uncertainty, while aiming at transformative change. Normative futures studies approaches, such as participatory backcasting, visioning and transition management, are increasingly applied, but their potential for climate change adaptation research and practice remains undervalued. This paper aims to advance the potential of backcasting in climate adaptation, by comparing various climate change adaptation studies that have used backcasting or visioning approaches. A framework has been further developed and applied to evaluate 10 cases in Africa, Europe and North America, using four dimensions: (i) inputs and settings; (ii) process and methods (iii) results, and (iv), impact. Our evaluation provides key insights into the use and further development of backcasting for climate adaptation. Key elements to add are advanced system modeling, robust elements, pathway switching and hybrid pathways, enhancing participation of marginal groups, and contributing to impact by facilitating the utilization of results and knowledge in practice and decision making.

1. Introduction

Due to climate change and the associated impacts of extreme weather events, floods and droughts observed in all continents (IPCC, 2022), a major challenge is to inform and guide long-term climate change mitigation and adaptation planning under deep uncertainty (Haasnoot, 2013; Lempert and Groves, 2010; Lempert and Schlesinger, 2000; Van der Voorn et al., 2017). In the pursuit of the Paris Agreement, countries have not only agreed on limiting global temperature increase to 1.5 °C above pre-industrial levels (Hooper et al. 2018) by reducing carbon emissions, commonly referred to as climate mitigation, but also to strengthen the global climate change

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response by increasing the ability of society to adapt to adverse impacts of climate change and foster climate resilience, referred to as climate adaptation.

However, climate adaptation and mitigation have been criticized for focusing more on adaptive change rather than transformative change and for neglecting the potential of normative approaches (Nalau and Cobb 2022). Transformative change entails reducing the root causes of vulnerability to climate change in the long-term by shifting systems away from unsustainable or undesirable trajectories (Fedele et al. 2019). After Park et al. (2012), we define transformative change as a process that fundamentally (but not necessarily irreversibly) results in change in the biophysical social or economic components of a system from one form function or location (state) to another thereby enhancing the capacity for desired systems states to be achieved given perceived or real changes in the present or future environment.

Without transformative change, climate adaptation runs the risk of focusing on incremental changes in adaptation to climate change, rather than achieving radical system change for transformative adaptation (Holden et al. 2016). Transformative change involves transformative and incremental adaptation as long as they are on the same path towards climate resilience (Wilson et al. 2013; Patterson et al. 2016). Nevertheless, due to the focus on transformative change and normative futures, climate change adaptation could obviously benefit from envisioning climate change adaptation futures, including exploring what decisions can move us towards these futures (Nalau and Cobb, 2022; Van der Voorn et al., 2017).

Normative futures studies approaches, such as backcasting, are useful in engaging stakeholders in the co-creation of climate change adaptation futures (Nalau and Cobb 2022). Backcasting is particularly useful for addressing different stakeholder interests, perceptions and perspectives to inform climate decision making and establish stakeholder support and commitment for climate adaptation that are guided by adaptation pathways (Bukvic and Harrald, 2019; Van der Voorn et al., 2017). Backcasting supports envisioning alternative futures and exploring which options and adaptation pathways enables us to reach the desired futures, which may add value to pathways approaches for adaptation planning like (Wise et al. 2014, Butler et al. 2016, Star et al. 2016, Pandey et al. 2021, Vizinho et al. 2021, Werners et al. 2021, See et al., 2022). Backcasting is also beneficiary for social learning, enabling stakeholders to explore and open up a possibility space for empowering transformative climate adaptation to reach desired impact, as acknowledged in recent studies on transformative climate adaptation (Lonsdale et al., 2015, Holden et al. 2016, Mendizabal et al. 2021). Due to its compatibility with various types of tools and methods, backcasting has potential to address climate uncertainties in long-term decision making on climate adaptation (Van der Voorn et al., 2017).

Compared to forecasting and exploratory scenario approaches, participatory backcasting and related vision-oriented normative approaches are the least applied futures approach in climate change adaptation planning (van der Voorn, 2012; Van der Voorn et al., 2017). Backcasting can be defined as generating a desirable future, and then looking backwards from that future to the present in order to strategize and to plan how it could be achieved (Quist and Vergragt, 2006; Quist, 2007).

A recent review by Nalau and Cobb (2022) shows that normative approaches are applied to climate adaptation but involve mainly visioning rather than backcasting. We define visioning as the process of creating a vision, as a representation of a desirable future state (Wiek and Iwaniec, 2013), which is also a key step in backcasting. In this paper we focus on backcasting approaches and their potential for use in climate adaptation research, as there is little research applying backcasting to climate adaptation (see section 2.1).

Backcasting for climate adaptation can draw from the substantive literature of backcasting on other topics (for overviews, see (Quist and Vergragt 2006, Bibri 2018). It can also benefit from backcasting for climate mitigation and climate related topics, e.g. urban climate adaptation (Carlsson-Kanyama et al., 2013), flood management (Sheppard et al. 2011), adaptive water management (van Vliet and Kok 2015). Moreover, a large variety and diversity in backcasting studies and methodologies can be found in the recent literature, which reflects the different ways in which backcasting traditions and practices have evolved over time (Vergragt and Quist 2011). Backcasting for climate adaptation may also benefit from related approaches, such as transition management (Loorbach et al. 2017) and visioning for climate adaptation (Nalau and Cobb 2022), which also use stakeholder engagement, future visions and pathways. Nevertheless, the relevance of backcasting for climate adaptation remains an under researched topic.

The aim of backcasting for long-term climate adaptation is to develop long-term visions and robust adaptation pathways that could lead to such visions in a participatory manner. In contrast to other futures methods, focusing on likely or possible futures, the key distinction with backcasting is its explicit normative nature, based on setting normative goals and envisioning (un)desirable but radically different futures, by thinking radically different about these futures and exploring how the required changes can be achieved incrementally. According to Dreborg (1996), backcasting is particularly useful when applied to complex and persistent problems, when dominant trends (climate change) are part of the problem, when externalities are at play, when there is a need for major change and when time horizon and scope allow development of radical alternative options. Climate adaptation obviously combines all these characteristics.

A key question that needs further investigation is: how to advance backcasting for climate adaptation? We therefore aim to investigate what is needed to apply backcasting to climate adaptation, making use of widely acknowledged strengths of backcasting as well as to identify elements that could add value for the topic of climate adaptation.

For this purpose, we have conducted a comparative study that complements other recent review efforts that focus on visioning (Nalau and Cobb 2022). We have done a systematic comparison of selected participatory backcasting studies on climate adaption to identify key insights and findings and to better understand under what conditions these approaches can be applied to reach impact. An existing framework has been refined and further developed before applying it to this comparative study with 10 cases in Africa, Europe and North America. The framework uses four dimensions: (i) inputs and project settings, and (ii) process, stakeholder engagement and methods, leading to (iii) results, including visions, scenarios and pathways, and (iv), impacts, including use of results and longer-lasting effects. Our study provides in depth insight into key aspects of backcasting studies. Moreover, we also looked into what approaches have been applied in different contexts?

This article proceeds as follows. Section 2 briefly describes recent progress in the use of backcasting approaches. Section 3 presents the research methodology and evaluation framework applied. Section 4 presents the case results. In Section 5, we discuss key insights and findings from the usage of backcasting and visioning approaches applied for climate change adaptation planning in the selected cases. We identify potential avenues for further methodological advancement. In Section 6, we present concluding remarks.

2. Backcasting for climate adaptation

2.1. The current progress in the use of backcasting for climate research

To assess progress in the use of backcasting for climate research, we conducted a quick bibliometric analysis of publications using the SCOPUS database (see Table 1). A search query with the keywords "backcasting" and "climate adaptation" results in just a few publications. Adding "OR adaptation" in the query leads to a larger variety of backcasting studies across various domains and sectors, addressing climate-related topics, but also bringing in less relevant studies.

The first query shows that backcasting has been applied in the field of climate adaptation, but there are few studies (4 records) where backcasting has been explicitly applied for climate adaptation (Jiricka-Pürrer, 2019; Roggema, 2021; van der Voorn, 2012; Van der Voorn et al., 2017). For example, Van der Voorn et al. (2012) proposed a methodology for how backcasting in combination with adaptive management could be used for implementing adaptation strategies and policies, with an example from South Africa. Van der Voorn et al. (2017) evaluated three cases on vision-based approaches for climate adaptation in coastal regions in three continents. The second query shows a larger number of backcasting studies (26 records) showing diversity across various domains and sectors, addressing climate-related topics.

The third query highlights that quite a few backcasting studies (25 records) focus on low-carbon futures and climate change mitigation. Banister and Hickman (2013), for instance, applied different backcasting scenarios to explore potential transport futures. The fourth query results in 134 studies, linking backcasting to other kinds of climate-related topics. Grêt-Regamey and Brunner (2011), for example, suggested a methodological framework for backcasting to support spatial adaptation to predicted climate change. In addition, the fifth query identifies 109 studies using visioning, but sometimes without explicitly referring to the term backcasting. Nalau and Cobb (2022) reviewed the current progress in the use of visioning approaches for climate adaptation. Their review includes cases on visioning, with a few as part of a backcasting approach. Finally, there is some overlap between the fifth and sixth query, showing six studies mentioning both visioning and backcasting for climate adaptation (2 studies) or mitigation (4 studies).

This quick bibliometric analysis shows that some papers report on the use of an explicit backcasting method, while others use the term visioning, without a clear reference to backcasting. Similarly, the terms backcasting and visioning are often used interchangeably in the literature. Backcasting refers to the entire methodology of which visioning is an integral part of the methodology. Despite the variety in the use of both terms, visioning and backcasting share a similar focus on long-term visions for change.

2.2. The relevance of visioning and impact

It has been argued that the impact of backcasting studies is key to making change happen, which is key to climate adaption studies as well (Van der Voorn et al., 2017). The same also applies to visioning studies. Recently, Nalau and Cobb (2022) have conducted a comprehensive review of how visioning is presently used in the field of climate change adaptation and identified where there is room for improvement. Their findings show that most visioning studies focus on the regional scale, involve mainly formal decision makers and employ a vast array of different methods, tools and data in the coproduction of futures. Predictive, exploratory and normative scenarios were used across all studies to support visioning. Compared to predictive and exploratory scenarios, normative scenarios were used the least but are highly suitable for addressing the potential to mobilize resources for future change (e.g., future water availability and access). Nalau and Cobb (ibid) also identified main constraints and enablers for visioning. For example, most studies did not report on learning processes to capture participant feedback, which is usually important for impact but could also enable more robust methodology development. A lack of stakeholder inclusion in terms of race, age, gender, education and professional background imposes a constraint on a representative co-development of futures. As pointed out by Nalau and Cobb (ibid:1), "*unintended and unexpected outcomes include increased anxiety in cases where introduced timeframes go beyond an individual's expected life span and decreased perceived necessity for undertaking adaptation at all*". Nalau and Cobb (ibid) also conclude that more explicit reporting on these constraints of the visioning process, a focus on transparent evaluation processes, diversity and inclusion of different viewpoints and interests as well as unintended and unexpected outcomes could improve visioning approaches.

Table 1
The results of the search queries in the SCOPUS database.

Search query	Records
TITLE-ABS-KEY ("backcasting" OR "back-casting" AND "climate adaptation")	4
TITLE-ABS-KEY ("backcasting" OR "back-casting") AND ("climate adaptation" OR "adaptation")	26
TITLE-ABS-KEY ("backcasting" OR "back-casting") AND ("climate mitigation" OR "mitigation")	25
TITLE-ABS-KEY ("backcasting" OR "back-casting") AND ("climate")	134
TITLE-ABS-KEY ("visioning") AND ("climate")	109
TITLE-ABS-KEY (("backcasting" OR "back-casting") AND "visioning") AND "climate"	6

Despite the relevance of impact, limited effort has been made to systematically evaluate the impact of backcasting studies, and more work is yet needed in order to improve the current and future backcasting practices (Vergragt and Quist 2011). Several authors like Quist (2007), Quist et al. (2011), and Van der Voorn et al. (2017) have developed frameworks for evaluating the impact of participatory backcasting studies, which offer relevance for framework development for impact evaluation in the context of climate adaptation.

In our study, we provide a more detailed and comprehensive analysis than the review by Nalau and Cobb (ibid), which focuses on visioning. Their aim was to distill key learning and general patterns across the growing literature on visioning for climate adaptation, revealing several key considerations that are fundamental in developing and conducting more robust visioning exercises for climate adaptation. Nalau and Cobb (ibid) guided their inquiry by straightforward questions like who is being involved in the studies, which tools, methods and data are most frequently used, and what are the key reported constraints, enablers and outcomes?

Through our study, we provide a complementary view to the Nalau and Cobb (2022) overview based on an in-depth case analysis, addressing how backcasting and visioning approaches could support dealing with climate uncertainties, stakeholder engagement in long-term climate adaptation planning and the use of various supporting tools and methods all of which influence the impact of backcasting studies. This offers a more comprehensive analysis of what factors constrain and enable participatory backcasting processes for climate adaptation and to what extent this leads to implementation and other impacts.

3. Framework and methodology

3.1. Analytical framework

For our comparative evaluation, we have adapted the framework by Van der Voorn et al. (2017), which builds on the evaluation frameworks developed by Quist (2007) and Quist et al. (2011), and propose four main dimensions along which backcasting studies for climate adaptation can be evaluated: (i) inputs & project settings, (ii) process and methods, (ii) results and (iv) impact of backcasting

Table 2
Evaluation criteria.

Dimension	Criteria	Score description
Inputs & project settings	Level of financial resources	0 = none; 0,33 = <10 k€; 100 k€ <; 0,67 = < 500 k€; 1 = >1M€
	Availability of knowledge & expertise	Yes /no
	Types of knowledge used	Scientific; contextual or interdisciplinary knowledge
	Presence of a commissioner	Yes/no
	Project duration	0 – 1 yr; 2—5 yr; > 5 yr
	Project goals	Content, process, methodological impact
Process & Methods Stakeholder engagement	Degree of stakeholder diversity	Degree of various stakeholder groups involved in the process (Out of 5 types distinguished: - business; research; government; civil society & ngo; citizens, including marginal groups? Low = (1 type); Medium = (3 out of 5 types); High = (all types)
	Degree of stakeholder influence	Low; Medium; High
	Presence of stakeholder involvement	Yes/no
	Presence of stakeholder commitment to results	Yes/no
Methods	Inclusion of various tools & methods	Examples of tools & methods for (i) analysis; (ii) Modelling and simulation; (iii) Design, scenario development, visioning, including process, model and system design; (iv) Stakeholder engagement and interaction; (v) Communication & dissemination
Results in backcasting studies	Presence of multiple visions	Yes/no
	Presence of transformative elements	Yes/no
Visions	Presence of goals & guiding targets?	No; partly = goals or targets; Yes = goals & targets
Pathway	Addressing uncertainties	Yes/no
	Inclusion of agency and measures	Yes/no
	Inclusion of robust elements	Yes/no
Scenarios	Inclusion of various types of uncertainties	Yes/no
	Types of scenarios	Qualitative or quantitative
	Scenario approach	Scenario-centered; Pathway-centered, Combinatory
Impact	Inclusion in formal decision making	Yes/no
	Examples of follow-up activities for implementation	Yes (what?)/no
	Examples of broader spin-off	Yes (what?)/no

studies.

As shown in Table 2, for each dimension we identify several evaluation criteria. These criteria allow for descriptive evaluation, but are here aggregated as scores on a three-point or five-point scale, or are dichotomously (yes or no). The dimensions are summarized below.

- **Dimension 1 on Inputs and project settings:** relates to different kinds of *inputs* allocated to backcasting for climate change adaptation, which involves the usage of different types of *knowledge* for vision, scenario and pathway development. Climate adaptation draws on various types of knowledge, which are valued to one another. Building on Van der Voorn et al. (2017), the availability of knowledge and expertise in the project is evaluated from the perspective of participation in the project consortium, as participants bring in knowledge.

This dimension also includes aspects regarding other project settings, such as the time duration of the project, design and goals of the project. An important aspect is the presence of a commissioner, who authorizes the project, has an interest in the results and may take care of follow-up. Building on Van der Voorn et al. (2017), the criteria for characterising inputs and resources in our evaluation are: (i) level of financial resources, (ii) presence of knowledge and expertise and (iii) types of knowledge, (iv) presence of commissioner, (v) project duration, (vi) project goals.

- **Dimension 2 on Process and methods:** addresses (i) key aspects of stakeholder engagement and (ii) applied methods. Stakeholders have different perceptions of problems and possible solutions, aspire different roles and may mobilize different resources to serve their interests. Stakeholder engagement improves the quality of the process and may lead to collective endorsement and implementation of the results generated in participatory backcasting studies. Quist (2007) and Quist (2013), building on Van de Kerkhof (2004), have used three levels of participation, clustering the eight levels from the participation ladder of Arnstein (1969). The level of participation reflects the degree of influence and involvement in the decision-making process. Stakeholder participation is important to account for stakeholders' knowledge and expertise and their different worldviews (Quist, 2007; van de Kerkhof et al. (2002).). The following criteria are used for evaluating stakeholder engagement (see Table 2): (i) Presence of stakeholder involvement?; (ii) Degree of stakeholder diversity (i.e. the different types of stakeholders involved, including business, research, government, civil society & ngo, and marginal groups); (iii) Presence of stakeholder commitment to the results?; and (iv) Degree of stakeholder influence.
- – This dimension is also used to evaluate the methodological diversity present in the cases for which several methodological criteria are used. Building on Quist et al. (2011) and Van der Voorn et al. (2017), the use of various types of tools and methods is evaluated as follows: (i) *analytical*, (ii) *modelling and simulation*, (iii) *design*, (iv) *stakeholder*, and (v) *communication & dissemination*. Participatory backcasting studies usually employ all five types of tools and methods (Van der Voorn et al., 2017, cf. Quist et al., 2011).
- **Dimension 3 on Results in backcasting studies:** distinguishes visions, pathway and scenario development. Building on Van der Voorn et al. (2017), visions are evaluated in terms of (i) the number of visions, (ii) inclusion of the *transformative elements* that set directions for adaptation, and (iii) *goals* and *guiding targets* related to these visions. Whereas goals articulate a desired change in general terms, guiding targets provide criteria that reflect measurable changes, such as 40% heat stress reduction.
- – Pathways, also building on Van der Voorn et al. (2017), are evaluated in terms of (i) *addressing uncertainties* about the implementation, (ii) *agency* (presence of actors with the capacity to contribute to or mobilize resources for goal fulfilment) and *adaptation measures* (physical, technological, social), and (iii) *robust elements*. Robust elements are pathway elements that allow for uncertainty management and pathway switching (van der Voorn et al. 2012; Haasnoot et al. 2013)
- – Scenarios are important because these can address (i) *uncertainties,* such as related to climate, social and political uncertainties (Kok et al. 2011, van Vliet and Kok 2015). Therefore, cases are also evaluated on (ii) *types of scenarios*: quantitative and qualitative and, (iii) *scenario*. Quantitative scenarios are usually based upon models or simulations, which have the advantage of providing transparent and comprehensive sets of assumptions in the form of model equations, model inputs and coefficients. Qualitative scenarios describe the changing context of a vision in words, narratives or visual symbols rather than numerical estimates. Such scenarios provide the context for (normative) visions. Scenarios can be used in different ways. A *scenario-centred* approach first develops (exploratory) scenarios, as a basis for and input to a quantitative model, which can be followed by a backcasting exercise. A *pathway-centered* approach first develops (normative) visions and pathways that can be subsequently tested by exposing them to different scenarios, possibly resulting in robust management options. A *combinatory approach* is when exploratory scenarios and (desirable) policy actions are combined. Scenarios are evaluated in terms of common characteristics such as the type of scenarios (qualitative or quantitative) and the types of usage of scenarios (scenario-centered, pathway-centered or combinatory).
- **Dimension 4 on Impact** addresses whether participatory backcasting studies lead to implementation, follow-up and spin-off (Quist, 2011; Van der Voorn et al., 2017). Impact is evaluated on (i) whether the results of the backcasting study was *included by formal decision making,* and examples of (ii) *follow-up* and implementation activities and (iii) broader *spin-off* in science (scientific debate and research), society (societal debate and initiatives) and, policy and practice (policymaking and application).

In this study we consider suitable assessment criteria of backcasting studies to evaluate sufficient inputs, favorable project settings, broad stakeholder engagement, and combining various types of tools and methods to achieve endorsed results that can contribute to long-term impact. Successful backcasting thus depends on various criteria from all dimensions of our framework. Moreover, we distinguish between conditional, result-oriented and impact-oriented criteria as follows. Conditional criteria refer to requirements for successful backcasting related to inputs, methods and stakeholder engagement. Result-oriented criteria reflect results in terms of visions, analyses, pathways and stakeholder commitment. Impact-oriented criteria reflect changes and impact achieved, but these can only be determined several years after completion of the backcasting study or even later.

3.2. Case selection and methodology

For our purpose, we conduct a multiple-case analysis that allows us to evaluate and compare backcasting studies within their own context, after which general patterns and conclusions can be drawn from the comparison of individual cases (Yin 1994).

This paper investigates ten climate change adaptation and mitigation studies that show a combination of common characteristics and diversity on other criteria. Common characteristics include: (i) vulnerable regions with changing climatic conditions, (ii) with a focus on climate change adaptation, (iii) application of backcasting approaches, (iv) conducted before 2020, and (v) availability of in-depth information and data on the cases accessible to the authors. Conducted and finalized before 2020 was a selection criterion, as it allows us to identify possible impact and spin-off. Availability of in-depth information was met by selecting cases, in which authors were involved themselves. As presented in Table 3, diversity is present through (i) the continent, (ii) governance context, (iii) type of participatory process, and (iv) overall case approach. Based on these criteria, we could select 10 cases from Africa, Europe and North America (see Table 3), including South Africa (SA1), USA (US), Netherlands (NL1 and NL2), Sweden (SE1 and SE2), United Kingdom (UK), two European cases (EU1 and EU2) and Canada (CA). The selected cases include backcasting studies that were conducted in the period between 2009 and 2019. The case selection agrees with our quick bibliometric analysis in Section 2.1, which confirms our initial assumption that there is a limited number of studies that explicitly applied backcasting for climate adaptation (search query 1).

In our view all selected cases are relevant to our research question and aim, because they contribute to our understanding how backcasting for climate adaptation can be defined, developed and applied. We take a broad view on backcasting, by including cases on vision development (case 2 and 3), as visioning is essential to backcasting. We consider these cases as relevant to backcasting as they involve visioning, including pathway or scenario development, like backcasting, but without explicitly referring to the term backcasting.

For the case analysis we applied the following procedure: the evaluation framework was used as a case assessment protocol to guide a secondary analysis of the cases, conducted by the authors most familiar with the case using a range of sources including reports, articles and project documents. Case studies were subject to internal validation and reflective discussions with all co-authors, enabling validation of findings and interpretation of the case results. By doing so, we analyzed and concisely report the ten cases and describe main similarities and differences in the use and potential of backcasting for climate change adaptation planning. Based on this analysis, we discuss methodological and conceptual developments and their potential for further methodological development of backcasting for climate change adaptation planning in section 5.

4. Results

4.1. Case descriptions

4.1.1. Case 1: SA – The South African Breede–Overberg Catchment Management Strategy

The SA case reports on the development of a Catchment Management Strategy (CMS) for the Breede-Overberg Catchment Water Management Area (BOCWMA) (BOCMA 2009, BOCMA 2010), which took place from 2009 to 2010 (van der Voorn, 2012; Van der Voorn et al., 2017). The aim was to develop a single, shared vision for the CMS for the BOCWMA. A backcasting approach was applied to develop short-term implementation pathways from the vision that supports local, provincial and national development objectives. Broad and diverse stakeholder engagement took place through a series of open stakeholder meetings in six management zones of the catchment to ensure support and ownership for the CMS. Substantial capacity building took place to support the participation of marginal people like poor black farmers, as prescribed by the 1998 National Water Act. Various types of tools and methods were used to support the CMS development process. The Minister of Water Affairs endorsed the CMS in July 2011, after which it was

Table 3
Case characteristics.

Case study settings	Case 1: SA	Case 2: US	Case 3: NL1	Case 4: SE1	Case 5: SE2	Case 6: UK	Case 7: NL2	Case 8: EU1	Case 9: EU2	Case 10: CA
Continent	Africa	North America	Europe	Europe	Europe	Europe	Europe	Europe	Europe	North America
Governance context*	TD	BMO	PNO	PNO	PNO	PNO	PNO	PNO	PNO	BLG
Type of participatory process**	GEO	BU	GPO	RI	RI	RI	RI	RI	RI	GRI
Overall case approach***	BC	V^+	V^+	BC	BC	BC	BC	BC	BC	BC

* TD = Traditional government; BMO = Bottom-up & market-oriented; PNO = Polycentric & network-oriented; BLG = Bottom-up by local government.

** GEO = Government-initiated & empowerment-oriented; BU = Bottom-up initiated & facilitated by a private think tank; GPO = Government-initiated & polycentric by different organizations; RI = Research-initiated; GRI = Government & research-initiated.

*** BC = Backcasting approach; V^+ = visioning, including pathway or scenario development.

implemented step by step. The Minister endowed the leading Catchment Management Agency with management capabilities for the implementation, but also more legal responsibilities for future follow-up activities, for which financial resources were allocated. The implementation of the CMS has been evaluated in 2015.

4.1.2. Case 2: US – The US Initiative Water Management Strategy

The US case reports on the US Initiative Water Management Committee (HIWMC), which conducted a strategic planning effort in 2010 to develop an integrated water management strategy (WMS) for the New Orleans region (Van der Voorn et al., 2017). The aim of the project was to seek opportunities to establish public–private partnerships to support the City of New Orleans in developing more integrated and adaptive water management approaches. The WMS development process took place during the period of May-July 2010, when two committee meetings were held. Prior to these meetings, a pre-assessment was made to identify the current state of water resources management and its future challenges in the region. Stakeholder engagement was limited since the WMS development process involved only HIWMC members, which form a think-tank group. During this process, vision development was conducted to evaluate how transformative elements of existing visions could be combined to guiding the Committee's effort to further promote integrated and adaptive water management in the region (Van der Voorn et al., 2017). This resulted in a list of 39 water management goals and plausible directions for further WMS developed but without any concrete pathways at that time. The WMS development process had limited impact due to limited inclusion by formal decision making at the city or state level and limited financial resources for the implementation of the WMS. Follow-up activities took place through establishing strategic partnerships and awareness raising initiatives.

4.1.3. Case 3: NL1 – The Rhine-Meuse Estuary sub-program of The Dutch Delta Program

The NL1 case reports on various vision studies on the Dutch Delta Program Rhine-Meuse Estuary, followed by strategy development for adaptive Delta management in the Rhine-Meuse Estuary sub-program of the Delta Program from May to October 2010 (Van der Voorn et al., 2017). The study involved an assessment of three visions studies that had been conducted, as part of the overall backcasting approach. The results of the assessment were used as input for two stakeholder workshops on strategy development held in March and April 2011. The aim of the workshops was to develop a better understanding of how various elements of the visions studies could support adaptive Delta management in the Rhine-Meuse Estuary and a set of regional climate scenarios, which provided further insight into possible pathways to adaptive delta management. Mainly experts were involved in the workshops, while broad and diverse stakeholder engagement took place in the vision studies; two of these studies produced pathways. The workshops resulted in regional climate scenarios for possible pathways to adaptive delta management and were used as inputs for formal decision making on adaptive delta management in the estuary. Follow-up and broader spin off activities were coordinated by the Dutch Government and took place in 2015.

4.1.4. Case 4: SE1 – Barriers in climate change adaptation in two Swedish municipalities

The SE1 case refers to a six month study conducted in 2013, which aimed at investigating barriers to adaptation in municipalities that were due to inaction by external decision makers themselves (Carlsson-Kanyama et al., 2013). The case study was part of a larger research program commissioned by the Swedish Environment Protection Agency. This study involved civil servants from two municipalities in Sweden, and resulted in five visions of the ideally adapted local society. Vision development was done during two stakeholder workshops, which had been supported by stakeholder tools and methods. The visions corresponded to what local civil servants considered as preferable solutions in order for the municipality to be fully adapted to climate change within 20–30 years. No real pathways were developed, but rather an action plan. Based on this exercise, civil servants were able to identify a group of external decision makers upon whose input these municipalities depend for achieving their goals. The results were included in formal decision making and used for follow-up activities. Moreover, at the municipal level, broader spin-off took place.

4.1.5. Case 5: SE2 – Understanding consistencies and gaps between desired forest futures: An analysis of visions from stakeholder groups in Sweden

The SE2 case reports on an exploratory study in Sweden on desired forest futures, which has relevance for climate adaptation. Its aim was to move beyond the current state by applying a long-term and integrated perspective through participatory backcasting, to identify stakeholders' desirable forest futures and then to compare these visions in order to highlight contemporary trajectories and identify changes that were conceived as desirable (Sandström et al. 2016). Six workshops took place at the Swedish Defense Research Agency (FOI), Kista, in April to June 2014. Three additional workshops were held in Lycksele in 2014 for the backcasting exercise. Stakeholder tools and methods were applied to support the stakeholder process, involving also indigenous Sami people. The aim of these workshops was to create group visions and to sketch possible policy events, including policy measures, necessary to reach these visions. This resulted in five visions, after which short-term pathways were derived from a backcasting analysis to coordinate actions for the coming 10 years. There was limited impact as the results were mainly used as input for an academic paper. There was no specific follow-up, but broader spin-off took place within academia and at the local level.

4.1.6. Case 6: UK – Visioning and Backcasting for Transport CO_2 reduction in London

The UK case refers to a London-based project from 2007 to 2009, which was developed as part of the UrbanBuzz program run by University College London, commissioned and funded by the UK Higher Education Funding Council (Hickman et al. 2010). The project aimed to (i) assess how London might reduce transport CO_2 emissions by 60% from 1990 to 2025 and subsequently to 80% by 2050, (ii) review policy measures and develop policy packages and scenarios to reduce CO_2 emissions supporting climate adaptation, and (iii) quantify the impacts of scenarios relative to CO_2 reduction using the London Transportation Studies model (Hickman et al. 2013, Hickman and Banister, 2014). A distinctive feature was that it combined backcasting with a transport and CO_2 simulation game (TC-SIM) and transportation models to explore strategic policy choices. Backcasting was used to assess whether the transport CO_2 reduction targets were possible to meet. Expert-led workshops were held at different stages throughout the study, which resulted in multiple visions tested against five central scenarios. Policy pathways were developed for each scenario, but there was no focus on uncertainties and pathway switching. These pathways were hybrid addressing both climate mitigation and adaptation options. The study had some impact as results were not directly used in formal decision making, but rather in the research context of transport strategy development in London. Follow-up research activities were carried out by the UK Department for Transport. Broader spin-off occurred in transport planning and consultancy practice.

4.1.7. Case 7: NL2 – Multi-scale visions, wild-cards, and participative backcasting to develop adaptation pathways for the future of the Overijsselse Vecht

The NL2 case refers to a study in the Overijsselse Vecht in the east of the Netherlands, an intensely used area with a long history of participatory management and cooperation between public and private sector stakeholders and scientists. It was carried out in the context of a larger EU funded project called SENSES, from 2017 to 2019. SENSES aimed at developing a "Climate Change Scenario Toolkit" to support the understanding of the new generation of climate change scenarios. In this Dutch case, local, bottom-up participatory and empirical knowledge was combined with top-down scientific input translated from global socioeconomic and climate impact scenarios, which were derived from the Shared Socioeconomic Pathways scenarios (Auer et al. 2021). A backcasting approach in combination with exploratory scenarios were used to develop pathways towards the vision on a climate robust and CO_2-neutral Overijsselse Vecht, while addressing both climate adaptation and mitigation in hybrid pathways. A novel aspect was that the project operated in a very information-rich environment, using several existing visions, pathways, and scenarios. Combining existing knowledge to develop pathways led to novel ways to develop a multi-scale vision and using exploratory scenarios to test the robustness and feasibility of resulting adaptation pathways.

4.1.8. Case 8: EU1 – Combining participative backcasting and explorative scenario development for envisioning the future of water in Europe

The EU1 case refers to a pan-European case study as part of a larger FP6 EU-funded project SCENES that run from 2006 to 2011, which set out to undertake a multi-dimensional multi-scale scenario process, with a strong foundation in science and broad participation of stakeholders. SCENES aimed to develop and analyze a set of comprehensive exploratory scenarios of Europe's freshwater futures up to 2050, including climate change impacts (Kok et al. 2011). A distinct feature of the SCENES project was its aim to combine exploratory and backcasting scenarios with a spatial explicit water quality and quantity model (WaterGAP) to assess the feasibility of the overall backcasting approach and the usefulness of the results for a pan-European case study. The case study consisted of similar processes in 10 regional and local cases. Stakeholders were involved for the duration of the SCENES project. The study produced stakeholder-determined products in an iterative procedure with expert modelers to ensure internal consistency, using a story and simulation approach. This was done in backcasting workshops, which resulted in several visions that were backcasted against the scenarios to develop roadmaps for actions up to 2050. A list of robust actions and strategies was compiled independently of the scenarios. The study had scientific impact as results were not used in formal decision making. Follow-up research activities took place in subsequent future studies in Europe, where the scenarios had been used. Broader spin-off occurred especially in academia (Kok et al. 2011).

4.1.9. Case 9: EU2- Combining participative backcasting and explorative scenario development for envisioning the future of water in Europe

The EU2 case was conducted under the umbrella of the SCENES project. This study reports on the results of nine local case studies and a Baltic regional case study. The aim of the study was to analyze the combined use of exploratory and backcasting scenarios, Fuzzy Cognitive Maps, and System Dynamics models (van Vliet and Kok 2015). The socio-environmental exploratory scenarios for this study were developed in two consecutive workshops. The workshops were held in local-, regional and pan-European-scale case studies between June 2009 and February 2010. Like in the EU1 case, stakeholders were involved in a longer process during the lifetime of the SCENES project. In this study, various types of tools and methods were used to produce meaningful outputs and support broad stakeholder engagement. The study resulted in a set of exploratory scenarios and visions for 2050. Like in the EU1 case, these visions were backcasted against the scenarios to develop roadmaps to set up actions up to 2050. Similar to the EU1 case, a list of robust actions and strategies was compiled independently of the scenarios. The study had limited impact as results were not used in formal decision making. Follow-up research activities took place across the different case studies of the SCENES project, whereas broader spin-off occurred mainly in academia (van Vliet and Kok 2015).

4.1.10. Case study 10: CA – Envisioning local climate change futures in the Delta context

The CA case includes a study that examined a new process for envisioning local climate change futures, which used an iterative, collaborative, multi-stakeholder approach to produce spatial scenarios with computer-generated 3D images of climate change futures in the flood-prone municipality of Delta, British Columbia, Canada (Sheppard et al. 2011). A novelty is the combined use of backcasting and 3D visualization tools. The study was conducted between 2005 and 2008. It projected scenarios up to 2100, using a local working group of experts and stakeholders, to co-develop four alternative narratives (visions) within a holistic framework integrating climate mitigation targets and adaptation options (Shaw et al. 2009). The aim of the project was to inform the revision of Delta's flood management strategy in the context of local land use and climate change scenarios, with the goal of carrying out public consultations to evaluate the desirability of a range of flood risk responses at some stage. A backcasting approach was applied to develop pathways from the visions and scenarios with some stakeholder input, which further advanced sea level rise modelling (Barron et al. 2012). Hybrid pathways were developed to address climate mitigation and adaptation options. The study had limited impact. Results were not used in formal decision making, but rather raised the awareness of Delta's political leaders on the implications of future climate change impacts in their region. As a follow-up, a similar study was conducted in the adjoining City of Surrey, British Columbia, while broader spin-off was identified in science and society.

4.2. Results

This section provides a concise and comparative overview of the case results. A more detailed description of the individual case results can be found in Tables S1-7 in the Supplementary Material (Appendix).

4.2.1. Inputs & project settings

The cases showed a wide range of project budgets (see Table S1 in Supplementary Material). In the two cases (EU1 and EU2) with the highest budgets, significant financial resources were allocated to the project (>1M€), whereas resources were lacking in the US case (Fig. 1). Only in three cases (SA, NL1, SE1), a commissioner was present, which comes together with funding and a higher interest in utilization and diffusion of the results. There were also differences in the project goals. For instance, all types of project goals were pursued in eight cases, while in two cases (US and SE1) the project goals were only content-related and impact-related.

4.2.2. Process and methods

All cases showed stakeholder involvement and their commitment (Table S2 in Supplementary Material). Differences can be observed in the degree of stakeholder diversity and influence. In one case (SA), there was not only a high degree of stakeholder diversity, but also a high degree of stakeholder influence, due to the presence of process arrangements that enabled stakeholders to influence the stakeholder process and content. Two cases (US and UK) showed lower degrees of both stakeholder diversity and influence. In these cases, stakeholder participation was limited to certain groups of stakeholders, such as experts or think tank members. In the remaining cases, there was a medium degree of stakeholder diversity and influence.

All cases used various types of tools and methods to support exploring different plausible futures by means of exploratory scenarios (See Table S3 in Supplementary Material), while all cases utilized stakeholder as well as communication and dissemination tools and methods. Five cases employed four types of tools and methods (Fig. 2). Moreover, in 6 cases (NL1, UK, NL2, EU1, EU2 and CA) advanced modelling and simulation tools and methods were also part of the overall backcasting approach. This allowed scenarios and pathways to be quantified in order to identify and discuss likely impacts and trade-offs.

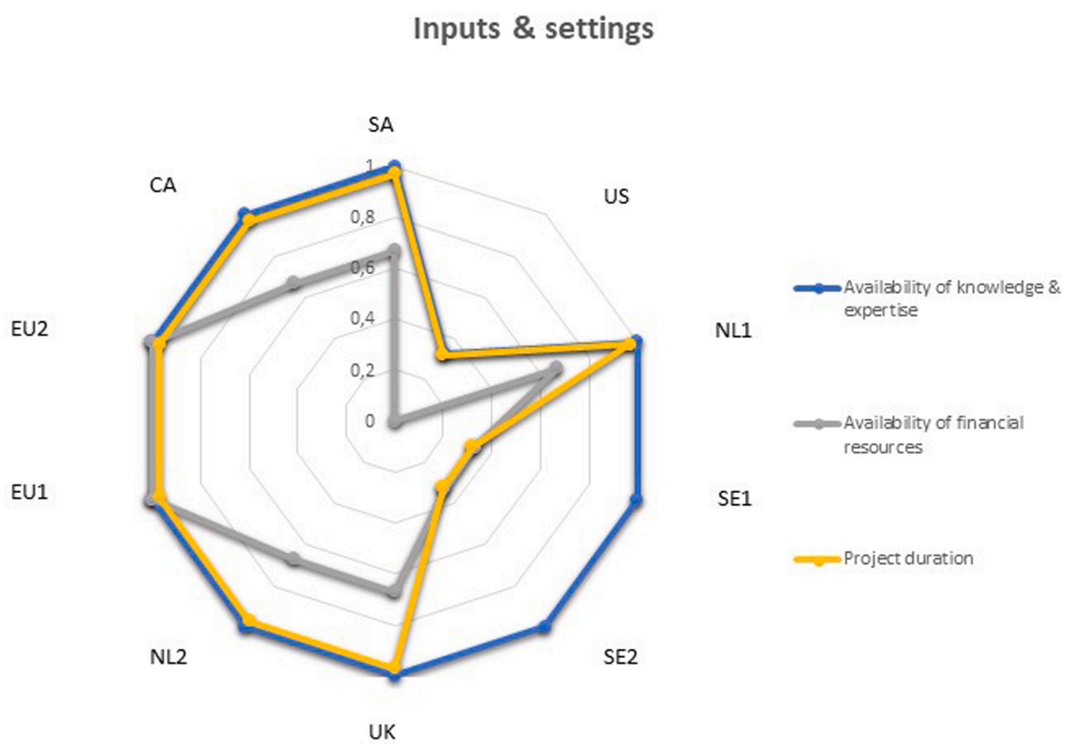

Fig. 1. Project inputs and settings (scores have been normalized between 0 and 1 to make the differences more visible).

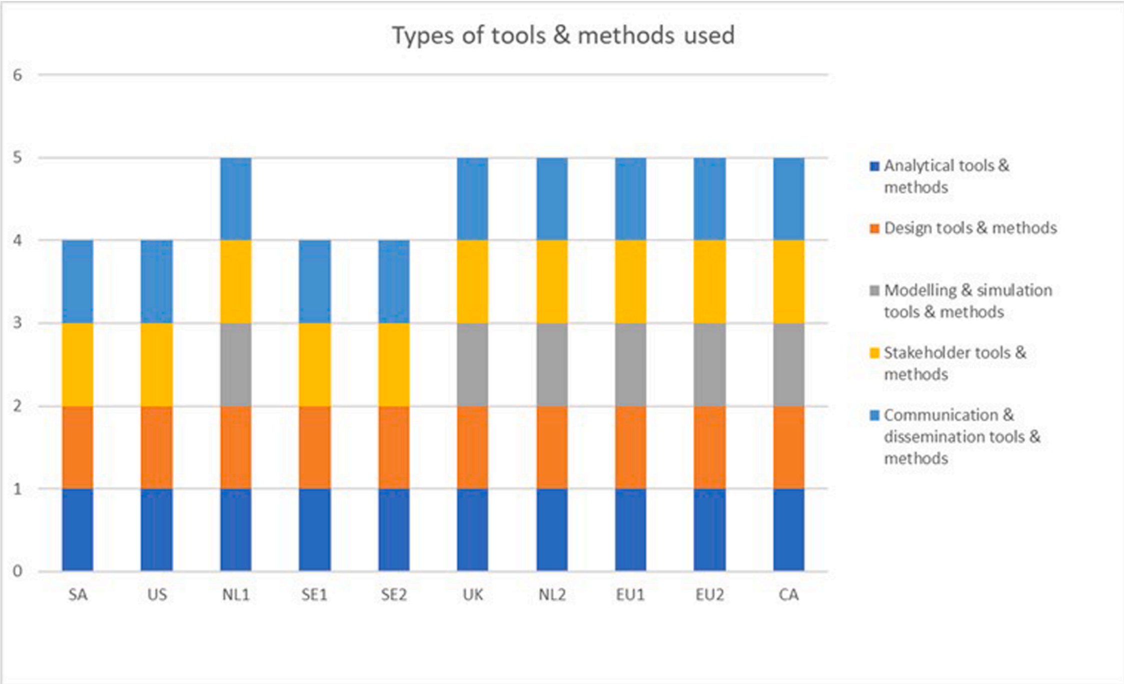

Fig. 2. Overview of various types of tool and methods used.

4.2.3. Results in the backcasting cases

Whereas a single, shared vision was the starting point for the SA case, multiple visions were developed in the other 9 cases. Most cases included transformative elements and goals or guiding targets (Fig. 3). In 9 out of 10 cases, transformative elements as well as goals or guiding targets were developed (Table S4 in Supplementary Material). Differences surface in the NL2 case, where thresholds were defined as guiding targets, while in the SE1 case vision development did not result in transformative elements, nor in goals and guiding targets, but rather resulted in an action plan.

Except for the US, SE1 and SE2 case, cases included scenario development (see Table S5 in Supplementary Material). In those cases where separate scenario development took place, scenarios were quantitative. In the UK, NL2, EU1, EU2, CA case, where scenario development was part of a backcasting framework it provided input for modelling to develop robust pathways. Cases that did not include scenario development, also lacked addressing uncertainty. Differences relate to the usage of scenarios, which can be either exploratory or combinatory (Fig. 4). In addition, in the UK, NL2 and CA case both climate mitigation and adaptation options were included in pathway development.

Considerable diversity can be found in pathway development and robust elements (Fig. 5 and Table S6 in Supplementary Material). In cases where short-term pathways were developed, these pathways do not include robust elements because uncertainty is considered

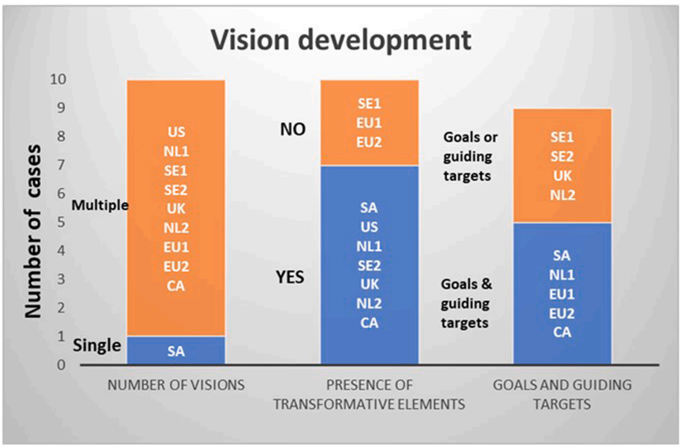

Fig. 3. Overview of results of vision development.

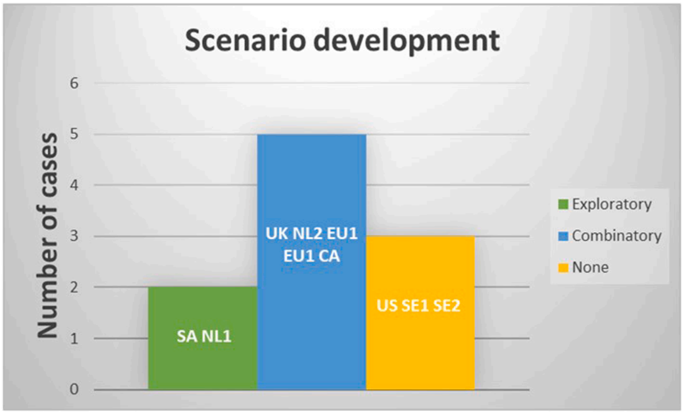

Fig. 4. Overview of results of scenario development.

low or negligible in the short run. Differences are also present in the types of pathways. In some cases, roadmaps were developed, whereas policy implementation pathways were developed elsewhere. It shows that different terms are used to refer to short-term or long-term pathways. Only in the NL1 case long-term pathways were generated that allow for pathway switching. In the NL2, UK and CA case, hybrid pathways, which address climate mitigation and adaptation options, were developed.

4.2.4. Impacts

Our analysis shows that most cases resulted in rather limited societal impact, though scientific impact occurred through accumulating knowledge on backcasting approaches, broader dissemination, follow up research or how widely cited. Only two cases (SA and NL1) resulted in significant impact because of inclusion in formal decision making (see Table S7 in Supplementary Material) leading to implementation in plans and practice. These cases show a varying degree of broader spin-off in science, society and practice (Fig. 6). The SE1 case did not result in significant impact despite being included in formal decision making. This suggests that inclusion in formal decision-making is 'necessary but insufficient' for enabling impact and that there are additional mediating factors (see section 5.1.3).

Other cases revealing limited and moderate impact due to a lack of inclusion in formal decision making. This led to limited examples of follow-up and spin-off (see Table S7 in Supplementary Material).

5. Discussion

5.1. Key insights and findings from the cases

In this paper, we have reviewed cases to advance backcasting for climate adaptation. Our aim is to identify what is needed to apply backcasting in an advanced way for climate adaptation, by drawing key insights and findings across these cases and offer new insights that can assist adaptation scholars and practitioners in developing and conducting more comprehensive design of backcasting studies (see Table 4).

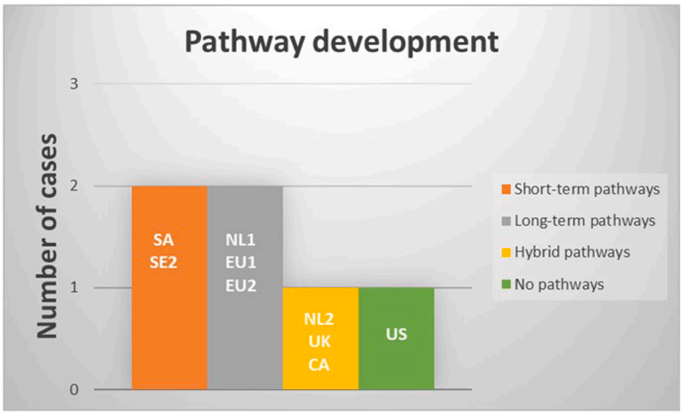

Fig. 5. Overview of results of pathway development.

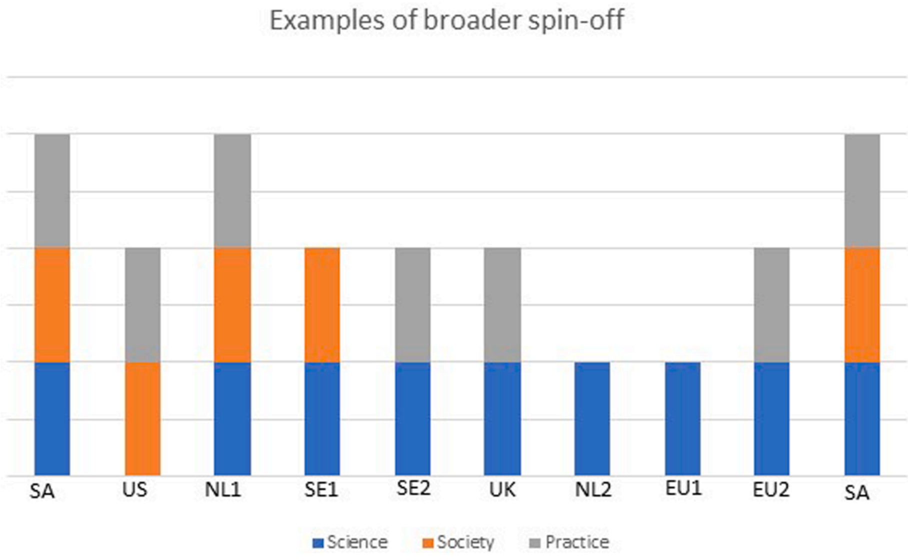

Fig. 6. Overview of examples of broader spin-off.

5.1.1. *Inputs & project settings*

Larger project budgets allow for a more comprehensive backcasting study, enabling the required knowledge and expertise for advanced modelling for system analysis from which possible adaptation pathways follow, as well as options for pathway switching. However, our results indicate that such budgets do not necessarily lead to more impact of the study in practice or among practitioners, as this depends on other factors like a commissioner or results being used in decision making (see 5.1.4). Short-term projects with relatively small project budgets are generally more focused, but lack sufficient resources to employ sophisticated tools and methods for advanced system analysis, which leads to results more at the level of visions. Both the size of the project budget and availability of relevant knowledge and expertise are essential for a backcasting study. A larger project budget is an important factor for the deployment of tools and methods for advanced system analysis, but is not decisive for the impact of a backcasting study.

Furthermore, the presence of a commissioner is important for reaching impact (see also Quist, 2011; Van der Voorn et al., 2017).

Table 4
Overview of key highlights from cases and discussion.

Dimension	Key highlights
Inputs & project settings (Table S1 in Supplementary Material)	1. Larger project budgets enable the deployment of comprehensive tool and methods for advanced system analysis 2. A commissioner has a positive effect on the impact of the project
Process & methods (Table S2 and S3 in Supplementary Material)	3. Broad stakeholder engagement enriches vision and pathway development and increases stakeholder support and commitment to results 4. Involvement of marginalized groups increases legitimacy of results but requires capacity building efforts 5. The degree of stakeholder influence is determined by arrangements for stakeholder influence on content or process 6. Advanced system analysis requires comprehensive modelling and simulation tools and methods
Results in backcasting studies (Table S4, S5 and S6 in Supplementary Material)	7. Multiple visions for climate change adaptation are more beneficial for addressing uncertainties than single visions 8. Adaptation pathways determine actions in the short and long run and can address uncertainties about these actions 9. Robust elements enable pathway switching and managing uncertainties 10. Pathways addressing synergies between mitigation and adaptation actions result in more hybrid pathways and allow for pathway switching 11. Scenarios enable robustness checks of visions and pathways and pathway switching 12. The monitoring and evaluation of climate actions requires goals and guiding targets 13. *When pursuing transformative adaptation this must become part of visions and pathways
Impact (Table S7 in Supplementary Material)	14. Inclusion by formal decision making has a positive effect on the impact of the project 15. Different types of impact can distinguished: scientifically, societal, policy, domain/sector specific (field of application) 16. *Transformative adaptation requires all types of impact 17. * Power relations may prevent the project outcomes from being included in formal decision making

*Key highlights from the discussion.

Such a key person has the capability to include the outcomes of the study to inform formal decision making and reflects the relevance of the results for the organization or network, contributing to the impact of the study (see 5.1.4).

5.1.2. Process & methods

In participatory backcasting, broad stakeholder engagement is important for addressing and reconciling different normative stakeholder interests, perceptions and perspectives to enrich vision, scenario and pathway development and establishing stakeholder support for and commitment to the outcomes of the backcasting study. Our evaluation shows that backcasting proved effective in engaging stakeholders in the co-creation of (alternative) climate change adaptation futures and scenarios, as well as pathways that could lead to these futures. Except for the US, SE1 and UK case, the cases show, building on observations of the researchers involved, that broad stakeholder engagement enabled social learning in which stakeholders explore and open up a possibility space for supporting climate adaptation (van der Voorn, 2012; Van der Voorn et al., 2017). Although we did not investigate learning effects in this study in detail, the authors involved in the cases confirmed that such learning processes took place in the cases.

The involvement of marginal groups is beneficiary for enhancing stakeholder engagement resulting in more comprehensive results and for enabling the stakeholder process more democratic, which increases the legitimacy of its outcomes (Muiderman 2022). However, their participation has methodological and procedural implications. For these groups to produce relevant inputs, their involvement may require capacity building effort as part of or prior to the backcasting study (Van der Voorn et al., 2017; Faldi and Macchi, 2017; Faldi and Rossi, 2014). Hence, the participation of marginal groups is important, but we also consider adequate process arrangements to be prerequisites for fostering effective participation.

In the context of climate adaptation, identifying robust options for climate adaptation is challenging due to large climate uncertainties and the complexity of the social-ecological systems under study. The use of comprehensive modelling and simulation tools and methods is therefore necessary for advanced system analysis, scenario and pathway development and switching for dealing with uncertainties (Muiderman 2022), while participatory (multi-)modelling in combination with backcasting has also advanced (Cuppen et al. 2021).

5.1.3. Results in backcasting studies

The development of visions, scenarios and pathways supports stakeholders and decision makers in mapping out the possibility space for adaptation. Transformative elements reflect the perceived gap between the current and desirable situation in climate adaptation (van der Helm 2009). In order to address climate uncertainties, multiple visions for climate adaptation are more beneficiary than single, shared visions because they broaden the possibility space for climate adaptation see (Van der Voorn et al., 2017). Goals and guiding targets help to operationalize visions into climate actions and their monitoring and evaluation, which is also key to advancing climate adaptation plans and actions (Van der Voorn et al., 2017).

As part of the overall backcasting approach, scenario development is considered important for modelling and developing robust pathways (Kok et al. 2011, van Vliet and Kok 2015). The NL1, NL2, EU1 and EU2 cases show that combining exploratory scenarios with backcasting makes it also possible to conduct robustness checks of visions and pathways against the backdrop of key drivers for change described in such scenarios (Kok et al. 2011, van Vliet and Kok 2015).

Pathway development is essential for determining adaptation actions in the short and long run, while taking into account uncertainties about these actions (Kok et al. 2011). Robust elements in pathways and transformative elements in multiple visions are also necessary for supporting transformative adaptation. The inclusion of robust elements in pathways allows for pathway switching, as a means for dealing with uncertainty (Haasnoot, 2018; Van der Voorn et al., 2017). Whereas scenarios are well equipped for mapping contextual uncertainties (climate uncertainties), pathways should include implementation-related uncertainties. Interestingly, pathways addressing synergies between mitigation and adaptation actions and options result in more hybrid pathways, (van der Voorn et al. 2020). The UK, NL2 and CA cases combine adaptation and mitigation options in the pathways, which could also counteract goal conflicts as suggested by van der Voorn et al. (2020).

5.1.4. Impact

With regard to impact, it makes a difference whether the backcasting study is initiated by government, civil society and NGOs, or research. Research-initiated backcasting studies are usually less connected to formal decision making, resulting in limited implementation-oriented follow-up activities and spin-off, yet generally showing more scientific impact. In a similar way civil society can use visioning or backcasting for lobbying and advocacy purposes providing input for public debates, as was done in the US case. By comparison, government-initiated backcasting studies are usually connected to formal decision making, which facilitates follow-up activities and broader spin-off. However, such studies can be less ambitious, being consensus driven and influenced by short-term interests. Therefore, we also argue that those backcasting studies that include transformative elements that go beyond the business-as-usual practice have the potential to contribute to transformative adaptation.

Our results indicate that the presence of a commissioner is important for ensuring institutional embedding and protection of the results and realizing follow up activities, as also shown in previous research (Quist et al, 2011). A connection to decision making is also a prerequisite for impact (see also Van der Voorn et al., 2017. A commissioner represents an authority or organization with power and interests, being able to set the agenda for follow up. However, power relations could prevent the outcomes from being included in formal decision making (Muiderman 2022).

Finally, there is no relationship between the size of project budgets (see section 4.2.1) and the degree of impact. Even though limited financial resources were present in the SE1 and SE2 case and none in the US case, limited impact was generated.

5.2. Reflections and limitations

5.2.1. Methodological reflections

Our main findings, shown as highlights in Table 4, have relevance and methodological implications for the further development of backcasting for climate adaptation. For effective backcasting for climate adaptation, essential add-ons are needed to conduct more advanced system analyses, develop more robust pathways and cope with uncertainty. These add-ons include more combinatory use of quantitative and qualitative scenarios, comprehensive modelling and simulation tools and methods for advanced system analysis, inclusion of robust elements for pathway switching and uncertainty management, and hybrid pathways for climate adaptation, e.g. (van der Voorn et al. 2020), which can be combined in new backcasting frameworks or can be added to earlier backcasting frameworks proposed like for instance proposed by Van der Voorn et al (2012).

Modelling and simulation tools and methods, scenarios and pathways are powerful tools to envision how nature might respond to different pathways of future human development and policy choices. The usage of different types of modelling and simulation tools helps to conduct advanced systems analyses and identify transformative elements for visions and robust elements for pathway switching and uncertainty management. The combined use of these tools could support backcasting in generating more transformative visions and transformative pathways to more sustainable societies. As such, we consider these add ons important to advance backcasting for climate adaptation.

We consider some of the key highlights (6, 7, 11 and 12) presented in Table 4 as novel contributions to the current understanding of backcasting for climate adaptation in the literature.

Backcasting for climate adaptation involves increasing resilience of social-ecological systems, whereas backcasting for climate mitigation focuses more on technical solutions for CO_2-emission reduction (Klein et al. 2005, Grafakos et al. 2020). As climate adaptation and mitigation can reinforce each other in exploring shared goals, assessing trade-offs and seeking mutually supportive outcomes (Klein et al. 2005, Kim and Grafakos 2019, Nwedu 2020, Iacobuţă et al. 2022), future backcasting studies for climate mitigation and adaptation would benefit from addressing synergies between mitigation and adaptation actions and options.

5.2.2. Conceptual reflections

Our evaluation offers room for conceptual reflections regarding the use of backcasting for climate adaptation and transformative climate adaptation and impact of backcasting studies. We consider the add-ons discussed in 5.2.1 important to advance backcasting for climate adaptation because they allow for advanced system analysis, vision and scenario and pathway development and switching for dealing with uncertainties, all of which seem relevant to climate adaptation.

Moreover, our cases show that backcasting is generally applied for regular climate adaptation, despite its potential to accommodate transformative change. In backcasting, usually limited attention is paid to the broader societal context, which is key to achieve transformative change. Instead, the existing system remains the point of reference for such changes, while backcasting has the potential to shift the societal debate from 'what is already there?' to 'what is needed?". It is important to combine the critical stance towards business as usual and the drive for systemic, transformative change with the ability to show society what is desirable and possible (Loorbach, 2022).

Yet more is needed to make backcasting fit for transformative climate adaptation. After Park et al. (2012), we define transformative climate adaptation as a process that results in fundamental change in the biophysical, social or economic components of a system from one form function or location to another, thereby enhancing the capacity for desired system states to be achieved given perceived or real changes in the present or future environment. Whereas regular climate adaptation involves relatively incremental changes in these system components or in their management, transformative climate adaptation relates to future desired fundamental system changes that can be envisioned through backcasting.

For backcasting studies to support transformative climate adaptation, it requires transformative capacity, as the ability of actors to create novelties and embed them in structures (social-cultural), practices and discourses. O'Brien (2011) proposes that building transformative capacity requires a combination of technological innovations, institutional reforms, behavior shifts and cultural changes among relevant stakeholders at various governance levels. A climate governance perspective on transformative capacity helps explaining and evaluating what new types of conditions for integrated, innovative and reflexive approaches to addressing climate change, sustainability and resilience (Holscher 2019). This perspective allows us to frame backcasting processes as a governance-related capacity building processes that shape the conditions for transformative capacity for climate governance (Faldi and Machi, 2017; Holscher et al. 2019).

There seems to be an unrealized potential in backcasting to support transformative change in our cases, which is likely to observed in the long run because fundamental systems changes take a long time to occur, although it needs to be included in visions and pathways.

For backcasting studies to achieve transformative impact, it is important to consider impact as a design criterion for the backcasting process. Different types of impact can be distinguished: scientific, policy, societal, domain or sector specific. We suggest that transformative adaptation requires all these types of impacts to contest default practices. However, we propose backcasting to be well equipped for making explicit vision statements influencing the potential direction of transformation, as well as to explore how transformative change can be achieved gradually. Building on Van der Voorn et al (2012), we consider transformative change as a prerequisite for transformative adaptation. Without transformative change, climate adaptation remains incremental changes in adaptation to climate change, failing to achieve radical system change for transformative climate adaptation.

5.2.3. Reflections on analytical framework

In section 3.1, we distinguished three types of criteria (conditional, result-oriented and impact-oriented) to determine meaningful or successful use/application of backcasting for climate adaptation. As a starting point, we consider successful backcasting studies to involve inputs related to the goal set, favorable project settings, broad stakeholder engagement, and combining various types of tools and methods to achieve endorsed results that can contribute to long-term impact. Our criteria involving all dimensions of our framework need to be met for successful backcasting. In this sense, the three types of criteria appear to be conditional with respect to each other. For example, backcasting studies with small budgets can also lead to results, but not as comprehensive as backcasting studies with larger budgets. Also, implementation and other impacts require good results that are based on broad and meaningful participation and good application of methods and tools.

In our analytical framework, change is only addressed by the criterion of 'transformative elements' in visions. We acknowledge that other aspects can also contribute to the transformational backbone for visions, which are not included in our framework. Wiek and Iwaniec (2014), for example, provided criteria for assessing the transformational quality of visions, including sharedness, motivational, nuance, and relevance. We suggest that inclusion of soft criteria could support evaluating the transformative potential of backcasting studies, as a driver for structural, technological and cultural change. Addressing the issue of transformation of a socio-ecological system also implies the consideration of further variables/criteria. As this is not currently included in our framework, we consider this as a limitation of our study, which merits further research.

5.2.4. Limitations

The execution and design of the backcasting processes are influenced by the related governance context, which appears to have less impact on the outcome of the process than expected. This may indicate that other dynamics are at play, such as learning processes among stakeholders, which were beyond the scope of our evaluation. Likewise, we have evaluated the results of vision, pathway and scenario development, but did not look into the underlying knowledge generation process. Such processes could provide further insight into how expertise and knowledge would have affected these results and stakeholder endorsement of the results. The scope of our analysis did not account for the blocking and opposition power by (non-involved) stakeholders that see their interests affected. Although we did not account for power relations in this study, the authors involved in the cases indicate that this most likely would have played a role. This can also be applied to non-involved groups of citizens or non-involved marginal groups. In addition, we have not compared the different modelling and scenario tools in a detailed way whereas this interesting for further research (see 5.2.1). Finally, most of our cases show rather limited impact, while a longitudinal study would be useful to develop a more in depth understanding of impact and their mechanisms over longer periods of time e.g., the political aspects (political will and power relations) that affect impact.

In our study, we analyzed a significant sample of cases. However, a larger number of cases could further substantiate our findings. Nevertheless, the sample size is typically smaller in qualitative research while acquiring more data does not necessarily lead to more information (Ragin 2014). In addition, determining an adequate sample size in qualitative research is ultimately a matter of judgment and experience in evaluating the quality of the information and the particular research method and purposeful sampling strategy employed (Blaikie 2018).

Our sample size can be justified according to the research methodology of multi-case study, ensuring adequate collection of relevant data as well as the case selection. The selected cases provide valuable insight into the different ways, in which backcasting processes took place in different governance contexts. We consider that the current set of cases have relevance, as there are more cases to compare, and that there is considerable added value in having cases from different contexts and different research groups, to get clearer differences and similarities. We agree that a smaller set of cases allows for more in-depth evaluations and some of the authors have previously done this (e.g. Van der Voorn et al., 2017), although our ambition was to bring this to a more aggregated level, as that is hardly done.

We have applied the selection criterion of "conducted and realized before 2020".. However, the cases show limited impact. In earlier work it has been found that in case of impact after 5–10 years clear institutionalization can be found, but still at a niche level, though with the potential to act as a stepping stone in an emerging transition if concerted effort takes place or relevant regulation is developed.

Backcasting processes aim to shift people's mindset from which follow up activities are likely to emerge after the backcasting study it is necessary for a researcher to create some distance from the study and prevent bias in the interpretation of case results. Changing people's mindset is part of the learning processes, which have not been evaluated in this study, but has been shown in other studies (e.g. Quist et al, 2011, Robinson, 2003). As our focus is on best practices based on available studies, it was not our aim to evaluate such processes in more detail in this study, but we suggest that this aspect warrants further research.

Our analysis increases our understanding what criteria determine successful backcasting for climate adaptation, although further evaluation of backcasting studies against these criteria would support building a strong case for participatory backcasting for climate change adaptation. In our view, successful backcasting is considered as a well-designed (see 5.2.2) and well-assessed conducted study that leads to measurable results and draws on endorsed visions and pathways used by stakeholders. As discussed in section 5.2.4, conditional, results-oriented and impact-oriented criteria, covering all dimensions of our framework, have to be met for having successful backcasting. We consider it is important that the three types of criteria appear to be conditional with respect to each other.

6. Conclusions and recommendations

In this paper, we have adapted and applied an existing framework for the evaluation and comparison of cases to advance participatory backcasting approaches for climate change adaptation. The framework has been useful to describe and analyze a diverse set of cases, showing both differences and similarities in very different contexts.

Our analysis also provides insights into how to further advance backcasting for climate adaptation. Based on these insights, we conclude that there is indeed a considerable potential in using backcasting for enhancing climate change adaptation. The potential of backcasting lies in its capability to support adaptation in a participatory manner for building more resilience of socio-ecological systems in different contexts e.g., water, mobility and forest management. To make backcasting fit for climate adaptation, it requires the use of different types of modelling and simulation tools and methods for advanced system analysis, inclusion of transformative elements in visions and pathways and robust elements for pathway switching and uncertainty management, and hybrid pathways.

In our view there is a so far unrealized potential of backcasting to enable a shift from incremental-based adaptation to transformative adaptation. The starting point for realizing that potential would be to explore transformative futures that could lead to pathways to different (sustainable) societies in which economic, ecological and societal structures will have fundamentally changed. This can be done in a backcasting study, which (i) adopts a systems approach, (ii) learns from practice, (iii) co-creates transformational knowledge, and (iv) invests in capacity building for inclusive transformational adaptation. These aspects enable backcasting to support transformative change, but transformative change must be present in visions and pathways too. Whether backcasting enables a transition to transformative adaptation can be considered a hypothesis that needs to be substantiated through further research.

Despite limitations, our review has scientific merit as it provides a detailed examination of how various backcasting approaches can be used for climate adaptation, while it provides clear suggestions and directions for further methodological improvement and methodology development. Our study also suggests that further development is possible for backcasting to support transformative adaptation. Comprehensive modelling and simulation tools and methods as applied in some of our cases are also useful for consolidating synergies between mitigation and adaptation actions and options in scenarios and pathways, which has not yet become mainstream in other domains like urban planning (Grafakos et al. 2020). These approaches work better when backcasting studies become more transdisciplinary reporting on key aspects of backcasting processes, including interdisciplinary teams from relevant knowledge fields, broad stakeholder involvement and connection to decision making processes, all of which can assist us in moving our knowledge forward in this area (Muiderman 2022).

Addressing the transformative potential of backcasting merits further research.

As such, we propose the following recommendations for future backcasting studies:

- More transdisciplinary research on backcasting studies for climate adaptation is needed to gain further insight into methodological advancements and other key aspects of backcasting supporting transformative adaptation;
- Broad stakeholder engagement is needed to increase the legitimacy, accountability and credibility of stakeholder processes and support and commitment to the results of backcasting studies;
- Backcasting studies benefit from interdisciplinary teams of experts and practitioners from various disciplines to mobilize various stocks of knowledge, expertise and skills needed for the use of comprehensive tools and methods for advanced system analysis;
- The use of robust elements and pathway switching combined with advanced tools and methods merits further attention, especially in domains that deal with large climate uncertainties and the complexity of the social-ecological systems under study.
- Backcasting for climate adaptation and mitigation would benefit from addressing synergies between mitigation and adaptation actions and options across various domains e.g., water, energy, land-use, resulting in more hybrid pathways and integrated scenarios.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary material

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References

Arnstein, S.R., 1969. A ladder of citizen participation. J. Am. Inst. Plann. 35 (4), 216–224.
Auer, C., et al., 2021. Climate change scenario services: From science to facilitating action. One Earth 4 (8), 1074–1082.
Barron, S., et al., 2012. A Climate Change Adaptation Planning Process for Low-Lying, Communities Vulnerable to Sea Level Rise. Sustainability 4 (9), 2176–2208.
Bibri, S.E., 2018. Backcasting in futures studies: a synthesized scholarly and planning approach to strategic smart sustainable city development. Eur. J. Futures Res. 6 (1), 13.
Blaikie, N., 2018. Confounding issues related to determining sample size in qualitative research. Int. J. Soc. Res. Methodol. 21 (5), 635–641.
BOCMA, 2009. Inception Report, Breede-Overberg Catchment Management Agency.
BOCMA, 2010. First Draft Breede-Overberg Catchment Management Strategy. Breede-Overberg Management Agency.
Bukvic, A., Harrald, J., 2019. Rural versus urban perspective on coastal flooding: The insights from the U.S. Mid-Atlantic communities. Clim. Risk Manag. 23, 7–18.
Butler, J.R.A., et al., 2016. Scenario planning to leap-frog the Sustainable Development Goals: An adaptation pathways approach. Clim. Risk Manag. 12, 83–99.
Carlsson-Kanyama, A., et al., 2013. Barriers in municipal climate change adaptation: Results from case studies using backcasting. Futures 49, 9–21.
Cuppen, E., et al., 2021. Participatory multi-modelling as the creation of a boundary object ecology: the case of future energy infrastructures in the Rotterdam Port Industrial Cluster. Sustain. Sci. 16 (3), 901–918.
Faldi, G., Macchi, S., 2017. Knowledge for Transformational Adaptation Planning: Comparing the Potential of Forecasting and Backcasting Methods for Assessing People's Vulnerability. In: Tiepolo, M., Pezzoli, A., Tarchiani, V. (Eds.), Renewing Local Planning to Face Climate Change in the Tropics. Springer International Publishing, Cham, 265–283.
Faldi, G., Rossi, M., 2014. Climate Change Effects on Seawater Intrusion in Coastal Dar es Salaam: Developing Exposure Scenarios for Vulnerability Assessment. In: Macchi, S., Tiepolo, M. (Eds.), Climate Change Vulnerability in Southern African Cities: Building Knowledge for Adaptation. Springer International Publishing, Cham, 57–72.
Fedele, G., et al., 2019. Transformative adaptation to climate change for sustainable social-ecological systems. Environ. Sci. Policy 101, 116–125.
Grafakos, S., et al., 2020. Integration of mitigation and adaptation in urban climate change action plans in Europe: A systematic assessment. Renew. Sustain. Energy Rev. 121, 109623.
Grêt-Regamey, A., Brunner, S.H., 2011. Adaptation to climate change through backcasting—a methodological framework for spatial planners. disP - The Plan. Rev. 47 (184), 43–51.
Haasnoot, M., et al., 2013. Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. Glob. Environ. Chang.
Haasnoot, M., et al., 2018. Designing a monitoring system to detect signals to adapt to uncertain climate change. Glob. Environ. Chang. 52, 273–285.
Hickman, R., et al., 2010. Transport and climate change: Simulating the options for carbon reduction in London. Transp. Policy 17 (2), 110–125.
Hickman, R., et al., 2013. Planning more for sustainable mobility. J. Transp. Geogr. 33, 210–219.
Hickman, R., Banister, D., 2014. Transport, Climate Change and the City. Routledge.
Holden, M., et al., 2016. From Resilience to Transformation Via a Regenerative Sustainability Development Path. In: Yamagata, Y., Maruyama, H. (Eds.), Urban Resilience: A Transformative Approach. Springer International Publishing, Cham, pp. 295–319.
Holscher, K., 2019. Transforming urban climate governance: capacities for transformative climate governance. PhD. Erasmus University Rotterdam.
Iacobuţă, G.I., et al., 2022. Aligning climate and sustainable development finance through an SDG lens. The role of development assistance in implementing the Paris Agreement. Glob. Environ. Chang. 74, 102509.
Jiricka-Pürrer, A., et al., 2019. Perspectives from 2037—Can Environmental Impact Assessment be the Solution for an Early Consideration of Climate Change-related Impacts? Sustainability 11 (15), 4002.
Kim, H., Grafakos, S., 2019. Which are the factors influencing the integration of mitigation and adaptation in climate change plans in Latin American cities? Environ. Res. Lett. 14 (10).
Klein, R.J.T., et al., 2005. Integrating mitigation and adaptation into climate and development policy: three research questions. Environ. Sci. Policy 8 (6), 579–588.
Kok, K., et al., 2011. Combining participative backcasting and exploratory scenario development: Experiences from the SCENES project. Technol. Forecast. Soc. Chang. 78 (5), 835–851.
Lempert, R.J., Groves, D.G., 2010. Identifying and evaluating robust adaptive policy responses to climate change for water management agencies in the American west. Technol. Forecast. Soc. Chang. 77 (6), 960–974.
Lempert, R., Schlesinger, M., 2000. Robust Strategies for Abating Climate Change. Clim. Change 45 (3–4), 387–401.
Lonsdale, K., Pringle, P., Turner, B., 2015. Transformative adaptation: what it is, why it matters & what is needed. UK Climate Impacts Programme. University of Oxford, Oxford: UK.
Loorbach, D., et al., 2017. Sustainability Transitions Research: Transforming Science and Practice for Societal Change. Annu. Rev. Env. Resour. 42 (1), 599–626.
Loorbach, D.A., 2022. Designing radical transitions: a plea for a new governance culture to empower deep transformative change. City Territ Archit 9, 30. https://doi.org/10.1186/s40410-022-00176-z.
Mendizabal, M., et al., 2021. Triggers of change to achieve sustainable, resilient, and adaptive cities. City Environ. Interactions 12, 100071.
Muiderman, K., 2022. Approaches to anticipatory governance in West Africa: How conceptions of the future have implications for climate action in the present. Futures 141, 102982.
Nalau, J., Cobb, G., 2022. The strengths and weaknesses of future visioning approaches for climate change adaptation: A review. Glob. Environ. Chang. 74, 102527.
Nwedu, C.N., 2020. Towards a Prioritized Climate Change Management Strategy: A Revisit to Mitigation and Adaptation Policies. Climate Change Manage. 351–367.
O'Brien, K., 2011. Responding to environmental change: A new age for human geography? Prog. Hum. Geogr. 35 (4), 542–549.
Pandey, A., et al., 2021. Matches, mismatches and priorities of pathways from a climate-resilient development perspective in the mountains of Nepal. Environ. Sci. Policy 125, 135–145.
Park, S.E., et al., 2012. Informing adaptation responses to climate change through theories of transformation. Glob. Environ. Chang. 22 (1), 115–126.
Quist, J., et al., 2011. The impact and spin-off of participatory backcasting: From vision to niche. Technol. Forecast. Soc. Chang. 78 (5), 883–897.
Quist, J., Vergragt, P., 2006. Past and future of backcasting: The shift to stakeholder participation and a proposal for a methodological framework. Futures 38 (9), 1027–1045.
Quist, J.N., 2007. Backcasting for a sustainable future: the impact after ten years. Eburon Publishers, Delft, Delft University of Technology. **PhD**.
Quist, J., 2013. Backcasting and Scenarios for Sustainable Technology Development. In: Kauffman, J., Lee, K.-M. (Eds.), Handbook of Sustainable Engineering. Springer Netherlands, Dordrecht, 749-771.
Ragin, C.C., 2014. The comparative method: Moving beyond qualitative and quantitative strategies. Univ of California Press.
Roggema, R., et al., 2021. Designing the Adaptive Landscape: Leapfrogging Stacked Vulnerabilities. Land 10 (2), 158.
Sandström, C., et al., 2016. Understanding consistencies and gaps between desired forest futures: An analysis of visions from stakeholder groups in Sweden. Ambio 45 (Suppl 2), 100–108.
See, J., et al., 2022. Diverse pathways to climate change adaptation through a postdevelopment lens: the case of Tambaliza Island, Philippines. Clim. Dev. 1–12.
Shaw, A., et al., 2009. Making local futures tangible—Synthesizing, downscaling, and visualizing climate change scenarios for participatory capacity building. Glob. Environ. Chang. 19 (4), 447–463.
Sheppard, S.R.J., et al., 2011. Future visioning of local climate change: A framework for community engagement and planning with scenarios and visualisation. Futures 43 (4), 400–412.
Star, J., et al., 2016. Supporting adaptation decisions through scenario planning: Enabling the effective use of multiple methods. Clim. Risk Manag. 13, 88–94.
Van de Kerkhof, M., 2004. Debating climate change: a study of stakeholder participation in an integrated assessment of long-term climate policy in the Netherlands. Lemma Publishers, Utrecht NL.

van de Kerkhof, M., et al., 2002. "Shaping diversity in participatory foresight studies: Experiences with interactive backcasting in a stakeholder assessment on long-term climate policy in the Netherlands." Greener Manage. Int. (37), 85-99.
van der Helm, R., 2009. The vision phenomenon: Towards a theoretical underpinning of visions of the future and the process of envisioning. Futures 41 (2), 96–104.
van der Voorn, T., et al., 2012. Combining backcasting and adaptive management for climate adaptation in coastal regions: A methodology and a South African case study. Futures 44 (4), 346–364.
van der Voorn, T., et al., 2020. Envisioning carbon-free land use futures for Sweden: a scenario study on conflicts and synergies between environmental policy goals. Reg. Environ. Chang. 20 (2), 35.
Van der Voorn, T., Quist, J., Pahl-Wostl, C., Haasnoot, M., 2017. Envisioning robust climate change adaptation futures for coastal regions: A comparative evaluation of cases in three continents. Mitig. Adapt. Strat. Glob. Chang. 22 (3), 519–546.
van Vliet, M., Kok, K., 2015. Combining backcasting and exploratory scenarios to develop robust water strategies in face of uncertain futures. Mitig. Adapt. Strat. Glob. Chang. 20 (1), 43–74.
Vergragt, P.J., Quist, J., 2011. Backcasting for sustainability: Introduction to the special issue. Technol. Forecast. Soc. Chang. 78 (5), 747–755.
Vizinho, A., et al., 2021. Framing the application of Adaptation Pathways for agroforestry in Mediterranean drylands. Land Use Policy 104, 105348.
Werners, S.E., et al., 2021. Advancing climate resilient development pathways since the IPCC's fifth assessment report. Environ Sci Policy 126, 168–176.
Wise, R.M., et al., 2014. Reconceptualising adaptation to climate change as part of pathways of change and response. Glob. Environ. Chang. 28, 325–336.
Yin, R.K., 1994. Discovering the future of the case study method in evaluation research. Eval. Pract. 15 (3), 283–290.