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A design framework towards a users' guide

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DOI
10.1016/j.techfore.2024.123285

Publication date
2024

Document Version
Final published version

Published in
Technological Forecasting and Social Change

Technological Forecasting & Social Change 202 (2024) 123285

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

Consolidating backcasting: A design framework towards a users' guide

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ARTICLE INFO

Keywords:
Backcasting
Design framework
Futures studies
Sustainability transitions
Foresight

ABSTRACT

Backcasting has become a widely applied approach to address sustainability challenges when transformative changes are required. However, dispersed and contextualized knowledge of backcasting methodologies and practices needs to be systematized, codified, and synthesized to support researchers, commissioners, practitioners, and stakeholders in backcasting projects. In this paper, we address these issues by (i) concisely reviewing the evolution and current body of literature on backcasting and how this relates to other major types of futures and scenario studies and (ii) developing a design framework for researchers and practitioners that systematically covers all methodological choices with regard to key guiding questions to develop a backcasting methodology for a particular backcasting project. The developed design framework is based on four parts, characterized by the interrogatives when, which, how, and what, creating a comprehensive framework for describing a backcasting study.

1. Introduction

Backcasting has become a widely used approach to address sustainability challenges, such as climate change, energy supply and use, transportation, urban planning, and land use (e.g., Berg Mårtensson et al., 2024; Bibri, 2018; Hickman et al., 2010; Höjer et al., 2011; Kishita et al., 2017; Musse et al., 2018; Vergragt and Quist, 2011). Problems characterized by complexity and stakeholder value conflicts, and situations when transformative changes at a systemic level are necessary, are suitable for backcasting (Börjeson et al., 2006; Dreborg, 1996; Quist and Vergragt, 2006). This is because backcasting first looks at a desirable or undesirable future endpoint, followed by looking backward from the future to the present (e.g. Robinson, 1990; Quist and Vergragt, 2006). A typical example is energy system design, in which a longer time horizon (e.g., 40–50 years) is considered if system-level changes, including the replacement of the energy supply infrastructure, are required (e.g. Lovins, 1977; Robinson, 1982). There are a range of benefits and a potential value of using backcasting to solve complex real-world problems by envisioning sustainable futures and transformation of socio-technical systems.

Backcasting is often used in combination with other foresight methods, such as scenarios and roadmapping (Popper, 2008), as well as with a range of analytical tools, design methods, simulations, and participatory methods (Börjeson et al., 2006; Kok et al., 2011; Quist et al., 2011; Vergragt and Quist, 2011). Since the 1970s, many scholars have proposed backcasting methodologies that provide guidance to understand, learn, and use backcasting. In this paper, a backcasting methodology has been defined as a set of principles, guidelines, and methods/tools that help people develop and conduct backcasting. Commonly, a backcasting methodology consists of several steps in which the target users are a range of stakeholders, including researchers, policymakers, c2orporate strategists, public interest groups, and consultants. It should be noted that a methodology must be tailored to address the problems and issues considered in a given project. For example, Robinson (1990) proposed a methodology that is generally applicable to backcasting projects and consists of seven steps (determining objectives; specifying goals, constraints, and targets; describing the present system; specifying exogenous variables; undertaking scenario analysis; and undertaking impact analysis). Robinson (1990)'s framework has been widely applied and customized by many scholars for particular applications (e.g., Tuominen et al., 2014). Other scholars have proposed their own methodologies, (e.g. Höjer et al., 2011; Holmberg, 1998; Quist and Vergragt, 2006; Quist, 2013). Details of some examples are provided in Section 3. Moreover, over the last four decades, there has been a steady growth in number of backcasting studies, owing to the recent interest in sustainability transitions,

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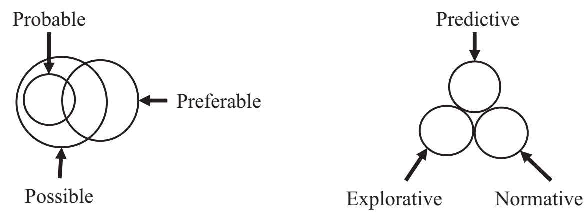
https://doi.org/10.1016/j.techfore.2024.123285
Received 14 August 2023; Received in revised form 15 January 2024; Accepted 17 February 2024
Available online 16 March 2024



(a) Amara's concepts (b) Börjeson et al.'s categories

Fig. 1. The relation between (a) the three concepts according to Amara, 1981 (Probable, Possible, Preferable) and (b) the three scenario categories proposed by Börjeson et al., 2006 (Predictive, Explorative, Normative).

Sustainable Development Goals (SDGs), climate action, and research on carbon-neutral and renewable energy futures. This has resulted in a flourishing and steadily growing scholarly community working in a range of domains and topics, such as energy, mobility, food and agriculture, climate adaptation, water, cities, rural areas, consumption, and the circular economy, in many countries worldwide.

Vergragt and Quist (2011), in their editorial of the only special issue on backcasting so far, have characterized backcasting research as highly diverse in terms of domains, use of methods and combining methods, level of participation, its extent, reporting and follow-up, spin-off, and other impacts, as well as the way in which the term backcasting is used. Thus, backcasting is not a well-defined or standardized term. This has resulted in different interpretations of backcasting, and may even lead to confusion among researchers and practitioners. Although some scholars have provided literature reviews of backcasting and compared different backcasting methodologies (e.g., Bibri, 2018; Höjer et al., 2011; Musse et al., 2018; Quist and Vergragt, 2006; Quist, 2007), a plea has been made for more systematic comparative research in backcasting (Vergragt and Quist, 2011) as only a few efforts (e.g., Quist et al., 2011; Van der Voorn et al., 2023; Wangel, 2011) have been made to address this knowledge gap by systematically bringing together and synthesizing various (and often fragmented) knowledge related to backcasting methodologies and practices.

To fill this knowledge gap, we aim to develop a design framework for researchers and practitioners to clarify and contextualize how they can plan and use backcasting. The design framework consists of a set of principles and guidelines that can be used to develop a methodology that addresses the problem being considered. In this paper, we want to take stock of developments in backcasting since 2011 (Vergragt and Quist, 2011) to contribute to developing a standardized manner enabling systematic comparison of various backcasting projects.

Towards this end, we conduct a mapping of backcasting (Section 2) including a literature review of diverse backcasting studies and examples from our own backcasting methodologies and experiences (Section 3). We demonstrate how the developed framework works using illustrative examples to show its usefulness (Section 4). We discuss the usefulness and limitations of this framework (Section 5) before we conclude the paper (Section 6).

2. Mapping backcasting research

2.1. Futures studies

Backcasting belongs to the field of futures studies. Therefore, we here give a brief conceptualization of futures studies, in order to be able to place backcasting in a futures studies context in Section 3.2. Futures studies are often referred to as studies dealing with probable, possible, or preferable futures (Amara, 1981; Bell, 2003; Börjeson et al., 2006; Quist, 2007; Van der Duin, 2016; Vergragt and Quist, 2011). Amara (1981) and Börjeson et al. (2006) discussed this extensively, leading to slightly different perspectives, as shown in Fig. 1.

In Amara's (1981) paper, "Probable" refers to the study of likely alternatives. "Possible" refers to forming perceptions of the future, while "Preferable" refers to making choices to execute a particular feature, and focus on what should or ought to be. All Probable scenarios are Possible, and some are Preferable (at least some). Some Possible scenarios are not Probable but are still Preferable, and other Possible scenarios are neither

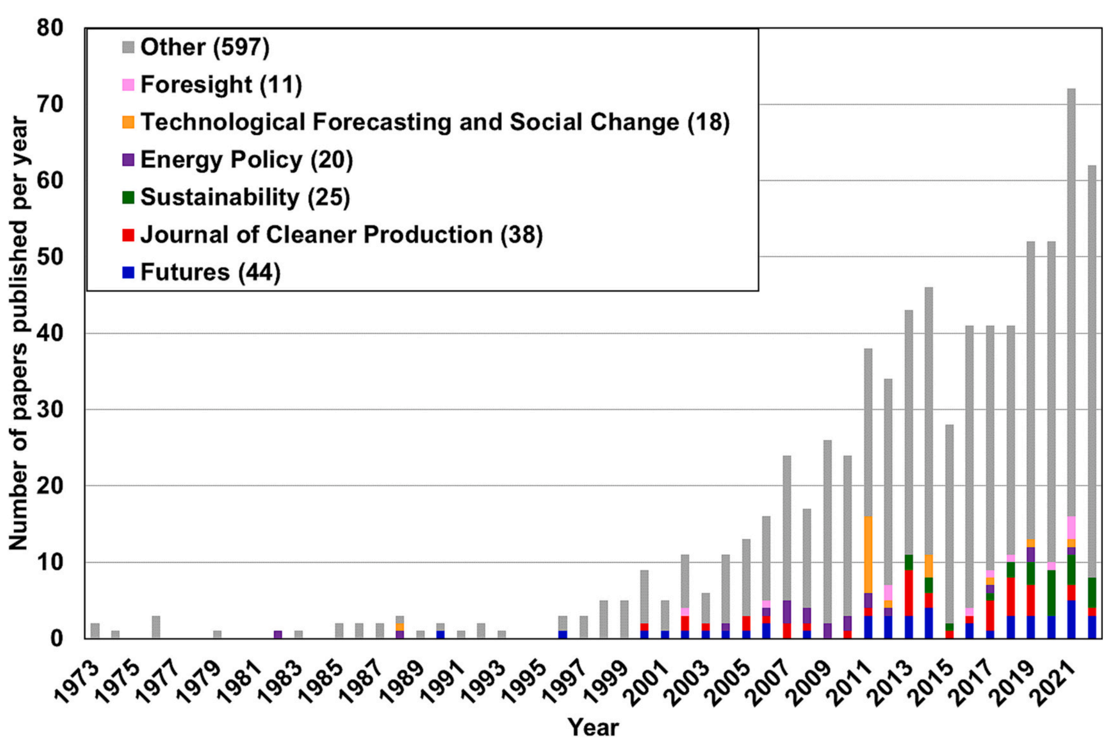


Fig. 2. Number of backcasting papers published from 1973 to 2022 ("backcasting" or "back-casting" in title, abstract or keywords). A total of 753 papers were published in the period of 1973–2022 as searched on 26 May 2023 via Scopus.

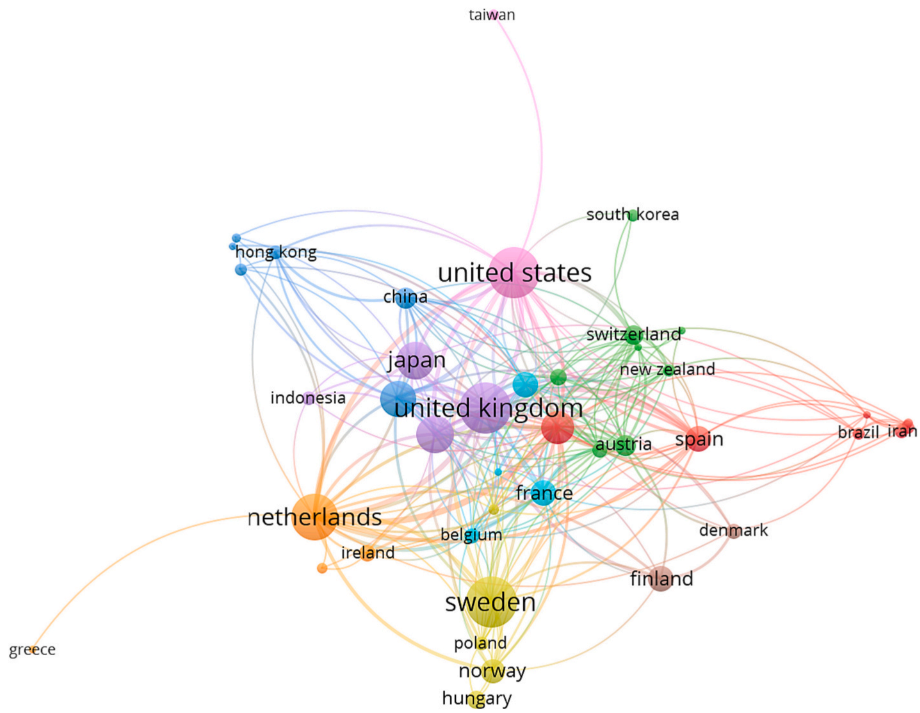


Fig. 3. Co-authorship network of backcasting papers across countries. The size of bubbles indicates the number of papers published from 1973 to 2022 as searched on 26 May 2023 via Scopus.

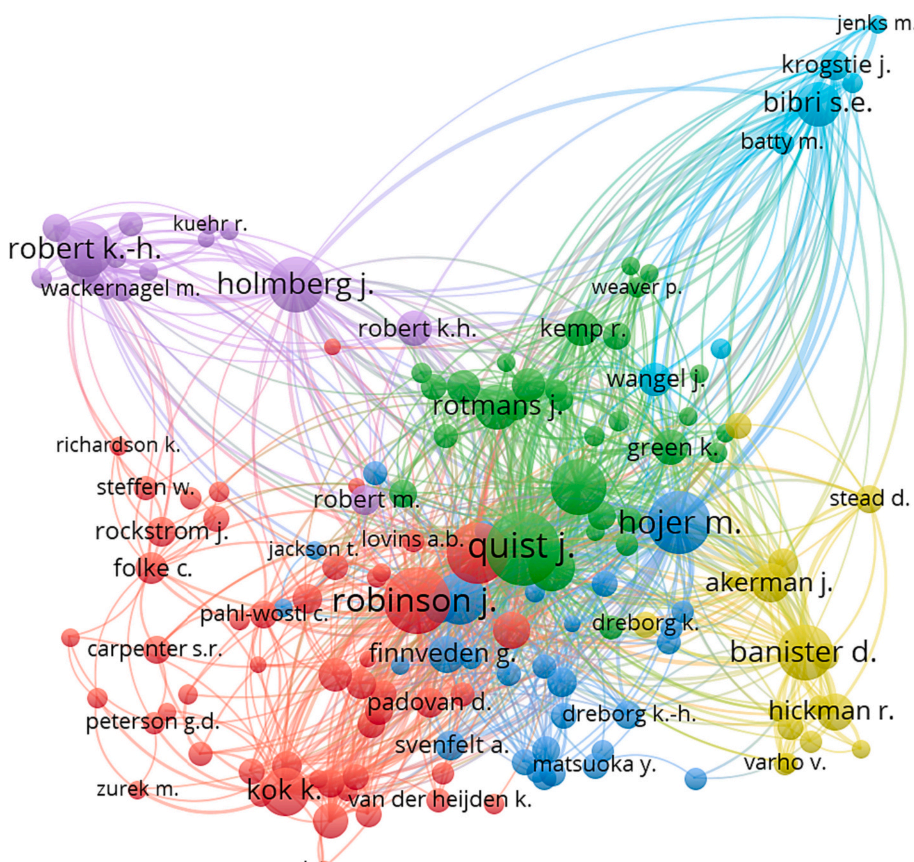


Fig. 4. Co-citation network of backcasting papers across authors. The size of bubbles indicates the number of citations that the author received from 1973 to 2022 as searched on 26 May 2023 via Scopus.

Table 1
Three backcasting methodologies developed by the authors.

	Participatory backcasting methodology developed by Quist and colleagues	Goal-oriented backcasting* methodology developed by Höjer and colleagues	Backcasting scenario design methodology developed by Kishita and colleagues
Purpose and underlying assumptions	To create sustainable vision and pathways with stakeholder engagement to support implementation	To create goal-fulfilling images of the future as a way of challenging unsustainable trends as a basis for planning.	To design sustainable scenarios, consisting of vision and pathways, with the involvement of researchers and stakeholders.
Process description in steps	1. Strategic problem orientation 2. Normative future image 3. Backcasting 4. Elaboration, analysis, pathway 5. Embedding, implementation	1. Goal setting 2. Goal analysis 3. Development of goal-fulfilling images of the future 4. Path analysis/development	1. Problem setting and data gathering 2. Vision creation 3. Describing pathways 4. Describing detailed scenario descriptions 5. Scenario evaluation
Characteristics	• The process plan and methodology used are determined in Step 1. • Step 2 includes distinction of 4 groups of methods and tools (analytical, design, interactive, organizational), 3 kinds of criteria (normative, process, knowledge), and different kinds of project goals. • In Step 3, what-how-who analysis is undertaken to clarify what is necessary to achieve the vision (s). • Embedding results in practice through implementation is explicitly added in Step 5.	• Much focus on Step 1 to formulate a goal. • Step 2 is to see if the goal seems reachable without structural change. If so, planning instead of backcasting is relevant. • Most emphasis is on the third step - the development of goal-fulfilling images of the future in order to indicate what can be required to achieve the goals. • The development of images of the future is typically based on in-depth studies of particular critical areas of importance for the goal in focus. Such studies are sometimes called "building blocks".	• Workshops involving stakeholders and back-office work done by researchers are combined, while how to combine them depends on the project. • Some tools (e.g., logic trees and roadmapping) are used to support systematic thinking for vision creation and pathway development in order to visualize ideas generated during the process. • Simulation models may be used for quantification where available. • The final outcomes are scenarios in a narrative format.
Examples of applications described in the literature	• Sustainable food and land use • Sustainable household consumption and lifestyles • Renewable energy	• Sustainable cities • Sustainable transport systems • Sustainable digitalization	• Sustainable urban system • Sustainable energy system • Sustainable consumption and production
References	Quist (2007, 2013, 2016), Quist et al. (2011)	Höjer et al. (2011)	Kishita et al. (2023), Onozuka et al. (2021), Uwasu et al. (2020)

* Höjer et al. (2011) originally called this "target-oriented backcasting."

Probable nor Preferable. Finally, some Preferable scenarios are neither Probable nor Possible (Fig. 1a).

Börjeson et al. (2006) considered Amara's three concepts as the starting point when they developed a widely used categorization of scenarios into predictive, exploratory, and normative scenarios. Each category was connected to a specific type of question, emphasizing that the starting point of the study strongly influenced the results. The first category from Börjeson et al., "Predictive scenarios," addresses the question "What will happen?". Predictive scenarios are strongly related to concepts, such as likelihood, probability, and causality. The second category, "Explorative scenarios," responds to the question "What can happen?". Explorative scenarios are typically developed as a group of scenarios that illustrate widely different futures and are often used as decision support when making strategic decisions to prepare an organization for different outcomes. The third category, "Normative scenarios," addresses the question "How can a specific target be reached?". Börjeson et al. divided normative scenarios into preserving normative and transforming normative scenarios, where the former refer to scenarios reaching the specified aim without changing prevailing societal and economic structures, whereas the latter are about scenarios that require transformative change, i.e., to break structures and reach targets, as argued in the field of Sustainability Transitions (e.g., Grin et al., 2010; Loorbach et al., 2017). Because the three categories are defined by the questions to which they respond, their definitions do not overlap, even though the outcomes may do so in such a way that, for example, predictive scenarios can lead to outcomes that are seen as preferable by some.

Although the three categories in Börjeson et al. (2006) seem quite similar to those in Amara (1981), Börjeson et al. built their categories as scenarios responding to specific questions. The Börjeson et al.'s category "Predictive" scenario overlaps with Amara's "Probable," the Börjeson et al.'s category "Explorative" engages in exploring selected futures, whereas Amara's Possible futures are much wider, and include non-explorative probable futures. Börjeson et al.'s term "Normative scenarios" focus on fulfilling goals without valuing them, whereas stating that something is preferable, as in Amara's concepts, requires valuing the goals.

2.2. Evolution of backcasting

Quist and Vergragt (2006) proposed three phases in the evolution of backcasting research. The first phase from the mid-1970s to the mid-1980s included the development of backcasting using system dynamics models and energy backcasting. The second phase of sustainability backcasting started around 1985, just before the publication of the Brundtland Report, leading to the application of backcasting to other domains, such as water and mobility. The third phase began in the early 1990s when backcasting was proposed as a participatory methodology engaging stakeholders and citizens, inspired by progress in participatory policymaking, which began in the Netherlands (Vergragt and Jansen, 1993), Sweden (Dreborg, 1996; Holmberg, 1998; Holmberg and Robèrt, 2000), and Canada (Robinson, 2003). It must be noted that practices from the previous phases continued, leading to more diversity in backcasting. For instance, energy backcasting studies continued after sustainability backcasting emerged (e.g., Hennicke, 2004).

Backcasting is rooted in normative, need-oriented forecasting, which was developed in the late 1960s and the early 1970s (Jantsch, 1967) and can be considered a major predecessor of backcasting. It has been used for goal-based technology development (Jantsch, 1967), and was contrasted with regular exploratory forecasting (Linstone, 1969).

When energy backcasting was developed in the mid-1970s it was also referred to as soft energy path studies (Lovins, 1977; Suwa, 2009), or end-use energy studies (e.g., Goldemberg et al., 1985), while there was also early work in Sweden (Lönnroth et al., 1980). Whereas Lovins (1977) introduced the term backward-looking analysis, Robinson (1982) coined the term energy backcasting. There has also been backcasting research related to world dynamics models, following the 'Limits to Growth' study of the Club of Rome (e.g., Bloomfield, 1985; Cole and Curnow, 1973; Erickson Jr. and Pikul, 1976), not only covering energy issues, but also broader resource use topics.

With the rise of the concept of sustainable development, marked by the Brundtland Report (WCED, 1987), backcasting was proposed as a promising approach for sustainable development topics and challenges (Robinson, 1990) and later as a core framework for sustainability science (Kajikawa, 2008). Backcasting has been increasingly applied to other topics and domains, such as natural resource management (Higgs, 1986; Higgs, 1987) and water management (Falkenmark, 1998; Gleick, 1998; Gleick, 2003; Mitchell and White, 2003; White et al., 2004), while the term soft water paths has been used for the latter. Other application domains and topics include sustainable technology development (Jansen and Vergragt, 1992; Vergragt and Van Noort, 1996; Weaver et al., 2000), food and agriculture (e.g., Gebhard et al., 2015), transport and mobility (e.g., Åkerman and Höjer, 2006; Banister et al., 2000; Camilleri et al., 2022; Geurs and van Wee, 2000; Hickman and Banister, 2007; Höjer, 1998), companies (Holmberg, 1998; Holmberg and Robèrt, 2000), new products and production (e.g., Partidario and Vergragt, 2002), households, consumption, and lifestyles (Doyle and Davies, 2013; Green and Vergragt, 2002; Höjer et al., 2011; Mont et al., 2014; Quist et al., 2001; Svenfelt et al., 2011), and circular economy (Mendoza et al., 2017).

In the early 1990s, participatory and interactive backcasting emerged in the Netherlands (Quist et al., 2001; Van de Kerkhof et al., 2003; Vergragt and Jansen, 1993; Vergragt and Van der Wel, 1998; Weaver et al., 2000), Sweden (Carlsson-Kanyama et al., 2008; Dreborg, 1996; Höjer, 1998; Holmberg, 1998) and Canada (Robinson, 2003). Both participatory and interactive backcasting have been in use, and refer to the involvement, participation, and engagement of stakeholders and citizens, driven by a wish to create commitment, endorsement, co-ownership, and follow-up, as well as to increase reflexivity and legitimacy (Quist et al., 2011; Van de Kerkhof, 2004), while emphasizing values (Paehlke, 2012). Citizen involvement, as a special type of stakeholder engagement, is also motivated by the enhancement of democracy. Interesting examples of local and citizen-focused backcasting include several local climate change studies in Sweden (Carlsson-Kanyama et al., 2013; Milestad et al., 2014). Citizens have been involved in vision development and backcasting workshops in sustainable urban planning (Carlsson-Kanyama et al., 2008) and in developing and evaluating local and regional energy futures in Canada (Robinson et al., 2011). Strong citizen involvement was also a part of local vision development (Kok et al., 2011), sustainable neighborhood communities (Quist et al., 2013), defining sustainability research agendas in the UK (Eames and Egmose, 2011), and local backcasting in Japan (Kishita et al., 2018; Onozuka et al., 2021). There is an increase in participatory backcasting on sustainable consumption and lifestyles (e.g. Davies, 2015; Doyle and Davies, 2013; Mont et al., 2014; Neuvonen et al., 2014; Quist and Leising, 2016), as well as on post-growth and degrowth (Fauré et al., 2019; Quist and Leising, 2016; Svenfelt et al., 2019) and Sustainable Development Goals (e.g., Kanter et al., 2016). The rise of participatory backcasting has also raised issues of implementation, impact, and follow-up (Olsson et al., 2015; Quist, 2007; Quist et al., 2011; Van der Voorn et al., 2017; Weaver et al., 2000).

The participatory methods that have mostly been reported use workshops (e.g. Höjer et al., 2011; Quist et al., 2001; Quist and Vergragt, 2006), but references have also been made to focus groups (Svenfelt et al., 2011), interviews (e.g., Quist et al., 2001), and Delphi method expert consultations (e.g., Bailey et al., 2012; Höjer, 1998; Hurmekoski et al., 2018; Zimmermann et al., 2012). In addition, interviews are widely applied as part of participatory backcasting, usually not as the main method of participation but in combination with workshops or focus groups (e.g., Quist et al., 2001).

Since 2010 backcasting has increasingly been combined with other approaches, which could be seen as marking a fourth phase of "blending" backcasting contributing to a growing diversity in backcasting research. For instance, backcasting has been combined with transition management in the Community Arena methodology (Quist et al., 2013; Wittmayer et al., 2014) and with participatory integrated assessment (Tansey et al., 2002; Van de Kerkhof et al., 2003). Authors associated with The Natural Step have incorporated backcasting into the Framework for Strategic Sustainable Development (FSSD; Broman and Robèrt, 2017), which can be considered an elaborate backcasting framework. While most authors combine various methods with backcasting in a single backcasting methodology, some authors consider backcasting to be part of a larger toolkit for sustainability (Robèrt, 2000; Robèrt et al., 2002). Other examples of combining backcasting with other approaches and methodologies include adaptive management (Van der Voorn et al., 2012; Van der Voorn et al., 2023), industrial ecology (Giurco et al., 2011), exploratory scenarios (Kok et al., 2011; Milestad et al., 2014), geographic information systems and spatial maps (Haslauer et al., 2012; Haslauer et al., 2016), policy analysis (Olsson et al., 2015), policy packaging (Soria-Lara and Banister, 2017), multi-criteria analysis (Soria-Lara and Banister, 2018), and agent-based modeling (Garcia-Mira et al., 2017; Van Berkel and Verburg, 2012), as well as resilience and fault tree analysis (Kishita et al., 2018), gamification and games (Andreotti et al., 2020; Bruley et al., 2021; Guillen Mandujano et al., 2021; Mangnus et al., 2019), role-playing (Hara et al., 2019), life cycle assessment and eco-design (Mendoza et al., 2017), multi-modeling (Cuppen et al., 2021), and living labs (Larsson and Holmberg, 2018; Nevens et al., 2013).

It should also be noted that some approaches and methodologies do not refer to the term backcasting, but work with normative and desirable futures similar to backcasting. For example, visioning in sustainability studies (e.g., Hara et al., 2021; Morita et al., 2020; Wiek and Iwaniec, 2014), imaginaries (Fergnani, 2019; Hara et al., 2019), and climate adaptation visioning (Nalau and Cobb, 2022). There are also links to normative scenarios (e.g., Iverson Nassauer and Corry, 2004; Milestad et al., 2014; Skea et al., 2021) and design scenarios (e.g., Gaziulusoy et al., 2013; Silvester et al., 2013). In addition, backcasting is sometimes used to denote just a backward-looking step, such as in transition management (Rotmans et al., 2001) and Participatory Integrated Assessment (Tansey et al., 2002; Van de Kerkhof et al., 2003). There are also links to roadmapping (Kishita, 2021; Okada et al., 2022; Phaal et al., 2004), which is also normative. Thus, there are similarities and differences between backcasting and related approaches, such as transition management, roadmapping, and visioning. However, that has not been discussed in detail in the current study.

2.3. *Bibliometric analysis*

This section describes some of the bibliometric trends in backcasting, including how the number of papers has developed over time (Fig. 2), an overview of the countries with the most backcasting studies (Fig. 3), and an overview of the main authors of backcasting (Fig. 4).

As illustrated in Fig. 2, the number of papers related to backcasting has increased, particularly since the early 2000s. Some reviews and overviews have also been published, such as Bibri (2018), Musse et al. (2018), Quist and Vergragt (2006), and Vergragt and Quist (2011), none of which are fully up to date and take either a historical development approach (Quist and Vergragt, 2006; Vergragt and Quist, 2011) or an application domain orientation (Bibri, 2018; Musse et al., 2018). Fig. 2 also indicates that the main journals are either futures and foresight oriented (Futures, Technological Forecasting, and Social Change, and Foresight), or sustainability or domain oriented (Journal of Cleaner Production, Sustainability, and Energy Policy). In addition, the six main journals have a share of only 21%, whereas the other journals account for 79%. This confirms both the diversity and dispersed nature of backcasting research, which is used in a range of different scientific communities and disciplines, but not necessarily connected to the overall backcasting research community.

Fig. 3 shows that Sweden, the Netherlands, the United States, and the United Kingdom are the top countries for journal publications on backcasting, followed by other developed countries, such as Canada, Japan, Australia, Germany, Norway, and France. As can be seen, only few countries from the Global South are in Fig. 3, and China as the quickly growing scientific powerhouse is not among the top ten. Regarding scientific institutions, the main institutions publishing on backcasting are from Sweden and the Netherlands, followed by the

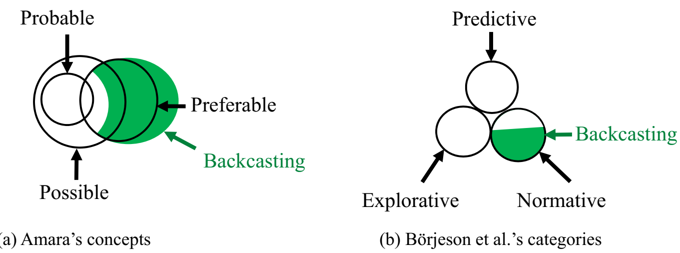


Fig. 5. Backcasting (in green) in relation to two widely used scenario concepts presented in Section 2 and Fig. 1. Note that the concepts used in the figure are to be interpreted in accordance with (a) Amara (1981) and (b) Börjeson et al. (2006). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

United Kingdom and Japan, all with more than one institution in the list. Fig. 4 shows main authors based on the number of co-citations, indicating key authors from the United States (Vergragt), Sweden (Holmberg, Höjer, Dreborg, and Robèrt), the United Kingdom (Banister), the Netherlands (Quist and Kok), Canada (Robinson), Japan (Kishita), and Norway (Bibri). The top five authors cocited in backcasting papers were Quist (the Netherlands), Höjer (Sweden), Dreborg (Sweden), Robinson (Canada), and Vergragt (the United States).

2.4. Diversity of backcasting

Sections 2.2–2.3 discuss the development of backcasting over time, as well as the diversity in how backcasting has been applied. Vergragt and Quist (2011) have summarized diversity as follows:

- Level of participation (from non-participatory to involving a broad range of stakeholders or citizens and influence given to participants)
- Scale (from local to global)
- Domain (considering an integral perspective)
- Whether a single vision or multiple visions are to be developed
- Use of the term backcasting (ranging from an overall approach to a specific step in other approaches)
- Whether or not impact or implementation has explicitly strived

In the special issue of backcasting in 2011, some papers touched upon various features of backcasting. For instance, Höjer et al. (2011) identified among other things target-fulfilling images of the future as a necessary feature of all backcasting studies and then defined target orientation, path orientation, and participation as three features included in backcasting, but with differences in which of these three parts are the most focused. This led to the definition of three different types of backcasting.

- Target-oriented
- Path-oriented
- Participatory backcasting

In sum, Section 2 shows that backcasting has become developed, more widely applied and more diverse over time. This confirms the need for a framework that not only makes diversity more visible but can also be used as a design framework for backcasting researchers and practitioners. In the next section, a few backcasting methodologies for particular cases to specify the characteristics of backcasting as inputs for developing the design framework are described.

3. Characterizing backcasting

3.1. Comparing backcasting methodologies

As shown in Section 2, there exists diversity in backcasting studies and practices owing to differences in purpose, application domains, available expertise, tools, and methods applied. The three authors of this paper have previously proposed the methodologies summarized in Table 1. When designing a project, a backcasting methodology must be developed.

Below, we use these three methodologies to extract the key commonalities and differences between different backcasting methodologies based on our own knowledge, observations, and experiences.

A comparison of the three methodologies revealed several similarities and differences. Backcasting is commonly used to address problems in which systemic changes from the present are required by drawing sustainable futures (see e.g., Dreborg, 1996). Setting goals at an early stage in the backcasting process and describing normative futures are particularly important. The execution of backcasting in these methodologies is commonly divided into three phases following the project design: (1) developing the project and setting goals to be achieved in the remote future, (2) describing what the future would look like, and (3) exploring ways to achieve them. Nevertheless, there are differences in terms of which phase to focus upon. For instance, the focus could be on describing goal-fulfilling images of the future, pathways, or stakeholder engagement and learning. The latter can be illustrated by the fact that Quist et al. and Kishita et al. included participation as an integral part of their purpose, whereas Höjer et al. focused on the image of the future and its goal fulfillment.

While all three methodologies aim at structural change towards fulfilling societal or organizational goals, the expected outputs differ among them. For instance, Quist et al. cover embedding results and achieving impact or implementation in the real world as an explicit step, while Kishita et al. focus on developing both visions and pathways and Höjer et al. have a strong focus on the "images of the future" as the final outcome. Additionally, all three methodologies consider learning among both researchers and engaged stakeholders during the process, leading towards final outputs as important parts of the results.

3.2. Relating backcasting to scenario concepts

By reviewing Fig. 1 in Section 2.1, it is now possible to use some of the commonalities between the three methodologies in Table 1 and place backcasting in Fig. 1. This enables us to illustrate how backcasting relates to other scenario categories according to our understanding of backcasting developed in this study (Fig. 4). Backcasting should, in our view, be seen as not overlapping at all with Probable and Predictive scenarios because predictions require some degree of stability in the system under study, whereas backcasting is used when systemic changes are required to achieve goals.

In addition, all three backcasting methodologies in Table 1 agree that backcasting concerns reaching certain goals. However, it is not the same as Preferable scenarios, as some Preferable scenarios are in line with current trends and can thus be achieved through regular planning, that is, within current structures. This illustrates that we do not see backcasting as regular planning starting from the present but as an approach to use when current trends lead in a direction other than the

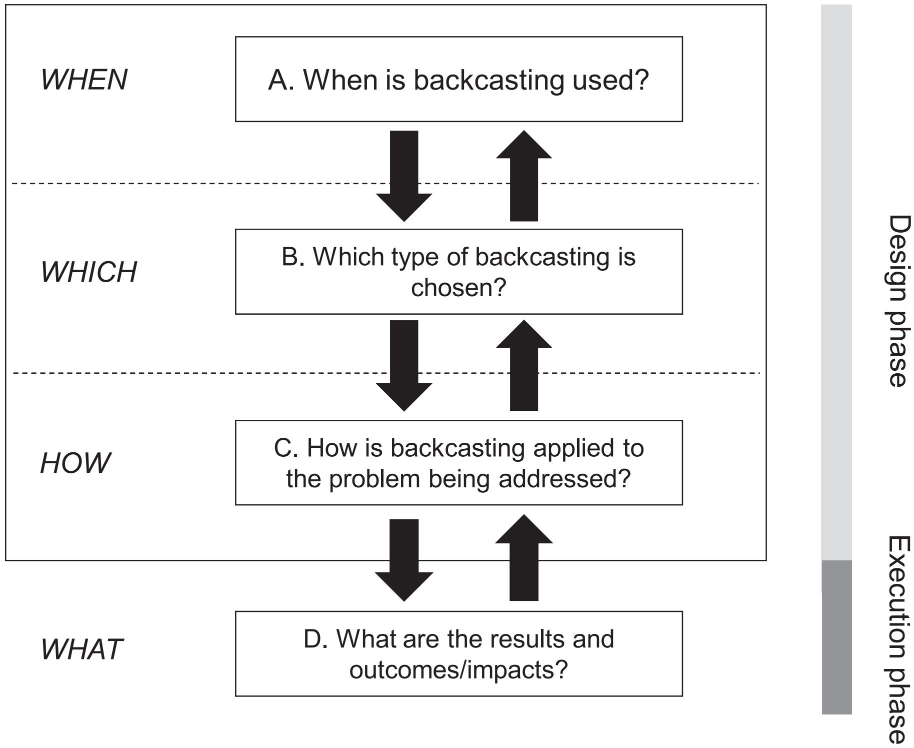


Fig. 6. Design framework for planning and operationalizing backcasting.

transformative goal in focus (cf Dreborg, 1996). Moreover, some studies may start with goals without stating how these goals are preferable or for whom. When such goals are not within the reach of regular planning, we call this backcasting; therefore, backcasting is, in our view, broader than Preferable scenarios (cf Höjer et al., 2011; Åkerman et al., 2021).

Thus, with regard to the concepts of Börjeson et al. (2006), backcasting is entirely within the Normative category because it always starts out with a goal. However, because backcasting is only concerned with major changes and not with any goal-oriented study, it is a subset of Normative scenarios. Although we define backcasting as something other than the Predictive and Explorative scenarios in Fig. 5, elements of prediction and exploration can still exist in backcasting studies.

Finally, regardless of whether backcasting is considered as an approach or a methodology, it can be combined with a range of methods and tools (Quist et al., 2011; Vergragt and Quist, 2011). Although backcasting is sometimes used as a backward-looking tool or step, providing a backward-looking analysis or creating a path from the future to the present, we argue that backcasting has its raison d'être as something that is both broader and more specific. It is broader in the way that backcasting includes more than just the path, and it is more specific in the sense that we highlight that in backcasting, the resulting futures must fulfil a goal that requires structural change.

4. Developing a design framework of backcasting

The essence of backcasting is to explore alternative futures and challenge the current structures, thereby blocking the development required to achieve certain targets. In this way, backcasting can help solve current and future problems, such as sustainability challenges, in contrast to forecasting, where there is a risk that forecasts will manifest future problems caused by current trends (Höjer and Mattsson, 2000). However, using backcasting and the methods applied in a backcasting project may differ according to how the problems are approached, how future visions are generated, whether and how stakeholders are involved, whether it increases citizens' awareness of the environment, what methods are applied, and how to identify effective measures to achieve ambitious sustainability goals and targets in organizations or society.

Given the diversity of backcasting practices, it is important to develop a shared understanding of the main features of backcasting and the possible choices to make when developing a backcasting methodology for a particular project. Therefore, we developed a design framework to help researchers, practitioners, and commissioners plan and operationalize backcasting. Based on an overview of backcasting in Section 2 and the essence distilled from the three backcasting methodologies described in Section 3, we developed this design framework using four essential questions, as illustrated in Fig. 6.

The framework in Fig. 6 intends to support researchers and practitioners in developing a backcasting methodology for a given problem based on four essential questions: when, which, how, and what? As illustrated by the bidirectional arrows in the figure, moving back and forth between questions is possible and generally required.

For each question, we defined a list of items and possible choices as shown in Table 2. The top question *"WHEN is backcasting used?"* corresponds to problem and goal setting. When applying backcasting, it is common and of essential importance to first define the problem to be addressed (A-1) and the goals to be achieved at a future end point (A-2). In addition, the time horizon (A-3), scale (A-4), domain (A-5), core partners and target groups will be involved (A-6) must be clarified.

The second question, *"WHICH type of backcasting is chosen?"* addresses the type used, for which we propose the following three items: (B-1) goal-oriented or path-oriented, (B-2) degree of participation (e.g., which part of the process is participatory), and (B-3) qualitative or quantitative. The choices here are not independent from those relating to the first question "*WHEN*." For example, goal orientation is chosen when the purpose is to highlight changes necessary to achieve a certain goal or create a shared vision, whereas path orientation is chosen when the purpose is to test the feasibility of a predefined vision (e.g., a decarbonized future) or explore possible ways to achieve the vision. For (B-1) and (B-3), choices are often combined in practice (i.e., combining goal-oriented and path-oriented choices, or combining qualitative and quantitative choices).

Table 2
List of items defined in the proposed design framework.

Item		Description
A. WHEN is backcasting used?		
A-1	Goals to be fulfilled in the project's vision or image of the future	Important long-term goals (e.g., carbon neutrality by 2050) highlighted to be achieved in the future and consequences of achieving them.
A-2	Objectives of the project	Defining project objectives (e.g., to create a shared vision, highlight goal conflicts, challenge forecast-driven planning) and the target application (e.g., policy making, business model development or strategy development, awareness making/commitment creation, methodological development, and research design). A distinction can be made between content-related objectives, process-related objectives, and knowledge-related objectives, the latter including methodology development.
A-3	Time horizon	Period covered within the project, such as short-term (e.g., 10–20 years), mid-term (e.g., 20–30 years), or long-term (e.g., 30 years or longer).
A-4	Scale	Scale and system boundaries being considered in the project. Examples include industrial sector, specific company, local, regional, national and global scale.
A-5	Domain/Topic	Domain and topic considered in the project. Examples include climate change, energy, transport, and urban systems.
A-6	Core partners & target groups	Core partners and target groups for the project. Key is whether there is a commission partner, or whether additional partners are needed to conduct all activities and have all (interdisciplinary) knowledge and expertise within the project, while different target groups are possible, e.g., researchers, policy-makers, and corporate strategists.
B. WHICH type of backcasting is chosen?		
B-1	Goal-oriented or Path-oriented	Emphasis on either goal-oriented or path-oriented depending on the objectives (A-2). Goal-oriented backcasting refers to what futures may look like while achieving predefined goals and targets (A-1). This may include necessary changes that need to be made from the present. On the other hand, path-oriented backcasting refers to how desirable/undesirable future endpoints may be reached from the present, and what technologies, policies, and other measures/actions are mobilized.
B-2	Degree of participation	To what extent the backcasting process is participatory including the parts involved. For instance, problem analysis and definition, goal setting, creation of scenarios, analysis, what target groups (e.g. citizens, policy makers, external experts, industry representatives) and what level of influence is given to the participants. Level of influence can be related to Arnstein's (1969) ladder of participation or the derived 3 level structure proposed in Quist (2007) and Quist et al. (2011).
B-3	Qualitative or quantitative	Whether qualitative or quantitative data is used, or both (Van Notten et al., 2003).
C. HOW is backcasting applied to the problem being addressed?		
C-1	Process	A sequence of steps to be followed to execute backcasting. The process may be developed based on existing backcasting methodologies (see Table 1 for examples) and can include both research and stakeholder engagement activities.
C-2	Methods and tools	Methods, tools, and techniques that are used to support the process. These are related to (i) design, (ii) analysis, (iii) modeling, (iv) participation, engagement, and co-creation, and (iv) project coordination, communication, and dissemination. For participatory projects, methods and tools for participation (e.g. using workshop, interview, and questionnaire) and co-creation are possible.
D. WHAT are the results and outcomes/impacts?		
D-1	Content (design, analysis, and methods) results	Different kinds of content results, such as: • Design results including visions, scenarios, pathways, proposals, and interventions • Analytical results informing design results as well as assessing designs • Knowledge regarding policies counteracting sustainability • Models and simulation results • Methodology development and refinement, aiming at new, tested, refined, and validated tools and methods within a backcasting approach
D-2	Process and learning results	Different kinds of process results and learning, related to: • Increasing awareness on issues, problems, possible solutions, required changes and actions, as well as on the views and preferences by other stakeholders • Changes in mindset, preferences, and values due to higher order learning • Commitment to solving issues and problems, as well as the solutions, changes and actions needed • Endorsement to joint/shared views and priorities reflected in joint/shared support for visions, pathways and actions
D-3	Outcomes	Outcomes and impacts obtained, such as: • Changes in behavior, relationships, actions, or activities of stakeholders as a result of sharing and uptake of research • Changes in organizational practices and decision making • Follow-up and implementation activities • Spin-off activities, which are inspired by the backcasting project yet not intended • Other use of results and knowledge, contributing to structural change • Awareness among public, practitioners and politicians about alternatives to forecasted futures

Table 3
Five illustrative examples of backcasting projects in Japan, The Netherlands, and Sweden.

	Example I (Japan) (Ashina et al., 2012)	Example II (Japan) (Uwasu et al., 2020)	Example III (The Netherlands) (Quist and Leising, 2016; Vita et al., 2019)	Example IV (The Netherlands) (Quist et al., 2001; Quist and Vergragt, 2006)	Example V (Sweden) (Höjer et al., 2023)
Title	Low carbon society in Japan	Sustainable energy vision in a Japanese municipality	Sustainable lifestyles & green economy	Sustainable food consumption	Sustainable transport system futures 2035
A. WHEN					
A-1	80% CO2 reduction of the country by 2050	75% CO2 reduction of the city by 2050	100% sustainable lifestyles & green economy	100% sustainable food consumption	63% reduction in greenhouse gas emissions (GHG) for 2018–2035 from Swedes' transport
A-2	To explore technologically feasible pathways to achieve a low-carbon society in Japan	To develop sustainable energy visions for a Japanese municipality in 2050	To explore scenarios for sustainable lifestyles and green economy in Netherlands	To explore scenarios for sustainable food consumption in the Netherlands	To explore scenarios for travel and freight transport in 2035 using a consumption-based lifecycle perspectives with respect to GHG emissions
A-3	2005–2050	2017–2050	2015–2040	2000–2040	2018–2035
A-4	National scale	City scale	National scale	National scale	Consumption-based, nation
A-5	Climate change	Energy and urban system	Lifestyles, consumption	Household consumption	GHG, transport, consumption perspective
A-6	Researchers	Researchers, policy makers, and citizens	Researchers, government, and NGOs	Researchers, government, business, and NGSs	Researchers
B. WHICH					
B-1	Path-oriented	Goal-oriented	Goal-oriented	Goal-oriented	Goal-oriented
B-2	Non-participatory	Participatory	Participatory	Participatory	Non-participatory
B-3	Quantitative	Combined (qualitative + quantitative)	Combined (qualitative + quantitative)	Combined (qualitative + quantitative)	Combined (qualitative + quantitative)
C. HOW					
C-1	1. Setting future visions 2. Assuming technologies considered in the study 3. Making detailed assumptions based on the future visions 4. Quantitative analysis to achieve the future visions 5. Developing technology roadmaps	1. Problem framing 2. Analyzing current situations 3. Visioning 4. Describing scenario descriptions 5. Drawing pathways to a vision 6. Scenario assessment	1. Problem orientation 2. Visioning & workshop 3. Scenario elaboration 4. Backcasting & pathway workshop 5. Pathway development 6. Elaborating lifestyle options & environmental assessment	1. Problem orientation 2. Stakeholder analysis & involvement 3. Stakeholder visioning workshop 4. Scenario construction 5. Scenario assessment 6. Backcasting & implementation workshop 7. Follow-up & implementation	1. Setting an emission reduction goal 2. Developing a goal-fulfilling image of the future 3. Comparing with an image of the future, based on trend development 4. Illustrating images of the future with considerable amounts of calculations
C-2	Simulation	Logic tree (step 3), spreadsheet calculation (step 4), and roadmapping (step 5). For stakeholder participation, workshops involving citizens to develop visions and pathways (steps 3–5) and an online questionnaire for citizens (step 6) were also used.	Stakeholder analysis (step 1), interviews (step 1), workshops (step 2 & 4), scenario elaboration (step 3), pathway development (step 5), environmentally extended multi-regional input-output analysis	Stakeholder analysis Workshops, scenario construction, economic evaluation, and environmental assessment. Consumer focus groups	Calculations (Step 4)
D. WHAT					
D-1	Graphs describing the trajectories of different scenarios to 2050 in terms of CO2 emissions and cost.	Images of the future visions in the form of narrative storylines and illustrations.	Visions, pathways, and lifestyle scenarios environmentally assessed	Three visions, evaluated for economic aspects, environmental gains & consumer attractiveness	Images of the future Policy advice based on the images of the future, identifying critical policy areas for goal fulfillment.
D-2	N/A	Aiming for learning effects for workshop participants (citizens)	Learning among researchers, workshop participants, and policymakers	Learning among researchers, and involved stakeholders	Aiming for changes in mindset among transport planners and decision makers, towards understanding of what it takes to achieve a sustainable transport system.
D-3	The authors developed reports for policy makers based on the described scenarios.	The authors shared the resulting visions with households living in the city and received feedback from them to gain insights into energy policy making.	No clear impact in the Netherlands	Limited implementation impact, only proposals, clear scientific impact (replication).	Too early to evaluate, but there will be a workshop series with practitioners during 2024 based on among other material, this study.

For the third question, *"HOW is backcasting applied?"*, more detailed choices to operationalize backcasting are made, based on the choices in the first two questions ("*WHEN*" and "*WHICH*"). The items defined here include (C-1) process and (C-2) selecting tools, methods, and techniques to execute the project and support the stakeholder or citizen engagement process. The process structure (C-1) refers to the sequence of steps and activities that are taken, which may be developed based on existing backcasting methodologies (see Table 1) and must be aligned with the objectives set in (A-2). In (C-1) and (C-2), a range of design choices are available, as shown in existing backcasting studies.

The fourth question is, *"WHAT are the results and outcomes/impacts?"*. Generally, backcasting projects generate content results (D-1), process and learning results (D-2), and outcomes (D-3). (D-1) includes the design results, analytical results, and methodological development.

The design results include visions, scenarios, pathways, process designs, and system designs, while analytical results range from initial assessments, such as actor analysis, system analysis, and problem analysis in the first step of the backcasting study, to assessments of design, and modeling and simulation results. Methodological development is a special type of content that includes methodology results, testing, validation, and improvement. (D-2) entails all social results due to learning among stakeholder participants, core partners, and the research team, which can be both cognitive and paradigmatic, contributing to awareness, change of mindset, and (higher) order learning. Finally, (participatory) backcasting projects can lead to outcomes (D-3) that relate to results and the generated knowledge put in practice. Outcomes can be described as any change in the behavior, relationships, actions, or activities of stakeholders as a result of sharing and uptake of the research and results of the backcasting project. For (D-3), we distinguish between changes in practices and decision-making, follow-up, implementation, spin-off activities, and increasing awareness among relevant stakeholder groups, which means that involved actors such as organizers, commissioners, or participants take action inspired by the results or participate in the backcasting process/study due to learning in the backcasting process.

It should be mentioned that as backcasting is generally used to identify certain goals or explore the ways to reach the goals, and there is a growing interest in putting results into practice. Therefore, some researchers refer to roadmaps (e.g., Kok et al., 2011), while others refer to pathways and follow-up agendas (e.g., Quist, 2007), or while evaluating the impact reference if it has been made to follow-up (intended actions and activities) and spin-off (unintended follow-up actions and activities) (e.g., Van der Voorn et al., 2017). The main point here is that backcasting aims to raise ideas on how to move to the future to achieve certain goals and to make an impact on stakeholder knowledge, awareness, and capacities.

5. Discussion

5.1. Usefulness

In this section, we discuss the usefulness of the proposed framework. For this purpose, we have provided five illustrative examples (see Table 3). Example I is a simulation-based backcasting project conducted by researchers to investigate technologically feasible pathways for achieving a low-carbon society in Japan. Examples II-IV, on the other hand, are workshop-based backcasting projects conducted by stakeholders (i.e., citizens and policymakers) and researchers together to develop sustainable vision in the energy, lifestyle, and consumption domains. Example V is a backcasting project executed by researchers to investigate the consequences and opportunities of reaching climate targets for transportation. By comparing the five examples in Table 3, we identified three major benefits of applying the proposed framework as follows.

First, the typology defined in B (WHICH) is useful for characterizing the target project. As pointed out by Vergragt and Quist (2011), backcasting studies show a large variety and diversity, which makes it difficult to share a common understanding of backcasting among researchers and practitioners. When compared to Höjer et al.'s (2011) backcasting typology (i.e., target-oriented, path-oriented, and participatory backcasting), the three mutually exclusive criteria defined in the proposed framework (i.e., B-1, B-2, and B-3) give a systematic way of identifying different types of backcasting. This typology can be used as a common language for users (e.g., researchers and practitioners) to clarify the objective and value of using backcasting in the target project. As seen from A-2 and B-1 in Table 3, goal-oriented is often used to describe a sustainable vision or future image, whereas path-oriented is often used to describe pathways to achieve a predefined vision.

Second, the proposed framework clarifies the design choices that can be made when developing a backcasting methodology for a particular project. As shown in Table 3, C-2 describes a range of methods and tools (e.g., calculations, logic trees, workshops, and questionnaires). If we correlate the typology defined in B (B-1, B-2, and B-3) and methods and tools in C-2, it seems possible to develop a 'toolbox,' which is practically useful for planning and operationalizing backcasting projects.

Third, the collection and accumulation of many backcasting projects in a way that is consistent with the proposed framework lead to the development of design guidelines for users. The idea here is to detail the framework in Fig. 5 by utilizing the above-mentioned 'toolbox' to connect B and C in Fig. 5 and also utilizing existing and accumulated examples to connect A to D. Empirically, the results of most existing projects are presented in the form of papers and reports, where the purpose and the backcasting process used are often mentioned. However, not all the elements defined in Table 2 are explicitly recorded. The design framework provides a systematic way of describing various backcasting projects based on the four questions (i.e., WHEN, WHICH, HOW, and WHAT). Consequently, we believe that the proposed framework enables the representation and accumulation of various backcasting practices in a comprehensive, comparable, and reusable manner.

5.2. Reflections

The design framework presented in this paper can be compared to the recent backcasting evaluation framework developed by Van der Voorn et al. (2023). That framework focuses on ex-post evaluation of participatory backcasting studies for climate adaptation and mitigation. It proposes four dimensions along which climate focused participatory backcasting studies can be evaluated: (i) inputs & project settings, (ii) process and methods, (iii) results, and (iv) impact. Despite building on similar sources, the design framework proposed in this paper is meant for developing a backcasting methodology for a particular study, while it places more emphasis on defining the system under study and the formulation of the aim of the study (WHEN). Another difference is that Van der Voorn et al. focused more on different versions of participation, whereas this paper focuses on classifying the general type of backcasting being used (WHICH). Furthermore, Van der Voorn et al. differentiated between results and impact, whereas in the design framework these categories are combined since our design framework is not aiming at evaluating backcasting studies.

This paper also presents an update on the evolution of backcasting and a concise bibliographic evaluation of scientific backcasting literature. The mapping of the backcasting literature shows that backcasting has become more often and more widely applied, leading to a growing diversity due to a growing range of topics and domains, methodological advancement and blending with other methods and frameworks. For instance, digital technology-assisted methods are emerging in the fields of futures studies and foresight, where online whiteboards, generative artificial intelligence (AI), virtual reality (VR), etc., tend to be used to augment people's imagination and increase the efficiency of the process (Geurts et al., 2022; Kishita, 2021; Ködding et al., 2023; Oliveira et al., 2023), while gamification and serious games are also attracting interest in the field (e.g., Andreotti et al., 2020; Guillen Mandujano et al., 2021; Mangnus et al., 2019).

Our efforts also relate backcasting better to existing perspectives on futures studies, such as Amara (1981) and Börjeson et al. (2006), as well as to other terms and concepts used for desirable and normative futures. This adds to the existing futures literature and might be useful for anyone wanting to get a broader perspective on backcasting.

5.3. Limitations

This study has several limitations. First, the design framework was developed based on the authors' methodological frameworks. However, many methodological frameworks have been developed by other scholars, as presented in Section 2. Therefore, there is room to update the 14 items defined under the four questions listed in Table 2, following advancements as reported in Sections 2 and 5.2, for instance if new backcasting methodologies apply digital technologies, the framework could be updated accordingly.

Second, the proposed framework has not been sufficiently validated. The results in Table 3 were mainly used for demonstration purposes, with limited examples focusing on climate change, energy and urban systems, as well as consumption and transport. Therefore, the framework can be further validated by applying to additional cases around various domains. The first set of examples were collected from the 753 papers shown in Fig. 2. In addition, to further test its validity, the design framework is yet to be applied to develop a new backcasting methodology for a particular project, which remains a part of our future work.

However, it is difficult to collect sufficient information on existing backcasting projects when accumulating them. A literature review generally works well as a primary data source; however, in many cases, supplementary data must be collected through follow-up interviews with the original authors or requires the involvement of the researchers who conducted the backcasting study, as has been done by some authors (Quist et al., 2011; Van der Voorn et al., 2017; Van der Voorn et al., 2023).

Finally, despite being outside the scope of this study, it is a future issue to make explicit 'tacit knowledge' to plan and operationalize backcasting, for example, knowledge about how to facilitate backcasting workshops. By doing so, it will be possible to develop more concrete guidelines that are practically even more useful for researchers and practitioners who wish to start new backcasting projects.

6. Conclusions

In this study, we set out to "**develop a design framework** for researchers and practitioners to **clarify and contextualize** how they plan and use backcasting". We demonstrated significant diversity in backcasting studies. In fact, we found that the diversity reaches such degrees that only stating a study as a "backcasting study" is not very informative. Instead of trying to stipulate a narrow definition of backcasting, we provided a design framework in this paper, highlighting a number of choices that together characterize a specific backcasting study.

Consisting of four guiding questions when, which, how, and what – for a total of 14 items, the proposed framework can be applicable to any backcasting project. To the best of our knowledge, this study is the first attempt to provide a design framework for backcasting that enhances the comparability and reusability of diverse backcasting methodologies. Interestingly, the proposed framework is not only useful for developing guidelines for a new backcasting methodology for a particular project, but also for characterizing existing backcasting projects. We believe that our framework will be helpful in better understanding the similarities and differences between different backcasting studies, and therefore also provide a much clearer view of how the results of backcasting can be used.

This paper also maps the evolution and progress of backcasting. It was found that backcasting has become more widely applied to a growing number of topics, but has also resulted in a larger diversity. Moreover, further methodological advancement has potential and is taking place. This will add to the repertoire for backcasting, but also shows the need and relevance of the design framework as developed in this paper.

Future work will include further testing of our framework based on more case studies, both focusing on the use of the design framework and ex-post evaluation studies, as this will contribute to further developing guidelines for backcasting methodologies based on the proposed design framework.

CRediT authorship contribution statement

Yusuke Kishita: Conceptualization, Funding acquisition, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Mattias Höjer:** Conceptualization, Funding acquisition, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Jaco Quist:** Conceptualization, Funding acquisition, Investigation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare no competing interests.

Data availability

No data was used for the research described in the article.

Acknowledgments

YK acknowledges the financial support from Scientific Research (21H01234 and 23H03676) of the Japan Society for the Promotion of Science (JSPS) and the Environment Research and Technology Development Fund (JPMEERF20223R04) of the Environmental Restoration and Conservation Agency provided by the Ministry of Environment of Japan. MH acknowledges the financial support from MISTRA - The Swedish foundation for strategic environmental research, the project "Mistra-SAMS, Mistra Sustainable Accessibility and Mobility Services. JQ acknowledges the financial support from the Dutch Research Council NWO for the project 'Regional Development Planning and Ideal Lifestyle of Future Indonesia' under the NWO Merian Fund grant Renewable Energy 2019, W482.19.509.

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