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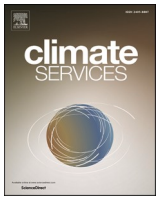

Stakeholder evaluation of the co-production process of climate services. Experiences from two case studies in Larvik (Norway) and Flensburg (Germany)

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ABSTRACT

Climate services (CS) are generally recognized as potentially effective tools to communicate climate-related risks to the general public, end-users and other stakeholders. However, empirical evidence indicates that there often is a gap in understanding between the producers of the CS and those that are meant to use them. It is therefore crucial to place the stakeholders in the centre of the process of CS-production to identify their actual needs. Facilitating iterative and collaborative processes that allow stakeholders to provide feedback bridges the process-content gap. This leads to an improvement of each step in the production of CS, and ultimately, helps building engaged communities.

One way of minimising the gap between providers and users of CS, is to incorporate evaluations in the co-production process. Our paper presents the evaluation of the co-production of CS at two case study sites, Larvik, Norway and Flensburg, Germany. The study illustrates how the stakeholders are involved in the development of the CS and specifically the use of questionnaires for evaluating the CS as well as the co-production process of developing these CS in the case study sites.

These results indicate that the Living Lab workshops, and the active use of questionnaires followed by evaluation, facilitates a more iterative process of developing CS by better involving stakeholders within the co-production of CS. Adequately addressing stakeholder needs and the usability of CS are also essential within the CS co-production process as these aspects give an indication to the uptake of CS to support climate adaptation planning outcomes and longer-term longevity that support climate adaptation policy and ultimately societal impacts.

1. Introduction

Climate Services (CS) are the provision of climate information to help CS users make climate smart decisions. According to the EC (2022): "Climate services help to understand current and future climate change and related impacts on different policy sectors across Europe by means of user-oriented products". CS are generally recognised as an important part of improving our capacity to manage climate-related risks.

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Specifically, the aim of CS is to provide people and organisations with timely, tailored, climate-related knowledge and information enabling them to reduce climate-related losses and enhance benefits, including the protection of lives, livelihoods, and property (Vaughan and Dessai, 2014). Thus, CS are meant to be useful; however, Vaughan and Dessai's summary of the origins of CS indicates that the process of developing CS has not been easy. They highlight for example the work of Changnon (2004) on the weak or non-existent connection between providers of climate information and envisaged users, as well as reflections by McNie (2007) that climate information providers do not necessarily consider the policy contexts in which decisions are being made. Furthermore, there is also empirical evidence that a scientific approach to, and differential understanding of, uncertainty and technical information may confuse rather than help decision-makers (André et al., 2021). Thus, the challenge is to reduce these existing gaps in understanding between the CS producers and those that are meant to use these CS.

Raaphorst et al. (2020) furthers the work of Lemos et al. (2012) and Weaver et al. (2013), referring to this challenge as the 'usability gap' and propose a more iterative process of developing CS by better involving stakeholders and end-users within the design of CS. The process places the stakeholder in the centre in order to identify their actual needs prior to translating existing climate knowledge (observations, forecasts and predictions, operational products) towards a final CS which will serve the local community in adapting to effects of climate change. As such, the process also reflects the increasing recognition that participatory processes are an essential element in the co-production of CS (Daniels et al., 2020; Singletary and Sterle, 2020; Bojovic et al. 2021; SEI, 2021). Although meaningful involvement of stakeholders and end-users is important throughout the entire CS development process (i.e., design, production, distribution), it is not without challenges. For example, Máñez Costa et al. (2021) recently summarised several studies focusing on the co-production of CS and found for the projects reported challenges in attracting stakeholders, keeping them committed throughout the co-production process, as well as understanding terminology and scientific paradigms. As such, involving stakeholders and end-users in the co-production of CS requires an investment of time and resources to facilitate the process and to overcome conventional top-down approaches that can be a barrier to the successful use of CS as well as for not meeting the needs of intended stakeholders and end-users (André et al., 2021, Dessai and Hulme, 2004). Further, by incorporating evaluations throughout the co-production process, with the aim of assessing stakeholder's satisfaction and providing feedback to bridge the process-content gap, the value or impact of the CS produced can accordingly be increased.

Studies that include the evaluation of CS are becoming more prevalent (Tall et al., 2018; Vaughan et al. 2019). However, there seem to exist only few examples that illustrate how evaluations are implemented and analysed as part of an iterative CS development process. For example, Tall et al. (2018) conducted a review of 25 studies to understand the evaluation methodologies used to assess climate services for agriculture in Africa and other parts of the developing world. The authors categorized these studies into ex-ante evaluation approaches which assessed needs and perceived impact for new CS, and ex-post evaluations to document impacts after CS delivery. They do not report on ongoing evaluation methods for use during CS development. Vaugh et al. (2019) reviewed evaluation practices associated with 19 seasonal-scale CS examples from across the Americas. The purpose of the evaluations for most of the CS examples were related to scoping and understanding stakeholder needs and documenting impact which could be categorised as ex-ante and ex-post evaluations, respectively. Only five of the 19 CS examples surveyed indicated that evaluation was used to improve the presentation of the CS with regard to content and language. However, the authors do not provide details as to how these evaluations were conducted nor to what degree they were part of an iterative CS development process.

Two studies published in the peer-reviewed literature, Singletary and Sterle (2020) and André et al. (2021), share detailed information on evaluation methods incorporated within the actual CS development process. Singletary and Sterle (2020) report on a collaborative modelling approach between the research team and local stakeholders to improve climate information, as a service to enhance resiliency of snow-fed river systems. For their study, the authors conduct a formative evaluation with interviews at the beginning of the project to understand expectations and information needs, as well as an evaluation instrument used to capture stakeholder perceptions on the perceived project outcomes. André et al. (2021) share their evaluation of a co-design CS process conducted at two case studies in Sweden. Their study focuses on assessing the quality of knowledge for climate adaptation that was generated from a CS co-design process including meetings, focus group meetings, workshops, and interviews. The authors report that although the number of case study participants varied over the process, a total of nine municipal officers were engaged in Karlstad Municipality and seven from the City of Stockholm.

Considering that there are such few studies which actively include the stakeholder and end-user perspective and incorporate the evaluation of CS, as well as the evaluation of CS co-production processes, within the iterative CS development, our contribution aims to add to the number of studies that show how evaluations are implemented and analysed as part of an iterative CS development process. Our study illustrates the use of questionnaires for evaluating the CS product and the CS co-production process through their use at two case study sites, in Norway and Germany. The results are presented and discussed in light of a three-phase approach for evaluations inspired by Vaughan et al. (2019); that CS providers, i) identify and understand the stakeholders that will use their products, ii) collect information on the stakeholder needs, and iii) assess the usability of the CS that are co-produced. Within these three phases, our results are compared to the previous studies of Singletary and Sterle (2020) and André et al. (2021). Further to this comparison, reflections are made as to how our CS products and the CS co-production process contributes to broader climate adaptation outcomes as signified by Singletary and Sterle (2020) and André et al. (2021). For this, we will draw on Theory of Change (ToC) concepts to frame the linkages between CS that have been produced (i.e. outputs), project outcomes and desirable impacts that have not yet occurred.

2. Methodology

2.1. Living Labs approach and co-production

In our study, we chose a Living Labs approach. Living Labs is a research concept defined as a user-centred, iterative, open-innovation ecosystem, often operating in a territorial context (e.g. city, agglomeration, region or campus), integrating concurrent research and innovation processes within a public–private-people partnership (Pallot, 2009). The Living Lab methodology has been further developed in recent years as a form of experimental and potentially inclusive mode of urban planning (Nordregio et al., 2016). Although the scope of Living Labs can vary in accordance with the scale and issue at hand, the general idea is to involve a range of committed stakeholders and end-users in a real-life "laboratory" setting to test and develop alternative solutions for complex challenges, such as climate adaptation.

Co-design and co-production are important ingredients in a Living Labs approach. Co-design refers to a participatory approach to designing solutions, in which community members are treated as equal collaborators in the design process. The approach goes beyond consultation, aiming to facilitate equal collaboration between citizens affected by, or attempting to, resolve a particular challenge. A key aspect of co-design is that stakeholders and end-users, as 'experts' of their own experience, become central to the design process (Steen et al., 2011). Broadly, the concept of co-production can be explained as the involvement of citizens in public service delivery (Verschuere et al., 2012). Specifically at local level, where the local community and the authorities can closely

interact, co-production is viewed as a useful solution to improve the quality and efficiency of CS. By involving citizens in the development of their own solutions, it is expected that they will be able to achieve results more relevant for their needs. Regarding CS, co-production is the terminology that has been most recently used to refer to all joint knowledge creation processes (Bremer et al., 2019; Daniels et al. 2020; Singletary and Sterle, 2020). Máñez Costa et al. (2021) further specifies that co-production includes the co-design process and uses co-production as the overarching term for engaging stakeholders and end-users in the process of CS production. As such, although there are nuances between the definitions, the term "co-production" is selected and used in this study.

This paper presents two case studies focusing on the co-production of CS, together with the intended stakeholders who will use these CS. The presented Norwegian case focuses on co-producing CS for use in the planning of a new residential area in the city of Larvik. Relevant stakeholders include representatives with technical knowledge from the municipality and building developers. For the German case, the CS focus on climate adaptation to coastal flooding in the city of Flensburg, with inhabitants of Flensburg as the most relevant stakeholders.

As the involvement of the stakeholders in both case studies followed a Living Labs approach, they were to be engaged in various activities, such as events, workshops, interviews and forums for testing concepts and producing a climate service within a given time frame (Swedish Geotechnical Institute, 2018). As Living Labs set the conditions for communication and coordinated activities over a period of time, they also allow for evaluation and validation of the co-production process of the CS to be used for actual cases. The process of developing the site-specific CS followed the 'climate information design' format as presented by Raaphorst et al. (2020), where stakeholders first identify their information needs prior to identifying the desired format of the CS.

2.2. Evaluating the CS co-production process with questionnaires

Placing stakeholder needs in the centre of the CS development incorporates the necessity of identifying stakeholders, for gathering information about their needs, and for gathering information about the usability of the CS. One method for accomplishing this is to ensure continuous evaluation of the CS development using questionnaires. An integral part at the Larvik and Flensburg Living Labs workshops was, therefore, to evaluate the collaborative Living Labs approach itself as well as the CS co-production process including the suitability of the actual CS products which were being developed.

A closed response format questionnaire was used in this study to collect end-user responses (Kumar, 2014). Efforts were made to ensure that the questionnaires were translated into the local language. Furthermore, the questionnaires were pre-tested with selected stakeholders. Furthermore, since the questionnaires were standardised to be used in several cases (also including cases in Sweden and the Netherlands, not analysed here), the questions did not always directly respond to the concrete setting the CS were developed for. This could have led to misunderstandings or missing replies in some cases.

For each Living Lab workshop, closed response questionnaire surveys were administered to participants to evaluate the stakeholder reflections both with regard to the Living Labs process and to the awareness and understanding of CS generally and developed for the case sites. The same questionnaires were distributed and completed in the workshops in Larvik and Flensburg held between 2018 and 2020 (see Tables 1 and 2). A total of 33 questions were included in the questionnaire and covered the following aspects:

- Living Labs approach
  - Perceptions of the actual meeting (Questions 1–6)
  - Perceptions of the Living Labs process (Questions 7–13)
- CS co-production process
  - Knowledge about Climate Change Adaptation (CCA) in the locality of the respondent (Questions 14–18)
  - Evaluation of CS (Questions 19–28)
  - Local CS (Questions 29, 30)
  - Concepts related to CS (Questions 31–33)

The respondents rated each question on a five-point 'Likert scale', ranging from strongly disagree (value of 1) to strongly agree (value of 5). In addition, the questionnaire included some general information about the respondent such as their role, social data as well as some information about the main interest of the stakeholder with regard to climate change adaptation. The questionnaire was distributed and completed during the workshops (see Tables 1 and 2). As mentioned above, the original questionnaire items were formulated in English and then bilaterally translated into Norwegian and German language. The full overview of the questionnaire is available in the Supporting Information (NGI, 2021). The answers were analysed anonymously and kept confidential. Due to the Covid-19 situation, the questionnaires after the workshops taking place in 2020 (one each in Flensburg and Larvik) were filled out and sent by e-mail. These questionnaires were also handled anonymously.

3. Case study sites, and their respective co-production processes

3.1. Larvik municipality

3.1.1. Setting: Urban development

Larvik is situated in southern Norway (see Fig. 1) with approximately 25,000 residents (47,000 in the whole municipality). Being a coastal city, Larvik is prone to coastal weather phenomena, including thermally driven effects, coastal cloud systems and fog, and historical occurrences of floods, strong winds, and storm surges. However, with the influence of climate change, these events are anticipated to be more frequent, more intense and costly in terms of damages incurred. The projected increase of extreme precipitation will result in an increase of intensity and frequency of urban flooding, erosion, clay slides, rock slides, and river flooding. Additionally, an escalation in storm activity in the Skagerrak region, coupled with a rising sea level will amplify the severity and frequency of storm surges, coastal flooding, and erosion in Larvik (Hanssen-Bauer et al., 2015).

This paper presents the use of CS in connection with the development of a potential new residential area, Martineåsen, an area one kilometre from today's city centre (Fig. 2). The municipality of Larvik is

Table 1
Evaluation of CS workshops conducted in Larvik. *Numbers include also participants from arranging organisations.

No.	Date	Workshop (WS) topic	CS introduced	Participants	No. of participants*/ responding participants
1	08.11.2018	Martineåsen feasibility study	Various traditional	Architect in charge of plan, municipality planners, land owners, technical experts	16/11
2	28.08.2019	Martineåsen WS with building developers	Blue-green factor, BREEAM Community	Building developers, municipality planners	15/10
3	15.09.2020	Martineåsen WS with building developers	Climate Menu (new CS)	Building developers, municipality planners	14/10

Table 2
Evaluation of CS workshops conducted in Flensburg. *Numbers include also participants from arranging organisations.

No.	Date	Workshop (WS) topic	CS introduced	Participants	No of participants*/ responding participants
1	07.11.2018	Understanding sea-level rise in Flensburg and creating information together	Flood map simulations.	General public, NGO, companies, employees of the city administration	40/25
2	20.11.2019	Adaptation to sea level rise in Flensburg	Flood map simulations (story map).	General public, NGO, companies, employees of the city administration	67/44
3	28.09.2020	Final discussion of project results with focus on adaptation	No new	Planners and politicians	8/5

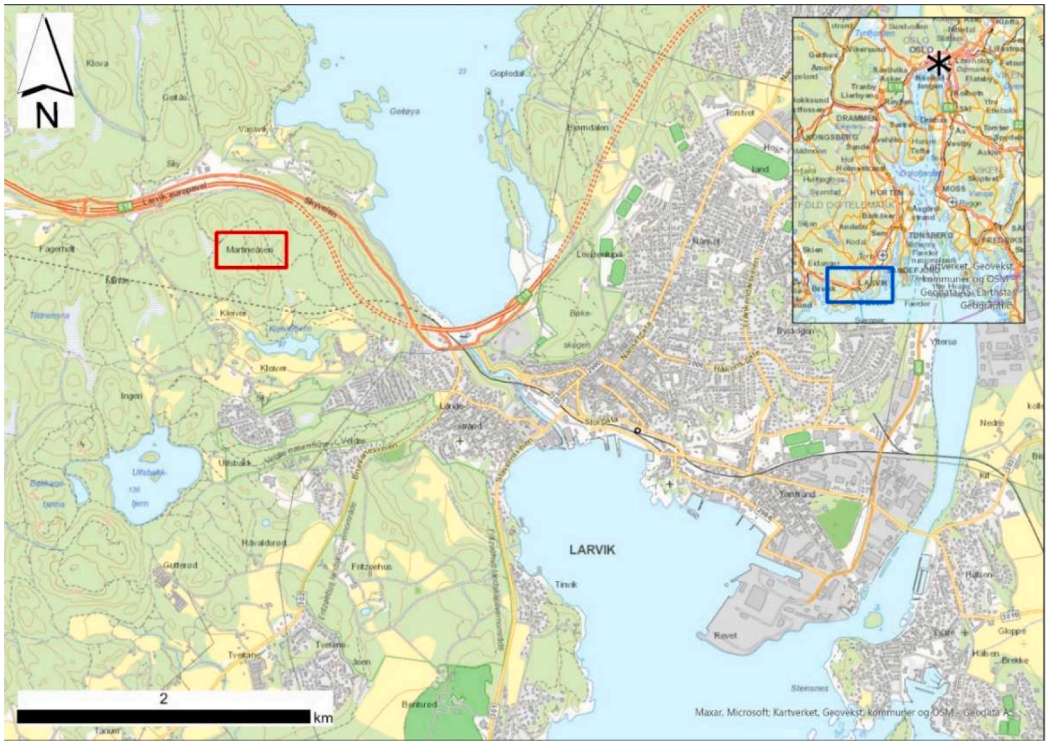

Fig. 1. Main panel: Location of the Martineåsen (marked with red rectangle), northwest of today's city centre of Larvik. Inset: Geographical position of the city of Larvik (marked with blue rectangle) in relation to Oslo, the capital of Norway, at the northern end of Oslofjorden (marked by a black Asterix). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

collaborating with multiple landowners and potential building developers to develop this particular area. A feasibility study conducted by Larvik municipality provides input to the area zoning plan, outlining potential solutions to establish a public–private partnership with the landowners. Simultaneously, it explores solutions to ensure that modifications to the landscape will not exacerbate the existing flooding issue in vulnerable areas adjacent to Martineåsen. The unique topography of Martineåsen, characterized by hills, tall deciduous trees as well as pine forests and heath, adds to the challenge of developing the area. A central feature of the area is a small lake, Kleivertjønn, surrounded by several bogs which is a type of wetland that accumulates peat. These physical attributes serve as vital components of blue-green infrastructure that must be considered in a comprehensive development of the area. It is particularly important to account for the combined impacts of climate change and land-use change. Specifically, changes in the current land coverage can influence infiltration and run-off, potentially intensifying the local flood hazard and leading to flooding in the city centre during periods of heavy rainfall. The CS introduced for this project were developed with the aim of ensuring a sustainable development of the area.

3.1.2. Stakeholder involvement through workshops

In the process of establishing appropriate CS for the Martineåsen development, a total of three workshops were arranged in Larvik. A list of the workshops is shown below in Table 1.

The first workshop was hosted by Larvik municipality and functioned as an introduction of the Martineåsen plan to the local landowners, with open discussions between the planners, landowners and invited technical experts. It was decided by the municipality that the target stakeholders for the further development of the CS would be building developers and contractors. Therefore, the two latter workshops were more narrowly focused with participation mainly from private building developers as well as municipality planners. Invitations to participate at the second workshop were sent to building developers with local affiliations and those that responded positively and participated in the second workshop were subsequently invited to participate in the third workshop.

3.1.3. Co-production and development of CS

In the first workshop the technical experts presented a general overview of available CS, such as mapping, guidelines, and detailed analyses. In the second workshop the methods of Blue-green factor (BGF) and BREEAM Communities were presented and discussed. BGF, a

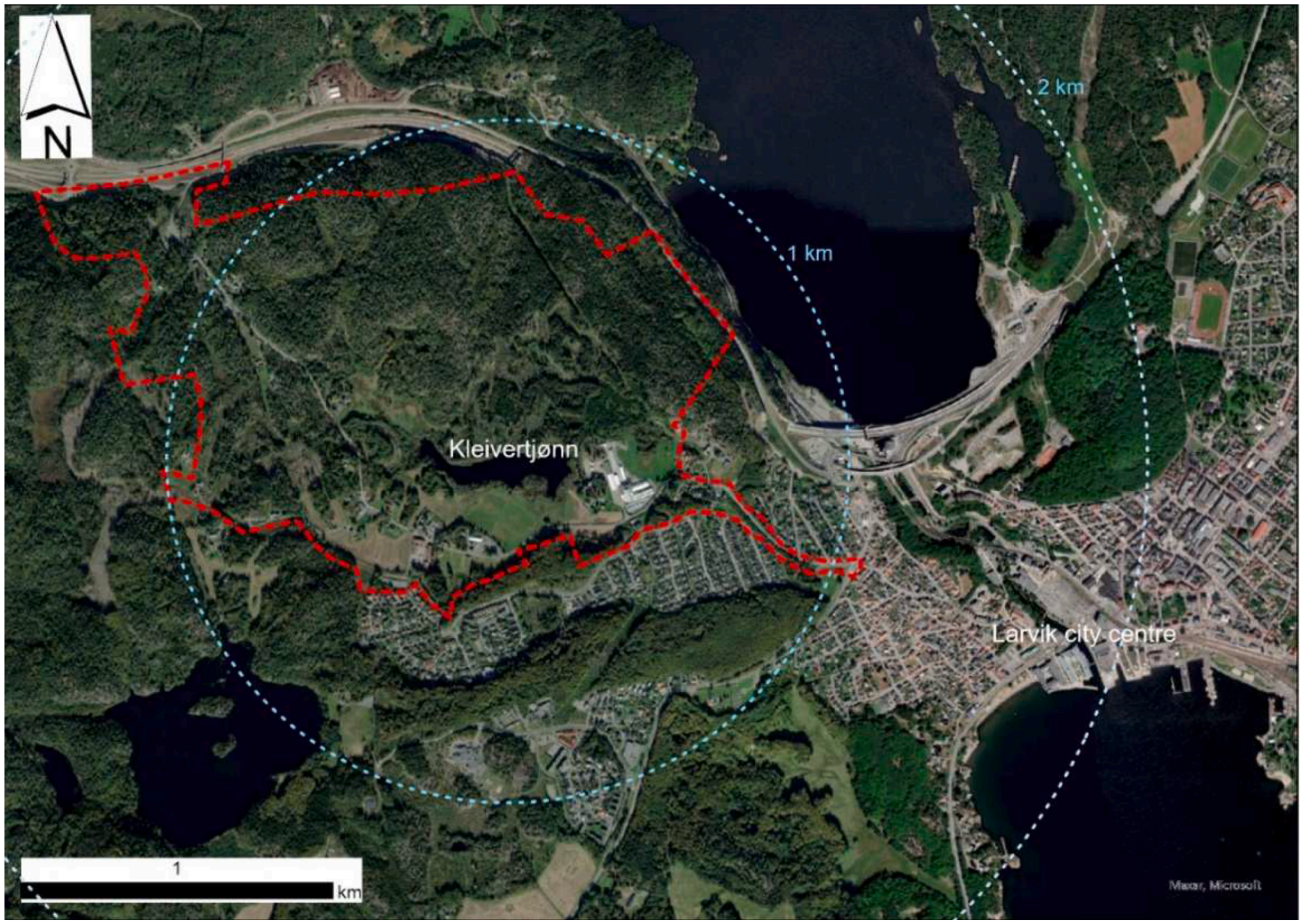

Fig. 2. Aerial photo of Larvik with the Martineåsen development project outlined by the red stippled line, lake Kleivertjønn in the centre of the image, and distance radii from Kleivertjønn marked by an inner (1 km) and outer (2 km) light-blue stippled circle, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

policy instrument to attain desired levels of vegetation and water surfaces in new property developments is developed by a few municipalities in Norway, among them Oslo (Oslo municipality, 2018). The BGF norm is well suited to raising awareness and making visible whether the projects contribute to a blue-green urban development that responds to these challenges. The main components of the method are a broad set of blue-green measures, which through various measure values collectively describe the ecological efficiency of a construction project in numerical equation.

BREEAM stands for Building Research Establishment Environmental Assessment Method. It is a sustainability assessment method that is used to masterplan projects, infrastructure and buildings. BREEAM Communities is both a framework and a classification system for assessing key environmental, social and economic sustainability in planning areas (NGBC, 2016). BREEAM Communities is built around three steps, where 40 different topics are distributed among these steps and reflect a gradual detailing of solutions. In step 1, the principles for planning are determined. In step 2, the plan approach is prepared on the basis of topics based on reports and strategies prepared in step 1. In step 3, the plan is further detailed. This includes design and requirements for landscaping, sustainable drainage solutions, transport facilities and more details related to the physical environment.

Before the third workshop Larvik municipality, together with researchers, developed a special tool called “Climate menu”. The “Climate menu” is intended to function as a discussion tool between planners in the municipality and developers for addressing climate adaptation measures. It is not meant to provide solutions but rather a starting point for discussions between the municipality and builders with the goal being to identify potential measures early in the process when conditions are more flexible. Currently the “Climate menu” has a table format with columns indicating relevant topics for climate adaptation such as flood, storm water, sea-level rise, storm surges, and landslides as well as columns that specify the current legislative requirements and existing knowledge for each of these topics relative to the land area to be developed. Examples of intervention measures are provided as well as a qualitative prioritising of their importance for climate adaptation, as well as investment and maintenance costs. The intention is that planners at the municipality can discuss interventions and prioritise trade-offs together with builders and developers.

3.2. *The city of Flensburg*

3.2.1. *Setting: Flood protection*

The city of Flensburg is situated on the northern coast of Germany, near the Baltic Sea (Fig. 3). The city is home to approximately 96,000 residents. Certain low-lying areas of Flensburg are prone to recurrent flooding, especially during periods of strong north easterly winds and shifts in wind direction. Coastal flooding is expected to escalate in the Baltic Sea region as a result of climate-induced sea-level rise and as of now there are no large-scale protection measures such as dikes in place to mitigate coastal flooding (Landesbetrieb für Küstenschutz, 2015). The city of Flensburg is currently initiating the development of an adaptation agenda in cooperation with local stakeholders. There is currently no existing assessment of vulnerability to coastal flooding for the region, nor are there any implemented measures. Consequently, a collaboration between the City of Flensburg and the Christian-Albrechts University of

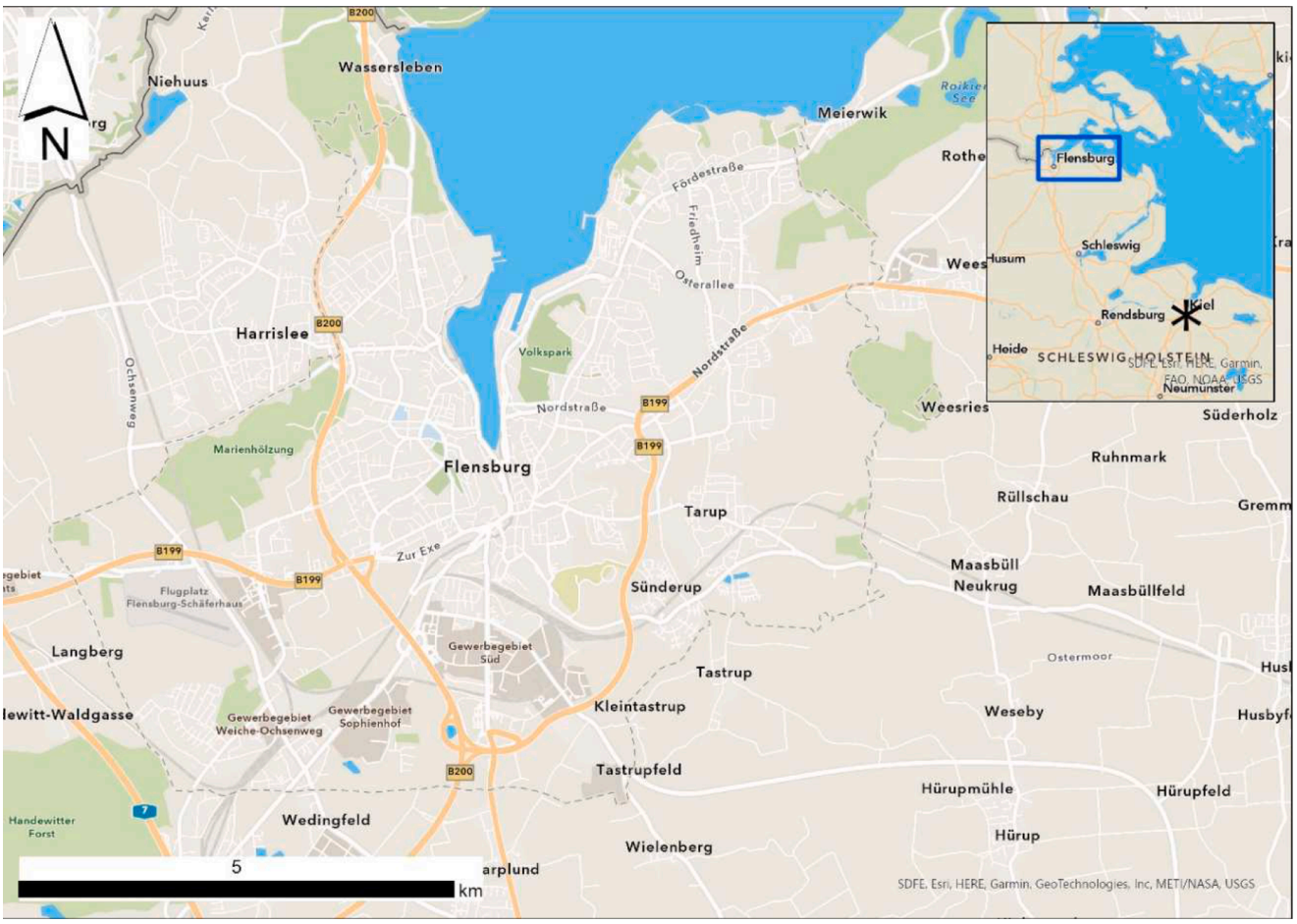

Fig. 3. Main panel: Location of the city of Flensburg, city outlines marked by black stippled line. Inset: Geographical position of the city of Flensburg (marked with blue rectangle) with respect to Kiel, the capital of the German state Schleswig-Holstein (marked by a black Asterix). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Kiel (CAU) has been established to assess vulnerability and explore potential adaptation options to address future flood risks.

3.2.2. *Stakeholder involvement through workshops*

Based on discussions with the city of Flensburg, a stakeholder analysis was carried out and used as a starting point to reach out to non-governmental organisations (NGOs) and local companies to make them aware of the CS via email. Additionally, to reach out to citizens, a distribution list of former project activities was used, and the first workshops were advertised in the local German and Danish newspapers, on Twitter and on the Facebook account of the city of Flensburg (Vollstedt et al., 2020). The reason for including citizens was to raise their awareness of climate change which is identified as an important component of coastal adaptation (Khan et al. 2020, Le Cozannet et al. 2017). A list of the workshops and events is shown below in Table 2. The final workshop only included planners and politicians in Flensburg. This smaller and different group of stakeholders was interested in the CS co-produced with the citizens in order to learn about the project results and discuss the use of the CS towards their climate adaptation activities.

3.2.3. *Co-production and development of CS*

The CS introduced in the Flensburg case involved the development of a prototype story map template for communicating and visualising scientific information to different stakeholders and end-users in an understandable way (Vollstedt et al., 2020). Story maps are an interactive communication tool that can be applied for education and information purposes. They are also particularly useful in getting the audience involved (Marta and Osso, 2015). Storytelling has a large potential to raise awareness for a specific topic (Harder and Brown, 2017) and can help to simplify complex information or to make it even more relevant for a specific target group. Story maps are also a valuable instrument to communicate scientific information to non-experts (Patterson and Bickel, 2016; Cope et al., 2018).

For the Flensburg case there was produced a pilot story map as a CS focusing on sea-level rise in Flensburg (CAU, 2021). As sea-level rise and the adaptation to potential impacts are new topics to the city of Flensburg, the story map had the goals to (CAU, 2019):

- Raise awareness of citizens and inform about sea-level rise in Flensburg.
- Contribute to decisions by city planners and politicians in dealing with local sea-level rise.
- Support the adaptation process in Flensburg.

Further, the story map had four main characteristics:

- Usability: the story map should be easily understandable and usable.
- Storytelling: the story map should tell a story.
- Visualisation: the story map visualises the topic.
- Translation: the story map translates complex information.

The story map included information on the physical process of global sea-level rise and its possible evolution in Flensburg. The first part included short information on the background, such as global mean sea-

level rise trends, uncertainty, risk of coastal flooding, and coastal adaptation. The next part visualised coastal flood risk and provided information on areas vulnerable to coastal flooding with the assistance of maps, see Fig. 4. The third part of the story map contained information on adaptation options in general, primarily in text-based form. Finally, the story map presented potential adaptation measures in various parts of Flensburg. The story map for Flensburg (in German) is accessible via: http://meeresspiegelanstieg-in-flensburg.info (CAU, 2021).

4. Results

4.1. Participants

The stakeholders involved at the two case studies were quite different (cf. section 3), which is reflected in the spread of the participants responding to the questionnaires (cf. Table 3 to Table 5) when it comes to age, organisational and professional background, and motivation for participation.

Flensburg informed a broad audience about CS for Flensburg municipality and invited a wide range of participants with an emphasis on reaching out to citizens in the first two workshops. They succeeded in ensuring a relatively high number of participants with 25 responding participants in the first workshop, increasing to 40 responding participants in the second workshop, of which 40 % had also participated in the first workshop. Furthermore, the participants represented a considerable age range (<20 to 70 years) and gender (m/f) as well as a broad range in their professional background and motivation to participate in climate adaptation activities (Fig. 5). The third and final workshop at Flensburg targeted a more specific group of stakeholders, planners and politicians (see Table 2) which was subsequently much smaller with only five responding participants (also due to Covid-19 pandemic). Of note was that there were only women participating at this last workshop.

The Living Lab workshops in Larvik, in contrast, focused much more narrowly on CS related to the development of a new residential area, and thereby mainly involved participants directly involved in the planning and building process (see Table 3 to Table 5). The total number of responding participants was smaller and varied between 10 and 11 for the three workshops. In Larvik, most of the participants were male, all were over the age of 30 and for the most part professionals working for the municipality or the building industry (Fig. 6). Furthermore, efforts were made at Larvik to ensure a similar organisational representation of participants in the second and third workshop by inviting the same construction developers to attend. This was partly successful.

Although the represented age range and participants background was much more varied in Flensburg than in Larvik, the main interests among the participants in both Flensburg and Larvik were identified as "Local action" and "Nature and environment" (Table 5, Fig. 7), closely followed by "Global action" in the case of Flensburg, and par to each other, but with considerable smaller shares, "Economy" and "Global action" in Larvik. Economical and education interest were mentioned by 8 % each of the Flensburg participants, while 4 % mentioned "Other" interests for their participation. In Larvik, 9 % mentioned education aspects as a motivation for participation.

4.2. Living Labs approach

The evaluation of the Living Labs approach was divided in two parts in the questionnaire: i) reflections of the actual meeting (i.e. the aim, presentations, organisation of meeting, atmosphere, the conclusions and practical implications were clear), and ii) reflections of the Living Labs process (i.e. platform for sharing and innovation, balanced representation, engaging communication, relevant, valuable and positive) (see Supporting Information also presenting the original questions used, Appendix A). As outlined in Section 3 the respondents rated each question on a five-point Likert scale ranging from strongly disagree (value of 1) to strongly agree (value of 5). All questions related to the

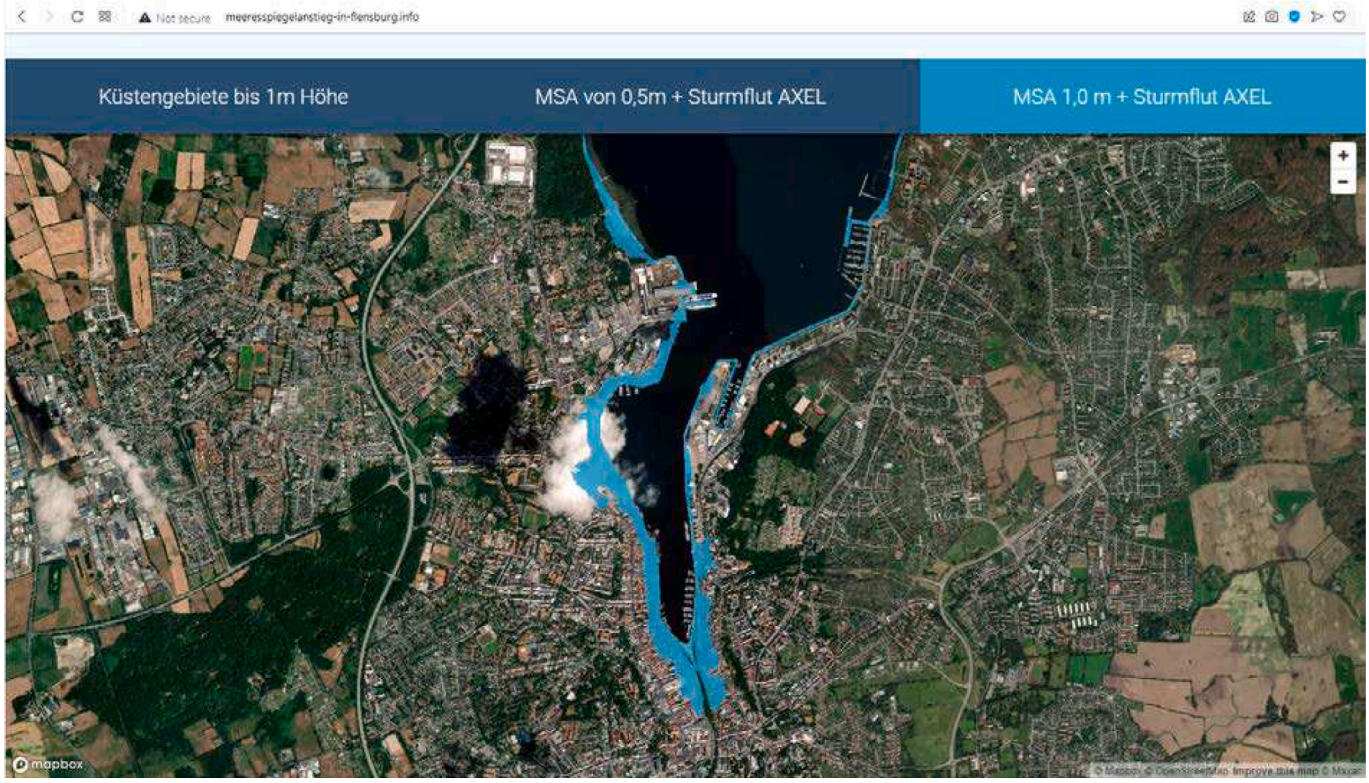

Fig. 4. Screenshot of the story map interface for visualising the flood extent of different SLR scenarios of the two approaches, static inundation and hydrodynamic modelling in the city of Flensburg. Here visualized for a 1.0 m sea level raise scenario, topped by a storm flood. .
Source: http://meeresspiegelanstieg-in-flensburg.info

Table 3
Participants in the various workshops, both case study sites.

Date	Workshop	No. of partic-pants	Male (%)	Female (%)	Age <20 (%)	Age 20–30 (%)	Age 30–40 (%)	Age 40–50 (%)	Age 50–60 (%)	Age 60–70 (%)
07.11.2018	Flensburg 1	25	68	32	0	4	21	38	29	8
20.11.2019	Flensburg 2	40	52	48	9	30	14	9	12	26
28.09.2020	Flensburg 3	5	0	100	0	0	20	40	20	20
08.11.2018	Larvik 1	11	60	40	0	0	27	18	45	9
28.08.2019	Larvik 2	10	80	20	0	0	40	40	20	0
15.09.2020	Larvik 3	10	62	38	0	0	30	30	30	10

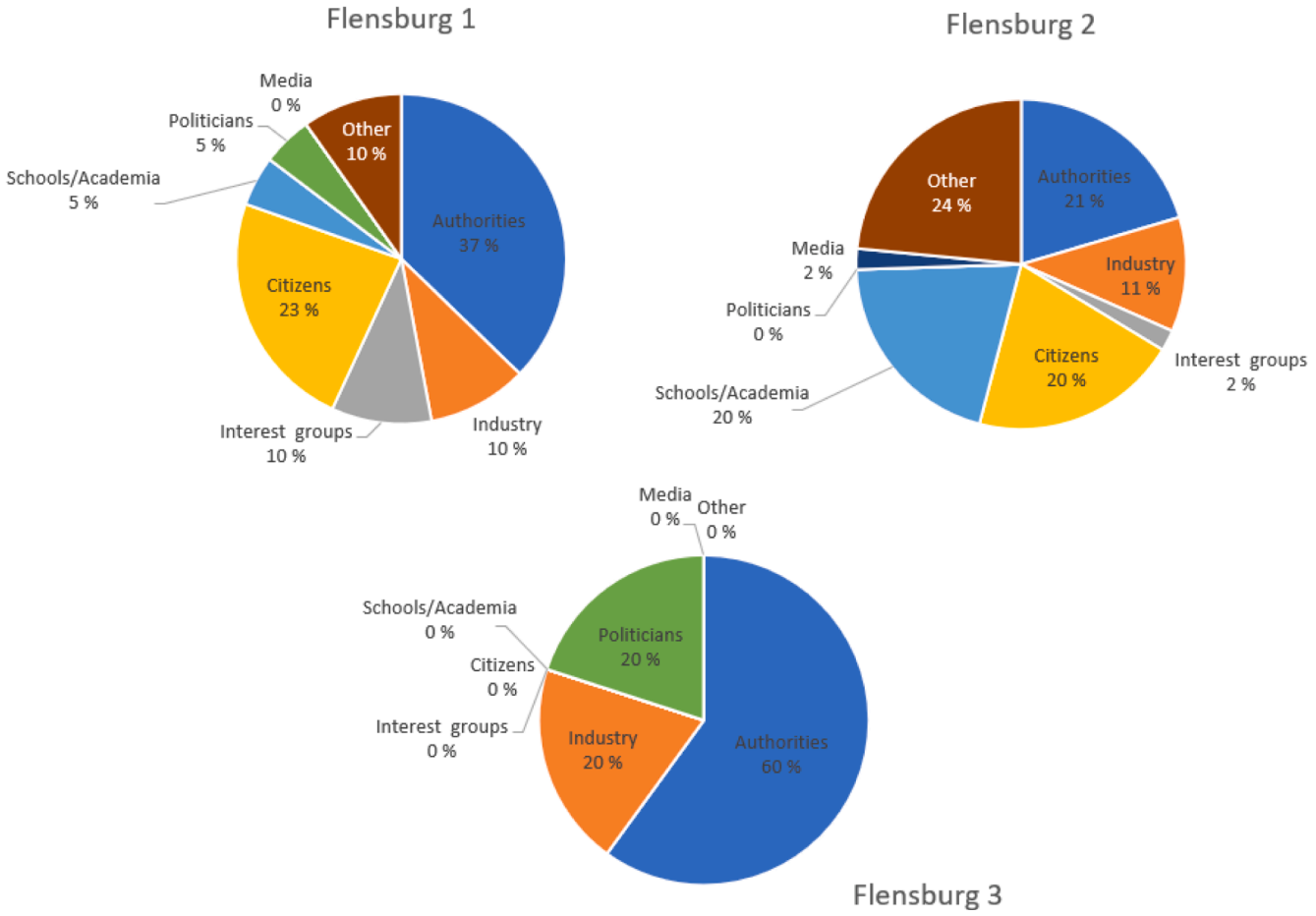

Fig. 5. Professional background of participants at Flensburg workshops. Flensburg 1 refers to the first workshop in Flensburg, Flensburg 2 to the second, and Flensburg 3 to the third one.

evaluation of the Living Labs approach had a "positive nomenclature", meaning that (strongly) agree responses were interpreted as positive signals, while (strongly) disagree responses were interpreted negatively.

Responses related to the participants assessment of the actual meeting are presented in Figures B1 (Larvik) and B2 (Flensburg) in the Supporting Information (questions 1 to 6). In general, the average response for all workshops at both Larvik and Flensburg are over a value of 3 and for the most part values between 4 and 5 indicating that they agree and strongly agree positively with how the workshops were run, the inclusive atmosphere and the information provided. The project team was better at articulating the aim of the meeting at the first Living Labs workshop as the average responses decreased from 4.3 to 4 over the three LL. Lowest scores (averages values between 3 and 3.6) were related to question 5 and if the conclusions of the meeting and way forward were clear. Although the range of averages responses for Flensburg were similar to Larvik, they were more variable between workshops. Furthermore, there was more variation within the responses for the participants from the first two workshops at Flensburg, particularly related to the conclusions having practical implementations for the participants field of work. This variation is understandable given that these workshops included a larger percent of citizens.

Responses on the participants assessment of the Living Labs process are shown in Figures B1 (Larvik) and B2 (Flensburg) in the Supporting Information (questions 7 to 13). Average responses for all workshops at Larvik and Flensburg are also over a value of 3 and mostly having a value between 3 and 4 indicating neutral and positive agreement. For Larvik, all responses had average values over 4 for the third and final workshop with the highest scores (4.5) related to the relevance of co-producing sustainable CS (question 10) and that the Living Labs co-production process has positive impacts for climate adaptation awareness (question 11). Although Flensburg records more variation for their perceptions of the Living Labs process, their highest scores (averages

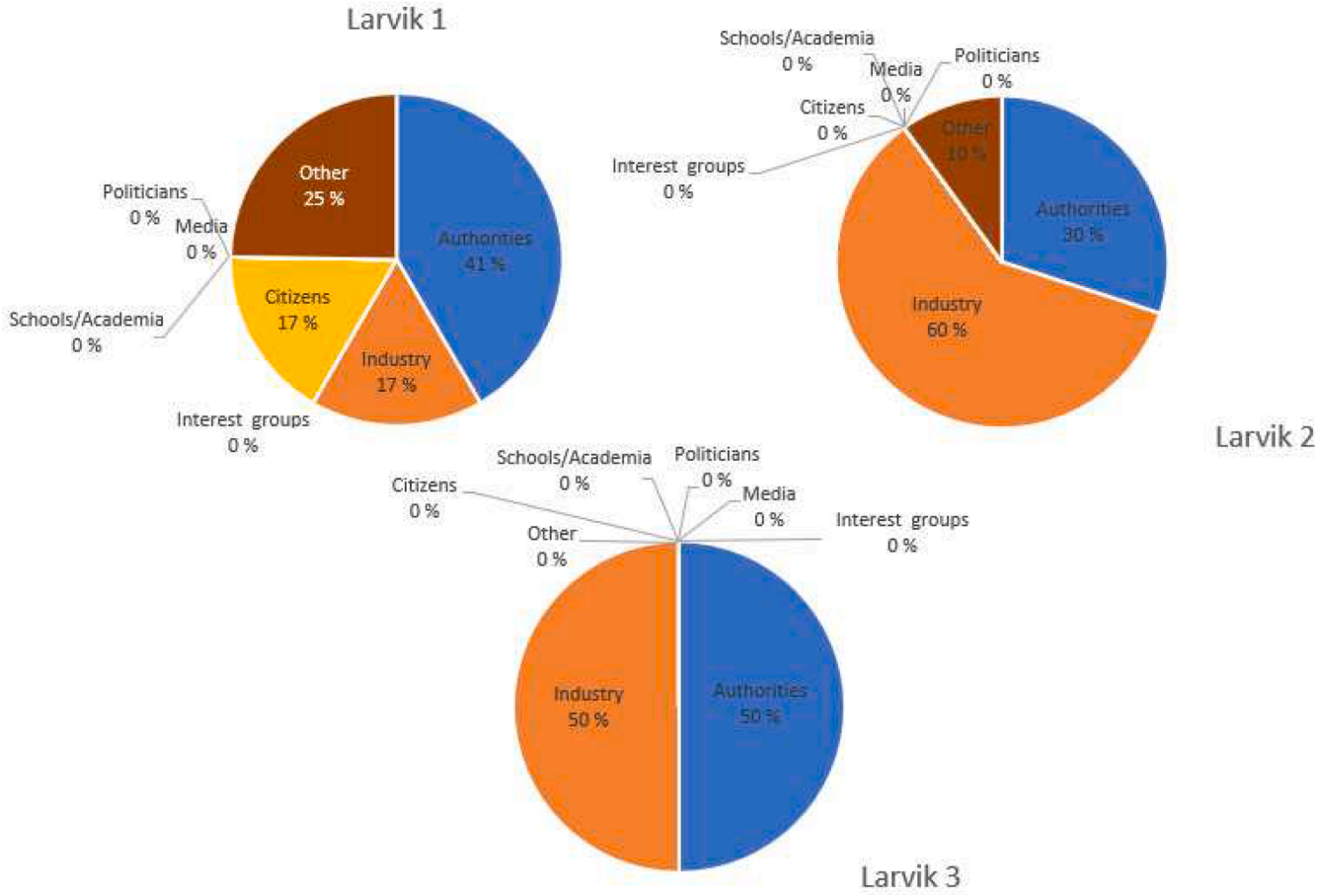

Fig. 6. Professional background of participants at Larvik workshops. Larvik 1 refers to the first workshop in Larvik, Larvik 2 to the second, and Larvik 3 to the third one.

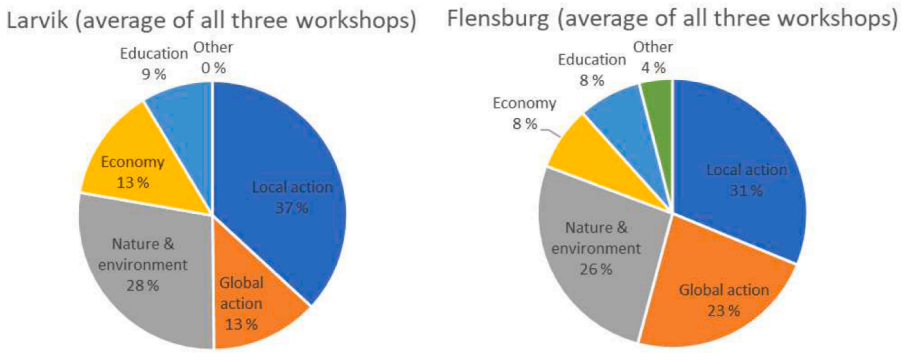

Fig. 7. Motivation/Interest of participants to participate in case study. Left panel: from Larvik case study; Right panel: results from Flensburg case study. Numbers are averaged over all three workshops at each of the two case study sites.

values from 4.3 to 4.7) for the evaluation of Living Labs process were related to the relevance of producing CS for local climate adaptation needs (question 11) in a sustainable way (question 12).

4.3. CS co-production process

The evaluation of the CS co-production process was divided in four parts in the questionnaire: i) knowledge about Climate Change Adaptation (CCA) in the locality of the respondent, ii) evaluation of CS presented, iii) awareness of local CS, iv) concepts related to CS (see Supporting Information for further details). In the following some results, interpretation and discussion related to the development and use of CS for the two cases are presented.

Responses related to the participants assessment of the actual meeting are presented in Figures B3 (Larvik) and B4 (Flensburg) in the Supporting Information. In general, the responses were much less positive to the evaluation of CS than to the evaluation of the meetings and the Living Labs process. The awareness of local CS (iii) were especially low both for Larvik and Flensburg (questions 28 and 29 in Figures B3 and B4), however with a somewhat larger variation for Flensburg (between participants) than for Larvik. For Flensburg the knowledge about CCA in the locality of the respondent (i) was also rather low. For Larvik this was also the situation for the second workshop (the first with construction developers and planners), however the knowledge of local CCA

had increased significantly to the third workshop attaining many of the same stakeholders.

Finally, the responses regarding group iv) related to the understanding of concepts such as risk and uncertainty in the use of CS. Here we could see a distinct difference between Larvik and Flensburg. The participants in Flensburg were often agreeing to include concepts such as risk and uncertainty in the production of CS (average of 4.5 – between agree and strongly agree) in comparison with Larvik (average below 4.0 – agree). In fact, this was the most positive response (gained highest score) of all groups related to CS.

There was also a possibility to add comments in the questionnaire. Limited comments were made and were outside the scope of stakeholder needs and usability of CS. Therefore, these comments are not included in this assessment.

5. Discussion

As mentioned previously, the results are presented and discussed using a three-phase approach for evaluations that emphasizes identifying and understanding the stakeholders and gathering specific information on their needs in order to evaluate the usability and subsequent outcomes and potential impact of the CS. As such, specific questions from the questionnaire that capture the perceptions on the Living Labs process as well as the CS co-production process are highlighted in this discussion. These selected questions are also those most relevant for comparing the results from our study to the previous studies of Singletary and Sterle (2020) and André et al. (2021).

5.1. Identification and understanding the stakeholders that will use the CS

The Living Labs process underpins the first phase of evaluating CS, which emphasises identifying and understanding stakeholders which is necessary for inviting and engaging those that are relevant for the CS (Swedish Geotechnical Institute, 2018). Indeed, Singletary and Sterle (2020) describe a comprehensive method for identifying stakeholders and end-users through preliminary conversations with about 250 stakeholders in water management, followed by semi-structured interviews with 66 stakeholders to identify a core group of 12 participants for their iterative CS co-production workshops. André et al. (2018) on the other hand used a more direct approach in the engaging and scoping phase of their study, where participants representing different departments in municipalities were invited to an initial meeting and subsequently invited to participate in focus group meetings, interviews and workshops. This approach resulted in total of 7 to 9 participants at their two case study sites. The identification of relevant stakeholders for Larvik is similar to the approach used by André et al. (2018). As mentioned previously (section 3.1.2), after initial conversations with Larvik municipality, it was decided to invite building developers and contractors with 10 to 14 participants at the three Living Lab workshops. Identifying the Flensburg stakeholders was also based on initial discussions with the city of Flensburg. However, in addition to this a more comprehensive approach was used: stakeholder analysis, email distribution list and advertisements in the paper and social media (Vollstedt et al., 2020). This approach was necessary to target the relevant stakeholders for the first two workshops, which were citizens, with 40 and 67 participating, respectively. The third workshop in Flensburg targeted a specific group of planners and politicians, a still relevant, but much smaller and more specific group of stakeholders.

Within each relevant group of stakeholders, effort was made to ensure sufficient representation and a balance of stakeholders for the specific CS to be developed. In other words, the balance of participants was to reflect the larger group of stakeholders intended for the CS, which in most cases represented diverse populations. As such, it is advantageous that the stakeholder groups are diverse. In the context of evaluation of CS, Tall et al. (2018) recommend considering the heterogeneity of the stakeholders and end-users because social factors such as gender, age, and position in the community are important in how climate information is used. Gender (e.g. Turner, 2019; Gumucio et al., 2020), age, education levels (e.g. Feinstein and Mach, 2019) and other socio-economic factors have shown to affect the position of stakeholders within the climate adaptation process that these climate services are supporting.

The questionnaires administered in our study capture age, gender and professional background. Citizens are the main end-user for the Flensburg case, and with the exception of the third Flensburg workshop, a heterogeneous group of stakeholders were engaged in the Living Labs process (Table 3, Table 4, Fig. 5). The Larvik case targeted a more specific group of end-users in an industry that is dominated by men. Thus, although most of the participants at the Larvik workshops were male and over the age of 30 (Table 3), they are currently seen as representative for the CS for that case study site. Although the studies reported by Singletary and Sterle (2020) and André et al. (2018) do not include details regarding gender and age of their stakeholders, their professional backgrounds reflect their organizational representation, which is relevant for the specific CS being co-produced in these two studies.

Further to documenting heterogeneity, question 9 of the questionnaire - related to the participants' own assessment on the representation and balance of stakeholders - is particularly relevant to assess, as the aspect of inclusiveness is becoming increasingly important within the field of climate services and adaptation (e.g. IPCC, 2022; Williams & Jacob, 2021). Inclusiveness also means that attention should be paid to differences between the different targeted and potential stakeholders and end-users that might use the CS, as these might affect their capacity to participate and co-produce.

Despite the broad representation at the first two workshops in Flensburg, the average scores of their perceptions on the representation of stakeholders present were 3.5 and 3.6 for the first and second workshops respectively, even though the number of participants increased from 25 to 40 between the two workshops. The results suggest that actual and relevant stakeholders were present; however, average scores below a value of 4.0 could indicate that the perception of a balance of stakeholders was not achieved or that some participants either believed that relevant stakeholders were not present or that some of the present stakeholders were not representative. Stakeholders that were invited to participate in the Living Lab workshops in Larvik represented a more specific group; their average scores regarding the perceived representation and balance of stakeholders present were 3.6, 3.4 and 4.2 for the three consecutive workshops. These scores are relatively similar to the Flensburg workshops, despite the less heterogeneous group. However, as mentioned previously, care was taken to invite a balanced group within the Larvik "Climate menu" CS co-production process and although less heterogeneous, the representation was seemingly heterogeneous enough for the particular business sector in focus. This could also be due to the participants knowledge of one another and, subsequently, their familiarity with one another's expertise. The stakeholders participating in the first two Flensburg workshops did not have such an overview of this knowledge. The results highlight an important aspect when striving to identify and understand relevant stakeholders. Most likely it is not sufficient to achieve a balanced and diverse group of stakeholders based on gender, age and organisation. The stakeholders that are participating in CS co-production must also be familiar with the knowledge others are bringing to the process to assess if this knowledge is diverse and balanced for the CS to be produced.

5.2. Specific information on stakeholders needs

The second phase of evaluating CS focuses on collecting specific information on the stakeholder needs, in this study this is conducted using the 'climate information design' format (Raaphorst, 2020). The Living Lab workshops in Larvik and Flensburg were designed following this format and the exchanges between the researchers and the stakeholders explored their information needs relative to the purpose of the CS

Table 4
Organisational representation of participants, both case study sites.

Date	Workshop	No. of partici-pants	Autho-rities (%)	Indu-stry (%)	Inter-est groups (%)	Citizens (%)	Schools/Acade-mia (%)	Politi-cians (%)	Media (%)	Other (%)
07.11.2018	Flensburg 1	25	38	10	10	24	5	5	0	10
20.11.2019	Flensburg 2	40	20	11	2	20	20	0	2	23
28.09.2020	Flensburg 3	5	60	20	0	0	0	20	0	0
08.11.2018	Larvik 1	11	42	17	0	17	0	0	0	25
28.08.2019	Larvik 2	10	30	60	0	0	0	0	0	10
15.09.2020	Larvik 3	10	50	50	0	0	0	0	0	0

Table 5
Interests of participants, both case study sites.

Date	Workshop	No. of partic-pants	Local action (%)	Global action (%)	Nature & environ-ment (%)	Economy (%)	Education (%)	Other (%)
07.11.2018	Flensburg 1	25	38	23	27	8	0	3
20.11.2019	Flensburg 2	40	29	19	26	8	16	2
28.09.2020	Flensburg 3	5	27	27	27	7	7	7
08.11.2018	Larvik 1	11	38	21	21	8	13	0
28.08.2019	Larvik 2	10	35	10	30	20	5	0
15.09.2020	Larvik 3	10	38	8	33	13	8	0

products that are being co-produced (the story maps in Flensburg and the "climate menu" in Larvik). In addition to the content generated and feedback received during the workshops, responses to the questionnaires that were administered provided further input on stakeholder perceptions of the CS. Responses to question 19 ("I have basic knowledge about CS") provide a point of departure for developing CS products as it gives insight to potential information knowledge gaps relative to knowledge. Responses related to questions 28 and 29 on the awareness of the local CS provide a backdrop to the stakeholders needs (question 28 "I know where to find CS appropriate for the local community", question 29 "It is easy to understand CS currently available for the local community"). These two questions reflect the focus of Vaughan et al.'s (2019) evaluation of meeting stakeholders needs by understanding how the CS is accessed and used by the stakeholders and end-users.

In general, all stakeholders at all workshops for both case study sites scored their knowledge of CS higher than their awareness of the locally available CS (Figure B3 and Figure B4). For stakeholders in Flensburg their basic knowledge of CS increased from an average score of 3.4 at the first workshop to a score of 4.0 at the second and third workshops. However, their knowledge on where to find local CS and understand locally available CS was about half a score lower (first workshop = 2.9 and 3.1, second workshop 3.2 and 3.4, third workshop 3.2 and 3.6). A similar result was also found for Larvik, with the stakeholders indicating slightly higher basic knowledge of CS (varying between average scores of 3.4 and 3.7) than knowing where to find and being able to understand the locally available CS, which were also about a half a score lower (first workshop = 3.3 and 3.3, second workshop 3.0 and 3.0, third workshops 2.9 and 3.1).

This pattern of responses implies that a basic knowledge of CS concepts was present; however, there was a need to improve the locally relevant CS which lies at the core intention of the work carried out at the Larvik and Flensburg case study sites. The CS evolved throughout the three workshops carried out in Larvik and Flensburg and responses to question 20 ("The CS promoted in the meeting today are relevant for me") and question 21 ("The CS promoted in the meeting today are understandable") give an indication of the degree the stakeholder needs in fact were addressed throughout the CS co-production process. The average Likert scale score responses to these two questions were higher for all workshops at each case study site illustrating a positive progression from existing CS to the development of the CS that were being co-produced in the Living Labs. For Flensburg, the average scores increased by an entire point (first workshop = 3.7 and 4.1, second workshop 4.1 and 4.3, third workshops 4.4 and 4.4). For Larvik, the average scores also increased, also by one point in the second and third workshops (first workshop = 3.4 and 3.6, second workshop 3.7 and 4.0, third workshops 4.2 and 3.9).

Singletary and Sterle (2020) indicate that meeting the stakeholder's and end-user's information needs is attributed to the co-production process and the collaborative iterations between the project researchers. In this respect it is useful to draw on the responses from our Living Lab approach (section 4.2) for comparison. Since the Living Labs approach is iterative, open and places the stakeholder at the center of the co-production process (Pallot, 2009, Steen et al., 2011), a positive Living Lab experience can indicate that the developed CS are more relevant for stakeholder needs. As presented earlier, the averages responses on the perceptions of the Living Labs process for all Living Lab workshops at Larvik and Flensburg were over a value of 3 and mostly between 3 and 4 (neutral to positive agreement). Interpreting our results in light of the fundings of Singletary and Sterle (2020) suggest that stakeholder information needs are being addressed and met in a satisfactory manner.

5.3. Usability of the CS

The third phase of evaluating CS includes assess the usability of the CS that are co-produced. For the purposes of our study, usability refers to the ability of the stakeholders to access, understand and subsequently use the CS (Raaphorst, 2020). This is similar to André et al (2018) who define usability as whether stakeholders "can actually access and use the information as it was provided." Singletary and Sterle (2020), on the other hand, do not emphasise usability but rather focus on the usefulness of the CS. Questionnaire responses in our study related to access to the CS and understanding the CS are discussed in Section 5.1. Further to these results, questionnaire responses to question 26 ("The CS promoted in the meeting today is useful") capture stakeholder and end-user perceptions related to CS usefulness. The responses to question 27 ("The CS promoted in the meeting today is advantageous/beneficial for local climate adaptation") also provide some insight into the usefulness of the CS.

The average Likert scale score responses for participants in Flensburg consistently indicated agreement for these two questions and throughout the Living Lab workshops (citizens in the first workshop = 4.0 and 4.1 and second workshop 4.1 and 4.2, city planners and politicians in the third workshops 4.4 and 4.0). For Larvik, average scores were slightly lower, but also trended towards agreement (first workshop = 3.5 and 3.6, second workshop 3.6 and 3.8, third workshops 4.2 and

4.2) with a positive progression over the course of the three workshops. These responses can be compared to some of the results provided by Singletary and Sterle (2020), who at the end of each of their collaborative workshops consistently administered evaluations with four questions related to climate information. The authors tracked if the climate information acquired was useful for their organization's adaptation planning (mean score of 3.6 increasing to 4.8 over the course of six workshops) and improved their organization's daily operations (mean scores varying between 3.4 and 4.3 over the course of the workshops). These results are in a similar range as the score responses from our study. Additionally, Singletary and Sterle (2020) also link the usefulness of the CS to meeting stakeholder needs through the iterative interaction between stakeholders and the researchers.

5.4. Reflections of CS outcomes and societal impact

The results presented above are evaluated according to a three-phase approach organised by understanding the stakeholders, their needs and the usability of the CS and compared to the previous studies of Singletary and Sterle (2020) and André et al. (2021). Further to this comparison, it is appropriate to reflect on how the CS products and the CS co-production process contribute to medium-term outcomes and longer-term climate adaptation impacts. In a recent article, Street et al. (2022) explicitly state that there remains a gap in the literature with regard to studies that report on the outcomes of CS after the first co-production processes. However, the long-term outcomes of the CS presented in this study and the societal impacts have not yet been able to be documented. In order to make some first reflections on outcome and impacts it is therefore useful to draw on ToC concepts to frame this assessment.

ToC is a methodology for outlining the process of change by identifying the pathways from activities in an initiative that lead to desired impacts. In a review on the use of ToC in international development, Vogel (2012) reports that the ToC is advantageous to support critical thinking. Although there is no consensus on one single definition of ToC, there are commonalities that include the context of the activity, the long-term change the initiative supports, and the sequence of change that leads to the desired outcome. As such, within the ToC there exists outputs (i.e. products), that lead to outcomes (which can be short-, medium- or long-term) and finally societal impacts.

The evaluation results from our study provide evidence that the Living Lab approach and the CS co-production process was perceived as positive. Furthermore, meeting stakeholder and end-user needs and CS usability were also evaluated as positive. Comparison with the results of previous studies indicates that meeting these two aspects can be ascribed to iterative and collaborative co-production processes. These results can also give an indication as to the potential uptake and longevity of the CS as recent studies indicate that participatory methods of co-production that tailor climate information lead to higher uptake among stakeholders (Chiputwa et al. 2020, Williams and Jacob, 2021). Based on these results, there is strong potential for the CS developed for Larvik and Flensburg to be used towards climate adaptation planning outcomes and indications that these will further contribute to climate adaptation policy. However, in order to determine if the CS co-production approach applied at these case study sites also result in positive societal impact, post-project evaluations are recommended to provide more insight on the long-term effects, including societal impacts (Singletary and Sterle, 2020).

6. Conclusion and reflections

The central premise for the work presented in this paper is the need for placing the stakeholder in the centre of the CS development, and for evaluating both the CS product as well as the CS co-production process. To achieve this, this study incorporated questionnaires in connection with Living Labs conducted at two case study sites, in Norway and Germany. Key findings can be summarised following the three areas of the evaluation process presented herein. The stakeholders invited to participate in the workshops at the two case study sites were identified based on their expertise for the specific CS that were to be co-produced (planners and constructors in Larvik and citizens in Flensburg). Although care was taken to ensure this knowledge was present the results indicate that this was not necessarily perceived as such by the participants. Thus, stakeholders that are participating in CS co-production should also be familiar with the knowledge others are bringing to the process to assess if this knowledge is diverse and balanced for the CS to be produced. Regarding collecting information on the stakeholder needs, the responses show that although basic knowledge of CS concepts was present at the workshops, there was still a need to improve the locally relevant CS. As such, the Living Labs and co-production process is relevant and although the long-term outcomes of the CS that are co-produced has not been able to be assessed, the initial responses on the perceived usefulness and benefit of CS towards climate adaptation capture positive short-term intentions.

The task of developing and disseminating CS relevant and comprehensible for local stakeholders is challenging. However, what is certain, is the need to include the stakeholders in the development of the various CS relevant for an actual case and to facilitate iterative and collaborative interactions between stakeholder and researchers. Continuous evaluation of this cooperative process is a useful tool for ensuring a better co-produced result. The results presented here are promising and will hopefully inspire other researchers to not only apply co-production approaches for the development of CS but also include evaluations to improve the CS product as well as the co-production. Furthermore, including evaluations at least 18 months after co-production of CS processes are completed are strongly recommended to provide further reflection and input towards ideal practices. Such an interview would be interesting to explore this specific question in more details and provide valuable insight into future workshops.

Practical implications

In order to produce usable Climate Services (CS), the stakeholders and end-users that will use the CS need to be placed in the centre of the CS development. This incorporates the need for identifying and understanding the relevant stakeholders and end-users, for gathering information about their needs, and for gathering information about the usability of the CS. One method for accomplishing this is to ensure continuous evaluation of the CS development using questionnaires. This paper presents the CS evaluation process at two case study sites: one in Norway and one in Germany. Questionnaires were used as part of Living Lab workshops, making it possible to evaluate stakeholder reflections both with regard to the Living Labs process and to the awareness and understanding of CS generally and developed for the case sites. In order to respond to these aims, the questionnaires were divided into six parts; two for evaluation of the Living Labs approach, i) reflections of the actual meeting, and ii) reflections of the Living Labs process; and four for evaluation of the CS co-production process, i) knowledge about Climate Change Adaptation (CCA) in the locality of the respondent, ii) evaluation of CS presented, iii) awareness of local CS, and iv) concepts related to CS.

Closed response questionnaires were distributed and completed by the participants at each of the workshops. The respondents rated each question on a five-point Likert-scale ranging from 'strongly disagree' (value of 1) to 'strongly agree' (value of 5). The results are presented and discussed in light of a three-phase approach for evaluations that CS providers, i) identify and understand the stakeholders that will use their products, ii) collect information on the stakeholder needs, and iii) assess the usability of the CS that are co-produced. Within these three phases, our results are compared with two previous studies that also evaluate CS co-production processes. The results and especially the comparisons presented herein illustrate that although the evaluation approaches differ, the studies consistently refer to stakeholder needs, CS usefulness and usability, and iterative and structured interactions with

stakeholders as necessary components for the successful co-production of CS. In this regard, the results from our study provides evidence that the Living Lab approach, and the active use of evaluating throughout the CS co-production process may facilitate a more iterative process of developing CS.

CRediT authorship contribution statement

Bjørn Kalsnes: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Amy Oen:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Regula Frauenfelder:** Formal analysis, Writing – review & editing, Visualization. **Ingrid Heggelund:** Methodology, Validation, Investigation, Visualization. **Marit Vasbotten:** Methodology, Validation, Investigation, Visualization. **Bente Vollstedt:** Methodology, Validation, Investigation, Visualization. **Jana Koerth:** Methodology, Validation, Investigation, Writing – original draft, Visualization. **Nassos Vafeidis:** Conceptualization, Methodology, Investigation, Resources, Project administration. **Lisa van Well:** Conceptualization, Methodology, Investigation, Resources, Project administration. **Gerald Jan Ellen:** Conceptualization, Methodology, Investigation, Resources, Project administration. **Gerben Koers:** Methodology, Validation, Investigation. **Kevin Raaphorst:** Methodology, Validation, Investigation, Writing – original draft, Writing – review & editing.

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 data

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