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# Technology and digitalisation

## An analysis of trends, future directions and potential missions to address societal challenges in Norway

Camilla d'Angelo, Emily Ryen Gloinson, Fay Dunkerley, Mann Virdee, Carolina Feijao, Gemma-Claire Ali, Mikkel Skjoldager, Andrea Skjold Frøshaug, Torben Bundgaard Vad and Salil Gunashekar

**Foresight study for the Research Council of Norway to help inform the future of research and innovation in Norway**

**RAND Europe team:** Salil Gunashekar, Emily Ryen Gloinson, Fay Dunkerley, Mann Virdee, Camilla d'Angelo, Carolina Feijao and Gemma-Claire Ali

**DAMVAD Analytics team:** Mikkel Skjoldager, Andrea Skjold Frøshaug and Torben Bundgaard Vad

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# Preface

As part of its current strategy (2020–2024), the Research Council of Norway (RCN) has three primary objectives: ground-breaking research and radical innovation, sustainable development, and restructuring of the business and public sectors. Against this backdrop, the RCN commissioned RAND Europe and DAMVAD Analytics to carry out a foresight study to help inform the future of research and innovation (R&I) in Norway. The work will contribute to the development of a robust evidence base for the RCN's input to the revision of the Norwegian government's Long-Term Plan for Research and Higher Education 2019–2028 (hereafter, LTP). The study will also help inform the RCN's internal decision making, strategies and organisational activities.

The study focuses on the five strategic areas identified in the RCN's current strategy: (i) oceans; (ii) green transition; (iii) health and welfare; (iv) cohesion and globalisation; and (v) technology and digitalisation. The specific aims of the study were to:

- Identify a set of potential priority missions or targeted, challenge-based policy actions within and across (or outside) the five strategic areas that the RCN, together with other stakeholders, could consider implementing in the future to help address societal challenges; and
- Identify system-level structural measures to potentially facilitate the development of a resilient R&I environment in Norway.

We adopted a mixed-methods, participatory approach to the research, involving a variety of methodologies, such as trend analyses, literature reviews, stakeholder interviews, focus groups, an online survey of the public, crowdsourcing ideas and information from experts, future scenario analyses and workshops. All of these methods are covered in this report.

We envisage that the research will be of interest to funders and academia, national and local government policymakers, innovators and practitioners, and industry, and, more broadly, to anyone – including the public – interested in R&I and wider societal challenges.

This report on technology and digitalisation is one in a series of nine reports presenting the findings of the study. The other reports are as follows:

- Health and welfare: An analysis of trends, future directions and potential missions to address societal challenges in Norway
- Oceans: An analysis of trends, future directions and potential missions to address societal challenges in Norway
- Green transition: An analysis of trends, future directions and potential missions to address societal challenges in Norway
- Cohesion and globalisation: An analysis of trends, future directions and potential missions to address societal challenges in Norway
- Structural measures to develop a resilient research and innovation environment in Norway
- A summary of potential cross-cutting missions to address future societal challenges in Norway

- Addressing future societal challenges in Norway: Detailed methodology report
- Addressing societal challenges in Norway: Key trends, future scenarios, missions and structural measures

We have been able to conduct this study because of the contributions of many individuals. We would like to thank the project team at the Research Council of Norway for their excellent guidance, support and advice over the course of the study. In particular, we would like to thank Stig Slipersæter and Philip Lorentzen. We are also grateful to the executive board of the RCN for constructively engaging with us at various points in the study. We would like to thank Andrew Curry (School of International Futures) for helping organise and run the stakeholder foresight workshops. We are grateful for the valuable inputs from the members of our advisory panel of experts, namely, Dr Sonja Marjanovic (RAND Europe, health and welfare expert), Stijn Hoorens (RAND Europe, cohesion and globalisation expert), Prof. Paula Kankaanpää (Marine Research Centre, the Finnish Environment Institute (Suomen ympäristökeskus, SYKE), oceans expert), Prof. Eeva Primmer (SYKE, green transition expert), Dr Jonathan Cave (University of Warwick, technology and digitalisation expert), Prof. Hakan Sicakkan (University of Bergen, cohesion and globalisation expert), and Mona Skaret (Bouvet ASA, research and innovation expert). We are also very grateful to the many stakeholders – across academia, industry, government, the third sector and the public – who kindly agreed to engage with the study at various stages. Finally, we would like to thank our quality assurance reviewers, Dr Susan Guthrie (RAND Europe) and Asbjørn Boye Knudsen (DAMVAD Analytics), for their valuable advice and critical review of the research.

RAND Europe is a not-for-profit research organisation that aims to improve policy and decision making in the public interest, through research and analysis. RAND Europe's clients include European governments, institutions, non-governmental organisations and firms with a need for rigorous, independent, multidisciplinary analysis. DAMVAD Analytics is a Nordic, research-based consultancy with offices in Copenhagen and Stockholm. DAMVAD's consultants have strong analytical and evaluation skills and specialised knowledge regarding research and innovation policy throughout the Nordic region, including Norway.

For more information about this document, please contact:

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| Dr Salil Gunashekar (Research Leader in Science and Emerging Technology)<br>RAND Europe Westbrook Centre, Milton Road<br>Cambridge CB4 1YG, United Kingdom<br>Tel. +44 (1223) 353 2562<br>Email: sgunashe@randeurope.org | Torben Bundgaard Vad (VD, Partner, Ph.D.)<br>DAMVAD Analytics<br>Overgaden Oven Vandet 58A<br>1415 Copenhagen K, Denmark<br>Tel. +45 2444 7554<br>Email: tva@damvad.com |

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# Abbreviations

| | |
|---|---|
| 3D | Three-dimensional |
| AI | Artificial intelligence |
| $CO_2$ | Carbon dioxide |
| Difi | Digitaliseringsdirektoratet [Agency for Public Management and eGovernment Norway] |
| EU | European Union |
| ERC | European Research Council |
| FUGE | The national programme for Functional Genomics in Norway |
| GDP | Gross domestic product |
| GDPR | General Data Protection Regulation |
| LTP | The Long-Term Plan for Research and Higher Education 2019–2028 – Meld. St. 4 (2018–2019) Report to the Storting (white paper) |
| NATO | North Atlantic Treaty Organisation |
| NOK | Norwegian kroner |
| OECD | Organisation for Economic Co-operation and Development |
| PESTLE | Political, economic, legal, societal, technological and environmental |
| RCN | Research Council of Norway |
| R&D | Research and development |
| R&I | Research and innovation |
| RRI | Responsible research and innovation |
| SDGs | [United Nations] Sustainable development goals |
| TRL | Technology readiness levels |
| UN | United Nations |

# 1. Introduction

The research and innovation (R&I) landscape in Norway is underpinned by Norway's overarching ambition for research and higher education, namely to help facilitate growth in overall value creation, to create new and profitable jobs, to restructure the Norwegian economy and to help implement a transition towards a greener society (Ministry of Education and Research 2019). The development of a strong knowledge base through research is necessary to fulfil these ambitions but also to train the Norwegian workforce (Ministry of Education and Research 2019). The Long-Term Plan for Research and Higher Education[1] (hereafter LTP) details the Norwegian government's ambitions and policy for research and higher education in Norway. The LTP establishes ten-year objectives and priorities and concrete goals for efforts in the upcoming four-year period. It sets the course for policy development and investments in research and higher education in Norway.

The Research Council of Norway (RCN) plays a critical role in the Norwegian and international research and innovation landscape, as the national funding agency for R&I. In its current strategy (2020–2024), the RCN details priorities and goals to help realise the objectives of the LTP (Research Council of Norway 2020a). As part of its current strategy, the RCN has articulated the following three primary objectives, with the overarching view of achieving a 'well-functioning research and innovation system' (Research Council of Norway 2020a):

- Sustainable development;
- Ground-breaking research and radical innovation; and
- Restructuring of the business and public sectors.

Within this framework, the RCN has also identified five core 'strategic areas' (as shown in Figure 1) within which to focus its priorities and portfolio plans and within which deliver high-impact research and innovation (Research Council of Norway 2020a).

**Figure 1. The five strategic areas identified by the RCN in its current strategy (2020–2024)**


[1] The Long-Term Plan for Research and Higher education 2019-2028 – Meld. St. 4 (2018-2019) Report to the Storting (white paper).

## 1.1. Objectives of the study

Against this backdrop, the RCN commissioned RAND Europe and DAMVAD Analytics to carry out a foresight study to contribute to the development of a robust evidence base for the RCN's input to the 2022 revision of the Long-Term Plan for Research and Higher Education 2019–2028 (Ministry of Education and Research 2019). The study will also help inform the RCN's internal decision making, strategies and organisational activities. The study focuses on the five main strategic areas identified in the RCN's current strategy for the next ten years (Research Council of Norway 2020a) and is intended to help frame thinking about the future of R&I in relation to these strategic areas in Norway. As noted above, the five strategic areas covered by this study are: (i) oceans; (ii) green transition; (iii) health and welfare; (iv) technology and digitalisation; and (v) globalisation and cohesion. In particular, the study aims to:

- Identify a set of potential priority missions or targeted, challenge-based policy actions within, across or outside the five strategic areas for the next ten years that the RCN, together with other stakeholders, could consider implementing in the future to help address societal challenges; and
- Identify a series of system-level structural measures to facilitate the development of a resilient R&I environment in Norway.

For this study, we regard missions as targeted, timebound, concrete priority actions to help solve one or more societal challenges that the RCN and other stakeholders could consider developing and implementing in the future. In the long term, the missions will help the RCN achieve its overarching objectives (over a roughly ten-year time frame) and eventually contribute to enriching lives locally, nationally and internationally.[2] Structural measures can be considered to be foundational, system-level instruments, policies, or tools in the R&I landscape that contribute to the translation of R&I into wider societal benefits. In the context of this study, they are intended to be a range of measures (with varying levels of specificity and generally cutting across multiple strategic areas) that help develop a resilient R&I environment in Norway and also address the wider performance of the R&I system in terms of the RCN's three overarching objectives.

This report, one in a series of nine reports, presents an analysis of trends, future directions and potential missions for the technology and digitalisation strategic area.[3]

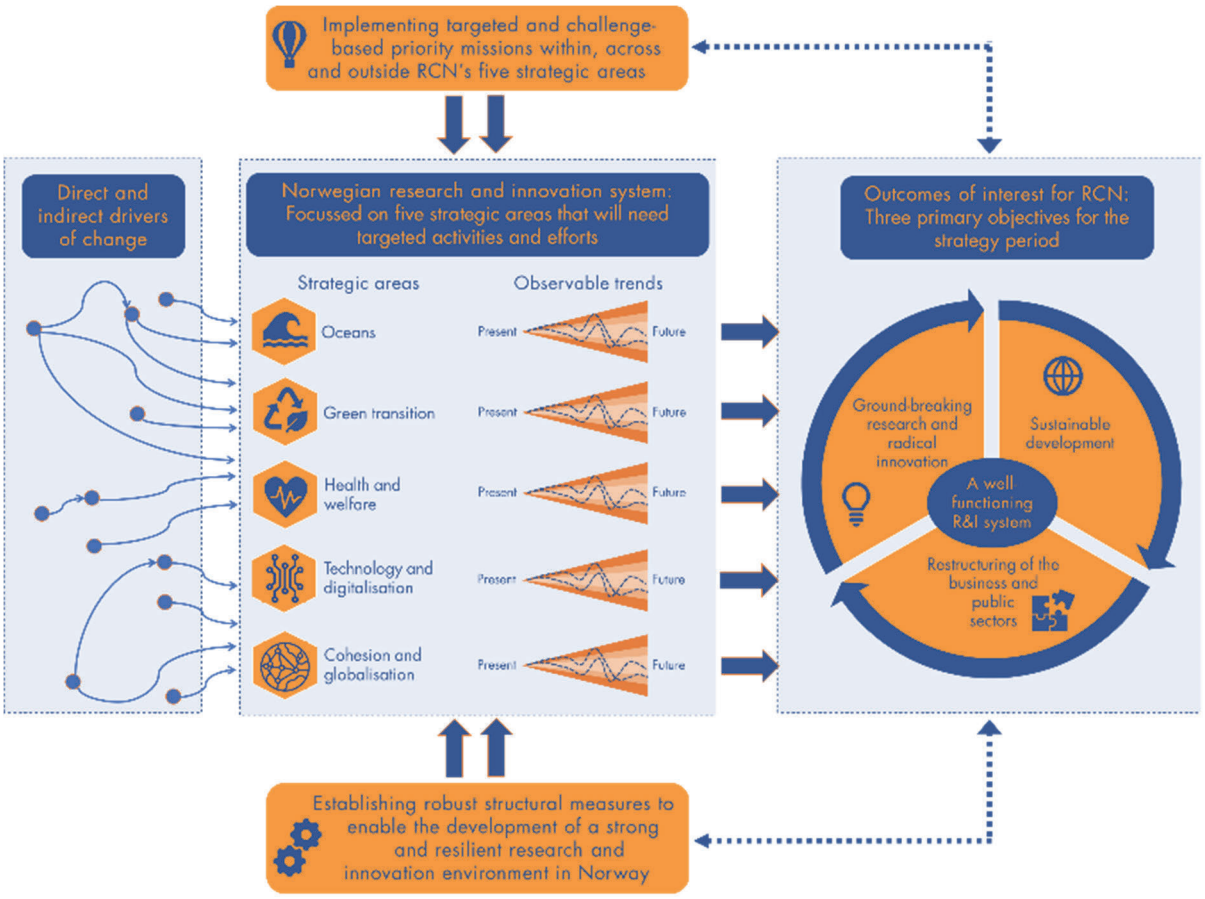
[2] More broadly, missions are systemic policies that operate both as a means of steering economic growth in a particular direction (by, for example, steering investments towards particular societal challenges) and as a tool that can be used to get there (by, for example, setting clear, problem-focused objectives) (Mazzucato 2018). Further details are provided in Chapter 6 of this report.

[3] This report on technology and digitalisation is one in a series of nine reports presenting the findings of the study: Health and welfare: An analysis of trends, future directions and potential missions to address societal challenges in Norway (Gloinson et al. 2021a); Oceans: An analysis of trends, future directions and potential missions to address societal challenges in Norway (Skjoldager et al. 2021b); Green transition: An analysis of trends, future directions and potential missions to address societal challenges in Norway (Skjoldager et al. 2021a); Cohesion and globalisation: An analysis of trends, future directions and potential missions to address societal challenges in Norway (Gloinson et al. 2021b); A summary of potential cross-cutting missions to address future societal challenges in Norway (Gunashekar et al. 2021a); Structural measures to develop a resilient research and innovation environment in Norway (Skjoldager et al. 2021c); Addressing societal challenges in Norway: Key trends, future scenarios, missions and structural measures (Gunashekar et al. 2021b); and Addressing future societal challenges in Norway: Detailed methodology report (Gunashekar et al. 2021c).

## 1.2. Conceptual framework for the study

Our overall conceptual framework (Figure 2) was targeted at providing a key analytical tool to enable us to carry out a rigorous, detailed and comprehensive futures analysis for the RCN. It is based on a participatory approach involving a range of diverse stakeholders, detailed trend analyses and rigorous scenario planning that contributed to the conceptualisation and achievement of the overarching aims of the study, i.e. to identify a set of potential priority missions related to the RCN's five strategic areas and underlying structural measures to enable the development of a robust, resilient and socially responsible research and innovation environment in Norway.

**Figure 2. Conceptual framework for the study**




Source: Study team analysis

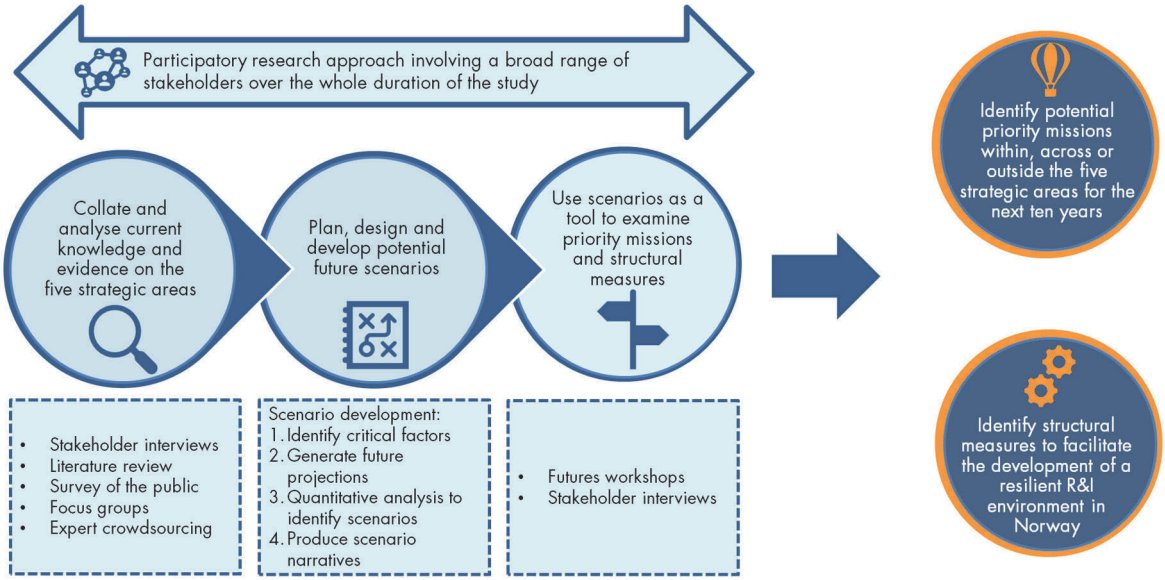
The conceptual framework for the study shown in Figure 2 provides a systems-level view of the various high-level interconnected components of the R&I ecosystem. A series of potentially interconnected drivers (as shown on the left of the figure) can either directly or indirectly influence or cause change in the wider Norwegian R&I system. The system itself is characterised by a series of observable trends or discernible patterns of change relating to the five strategic areas, as illustrated in the middle of the figure. An evidence-based foresight approach to explore a range of plausible futures can help the RCN arrive at decisions 'today' that will potentially mitigate future risks and enable future opportunities to be better anticipated. The conceptual framework therefore illustrates the importance not only of realising benefits for the Norwegian R&I system, but also of managing and mitigating against risks. As shown on the right of the figure, the

system is also composed of the main outcomes of interest to the RCN, which are their primary objectives over the current strategy period (2020–2024) (i.e. sustainable development, ground-breaking research and radical innovation, and restructuring of the business and public sectors). If these outcomes are achieved, this could help realise the RCN's overarching desired outcome of a 'well-functioning research and innovation system'. To accomplish these high-level goals, it is necessary to have a set of policy levers or actions that can help steer the system towards the outcomes of interest. Therefore, identifying and implementing a set of targeted, timebound and challenge-based actions – or priority missions – within and across (or even outside) the RCN's strategic areas could form the basis for recognising concrete focus areas for the future. Furthermore, implementing the missions successfully will require the establishment or improvement – in parallel – of key underpinning structural measures at a systemic level. Thus, a mix of appropriate structural measures, together with a set of carefully developed priority missions – and both involving diverse stakeholders – could help the RCN meet its current objectives and ultimately contribute to enriching lives locally, nationally and internationally.

## 1.3. Summary of the methodology

This section provides a summary of the research approach and methodology. A detailed description of the methodology is provided in the accompanying methodology report (Gunashekar et al. 2021c). We adopted a mixed-methods, participatory approach to the research to achieve the study objectives, as illustrated in Figure 3. The methods included literature reviews, stakeholder interviews, focus groups, a survey of the public, crowdsourcing ideas and information from experts, future scenario analyses and workshops. Over the course of the study, we engaged with a broad range of stakeholders across academia, government, industry, the not-for-profit sector, the RCN and the public.

**Figure 3. High-level overview of our approach to implementing the research**

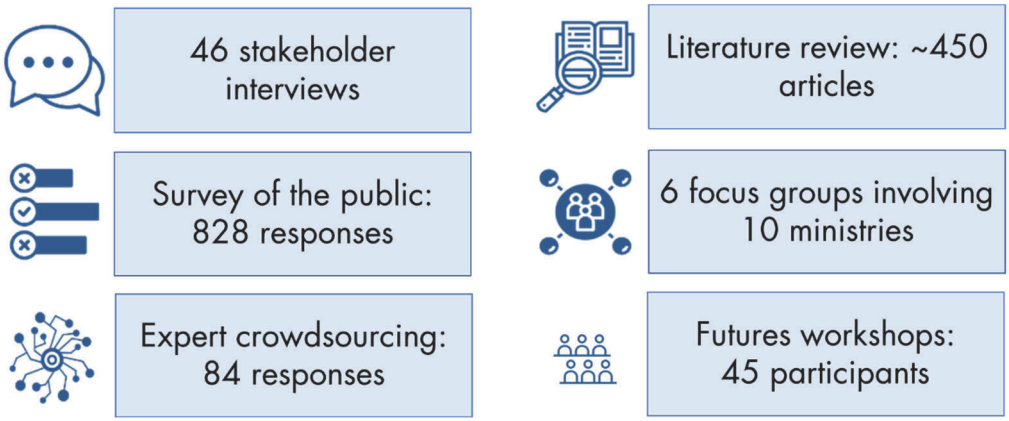



Source: Study team analysis

## Trend analyses

As noted in the previous section, each strategic area is characterised by several trends that are shaping developments and driving change within those areas. In the first phase of the study, we carried out a detailed trend analysis for each strategic area, by collecting and analysing wide-ranging evidence to help develop a robust knowledge and information base. The information collected in the trend analysis enabled us to develop a deep and rounded understanding of the status quo and direction of travel within (and outside) the R&I landscape for each strategic area (oceans, green transition, health and welfare, technology and digitalisation, and globalisation and cohesion). Specifically, we identified the main trends, enablers, barriers and uncertainties that will potentially shape the strategic area over the next ten years or so. The trend analyses also directly informed the indicative priority missions[4] and structural measures. The trend analysis synthesised evidence from the main data collection activities, as outlined in Figure 4.

**Figure 4. Main data collection activities undertaken in the research**




Source: Study team analysis

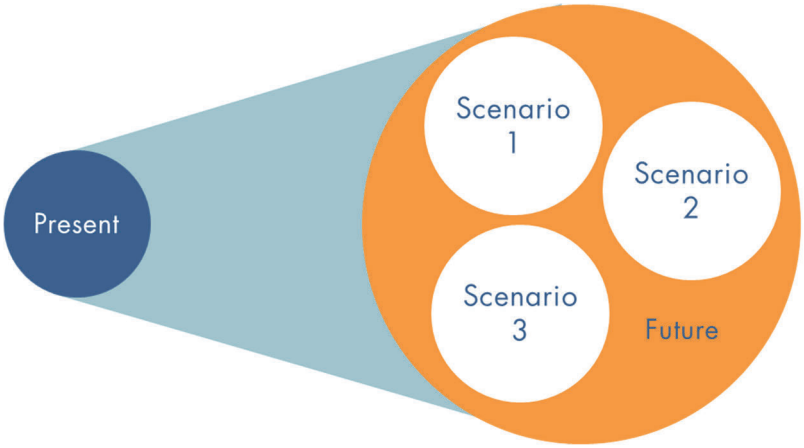
## Scenario methodology

In the second phase of the study, we designed and developed plausible future scenarios using the information collected in the trend analyses (Figure 5). Scenarios are stories or narratives that are used to describe the alternative and possible ways in which a situation or environment might develop in the future (Government Office for Science 2017). Within each scenario, there is a complex network of influence factors[5] that shape that future (Gausemeier et al. 1998).

[4] For clarity and ease of reference, we reiterate what we mean by missions in the context of this study. We regard missions as targeted, timebound, concrete priority actions to help solve one or more societal challenges that the RCN, together with other stakeholders, could consider implementing in the future. The missions will help the RCN achieve its overarching objectives (over a roughly ten-year time frame) and eventually contribute to enriching lives locally, nationally and internationally. Further information is provided in Chapter 6 of this report.

[5] In this study, the influence factors have been found based on the trends, barriers, enablers and uncertainties we identified in the trend analyses.

Figure 5. Plausible future scenarios, presenting a wide range of potential future states




To build scenarios of sufficient depth and distinctiveness, we used a rigorous and iterative process that involved the examination of the different factors, enablers, barriers and drivers of change that are shaping developments within, across and outside the five strategic areas. We generated two sets of scenarios by combining different aspects of the five strategic areas (in Figure 5, the orange area represents an exemplar set of three distinct future scenarios). Each scenario set comprised four distinct scenarios based on 15–20 prioritised political, economic, social, technological, legal and environmental (PESTLE) factors from the trend analyses that could influence the strategic areas (specifically, these factors were derived from the trends, enablers, barriers and uncertainties that were identified in the trend analyses). The two scenario sets were as follows:

- **Scenario set 1 (*Norway in a national context*):** The first scenario set broadly focuses on Norway in a national context, largely relating to the Norwegian domestic agenda. This scenario set encompasses health, welfare, education, work and skills, cohesion, and relevant aspects of technology and digitalisation, and it also covers some aspects related to green transition (for example, in relation to the circular economy).
- **Scenario set 2 (*Norway in a global context*):** The second scenario set focuses on Norway in an international or global context, primarily relating to Norway's outward-facing role. It broadly covers themes related to climate, oceans, energy, transport, food, biodiversity, globalisation and relevant aspects of technology and digitalisation.

## Examining potential missions and structural measures

The different scenarios facilitate the anticipation of what might happen in the next 20 years and help reflect changes in the R&I system as well as the wider, 'macro' environment. We used the scenario sets as the basis for discussions at two virtual foresight workshops, attended by a total of 45 stakeholders (across academia, industry, the third sector and the RCN). Using the scenarios to represent a range of distinct and plausible future states, workshop participants examined and validated a series of indicative priority missions and discussed potential structural measures. Following the workshops, a set of interviews were conducted with additional stakeholders and further desk research was carried out. The indicative missions and structural measures were further refined and updated based on feedback received at the workshops and on the additional desk research and interviews.

### 1.3.1. Caveats of the analysis

When reading and interpreting the analyses presented in this report, the reader needs to consider some caveats. This report analyses the trends, future directions and potential missions in the technology and digitalisation strategic area of the RCN's current strategy. Technology and digitalisation are wide-ranging, complex and rapidly evolving areas, not just in Norway, but also more broadly, in a global context. To accomplish the key objectives of the study while implementing the research within the timelines, we have had to keep the research focused on key topics of importance, not aiming for a systematic coverage of all topics. While the areas of focus might not be exhaustive, as outlined in the previous section, we adopted a participatory approach to the study – involving a diverse range of stakeholders – and incorporated a variety of different methods to triangulate the evidence. This has enabled us to cover a wide spectrum of important issues related to technology and digitalisation in Norway.

Furthermore, the research presented in this report is part of a larger study that also includes four other broad strategic areas (oceans, green transition, health and welfare, and cohesion and globalisation). Depending on the discussion in the literature and supported by interviewee inputs, where relevant in the analysis presented in this report, we have also considered cross-cutting implications of the strategic areas on each other. Notably, the technology and digitalisation and cohesion and globalisation strategic areas are predominantly cross-cutting in terms of their breadth of influence on the other strategic areas. Nevertheless, this report is intended to be stand-alone, and therefore the emphasis is on the trends and future socio-economic directions observed in relation to technology and digitalisation.

Finally, the ideas for the priority missions that we have articulated are not intended to be definitive or exhaustive. Each mission is proposed as an indicative idea at this stage, based on the evidence collected during the research. The missions were examined and validated at stakeholder workshops and then further updated based on feedback received at the workshops and from the RCN. The collection of missions that we have presented for the technology and digitalisation strategic area represent a broad spectrum of ideas for further consideration and exploration by the RCN – and other stakeholders that might be involved in the process to implement any potential missions in the future.

## 1.4. Outline of the report

The remainder of the report is structured as follows:

- In Chapter 2, we describe the trends shaping the technology and digitalisation landscape in Norway.
- In Chapter 3, we provide an overview of the barriers and enablers to technology and digitalisation research and innovation in Norway.
- In Chapter 4, we describe the key uncertainties and policy challenges that influence developments regarding technology and digitalisation in Norway.
- In Chapter 5, we summarise the future scenarios we employed at the foresight workshops to examine the indicative missions and structural measures related to the technology and digitalisation strategic area (as well as the other strategic areas).

- Finally, in Chapter 6, we provide a list of indicative priority missions for the technology and digitalisation strategic area in Norway.
- In the Annexes, we present the comprehensive versions of the scenario narratives for both scenario sets and a high-level overview of all the indicative mission ideas that have been articulated within and across the RCN's five strategic areas.

# 2. Trends shaping developments related to the technology and digitalisation strategic area

This chapter presents the key trends influencing the development of the technology and digitalisation landscape in Norway. In the following discussion, we have drawn on the published literature (both peer-reviewed and grey literature) and additional information and insights provided by a range of stakeholders across academia, industry, government, the third sector and the RCN.[6]

**Box 1. Summary of key trends related to the technology and digitalisation strategic area**

- **Trend 1:** Digitalisation is facilitating increasing convergence of technologies.
- **Trend 2:** Artificial intelligence, 'big data' and biotechnology will be central components of digitalisation.
- **Trend 3:** Digitalisation is shaping innovation processes to make them data-driven, swifter and more collaborative.
- **Trend 4:** Data-driven technologies and advanced materials are expected to reduce greenhouse gas emissions and help improve the environment.
- **Trend 5:** Digitalisation is expected to provide improved services in the public sector.
- **Trend 6:** Digital and enabling technologies are expected to underpin the development of medicines and diagnostic tools in health and healthcare.
- **Trend 7:** Biotechnology is expected to play an important role in the biomarine industry
- **Trend 8:** Industrial biotechnology is expected to contribute to environmentally friendly industrial processes and products.
- **Trend 9:** Socially responsible research and innovation will be a key priority.

## 2.1. Context

Technology[7] and digitalisation present enormous potential for growth and solving major societal challenges (DG GROW 2021). Key areas that present important opportunities include advanced technologies, such as the Internet of Things, industrial data, advanced manufacturing, robotics, 3D printing, blockchain technologies, and artificial intelligence (AI). Advanced technologies have been defined as a convergence of digital technologies with broad enabling technologies (e.g. biotechnology and nanotechnology). Advanced technologies present a wide range of potential applications and ability to contribute to key changes and solutions in society and across multiple sectors (Research Council of Norway 2020c). Some changes in society and the wider economy that are driven by the rapid growth of these technologies include 'industry

[6] Interviewee inputs are cited in the discussion using anonymised, unique identifiers 'INT-TD-XX' where XX is a number between 01 and 06.

[7] This report does not distinguish between the terms 'technology' and 'emerging technology'.

4.0', and more recently 'industry 5.0' (that emphasises societal needs and sustainability), the green transition and restructuring in the private and public sector (Müller 2020; Research Council of Norway 2020a).[8]

Today, the impacts of digitalisation are felt at differing stages of development, across many sectors including, agri-food, automotive and transportation, retail, health, banking, the media, music and gaming industries and many more (OECD 2019). Digitalisation has been defined as the large-scale adoption of digital technologies (Randall & Berlina 2019). In the future, digitalisation is expected to underpin innovations across many sectors, including personalised solutions, greener solutions, new services, and lower production and service costs – leading to increased productivity (Research Council of Norway 2020a; Ministry of Local Government and Modernisation 2016).

Technology and digitalisation is expected to play a key role in Norway's transition to a more knowledge-based economy (Ministry of Local Government and Modernisation 2016).[9] In the Norwegian Government's 'Long-term Plan for Research and Higher Education 2019–2028', 'enabling and industrial technologies' is one of five priority areas (Ministry of Education and Research 2018). As part of the RCN's strategy, the technology and digitalisation area will focus on developing three key technology areas that are deemed to be 'enabling' technologies[10] (Research Council of Norway 2020c). Enabling technologies can underpin innovation across many different sectors and societal challenges (Research Council of Norway 2020b). The three key technology areas are digital technology,[11] biotechnology and nanotechnology.

## 2.2. Key trends shaping the technology and digitalisation strategic area

### Trend 1: Digitalisation is facilitating increasing convergence of technologies

Technologies are often most disruptive where they overlap or converge, i.e. the combination of several technologies such as advanced materials, biotechnology and computing (NATO 2020). Research areas not traditionally associated with digitalisation, and on which advanced economies depend, from materials science to biology, are increasingly digital (OECD 2020b). Technological progress and innovation over the next century is expected to come from the increasing and complex convergence of enabling technologies, such as nanotechnology, biotechnology and digital technologies (Innovation Policy Platform 2013).[12]

[8] Input from survey of the public.

[9] Furthermore, in Norway, it is estimated that in 2060 there will be four people aged over 67 for every 10 people of working age, compared with 2.2 people in 2012 (Ministry of Local Government and Modernisation 2016). These changes entail a need for extensive adaptations. For example, the use of welfare technology and automation (i.e. robotics) could help assist the elderly (Ministry of Local Government and Modernisation 2016).

[10] These can be defined as basic technologies that underpin innovations across multiple sectors and can contribute to major societal challenges.

[11] Technologies that are based on data.

[12] For example, synthetic biology is a rapidly advancing field that is characterised by the convergence of molecular biology, engineering principles and, more recently, advanced computing (NATO 2020). Similarly, AI and biotechnology are developing exponentially and their convergence is expected to have a massive impact on health and the economy (NATO 2020). Other areas of convergence include nanotechnology, advanced materials and computing. Advanced (nano) materials and quantum dots may form the physical basis for the development of quantum computing, which is a highly specialised field in very fast development (Technopolis 2017).

> *'New technology and digitalisation provide opportunities for streamlining existing businesses, which is both more profitable and more sustainable. We also have to develop new technology to solve climate challenges.'*
>
> Survey respondent

The integration of biology with data and computer sciences holds great potential for the Norwegian bioeconomy (Centre for Digital Life Norway 2017). For example, the digitalisation of biotechnology is expected to increase innovation and research and development (R&D) efficiency, reduce costs and facilitate business development (Centre for Digital Life Norway 2017). Norway is starting to build strengths in this area, for example it has established Digital Life Norway, a national centre for biotechnology research led by the University of Oslo (Egeland et al. 2019). However, for Norway to fully exploit the potential of technology convergence more generally will require education and recruitment of candidates who are able to work and connect different types of knowledge within transdisciplinary collaboration (Research Council of Norway 2020b).[13]

## Trend 2: Artificial intelligence and 'big data' will be a central component of digitalisation and the Fourth Industrial Revolution

AI is considered one of the most strategically important technologies of the 21st century and is expected to contribute to increased productivity and economic growth (DG GROW 2021). In addition, other important digital technologies include cloud computing,[14] robotics,[15] 3D printing,[16] the Internet of Things,[17] and 'big data'[18] and digital platforms[19] – the latter have grown significantly over the past decade and are radically transforming every industry (DG GROW 2021).

In Norway, AI and other data-driven technologies are already beginning to play a key role in the digitalisation of several sectors. Going forward, artificial intelligence and big data are expected to continue to be a key component of the digital transformation across many sectors (Ministry of Local Government

[13] Input from survey of the public.

[14] Cloud computing is a model that enables on-demand network access that is convenient to a shared pool of computing resources that are configurable (such as servers, networks, storage, applications and services) that can be provisioned in a rapid way and released using minimal management effort or service provider interaction network (European Commission 2021c).

[15] Robotics refers to the science of 'design, engineering and use' of machines that are increasingly intelligent and able to sense, act in a purposeful way and perform work that is autonomous, as well as their control and information processing systems network (European Commission 2021c).

[16] 3D printing is a manufacturing process whereby two-dimensional cross sections are layered sequentially to fabricate three-dimensional objects (Britannica 2021).

[17] The Internet of Things (IoT) is global network infrastructure that is dynamic and that has self-configuring capabilities based on communication protocols that are standard and operable. In the protocols, physical and virtual 'things' have virtual personalities, physical attributes and identities and are integrated seamlessly into the information network (European Commission 2021c).

[18] Big data is a phenomenon that results from three factors: volume, variety and velocity, and describes the challenge presented to traditional data-handling and processing by the volume of data collected and stored, the variety of these data in terms of structure and formats, and velocity due to Web 2.0 possibilities (European Commission 2021c).

[19] Digital platforms use information and communication platforms to enable interactions between users, collect and use data about these interactions, and network effects whereby the use of the platforms with the most users is the most valuable to other users (European Commission 2021c).

and Modernisation 2020; OECD 2019). These technologies are also expected to contribute to increasing technology convergence with other enabling technologies (OECD 2020c).[20]

Norway is well positioned to excel with artificial intelligence due to various factors, including a high level of public trust; a digitally competent population (96 per cent of the population uses the Internet); excellent infrastructure (Norway currently has 100 per cent 4G coverage); and well-developed e-governance and public agencies (Ministry of Local Government and Modernisation 2020). Particular sectors in which Norway has an advantage include: health, seas and oceans, public administration, energy and mobility (Ministry of Local Government and Modernisation 2020). In particular, the government considers Norway to be well placed to succeed with human-friendly and trustworthy AI that takes data protection and ethical considerations into account, and with AI in industrial applications (Ministry of Local Government and Modernisation 2020). There is also increased political emphasis on requiring fair, transparent AI/machine learning technologies that avoid bias (Ministry of Local Government and Modernisation 2020).

### Trend 3: Digitalisation is shaping the R&D and innovation processes to make it data-driven, swifter and more collaborative

The research process itself is increasingly data-driven, with access to increasing and more complex amounts of data from multiple sources, and advanced methods for processing this (Research Council of Norway 2020c). For example, the use of AI and machine learning-based techniques allow for conducting large-scale computerised experiments on a scale that is unprecedented (OECD 2019). AI is currently used at all stages of the scientific process, including for: automated extraction of information in scientific literature, experimentation (e.g. the pharmaceutical industry uses automated high-throughput platforms for drug design), large-scale data collection and to optimise experimental design (OECD 2020c). Digital technologies (e.g. generative design software and three-dimensional (3D) printing) are also used further down the innovation pathway, for example for developing, prototyping and testing new products (OECD 2019). Key technologies in this regard include the use of big data analytics and large-scale computerised experiments for research, virtual simulation and 3D printing (OECD 2019). These technologies reduce the cost and time devoted to designing, prototyping and testing processes. They also enable 'beta' versions of innovations to be launched onto the market and gather consumer feedback. Together, this is expected to accelerate innovation cycles, reducing R&D costs and time to market (OECD 2019).

Digitalisation is also making innovation ecosystems more open and diverse, with increasing collaboration between actors (OECD 2020c).[21] New mechanisms enabling actors to collaborate include crowdsourcing, open challenges, so-called living labs and open source software (OECD 2020c).[22] In the future, modelling and simulation driven by AI and machine learning are expected to play an increasingly important role in the research process (INT-TD-03; INT-TD-04). Digitalisation of research is a focus for Norway, which has developed a strategy for the digitalisation of the higher education sector (Ministry of Education and

[20] Amongst the technology areas in the RCN portfolio, AI, robotics and big data are the ICT technology areas that grew the most between 2015 and 2019 (Ministry of Local Government and Modernisation 2020). The Portfolio Board plan outlines that within ICT research, a number of technology areas will be prioritised going forward, including: big data, artificial intelligence, robotics, autonomous systems and the Internet of Things (Research Council of Norway 2020c).

[21] Input from expert crowdsourcing exercise.

[22] Input from expert crowdsourcing exercise.

Research 2017). For Norway to fully capitalise on the innovation potential of AI, data analytics and advanced computing methods applied to research will require the building of strengthened skills and competence in key disciplines such as biostatistics and mathematical subjects (Research Council of Norway 2020b).

### Trend 4: Digital technologies and advanced materials underpinned by nanotechnology are expected to reduce greenhouse gas emissions and help improve the environment

Developments in several enabling technologies (digital and nanotechnology in particular) could contribute to reduced greenhouse gas emissions, solutions for monitoring emissions, new environmentally friendly and sustainable materials, more environmentally friendly and energy efficient manufacturing processes and the transition to a circular economy (Technopolis 2017). For example, there is a critical need for the clean-up and monitoring of landfill pollution in Europe.[23] Developments in digital technologies could enable the transport sector to become climate neutral, with electrification particularly important for the development of a low-emission society. Digital technologies also play an important role in distribution and security issues in the energy sector (Research Council of Norway 2020b). For example, use of digital technology can provide more efficient ways of exploiting resources and consuming energy (Ministry of Local Government and Modernisation 2016).

> *'Use technology and digitisation to accelerate the green transition. Have a greater focus on green, safe and secure in connection with the use of technology and digitalisation. For instance, set higher requirements for risk analyses in advance, instead of paying for mistakes afterwards.'*
>
> Survey respondent

Similarly, developments in advanced materials and nanotechnology are considered to be fundamental in energy technology (energy generation and storage) and are expected to contribute to environmentally friendly energy and low emissions (Research Council of Norway 2020c).[24] This includes innovations in batteries/energy storage, solar cells, hydrogen production and use, energy efficiency, catalysis, carbon dioxide ($CO_2$) capture and storage, amongst others (Research Council of Norway 2020c). Nanotechnologies are developing rapidly and are increasingly used in a variety of products and industries, including clean car technologies and materials, environmental sensing and remediation, batteries, building materials and technologies and water purification (Innovation Policy Platform 2013; Pathakoti et al. 2018).

Norway has particular strengths in developing technology solutions in the ocean sector, with expertise in developing digital innovations at sea (e.g. autonomous vessel technology), and is well positioned to participate in the market for green shipping and maritime operations (Research Council of Norway 2020a; Skjoldager et al. 2021b).[25]

[23] Input from expert crowdsourcing exercise.

[24] Input from expert crowdsourcing exercise.

[25] Furthermore, it was noted by experts in the crowdsourcing exercise that there is political support for more sustainable and environmentally friendly technologies.

### Trend 5: Digitalisation is expected to provide improved services in the public sector

Digitalisation of the public sector aims to improve services and ensure more efficient use of resources in public institutions for citizens (Research Council of Norway 2020b). This includes the use of, for example, cloud-based services and data analytics to modernise the government's activities (OECD 2017) and the adoption of large-scale digital platforms in the public sector (such as healthcare or municipalities, e.g. child services).[26] Digitalisation of the public sector is already well underway in the Nordic region and Norway overall (Randall & Berlina 2019). In the future, it is expected that the public sector will use AI to deliver more targeted and user-adapted services, improve operations and work processes, and reduce risk (Ministry of Local Government and Modernisation 2020). It is anticipated that the use of AI will lead to new, more effective business models and to effective, user-centric services in the public sector (Ministry of Local Government and Modernisation 2020).

Digitalisation of public services is a priority focus in Norway (Randall & Berlina 2019; Ministry of Local Government and Modernisation 2019). The public sector is an increasingly important area of focus for R&D and technology development. Norway is relatively advanced in the digitalisation of the public sector compared with other countries (Research Council of Norway 2020b). Norway has good basic data registers, a well-developed digital infrastructure and a high level of digital competence in the population (Ministry of Local Government and Modernisation 2019). In addition, citizens and organisations based in Norway place a relatively high level of trust in having their data used by public authorities to deliver a range of services (OECD 2020a). However, it has been noted that Norway could utilise this sector better and this could be a strong area for export (INT-TD-03).

### Trend 6: Biotechnology, nanotechnology and digital technologies are expected to underpin the development of medicines and diagnostic tools in health and healthcare

In recent years, biotechnology, nanotechnology and digital technologies have contributed to medical developments such as advanced diagnostics, regenerative medicine and bio- and nano-based medicines (Research Council of Norway 2020c). Going forward, these technologies, and their convergence, are expected to play an increasingly important role in life sciences and the development of personalised medicine (Research Council of Norway 2020c; Egeland et al. 2019).

Developments in biotechnology and nanotechnology are expected to underpin the development of medicines and diagnostic tools in health and healthcare (Ministry of Education and Research 2012). This includes advanced cell therapy, vaccine development and immunotherapy, the use of genetic information in personalised prevention and treatment, and new drug delivery systems (Research Council of Norway 2020b). Specifically, developments in bioinformatics and genetic engineering could provide new opportunities in personalised medicine (Research Council of Norway 2020a). Increasingly, medicines and diagnostic tools are being developed and produced using biotechnological methods. New forms of biotechnology-based treatment, such as the use of stem cells and gene therapy, are approaching clinical application. Biotechnology may also contribute to better public health and reduced public expenditures through a focus on prevention, and early diagnosis and treatment (Ministry of Education and Research 2012). A key area of research is around nanosensors for diagnostic applications that, at low cost, can detect,

[26] Input from expert crowdsourcing exercise.

identify and quantify disease markers or environmental contaminants in the body very early in disease progression (Technopolis 2017).[27] Underpinning all this, digital technologies (e.g. through mobile apps, robotics, and developments in artificial intelligence) are converging with other enabling technologies and expected to contribute new capabilities and insights through the exploitation of large amounts of patient data (Research Council of Norway 2020a; OECD 2019).

Biotechnology applied to health is an area of strength for Norway, which has been investing in infrastructure and research groups in health-related biotechnology (Ministry of Education and Research 2012). For example, the national programme for research in functional genomics in Norway (FUGE) allocated considerable funding to develop sequencing and genome analysis, and represents an important foundation for further biotechnological research within medicine and the health sciences (Ministry of Education and Research 2012). In addition, an international trend is for large pharmaceutical companies to reduce their own internal research and purchase new technology from external research communities. This gives innovative biotechnology companies the opportunity to introduce their own products to an international market. This could be beneficial for companies in countries such as Norway, which lacks large domestic pharmaceutical industry players (Ministry of Education and Research 2012).

### Trend 7: Biotechnology is expected to play an important role in the biomarine industry

Biotechnological research is expected to play an important role in ensuring safe, healthy seafood, and creating new food products from marine resources (Ministry of Education and Research 2012; Egeland, et al. 2019). Biotechnology could contribute to the development of new commercial products from marine resources, including the cultivation of seaweed, kelp and single-celled algae (Ministry of Education and Research 2012).[28] Aquaculture is one of the fastest growing industries in the food sector, and is expected to play a vital role in global food supply (Centre for Environment, Fisheries and Aquaculture Science 2020). In addition, biotechnology can provide tools for environmental monitoring, e.g. to track escaped farmed fish, confirm species identity, measure breeding parameters, and identify non-native species (Ministry of Education and Research 2012).

Knowledge from biotechnology is expected to help to boost the marine industry, a key industry for Norway and one in which it maintains a strong international position (Skjoldager et al. 2021b). The oceans have a high capacity for biomass production, and Norway has large resources associated with ocean areas. However, it is crucial that Norway seeks an international role in the development of marine biotechnology, not only to secure its competitiveness, but also to enhance its reputation in an area in which it is expected to lead (Ministry of Education and Research 2012).

[27] Another rapidly growing area is tissue engineering, which includes, for example, repairing damaged tissues by creating stem cell niches with nanostructured surfaces, bioactive cues and gene expression modifiers (e.g. for bone, cartilage, muscle or spine/nerve regeneration) (Technopolis 2017).

[28] For example, seaweed is currently being used for products in the areas of healthcare, nutrition, feed and speciality chemicals (Ministry of Education and Research 2012).

## Trend 8: Industrial biotechnology is expected to contribute to environmentally friendly industrial processes and products

Several areas of industrial biotechnology are expected to help industries to reduce greenhouse gas emissions and reduce dependence on fossil fuels (Biotechnology Innovation Organisation 2017; Innovation Policy Platform 2013). This includes bio-based plastics and biofuels, including cellulosic biofuels derived from wood, grasses or the non-edible parts of plants, and alga biofuels (Innovation Policy Platform 2013; Ministry of Education and Research 2012). The OECD expects rapid growth in environmentally friendly bioplastics between now and 2050 (Ministry of Education and Research 2012). In addition, biotechnology is expected to play an important role in the environmental services sector, particularly environmental remediation to clean or monitor environmental conditions, including: the clean-up of heavy metals and chemicals; pre-treatment for chemicals or fuels to reduce the presence of certain harmful compounds; and wastewater and water purification for waste management and bio-monitoring (Innovation Policy Platform 2013; Kremer 2017).

Although the industrial application of biotechnology is a relatively immature field in Norway (Ministry of Education and Research 2012), it is a strength in the Norwegian economy (Egeland et al. 2019). Norway has a high level of biotechnological expertise and industrial traditions, as well as unexploited biomass resources, which places it in a good position to take on a prominent role in industrial biotechnology (Ministry of Education and Research 2012). Indeed, it is an area that Norway is developing strengths in – for example, industrial biotechnology has in recent years been increasingly used in biorefining of different types of biomass (Research Council of Norway 2020c). In addition, Norwegian researchers are internationally recognised in the field of enzymatic degradation of complex polymers (Research Council of Norway 2020c). However, to date the industrial biotechnology sector has demonstrated little awareness of digital biotechnology, which is expected to be increasingly (Egeland et al. 2019).

## Trend 9: Socially responsible research and innovation will be a key priority

Responsible research and innovation (RRI) aims to anticipate and take into account the long-term societal consequences of research and innovation, including any unintended side effects on society and the environment (Research Council of Norway 2020c). RRI recognises that the long-term impacts of new developments in science and technology are often unknown, and this presents ethical challenges.[29] In addition, an increasingly digitalised and data-dependent economy raises concerns around privacy and data protection (Ministry of Education and Research 2012). Other negative externalities include disparities between and within regions (Thapa et al. 2019). Some of the literature on RRI has focused on the development of sensitive technologies, such as nanotechnology, biotechnology and different forms of digitalisation (Jakobsen et al. 2019). Therefore, RRI aims to identify and mitigate any potential negative impacts of technology development. This requires independent health and environmental risk research, and

[29] For example, the field of synthetic biology raises a number of concerns around the misuse of modified lifeforms and potential risks to human health and the environment (Ministry of Education and Research 2012; Egeland, Forsberg, and Maximova-Mentzoni 2019).

research on the ethical, legal and social aspects of these technologies (Ministry of Education and Research 2012).[30]

> *'It is important to consider how to ensure legislation that safeguards privacy and human rights in the face of new technologies and digitalisation. How to democratize the internet, ensure the quality of information and prevent echo chambers. (It is important to) be able to maintain digital ethics while making use of AI.'*
>
> Survey respondent

The RCN has developed an RRI framework and Digital Life Norway has put this framework into practice, with all its activities supposed to be underpinned by the principle and practice of RRI (Egeland et al. 2019). As such, the recent project Res Publica was created to provide a platform that will improve RRI activities across Digital Life Norway and its research projects. However, for Norway to succeed, this will require strengthened interdisciplinary perspectives, through greater integration of social sciences, legal and humanities research into the sciences. Research on human-technology interaction will also be important to inform how new technological and digital solutions are deployed (Research Council of Norway 2020a). In addition, the concept of RRI needs to be better embedded and mainstreamed along the research and innovation process (Egeland et al. 2019). This will require education about RRI theory and practice for researchers to ensure RRI is integrated within research projects early on (Egeland et al. 2019).

[30] The concept of RRI, as well as Open Science and Open Innovation, has been particularly prominent in the Horizon 2020 framework programme (Technopolis 2017).

# 3. Barriers to and enablers of technology and digitalisation-related R&I in Norway

This chapter discusses the main enablers of and barriers to developing the technology and digitalisation area in Norway. As with the previous chapter, we have collated evidence from the published literature and also drawn on the insights provided by stakeholders that we interviewed from across academia, industry, government, the third sector, and the RCN.[31]

### Box 2. Summary of key barriers and enablers related to the technology and digitalisation strategic area

**Key barriers**

- Funding and continuity of funding is necessary for translation and innovation.
- The level of public trust in science and technology can affect the uptake of new technologies.
- Awareness and uptake of RRI amongst the scientific community is low.
- Digital security and privacy protection challenges are increasing.
- Risks of harm to the environment.
- New technology creates challenges for the intellectual property system.
- New frameworks and indicators are needed to assess the socio-economic benefits of biotechnologies.
- Industrial upscaling and standardisation of production remains a limiting factor for the commercialisation of nanotechnology and biotechnology.
- Regulation shapes the speed of innovation.

**Key enablers**

- The volume and availability of high-quality data is increasing.
- The free flow of data and digital services is essential for digitalisation.
- National strategies and policies enable the development of technology and digitalisation.
- Digital skills and inclusion are necessary for the digital economy.
- The availability of high-quality electronic communication networks and services will speed up the delivery of data.
- The processing capacity of computers is increasing.
- New knowledge within the science and technology area is expected to contribute to technological innovation.
- Technology convergence is driving innovation.
- Access to high-performance computing and developments in advanced analysis methods represent great potential for innovation.

[31] As noted previously, interviewee inputs are cited in the discussion using anonymised, unique identifiers 'INT-TD-XX' where XX is a number between 01 and 06.

## 3.1. Key barriers

### Funding and continuity of funding is necessary for translation and innovation

Funding and continuity of public and private sector funding is necessary for translation and innovation and, conversely, the absence of funding and stability of funding can be a barrier to translation and innovation. Although in Norway there is a large amount of technology development, translating pilot projects into new products, processes or services is often held back by the lack of follow-on investment (The Innovation Policy Platform 2013). In Norway, there is a lack of funding for later-stage research (e.g. applied research) (INT-TD-01; INT-TD-02; INT-TD-06). It is especially difficult for newly established technology companies to make the transition from the laboratory to production, and many start-ups find it challenging successfully to commercialise their product (INT-TD-01; INT-TD-02; INT-TD-06). Innovation and industrial development activities typically require additional financial support to achieve upscaling from the laboratory to the market (Research Council of Norway 2013).

### The level of public trust in science and technology can affect the uptake of new technologies

The level of public trust around new science and technology can lead to backlashes if not managed appropriately. For example, wide scale public controversies were experienced around the introduction of biotechnology applications, such as genetically modified crops (Technopolis 2017). To date there is generally low approval of genetically modified products, including genetically modified organisms, for use in agriculture or in relation to the import of genetically modified food and feed (Ministry of Education and Research 2012). Avoiding such controversy is a key motivator for the responsible development of science and technology (Technopolis 2017). In Norway, there is generally a high level of public trust in public institutions (OECD 2015) and science and technology (European Commission 2011). However, managing public trust and approval going forward will be important in ensuring the uptake of new science and technology (INT-TD-01). There are ethical and privacy concerns around the use of digital technologies, for example in the public sector.[32] There may also be increasing popular distrust in 'big tech' and the sale of personal data for instance.[33]

### Awareness and uptake of RRI amongst the scientific community is low

There exists a discrepancy between the uptake of the term RRI in some policy circles and the research community as a whole. For example, in general the awareness of RRI is uneven in nano-scientific communities in European countries (as well as in other parts of the world). While some nano-scientists have been engaged in discussions of the social desirability of their research for more than a decade in Norway, many other groups have not heard about this concept and are critical of it. They consider this to represent an increased burden and grant application 'box-ticking', which will have no real impact on science. Some nano-scientists have commented that the RRI agenda is very remote from what they do in their laboratories (Technopolis 2017). In Norway, the key challenge to RRI has been a lack of communication and clear

[32] Input from expert crowdsourcing exercise.

[33] Input from expert crowdsourcing exercise.

understanding of what it is, what RRI tries to achieve, and why it is important to incorporate RRI (Egeland, Forsberg, and Maximova-Mentzoni 2019). In line with RRI principles and with the EU's ethical guidelines and principles on AI, the Norwegian 'National Strategy for Artificial Intelligence' has committed to developing trustworthy and responsible AI in Norway (Ministry of Local Government and Modernisation 2020). The development of AI will be based on ethical principles, respect for privacy and data protection, and good cyber security.

### Digital security and privacy protection challenges are increasing

An increasingly digital and data-dependent economy and society raises increasing cyber security and data protection challenges. It is difficult to forecast which threats will come to dominate in the future, but it is likely that specific types of threats such as ransomware, industrial espionage, sabotage, blackmail, cyber-bullying and identity theft will remain prominent over the coming years (Norwegian Ministries 2019). A key challenge is to reduce these risks to increase public trust, without inhibiting the opportunities offered by the digital economy (that relies on the reuse and sharing of data) (OECD 2018b). This requires research to strengthen competence and find new solutions to increasingly complex cyber security challenges (Research Council of Norway 2020b). Data protection and information security form one of the key priorities in the Norwegian government's ICT policy (Ministry of Local Government and Modernisation 2016). Cybersecurity also forms one of the key priorities in the European Union (EU) Framework Programme (Horizon Europe) (Research Council of Norway 2020b).

### Risk of harm to the environment

The wide range of potential applications of manufactured nanomaterials have a variety of unquantified and unverified risks (e.g. environmental, health and safety risks from the release of nanoparticles into the environment and health concerns for workers and consumers) (Innovation Policy Platform 2013; Bakiu 2018). Understanding the interactions of nanostructures with biological systems is a key challenge both for the development of nano-based products (e.g. in medicine, bio-nanotechnology) and for the assessment of potential hazards to workers in nanotechnology research and manufacturing processes, to consumers, and to the environment (Technopolis 2017).

### New technology creates challenges for the intellectual property system

It is widely acknowledged that intellectual property (IP) (e.g. trademarks, copyright and patents) plays a key role in driving innovation and economic growth (Intellectual Property Office UK Government 2019; Ministry of Education and Research 2012). Therefore, safeguarding intellectual property rights is important for commercialisation and industrial development, especially in a knowledge economy (Norwegian Ministry of Higher Education and Research 2021). However, new technologies and increasing technology convergence creates a challenge for the current IP system (Iversen 2013; INT-TD-04). The IP system in Norway may be inadequate to deal with new technologies such as digital technologies and genetic engineering, and digitalisation in particular represents difficulties related to copyright (Iversen 2013). One interviewee noted that Norway currently lacks the knowledge and tools to adapt its IP system (INT-TD-04).

### New frameworks and indicators are needed to assess the socio-economic benefits of biotechnologies

It is necessary to develop appropriate economic indicators and frameworks to assess the socio-economic benefits of new biotechnologies. One of the aims of using biotechnology in industrial processes is to make production more sustainable and reduce the environmental impact (Ministry of Education and Research 2012). Reliable frameworks, indicators and internationally recognised standards and methods for life-cycle assessment are needed to enable both consumers and governments to assess the degree to which biotechnology-based products and processes are sustainable. One of the problems behind the lack of investment for development and deployment of biotechnology is the paucity of recognised frameworks to assess the socio-economic benefits of new biotechnologies that are still in the R&D or pilot phase (Innovation Policy Platform 2013).

### Industrial upscaling and standardisation of production remains a limiting factor for the commercialisation of nanotechnology and biotechnology

Industrial production challenges in bringing nanomaterial research from the laboratory to market remain a limiting factor for the commercialisation of nanotechnology. This area has consequently received attention in recent European research programmes (Technopolis 2017). Similarly, there are environmental, industrial and regulatory challenges associated with upscaling seaweed and algae production. Upscaling from experimental cultivation schemes to commercial production requires an assessment of the risks and benefits associated with seaweed aquaculture, as well as the development of a regulative framework adapted to this industry (Stévant et al 2017).

### Regulation shapes the speed of innovation

Regulation can strongly shape the course of science and technology development and innovation. It is necessary to ensure the safety and efficacy of new technologies, but outdated or suboptimal regulatory approaches can act to constrain innovation. New technology creates challenges for regulation – for example, wider existing legislation in Member States and the EU are already applicable to AI, but new legislation or adjustments will also likely be needed due to the specificities intrinsic to AI, its evolution, the opacity of black-box algorithms, and unintended or negative consequences (Brattberg et al. 2020). The Norwegian government aims to adapt regulations and create favourable framework conditions to enable Norway to exploit the opportunities for value creation and innovation from enabling technologies (Ministry of Local Government and Modernisation 2016). The Norwegian government aims to establish a regulatory framework that safeguards against risks (including minimum regulation, technology neutrality and predictable framework conditions) whilst enabling the major changes the industry is currently experiencing (Ministry of Local Government and Modernisation 2016).

## 3.2. Key enablers

### The volume and availability of high-quality data is increasing

Today, vast amounts of different types of data are generated from many different sources (e.g. personal, business, research) (Ministry of Local Government and Modernisation 2019). For example, the volume of data is expected to grow from 33 zettabytes globally in 2018 to an expected 175 zettabytes in 2025 (1

zettabyte is equal to 1 trillion gigabytes) (OECD 2019). This, combined with the new possibilities for gathering and exploiting such data, have made them core inputs of innovation in all sectors of the economy (OECD 2019). Access to high-quality data is vital for the development and use of data-driven technologies, including AI/machine learning, Big Data analytics, and the Internet of Things, all of which underpin digitalisation (Ministry of Local Government and Modernisation 2019). The development and deployment of Industry 4.0-related technologies (e.g. IoT, AI and machine learning, and blockchain) contributes to steady increases in data generation and value, as more devices and activities are connected.

## The free flow of data and digital services is essential for digitalisation

The free flow of data and digital services is essential to fully develop the data economy and for digitalisation (European Commission 2020). Although cross border data-flows are projected to grow faster than growth in world trade (OECD 2020c), barriers remain to the free flow of digital services across national borders (World Economic Forum 2020). For example, regulations and policies that mandate the storage of data within geographical territories and act as barriers to this type of international data sharing are on the rise (World Economic Forum 2020). Nonetheless, this situation is being addressed by the EU as part of their Digital Single Market strategy (European Commission 2020). Similarly, Norway acknowledges that its priorities in its national ICT policy are affected by international (including EU) trends, and that collaboration on ICT policy is important (Ministry of Local Government and Modernisation 2016). Norway intends to participate in the EU Digital Single Market, and the EU's strategy in this area constitutes an important basis for Norway's ICT policy (Ministry of Local Government and Modernisation 2016).

## National strategies and policies enable the development of technology and digitalisation

The existence of policies or strategies is important to enable the development of technology and digitalisation in Norway. The Norwegian government has developed national strategies in several strategic areas, including biotechnology, nanotechnology and digitalisation (Ministry of Local Government and Modernisation 2019; Ministry of Education and Research 2012; Research Council of Norway 2013). The national strategy for biotechnology runs from 2011 to 2020 and has been designed to balance basic and applied research, innovation and commercialisation in biotechnology (Ministry of Education and Research 2012). It is backed by the Research Council of Norway and Innovation Norway, two organisations that promote and support innovation in industry. The national strategy for nanotechnology runs from 2012 to 2021 (Research Council of Norway 2013). The national strategy for digitalisation runs from 2019 to 2025 (Ministry of Local Government and Modernisation 2019). Digital 21 is a government-elected committee that was initiated by the Ministry of Trade and Industry to support and accelerate digitalisation in the business and industry sector (Digital21 2018). The committee has identified and established expert groups in six areas of strategic importance: emerging technologies; research, development and innovation; competence; computer resources and infrastructure; safety; public framework (Digital21 2018, 21). In line with RRI principles and with the EU's ethical guidelines and principles on AI, the Norwegian 'National Strategy for Artificial Intelligence' has committed to developing trustworthy and responsible AI in Norway (Ministry of Local Government and Modernisation 2020). In addition, the 21 processes initiated since 2001 by the Norwegian government, that aim to develop strategies and to promote dialogue and collaboration between different stakeholders in the Norwegian research and innovation landscape, all have

elements of digitalisation and technology (Norwegian Board of Technology and Research Council of Norway 2015). For instance, the Norwegian Ministry of Trade, Industry and Fisheries has through the Digital 21 process developed a strategy to contribute to digitalisation in Norwegian industry. The strategy recommends 64 measures, which are all oriented towards five main tasks: (i) establish a relevant knowledge and technology base and develop new businesses; (i) ensure adequate competencies with the right focus; (iii) make data resources available and develop a business-oriented infrastructure; (iv) ensure cybersecurity as a necessary principle; and (v) develop a public framework that can stimulate innovation and digitalisation (Digital21 2018).

### Digital skills and inclusion are necessary for the digital economy

For digitalisation and the digital economy to 'work' for everyone, it is important to ensure that everyone has the digital skills required to participate. The level of digital competence in the Norwegian population is high and Norway has one of the smallest internet use age gaps in the OECD area (OECD 2017). Over 90 per cent of 55-74 year olds in Norway reported using the Internet in 2016 (OECD 2017). Nonetheless, many individuals for various reasons remain digitally excluded (Ministry of Local Government and Modernisation 2016). In addition, recent structural challenges such as rapid changes in technologies, the increasing internationalisation of markets, and a workforce that is changing because of migration and demographic changes also challenges the Norwegian skills system (OECD 2020b). It will also be necessary to provide the Norwegian public with soft skills that can help them to succeed in the labour market and to contribute to better social outcomes (OECD 2014).

### The availability of high-quality electronic communication networks and services will speed up the delivery of data

The availability of digital infrastructure[34] and developments in the global mobile network, including the establishment of next-generation broadband infrastructure such as 5G, will enable the capacity to deliver data traffic increasingly faster (Ministry of Local Government and Modernisation 2016; European Parliament 2019). In addition, this will continue to reduce the costs of communication to allow greater interaction (OECD 2020c). These developments are necessary for increased digitisation (Ministry of Local Government and Modernisation 2016), and will enable multiple new innovative services across sectors, including manufacturing, energy, vehicle manufacturing and health (European Parliament 2019). Norway has a well-developed digital infrastructure (Ministry of Local Government and Modernisation 2016).

### The processing capacity of computers is increasing

Computers and networks are increasingly able to process larger amounts of data due to the development of smaller and faster electronic and optical circuits/devices (Ministry of Local Government and Modernisation 2016). This is enabling the continued growth in computational processing speed, transmission and storage of data, which forms the foundation for digitalisation (Technopolis 2017). This is driving new innovations – for example, recent developments in AI-based technologies have been made possible due to algorithms

[34] Input from expert crowdsourcing exercise.

that were available but could only be fully applied once it became possible to compile large amounts of data combined with an exponential increase in processing capacity (Research Council of Norway 2020a).

### New knowledge within the science and technology area is expected to contribute to technological innovation

International developments within key technology areas such as data-driven technologies, nanotechnology and biotechnology is moving rapidly (Research Council of Norway 2020a). This is expected to contribute to technology development and innovation. Norway has a lot of expertise and knowledge in several science and technology areas (INT-TD-04). However, it is important for Norway to collaborate with international research environments in order for Norwegian research to remain competitive, and participate actively and successfully in the development of new knowledge and methodology (Research Council of Norway 2020a). Moreover, Norway currently lacks capacity in translating research (INT-TD-04).

### Technology convergence is driving innovation

Research areas not traditionally associated with digitalisation, and on which advanced economies depend, from materials science to biology, are increasingly digital (OECD 2020c). For example, the development of biotechnology increasingly requires interdisciplinary work at the interface between biology, data and computer sciences (Centre for Digital Life Norway 2017; INT-TD-04). Norway is starting to build strengths in this area, for example it has established Digital Life Norway, a national centre for biotechnology research led by the University of Oslo (Egeland et al. 2019). However, for Norway to fully exploit the potential of technology convergence more generally will require education and recruitment of candidates who are able to work and connect different types of knowledge within transdisciplinary collaboration (Research Council of Norway 2020a).

### Access to high performance computing and developments in advanced analysis methods represent great potential for innovation

Developments in advanced computing systems (with extremely high computational power that are able to solve hugely complex and demanding problems) is expected to lead to new insights and business opportunities. High performance computing is key to processing and analysing the growing volume of data. For example, new large-scale analysis methodologies of genetic material and other biomolecules have led to large amounts of data, which represents a great potential for innovation (Research Council of Norway 2020a). It is hoped that significant advances in computing will stem from research breakthroughs in optical computing (using photons instead of electrons), biological computing (using DNA to store data and calculate) and/or quantum computing. For example, high performance optoelectronic nanomaterials (e.g. graphene, MoS2, hNB, and 1D materials such as carbon nanotubes or semiconductor nanowires) and quantum dots may form the physical basis for the development of quantum computing, which is a field in very fast development (Technopolis 2017). Although next-generation quantum technologies are developing at a fast rate (NATO 2020), currently no quantum device approaches the performance of conventional computers (OECD 2018b). Europe generally underinvests in digital ICT, including quantum computing (McKinsey Global Institute 2019). In addition, the demand for high performance computing capabilities in Europe exceeds the current European supply of resources (Gigler et al. 2018). It will be important for Norway to maintain its capacity to build and maintain high performance computing infrastructure to stay

competitive and reduce risks. In 2018, Norway signed the declaration for the European High-Performance Computing Joint Undertaking (Uninett Sigma2 2019).

# 4. Uncertainties and policy challenges associated with transforming the technology and digitalisation ecosystem in Norway

In this chapter, we discuss the various uncertainties and policy challenges associated with potentially transforming the technology and digitalisation area in Norway. Where relevant, and drawing on the evidence from the literature and expert insights, we also present ideas for potential solutions to some of these challenges. As noted previously, to achieve its overarching objectives and strategic area–related vision, the RCN will need to adopt a multi-stakeholder approach of collaborating and engaging with diverse stakeholders in the wider R&I network in Norway and develop targeted priority missions, while also establishing new (or updating existing) underpinning structural measures.

### Box 3. Summary of uncertainties and policy challenges

**Uncertainties**

- The long-term effects of AI and digitalisation, biotechnology and nanotechnology on society are unknown.
- Sudden breakthroughs in quantum computing could change the course of science and technology development.
- It is difficult to forecast which cybersecurity and data protection challenges presented by digitalisation will come to dominate in the future.

**Policy challenges and potential solutions**

- There are challenges related to funding and continuity of funding.
- There is an education, skills and competence gap in key disciplines.
- There are knowledge gaps in key research areas and interdisciplinary research practices.
- There are insufficient national and international networks and collaboration
- There is limited access to (open) data and relatively insufficient data sharing.
- There are important structural and regulatory challenges that need to be overcome

## 4.1. Uncertainties

### The long-term effects of AI and digitalisation, biotechnology and nanotechnology on society are unknown

The long-term effects of technology development are often unknown, which raises important ethical challenges. It therefore becomes important to ensure that knowledge, values and ethical considerations are taken into account during technology development (Research Council of Norway 2020c). The long-term impacts of widespread digitalisation on society are unknown.[35] For example, there is a growing need for research on the long-term effects of the use of Big Data and digitalisation on society, human interaction,

[35] Input from expert crowdsourcing exercise.

culture and business in Norway and internationally (Research Council of Norway 2020a). Similarly, the implications of advanced AI are not yet clear, and neither are the policy measures that will be needed to properly address risks (Brattberg et al. 2020). Regarding biotechnology and nanotechnology, there are uncertainties also about the risk of unintended harm to human health and the environment, and potential conflict with ethical norms or other, unwanted, social consequences (Ministry of Education and Research 2012).

### Sudden breakthroughs in quantum computing could change the course of science and technology development

New knowledge leading to sudden breakthroughs could change current and accepted knowledge. Although this could apply to all technology areas, this is perhaps especially important for developments in digitalisation, due to the high and ever-increasing rate of change observed. For example, developments in quantum technologies and quantum computing could be incredibly disruptive (NATO 2020). Developments in quantum computing could also lead to greater challenges around cybersecurity (NATO 2020). This means that research must be able to change focus quickly, with new methods, approaches and ways of thinking able to be developed swiftly.

### It is difficult to forecast which cybersecurity and data protection challenges presented by digitalisation will come to dominate in the future

Unexpected events such as pandemics, cyber-attacks or terrorism could have unforeseen consequences on the course of science and technology development. For example, the COVID-19 pandemic has accelerated the digitalisation of society, including research with decentralised clinical trials and work (INT-TD-03; INT-TD-04).

> *'For many people, the pandemic has caused a steep digital learning curve. Simultaneously, the difference between people who master technology and the ones that don't has increased. Here, municipalities, in collaboration with voluntary organisations have a great responsibility.'*
>
> Survey respondent

In general, the increasing digitalisation of society raises mounting cyber security and data protection challenges, but it is difficult to forecast which threats will come to dominate in the future. The development of ever more advanced and complex computing systems could lead to greater challenges around cybersecurity (NATO 2020). Therefore, the Norwegian research and innovation system must be able to respond quickly in order to provide new technological solutions aimed at minimising the societal consequences of such crises.

## 4.2. Key policy challenges and potential solutions associated with transforming the technology and digitalisation area

### There are challenges related to funding and continuity of funding

In Norway, there are challenges related to funding and continuity of funding along the R&D pipeline (INT-TD-03; INT-TD-04; INT-TD-06). Whilst Norway has good basic research programmes, it has less of a focus on applied and user-driven research, and other measures to enable the translation of research (e.g.

user-led innovation and innovation in public sector procurement) (INT-TD-03; INT-TD-04). One interviewee felt that cross-sectoral working was difficult because Norway lacks the right funding schemes (INT-TD-06). One interviewee noted that Norway has decent funding programmes for early stage projects; however, there is often insufficient mid- and late-stage private sector funding to pull projects through (INT-TD-04). For example, projects that are supported by Digital Life Norway are often projects on early Technology Readiness Levels (TRL), around levels 2–4 (Egeland et al. 2019). Similarly, SkatteFUNN, an R&D tax incentive scheme, has a particularly strong effect on increasing R&D efforts amongst companies in the early stages of doing R&D (Åström et al. 2017). There are also many new companies (in particular start-ups) being formed in Norway, but challenges exist in scaling these up (Egeland et al. 2019). Therefore, there is a need to consider the balance between public and private sector funding.[36] One solution may be to increase private sector funding, and industry needs to increase its share of R&D (Ministry of Education and Research 2012). In general, there is good state support for research and innovation in Norway, but perhaps a need for better coordination between actors in the R&I system (i.e. Innovation Norway, SIVA and the Research Council), and other actors, including the government-funded investment company Investinor AS, regional innovation players and investors (Research Council of Norway 2013).[37] Norwegian research and innovation communities within health-related biotechnology do not make adequate use of the funding schemes under the EU Framework Programmes. To achieve this, national funding schemes must be linked more closely to the existing international arenas. (Ministry of Education and Research 2012).

### There is an education, skills and competence gap in key disciplines

The fast pace of technological change (including digitalisation) is contributing to a skills shortage, particularly digital skills (OECD 2020c). Advanced digital competence constitutes a fundamental precondition for the digitisation of Norway (Ministry of Local Government and Modernisation 2016).

> *'It is frightening to see how far behind we are in some situations, for example, in the municipal sector and in the administration of higher education. We have the technical possibilities, but we have too little expertise on how it can be used. Use technology to increase inclusion, but this is a challenge as it requires smart solutions. Battery technology is key. We need to focus on the ideas behind digitalisation.'*
>
> Survey respondent

Advanced use of digital technologies is now an integral part of research in many disciplines (which is increasingly data-driven) and in the workplace (as AI and data-driven technologies become more widespread in the labour market) (Ministry of Local Government and Modernisation 2020). For example, a lack of data specialists is impeding the use of data analytics in business (OECD 2020c). There is currently some uncertainty about whether Norway will have adequate levels of digital skills such as data analytics capabilities in the population.[38] A failure to tackle the skills shortage and divide could lead to increasing inequality (McKinsey Global Institute 2019). Related to this, there is a significant gender gap in the access, uptake

[36] Input from expert crowdsourcing exercise.

[37] Norway spends 2.06 per cent of its gross domestic product (GDP) on R&D (UK Science & Innovation Network 2020). The RCN is the main funder for R&D, and Innovation Norway leads on general business development and non-R&D-based innovation (Egeland, Forsberg, and Maximova-Mentzoni 2019).

[38] Input from expert crowdsourcing exercise.

and use of digital technologies, as well as associated digital skills in many G20 economies, with women less equipped than men with the skills that are needed in the digital transformation (OECD 2018a). In schools it is necessary to adapt existing curricula but also design entirely new fields of tuition (e.g. dedicated programmes for the autonomous vehicle industry) (OECD 2020c). It is necessary to build skills and competence in data analysis, as well as disciplines such as biostatistics and mathematical subjects to analyse the large amounts of scientific data that are being generated (Research Council of Norway 2020b). For example, an increased focus on data analysis and multidisciplinary education is needed (OECD 2020c). Therefore, digital competence needs to be improved from primary education throughout the life course (OECD 2020c), and the promotion of necessary competences and skills constitutes a key element of the Norwegian government's ICT policy (Ministry of Local Government and Modernisation 2016; Randall & Berlina 2019). Norway is in a relatively good position – in 2018, the OECD estimated that only 6 per cent of jobs in Norway were at risk of automation; this figure is the lowest of all OECD member countries (Nedelkoska & Quintini 2018). In addition, Norwegian employees – both those with and those without higher education – were amongst those who receive most training in the workplace (Nedelkoska & Quintini 2018).

## There are knowledge gaps in key research areas and interdisciplinary research practices

In Norway there are knowledge gaps in key research disciplines, interdisciplinary research and applied research (INT-TD-03; INT-TD-04).[39] Norway has a good knowledge base in key emerging technologies such as synthetic biology and AI (INT-TD-04) but long-term, basic and strategic research is needed to further develop the knowledge base. For example, in order to fully exploit the potential of industrial biotechnology and biorefining, it will be particularly important to increase expertise in the areas of microbiology, biocatalysis, systems biology and fermentation processes (Ministry of Education and Research 2012). Similarly, developing capacities in advanced ICT research constitutes a fundamental precondition for the digitalisation of Norway (Norwegian Ministry of Local Government and Modernisation 2016; INT-TD-05). The increasing digitalisation of society presents considerable cybersecurity challenges, and currently more research is needed on information and communications security (Research Council of Norway 2020a). There is currently a fragmentation of cybersecurity research infrastructure and an insufficient cybersecurity-skilled workforce.[40] A key challenge is to foster and incentivise collaboration amongst cybersecurity research groups in academia and industry.[41] There is also the increasing application of systems engineering across research and industry domains, which is key to responding to technological and global trends.[42] This will require expanding the workforce capacity in systems engineering through enhancing education and training to grow a workforce that meets the increasing demands, a stronger theoretical foundation for systems engineering, as well as advancing the tools and methods to address increasing complexity in engineering.[43]

[39] Input from survey of the public.

[40] Input from expert crowdsourcing exercise.

[41] Input from expert crowdsourcing exercise.

[42] Input from expert crowdsourcing exercise.

[43] Input from expert crowdsourcing exercise.

The convergence of different technology areas, such as enabling technologies with computer sciences, is creating greater levels of complexity and interdependence of systems, which requires collaboration and interdisciplinary competence.[44] Therefore, interdisciplinary research projects that extend across the boundaries of subject areas and disciplines in which researchers do not traditionally cooperate should be encouraged (Research Council of Norway 2013; Technopolis 2018). This in turn will require the education and recruitment of candidates who are able to work and connect different types of knowledge within transdisciplinary collaboration, which is currently lacking in Norway (Research Council of Norway 2020c). The RCN research portfolios focusing on emerging technologies and digitalisation are currently largely dominated by projects in technology or natural sciences. However, in order to succeed with the goal of socially responsible research and innovation, there will be a need to strengthen efforts in the humanities and social sciences. In addition to research on the need for technological change, it is equally important to understand the conditions that must be met for us as humans and society to adopt new technology and new knowledge. It is also important to explore the moral and political values that such change mechanisms may conflict with. (Research Council of Norway 2020c).

### There are insufficient national and international networks and collaboration

The formation of clusters and networks help innovation processes to advance by facilitating cooperation across organisations (e.g. academia and industry), the interdisciplinary exchange of expertise and international collaboration (Ministry of Education and Research 2012). A lot of research is performed outside of Norway, with most breakthroughs expected to occur in the international arena (INT-TD-03). Therefore, Norway must track international developments in key technology areas (e.g. biotechnology) to ensure high-quality research and innovation, and for this it needs to have an extensive international network (Research Council of Norway 2013; Ministry of Education and Research 2012). Norway has challenges around public-private collaboration, such as between academia and industry (INT-TD-04). There is often a lack of understanding between the two sides, with a disparity between researchers' views of what an industry partner actually requires (Egeland et al. 2019). Therefore, there is a need to enable better and more effective and efficient collaboration between public and private sector entities. One way to do this would be to ensure shared interests and mechanisms (e.g. through a platform) to facilitate working together to stimulate collaboration.

Digital Life Norway is a good example of a national initiative that aims to develop a research community in the area of digital biotechnology that is well recognised and connected internationally (Egeland et al. 2019). Norway also aims to be an active participant in various European initiatives, such as the European Strategy Forum on Research Infrastructures, the Joint Programming Initiatives and Joint Technology Initiatives. Norway is a member of the European Molecular Biology Laboratory, which is one of the most important European institutions for life sciences and biotechnological research (Ministry of Education and Research 2012). In particular, Norway needs to take an active part in the EU's mobility and cooperation

[44] Input from expert crowdsourcing exercise.

programmes under the European Research Council (ERC) and in programmes for industry (e.g. Eurostars) (Ministry of Education and Research 2017).[45]

## There is limited access to (open) data and relatively insufficient data sharing

The increasing digitalisation of society and development of the data economy requires access to high-quality data (OECD 2020c). Therefore, a key challenge for policy is to ensure the broadest possible access to data (incentivising sharing and reuse), whilst at the same time respecting data privacy, ethics and intellectual property rights, amongst others (OECD 2020c). Europe is considered a leading actor on data governance and privacy protection with the 2018 General Data Protection Regulation (GDPR) and, most recently, legislation on the free flow of data (McKinsey Global Institute 2019). Sound data protection is also one of the key priorities in the Norwegian government's ICT policy (Ministry of Local Government and Modernisation 2016). There are, however, strict privacy regulations in Norway, which makes it difficult to use data (INT-TD-03). In general, limited access to open data presents a hurdle to developing the powerful algorithms necessary for AI development (Brattberg, Csernatoni, and Rugova 2020).

It will be important for Norway to develop policies to increase accessibility of data. One way could be to collaborate with the EU, which in its AI strategy proposes to harness the potential of non-personal anonymised data by developing a legislative framework and operating standards for European data spaces to allow governments and researchers to store their data and access trusted data shared by others (Brattberg et al. 2020). Related to the issue of access to data, one way to make more data available is to ensure digital technologies, content and data become digital public goods (e.g. open source software, open data, open AI models, open standards and open content that adhere to privacy and other applicable laws) (United Nations 2020).[46,47] Norway is well positioned to support this initiative, having an international leadership position in the field (through leadership in the Digital Public Goods Alliance).[48]

Alongside data, there will be a need for substantial investment in electronic infrastructure and secure storage to achieve open access to publicly funded research data, and to keep up with other trends, such as a greater need to utilise increasing amounts of data for research and innovation purposes. The Research Council will contribute to national and international cooperation on high-cost research infrastructure (Research Council of Norway 2020a). For example, the development and use of AI requires a sound communication

[45] Several Norwegian programmes (such as the nanotechnology and biotechnology programmes) also work to enhance the internationalisation of Norwegian research in the technology sphere by encouraging international participation in research projects and by participating in international programme cooperation. For example, The NANO2021 programme, which contributes to implementing the national nanotechnology strategy, sought to advance the main priorities of the EU framework programmes (Research Council of Norway 2013). As such, many of the NANO2021 programme's objectives harmonise with focus areas for Horizon 2020, such as the development of outstanding science, academic and industrial leadership and solutions to societal challenges.

[46] Input from expert crowdsourcing exercise.

[47] Currently, access to digital technologies is often limited through copyright regimes and proprietary systems (United Nations 2020). Creating digital public goods could help to attain some of the Sustainable Development Goals and is particularly relevant for low- and middle-income countries (United Nations 2020).

[48] Input from expert crowdsourcing exercise.

infrastructure and access to high-performance computing, which can be extremely expensive (OECD 2020c).[49]

### There are important structural and regulatory challenges that need to be overcome

The fast-moving nature of technologies such as AI presents challenges for developing an appropriate regulatory framework (Brattberg et al. 2020). AI currently lacks a clear definition and such a definition would need to be flexible enough to capture the evolving nature of the technology, whilst at the same time providing enough legal clarity for enforcement (Brattberg et al. 2020). Digitalisation presents challenges around the regulation of public access to public data, with a risk for the monopolisation of data by commercial entities.[50] The increased digitalisation of society could lead to the emergence of market monopolies.[51] Solutions to ensure a more democratic digitalisation could include the development of a public digitalisation protocol, and the integration of multiple small actors into the digitalisation process to ensure that a multi-actor innovation environment thrives.[52] It would be important to determine what type of data-protection and market regulations would promote such an environment.[53] There is a trend towards national regulation of digital technology developed by 'Big Tech', with uncertainties around how to regulate technology on a national level.[54] A key challenge is around developing national policies that give accountability, transparency and sovereignty.[55]

[49] The work on communication infrastructure, and on 5G networks in particular, is a priority area for the government (Ministry of Local Government and Modernisation 2020).

[50] Input from expert crowdsourcing exercise.

[51] Input from expert crowdsourcing exercise; input from survey of the public.

[52] Input from expert crowdsourcing exercise.

[53] Input from expert crowdsourcing exercise.

[54] Input from expert crowdsourcing exercise.

[55] Input from expert crowdsourcing exercise.

# 5. Future scenarios to examine potential missions and structural measures

This chapter presents the scenarios (to 2040) that were developed to examine the future of the different strategic areas and the wider R&I system in Norway. It is important to highlight that the scenarios are not intended to be predictions or forecasts of the future. Instead, they represent a range of plausible future states that have been generated using a combination of factors and future projections of the factors that could reasonably occur together. The scenarios represent a wide spectrum of possible futures that are sufficiently differentiated from each other. A summary of the approach to developing and using the scenarios is provided in Section 1.3 and further elaborated upon in the following sections. A detailed description of the methodology used to develop the scenarios is provided in the accompanying methodology report (Gunashekar et al. 2021c).

## 5.1. Future scenarios to 2040

As noted in Section 1.3, to build scenarios of sufficient depth and distinctiveness, we constructed two scenario sets, by combining various elements associated with the five strategic areas (oceans; green transition; technology and digitalisation; technology and digitalisation; and cohesion and globalisation). Each scenario set comprised four future scenarios based on 15–20 prioritised political, economic, social, technological, legal and environmental (PESTLE) factors from the trend analyses[56] that could influence the strategic areas (specifically, these factors were derived from the trends, enablers, barriers and uncertainties that were identified in the trend analyses).

By having two sets of scenarios, each with a relatively large number of PESTLE factors, we were able to maintain the detail and richness required in the scenarios to support the examination of meaningful missions and policy actions for each of the strategic areas, while at the same time allowing the missions to be set against a broader landscape. Furthermore, with the two sets of scenarios, we were able to effectively deal with the relatively wide-ranging strategic areas of cohesion and globalisation and technology and digitalisation (as well as green transition, to a degree).[57] Below we recap the two scenario sets:

- **Scenario set 1 (*Norway in a national context*):** The first scenario set broadly focuses on Norway in a national context, largely relating to the Norwegian domestic agenda. This scenario set encompasses such themes as health, welfare, education, work and skills, cohesion, and relevant aspects of technology and digitalisation, and it also covers some aspects related to green transition (for example, in relation to the circular economy).
- **Scenario set 2 (*Norway in a global context*):** The second scenario set focuses on Norway in an international or global context, primarily relating to Norway's outward-facing role. It broadly

[56] In the first phase of the study, we carried out a detailed trend analysis for each strategic area, by collecting and analysing wide-ranging evidence to help develop a robust knowledge and information base. Specifically, we identified the main trends, enablers, barriers, and uncertainties that will potentially shape the strategic area over the next ten years or so.

[57] These two strategic areas are very interconnected with different sectors, cut across the other strategic areas, and are inter-related with each other as well.

covers themes related to climate, oceans, energy, transport, food, biodiversity and globalisation, as well as relevant aspects of technology and digitalisation.

As noted above, we developed four distinct future scenarios to 2040 for each scenario set. Because of their cross-cutting and wide-ranging nature, the technology and digitalisation and cohesion and globalisation strategic areas and some of the corresponding indicative missions were discussed in relation to both scenario sets. The scenarios were used as methodological tools during two foresight workshops to examine a series of indicative priority missions and discuss ideas for potential structural measures.[58] The workshops were attended by a range of diverse stakeholders from across academia, industry, the third sector and the RCN.

In the sections below, for both scenario sets, we provide the high-level summaries of the corresponding scenarios followed by a table containing the key characteristics and underpinning factors of the four scenarios. In Annex A, we present more detailed one-page narratives of the scenarios that have been developed.[59]

[58] The two workshops covering the two scenario sets – Norway in a national context and Norway in a global context – were organised on 23 and 24 March 2021, respectively.

[59] The scenario narratives were shared with the workshop participants in advance of the workshops and were discussed in detail during the workshops.

## 5.2. Summaries of the scenarios corresponding to future scenario set 1: *Norway in a national context*

*As noted previously, different aspects of the technology and digitalisation strategic area were covered in both scenario sets and were discussed at both workshops (see Annex A for the full scenario narratives).*

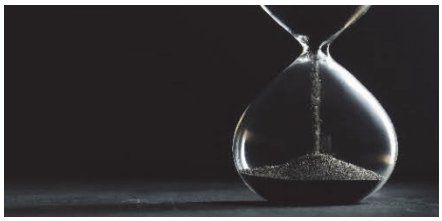
### Scenario 1: Protectionist decline

**Key storyline:** Against a backdrop of global protectionist trends, technology adoption and innovation in Norway's healthcare sector has stalled. Greater national spending on health and welfare has led to some advances in care but has so far failed to deliver a joined-up system. Despite increased growth in some sectors, such as domestic food production, overall productivity growth and labour force participation are low and trust in public institutions is declining.

### Scenario 2: Going green together

**Key storyline:** Sustainability, an inclusive society and local delivery of services are now at the core of Norway's approach. Healthcare has been decentralised, and, in common with other sectors, targeted use of technology is seen as a way to improve efficiency and reduce waste. There has also been a focus on education and digital competence to reduce social inequalities. Open science has been key to the success of green initiatives at the national and local level, from green builds and urban farms, as city living remains popular.

### Scenario 3: Slowly changing society



**Key storyline:** Norway has experienced only gradual change over the past several years. There has been some success in the healthcare sector in responding to more complex needs of a changing population, compounded by the effects of climate change. But limited interdisciplinary collaboration and cooperation with industry, as well as a lack of vision on green initiatives, give rise to concerns that Norway will not have the necessary skills to adapt to future changes in the national and global landscape.

### Scenario 4: Technological trajectory

**Key storyline:** Norway has focused on technological advances to promote economic growth and support its sustainability goals. Digital solutions have been extensively integrated into healthcare. Most Norwegians have internet access, but digital literacy and a willingness to share data are prerequisites for participation in many activities. The technological transformation of employment has also meant many Norwegians have been able to move out of cities to escape effects of climate change.

**Figure 6. Key characteristics and underpinning factors of the four scenarios associated with scenario set 1 *(Norway in a national context)***

| | | Protectionist decline | Going green together | Slowly changing society | Technological trajectory |
|---|---|---|---|---|---|
| Health and welfare | Demand and access to health and welfare services | ↔ | ↑ | ↔ | ↔ |
| | Collaboration and interdisciplinarity | ↓ | ↑ | ↔ | ↑ |
| | Development and adoption of telemedicine and telecare | ↔ | ↑ | ↔ | ↑ |
| Economy and society | Discrimination and hate speech | ↑ | ↓ | ↔ | ↔ |
| | Use of social media to spread disinformation | Increasingly used, with impact on the spread of misinformation | Increasingly used, but little impact on misinformation | Increasingly used, with impact on the spread of misinformation | Increasingly used, with impact on the spread of misinformation |
| | Trust in public administration | ↓ | ↑ | ↔ | ↔ |
| | Net immigration | ↔ | ↓ | ↔ | ↔ |
| | Natural resource wealth | Slow growth or stagnation | Steady growth, with greater share from sustainable sources | Steady growth, but no change in share from sustainable sources | Steady growth, but no change in share from sustainable sources |
| Location of jobs and housing and greening initiatives | Skilled labour availability to match employment demand | ↓ | ↑ | ↔ | ↑ |
| | Location of jobs and housing | More dispersion with mixed transport links | Continued trend for jobs to be located in large cities and transport-friendly locations | Continued trend for jobs to be located in large cities and transport-friendly locations | More dispersion with mixed transport links |
| | Ability of Norway to adapt to environmental change | ↔ | ↑ | ↔ | ↑ |
| | Circular infrastructure for energy, water and waste supply | Focussed on current approaches | Develop rapidly and are implemented at national, regional and local levels | Rapid development, but implementation is localised | Rapid development, but implementation is localised |
| Technology, digital skills and digital threats | Digital skills | Digital divide increases | Digital skills increase, digital divide decreases | Digital skills and digital divide remains as now | Digital divide increases |
| | Digital security and cyber security protection | Norway is unable to respond, digital and cyber security threats demand increase protection | Norway is better able to respond, decreasing digital and cyber security threats | Norway is unable to respond, digital and cyber security threats demand increase protection | Norway is better able to respond, decreasing digital and cyber security threats |
| | Data sharing | ↓ | ↑ | ↑ | ↑ |
| | Technology convergence and use of enabling technologies | ↓ | ↑ | ↔ | ↑ |
| Research and innovation | Globalisation of research and innovation and data sharing | Decrease in international data sharing and collaboration | Increasing international data sharing and collaboration (open and distributed) | Increasing international collaboration and data sharing (closed) | Increasing international data sharing and collaboration (open and distributed) |
| | Funding for research and innovation | Decreases | Sufficient and continuous for different actors | Fragmentation | Sufficient and continuous for different actors |

Source: Study team analysis

## 5.3. Summaries of the four scenarios corresponding to future scenario set 2: *Norway in a global context*

*As noted previously, different aspects of the technology and digitalisation strategic area were covered in both scenario sets and were discussed at both workshops (see Annex A for the full scenario narratives).*

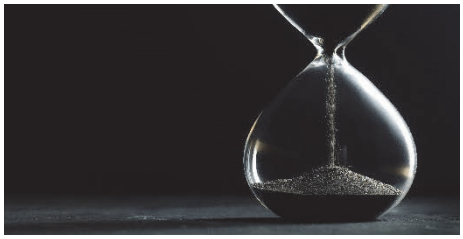
### Scenario 1: Protectionist decline

**Key storyline:** Political instability has led to a poorly performing global economy and protectionist attitudes towards trade and research and innovation. Even within Norway, there has been little progress so far on initiatives to green the economy, which continues to focus on developing the oceans.

### Scenario 2: Global greening

**Key storyline:** Products and services that have a low impact on the environment and climate are now central to the global economy. Change is being achieved through government-, industry- and consumer-led initiatives, with Norway at the forefront of all of these. There has been a focus on ensuring openness and transparency of research, seen as key to a green future.

### Scenario 3: Slowly shifting power

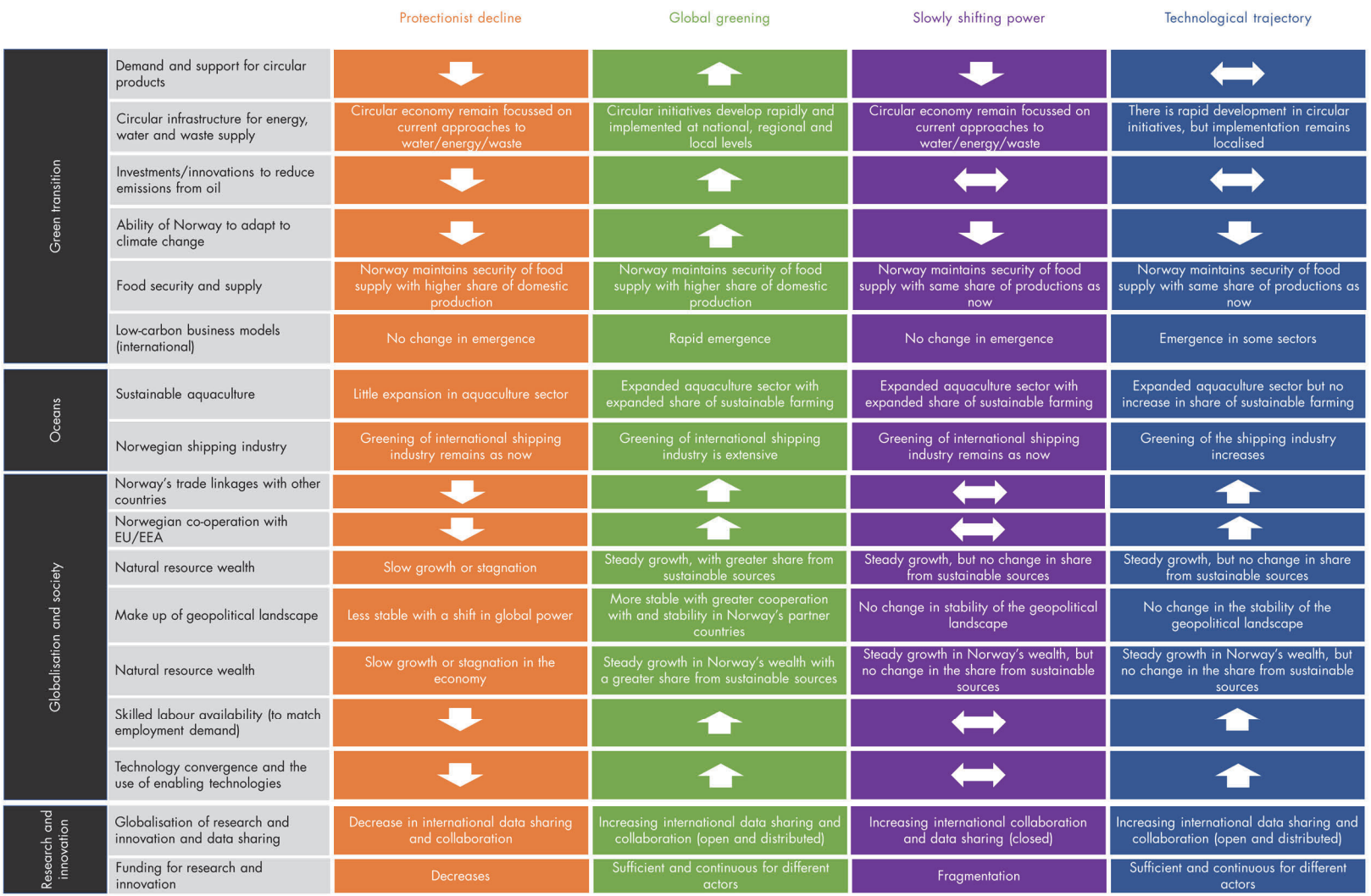


**Key storyline:** A lack of clear international vision has resulted in slow progress by 2040 on both climate change goals and transformational change from technology convergence, as research remains fragmented. Global trading pattern relationships reflect the steady drift of economic power away from the west, while melting ice in the High North has created commercial opportunities and tensions for Norway.

### Technological trajectory

**Key storyline:** By 2040, technology is all-pervasive: a key driver of economic growth, changing the nature of employment for many and impacting on daily life. Technological advances have not delivered on climate change goals and continue to be resource intensive. Norway is increasingly looking to new international partners for trade and research collaboration.

Figure 7. Key characteristics and underpinning factors of the four scenarios associated with scenario set 2 *(Norway in a global context)*



| | | Protectionist decline | Global greening | Slowly shifting power | Technological trajectory |
|---|---|---|---|---|---|
| Green transition | Demand and support for circular products | ↓ | ↑ | ↓ | ↔ |
| | Circular infrastructure for energy, water and waste supply | Circular economy remain focussed on current approaches to water/energy/waste | Circular initiatives develop rapidly and implemented at national, regional and local levels | Circular economy remain focussed on current approaches to water/energy/waste | There is rapid development in circular initiatives, but implementation remains localised |
| | Investments/innovations to reduce emissions from oil | ↓ | ↑ | ↔ | ↔ |
| | Ability of Norway to adapt to climate change | ↓ | ↑ | ↓ | ↓ |
| | Food security and supply | Norway maintains security of food supply with higher share of domestic production | Norway maintains security of food supply with higher share of domestic production | Norway maintains security of food supply with same share of productions as now | Norway maintains security of food supply with same share of productions as now |
| | Low-carbon business models (international) | No change in emergence | Rapid emergence | No change in emergence | Emergence in some sectors |
| Oceans | Sustainable aquaculture | Little expansion in aquaculture sector | Expanded aquaculture sector with expanded share of sustainable farming | Expanded aquaculture sector with expanded share of sustainable farming | Expanded aquaculture sector but no increase in share of sustainable farming |
| | Norwegian shipping industry | Greening of international shipping industry remains as now | Greening of international shipping industry is extensive | Greening of international shipping industry remains as now | Greening of the shipping industry increases |
| Globalisation and society | Norway's trade linkages with other countries | ↓ | ↑ | ↔ | ↑ |
| | Norwegian co-operation with EU/EEA | ↓ | ↑ | ↔ | ↑ |
| | Natural resource wealth | Slow growth or stagnation | Steady growth, with greater share from sustainable sources | Steady growth, but no change in share from sustainable sources | Steady growth, but no change in share from sustainable sources |
| | Make up of geopolitical landscape | Less stable with a shift in global power | More stable with greater cooperation with and stability in Norway's partner countries | No change in stability of the geopolitical landscape | No change in the stability of the geopolitical landscape |
| | Natural resource wealth | Slow growth or stagnation in the economy | Steady growth in Norway's wealth with a greater share from sustainable sources | Steady growth in Norway's wealth, but no change in the share from sustainable sources | Steady growth in Norway's wealth, but no change in the share from sustainable sources |
| | Skilled labour availability (to match employment demand) | ↓ | ↑ | ↔ | ↑ |
| | Technology convergence and the use of enabling technologies | ↓ | ↑ | ↔ | ↑ |
| Research and innovation | Globalisation of research and innovation and data sharing | Decrease in international data sharing and collaboration | Increasing international data sharing and collaboration (open and distributed) | Increasing international collaboration and data sharing (closed) | Increasing international data sharing and collaboration (open and distributed) |
| | Funding for research and innovation | Decreases | Sufficient and continuous for different actors | Fragmentation | Sufficient and continuous for different actors |

Source: Study team analysis

# 6. Indicative priority missions to help develop the technology and digitalisation strategic area

As noted previously, a set of policy levers or actions will be required by the RCN to help steer the R&I system towards its main outcome of interest (i.e. achieving a 'well-functioning research and innovation system') through its three overarching objectives for the current strategy period (i.e. ground-breaking research and radical innovation; sustainable development; and restructuring of the business and public sectors) (Research Council of Norway 2020a). Developing a series of strategically selected priority missions – within and across (or even outside) the RCN's five strategic areas – that could potentially be implemented over the next few years could help contribute to this. For this study, we regard missions as targeted, timebound, concrete priority actions to help solve one or more societal challenges that the RCN, together with other stakeholders could consider implementing in the future. These challenge-based missions will help the RCN achieve its overarching objectives (over a roughly ten-year time frame) and eventually contribute to enriching lives locally, nationally and internationally. More generally, missions are systemic policies that operate both as a means of steering economic growth in a particular direction (by, for example, steering investments towards particular societal challenges) and as a tool that can be used to get there (by, for example, setting clear problem-focused objectives) (Mazzucato 2018). Because missions are so closely connected to societal challenges, public purpose and societal impact lie at the heart of missions. They also aim to generate innovation across sectors, actors and disciplines and to enable bottom-up solutions and experimentation across multiple sectors. Missions are challenges that cannot be solved by a single project in research and innovation, but, rather, require a portfolio of interacting projects as well as the implementation of wider policy measures.

In the sections below, we discuss a set of indicative priority missions for the technology and digitalisation strategic area. As technology and digitalisation is a comprehensively defined strategic area with an extensive scope (as illustrated in the trends, enablers, barriers, and uncertainties presented above), we have suggested a relatively large number of mission ideas that span many areas. However, several of the mission ideas are relevant to one or more other strategic areas and are therefore also included in the respective strategic area reports. Some of the indicative missions might focus on a different area (for example, they might have a stronger link to oceans or green transition) but are touched on by issues related to technology and digitalisation. Thus, the areas covered by the missions are also broad and comprehensive, and require actions across a range of different fields, for example, from skills and digitalisation to health and environment.

Drawing on information collected during the trend analyses and expert inputs throughout the study, the mission ideas have been proposed, as far as possible, for areas where Norway has competitive advantages; where its institutional capacities and capabilities are strong; and where national, social, economic or environmental challenges are critical – nationally and where, relevant, internationally. The priority mission ideas we have highlighted are not intended to be definitive and are proposed as indicative ideas at this stage, based on the analysis of the evidence gathered. They represent a broad spectrum of ideas for further consideration and exploration by the RCN and other stakeholders that might be involved in the process to implement potential missions in Norway in the future. Some mission ideas are wide ranging and cover one or more other strategic areas while others are more specific. Furthermore, some missions overlap and interact

with other missions. All the missions will require an active, multi-stakeholder approach in order to be implemented and are cross-cutting in terms of sectors and disciplines involved. In general, their implementation will also need to effectively incorporate relevant social sciences, humanities, legal and ethical perspectives. Finally, the missions must engage the public regularly and be evaluated against a set of clearly defined criteria set out upfront.

A preliminary set of priority missions and associated focus areas were discussed and validated by stakeholders (across academia, industry, the third sector and the RCN) at two foresight workshops to understand their implications (for example, in terms of impact and feasibility) against the RCN's objectives across the different futures exemplified in the scenarios.[60] We also tested the mission ideas in interviews with a selection of stakeholders from academia, industry, the third sector and the public sector. Following the workshops, the indicative missions were refined based on feedback received at the workshops and from the RCN. For each indicative mission presented below, we have also suggested a selection of potential targeted focus areas, in addition to highlighting broad links to the United Nations (UN) Sustainable Development Goals (SDGs) (United Nations 2021),[61] the clusters under Pillar II of Horizon Europe (European Commission 2021a),[62] and other EU missions identified in Horizon Europe (European Commission 2021b).[63] The focus areas[64] are exemplar and are not intended to be definitive; rather they represent a range of potential areas of emphasis in relation to the missions for further consideration by the RCN and other stakeholders. It is important to note that each of the target focus areas presented below will eventually need to be specified with clear, measurable and timebound goals, arrived at by the stakeholders involved in selecting and implementing the missions.

In addition, we have articulated a set of indicative, cross-cutting missions (which are also related to technology and digitalisation) that are intentionally comprehensive and could apply horizontally to several (and in some cases all the) strategic areas and potentially to other areas of R&I as well. These have been discussed in an accompanying report (Gunashekar et al. 2021a).

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[60] The two workshops covering the two scenario sets – Norway in a national context and Norway in a global context – were organised on 23 and 24 March 2021, respectively.

[61] The UN SDGs are: SDG1: No poverty; SDG2: Zero hunger; SDG3: Good health and well-being; SDG4: Quality education; SDG5: Gender equality; SDG6: Clean water and sanitation; SDG7: Affordable and clean energy; SDG8: Decent work and economic growth; SDG9: Industry, innovation and infrastructure; SDG10: Reduced inequalities; SDG11: Sustainable cities and communities; SDG12: Responsible consumption and production; SDG13: Climate action; SDG14: Life below water; SDG15: Life on land; SDG16: Peace, justice and strong institutions; and SDG17: Partnerships for the goals.

[61] The Horizon Europe Clusters under Pillar II includes: (1): Health; (2): Culture, Creativity and Inclusive Society; (3): Civil Security for Society; (4): Digital, Industry and Space; (5): Climate, Energy and Mobility; and (6): Food, Bioeconomy, Natural Resources, Agriculture and Environment.

[62] The Horizon Europe Clusters under Pillar II includes: (1): Health; (2): Culture, Creativity and Inclusive Society; (3): Civil Security for Society; (4): Digital, Industry and Space; (5): Climate, Energy and Mobility; and (6): Food, Bioeconomy, Natural Resources, Agriculture and Environment.

[63] Five EU mission areas have currently been proposed as part of Horizon Europe: (i) Conquering Cancer: Mission Possible; (ii) A Climate Resilient Europe – Prepare Europe for Climate Disruptions and Accelerate the Transformation to a Climate Resilient and Just Europe by 2030; (iii) Mission Starfish 2030: Restore our Ocean and Waters; (iv) 100 Climate-Neutral Cities by 2030 – By and for the Citizens; and (v) Caring for Soil Is Caring for Life.

[64] To varying degrees, the missions and focus areas capture evidence analysed during the trend analyses. Specifically, we analysed the key trends, barriers, enablers and uncertainties identified in the trend analysis to suggest potential areas of focus for each priority mission.

Finally, it is important to note that the priority missions will need to be developed and built on top of a set of robust and coordinated structural measures in the Norwegian R&I environment. Structural measures will address the performance of the Norwegian R&I system in terms of the three overarching objectives of the RCN for the current strategy period. Establishing new and/or strengthening existing underpinning structural measures will enable the development of a resilient, inclusive and thriving R&I environment in Norway within which the missions can be effectively and efficiently implemented in the future. We have proposed a series of potential structural measures in an accompanying report (Skjoldager et al. 2021c).

In Box 4 below, we summarise the indicative missions (and corresponding exemplar targeted focus areas) for the technology and digitalisation strategic area and from Section 6.1.1 onwards, we present details of the missions using a standard template (in Box 5, we provide a key to the missions template). In Annex B, we present an infographic that provides a high-level overview of *all* the indicative mission ideas that have been articulated within and across the RCN's five strategic areas (oceans; green transition; health and welfare; technology and digitalisation; and cohesion and globalisation).

### Box 4. Summary of indicative missions and corresponding exemplar targeted focus areas related to the technology and digitalisation strategic area[65]

- ***Indicative mission 1:*** Contribute to Norway's digital transformation by creating a diverse, digitally and soft-skilled workforce
  ***Exemplar targeted focus areas:*** Progressively reduce and eliminate the shortage in advanced digital and soft skills, training and competencies, to enable people to work in and adapt to the rapidly evolving digital economy in Norway and globally (including upskilling and reskilling workers); and lead the way and demonstrate knowledge leadership in ensuring equal opportunities, eliminating disparities and overcoming bias and systemic barriers for all segments of the population working in the digital economy (e.g. women, minority ethnic communities, older people, the young workforce, disabled people).
- ***Indicative mission 2:*** Actively enable digital transformation at all levels of government in Norway
  ***Exemplar targeted focus areas:*** Make better and more responsible use of a range of digital technologies, data and platforms as enablers of public services at both local and national level (to deliver more targeted, inclusive and user-centric services); improve operations, work processes, productivity, user experience, accountability, and transparency (and reduce risks); promote activities and behaviours that involve the responsible use of data and evidence to inform decision making; proactively focus on workforce development related to developing and maintaining skills (digital and soft); and promote cooperation/collaboration within and across ministries/municipalities and with other stakeholders (including the private sector) (e.g. to share learnings, to share good practice, to build capacity).

[65] As noted above, due to the wide-ranging nature and scope of the technology and digitalisation strategic area, these missions span many areas. Some of the missions might have a focus in a different area (e.g. a stronger link to the oceans strategic area) but are touched on by issues related to technology and digitalisation. These areas covered by the missions are broad and comprehensive and require actions across a range of different fields from skills and digitalisation to health and environment.

- *Indicative mission 3:* Play a leading role in Norway and internationally to substantially increase the use of renewable energy in a sustainable and long-lasting manner and accelerate R&I in this area
  *Exemplar targeted focus areas:* Improve energy security by substituting fossil fuels with renewable sources across all sectors; improve access to modern, reliable and cost-effective clean energy sources across all segments of the population; substantially improve energy efficiency (e.g. in the built environment); accelerate R&I and increase public and private sector investment in renewable energy infrastructure and technology; mobilise knowledge exchange and cross-sectoral/international collaboration (e.g. to share lessons, reduce duplication); and provide thought leadership to help improve awareness and understanding.
- *Indicative mission 4:* Enhance Norway's world-leading capabilities and expertise in future maritime technologies
  *Exemplar targeted focus areas:* Put Norway at the forefront of successfully developing, deploying and scaling up a range of innovative, clean technology solutions applicable to the marine environment around Norway; responsibly use data to inform ocean management–related decision making; strengthen Norway's position as an international leader in green shipping; position Norway as a global leader in leveraging the opportunities offered by maritime technologies while addressing the risks and challenges associated with deploying these technologies; and actively promote cooperation (regional and international) between relevant stakeholders in this area.
- *Indicative mission 5:* Accelerate people-centred, data-driven strategies to digitally transform and improve Norway's health and welfare system
  *Exemplar targeted focus areas:* Further leverage Norway's research and innovation strengths in data-driven technologies (e.g. AI, machine learning, nanotechnology, biotechnology) and the translation of these into practice to improve the prevention, diagnosis and treatment of diseases and illnesses; actively address the potential ethical, societal and legal challenges involved in development and adoption; and ensure that all segments of the population in Norway are positively impacted.
- *Indicative mission 6:* Establish Norway as a global knowledge leader in personalised medicine and healthcare
  *Exemplar targeted focus areas:* Put Norway at the forefront of developing cutting-edge and responsible personalised medicine approaches and patient-centred care; translate these into practice to improve patient care and outcomes and to avoid unnecessary health costs; roll these out across all segments of the population in Norway; and actively address the potential ethical, societal and legal challenges involved in development and adoption.
- *Indicative mission 7:* Make Norway's (largest) cities climate neutral

  *Exemplar targeted focus areas:* Further reduce (X% reduction in) greenhouse gas emissions in key sectors across Norway's (largest) cities, aimed at ultimately achieving carbon neutrality; and implement sustainable, greener, resource-efficient and inclusive measures (for example, in relation to land use and transport, energy use in the built environment, consumption and waste, and adaptation to climate change).
- *Indicative mission 8:* Significantly reduce Norway's transport-related emissions
  *Exemplar targeted focus areas:* Considerably reduce (X% reduction in) greenhouse gas emissions from the entire transport sector in Norway (including terrestrial and maritime transport) and make it fully sustainable; promote and invest in R&I activities to develop and adopt climate-friendly technologies, innovations and infrastructure at scale across all segments of the transport value chain (e.g. including but not limited to making shipping and maritime passenger transport greener); and play a leading role in developing collaborations, improving education, understanding behavioural patterns, raising awareness and enhancing capacity-building measures related to climate change mitigation, adaptation and impact reduction.

- *Indicative mission 9:* Actively contribute to healthy, safe and sustainable food systems
  *Exemplar targeted focus areas:* Increase sustainable, climate-resilient food production – nationally and globally; increase access to safe and healthy food while reducing food waste and loss; ensure that food production systems can provide food to improve quality of life and health; stimulate innovations/technology development and adoption to accelerate the transformation of food systems (e.g. in relation to improving productivity, supply chain efficiency and transparency); actively position Norway as an international thought and knowledge leader with regard to effective food systems governance; and promote international cooperation (e.g. in relation to R&D, agricultural practices) between stakeholders to stimulate the creation of economically, socially and environmentally sustainable food systems.
- *Indicative mission 10:* Ensure decent work for all people in Norway
  *Exemplar targeted focus areas:* Promote and accelerate inclusive, diverse and decent work for all people in Norway across all segments of the population (including integration of immigrants into the labour market); increase youth employment; improve quality of work, working conditions, job satisfaction, etc.; ensure equal access; and achieve productive employment for the Norwegian workforce that can adapt to digitalisation/automation.

Box 5. Key to the mission templates presented below

- **Key challenges that the mission aims to address:** Details some of the challenges that the mission will contribute to addressing.
- **Exemplar targeted focus areas:** Lists a selection of potential targeted focus areas for the mission. Implementing the priority missions will require the design and implementation of a portfolio of diverse projects involving multiple stakeholders, ideally, as noted previously, in areas where Norway demonstrates strengths and has competitive advantages. The exemplar targeted focus areas could be used to inform the development of potential R&I projects. Furthermore, it is important to note that each of the target focus areas will need to be specified with clear, measurable and timebound goals that are decided by the stakeholders involved in implementing the mission.
- **Links to the RCN strategic areas:** Specifies the links to the strategic area(s) identified in the RCN's current strategy for the next ten years (Research Council of Norway 2020a).
- **Links to UN Sustainable development goals (SDGs):** Specifies the UN SDG(s) that the priority mission is linked to (United Nations 2021).
- **Links to clusters of Horizon Europe's Global Challenges pillar (Pillar II):** Specifies the cluster(s) within Pillar II of Horizon Europe) (Global Challenges and European Industrial Competitiveness) that the mission is linked to (European Commission 2021a).
- **Intersection with other priority missions:** Specifies the other indicative priority mission(s) that the priority mission is interconnected with.
- **Involvement of key stakeholders:** Implementing this priority mission will require targeted research, innovation and investment from the RCN and other potential stakeholders (e.g. the public sector; the private sector and industry; civil society organisations; citizens). Importantly, it will also necessitate catalysing active cooperation and collaboration among these diverse stakeholders (including public engagement). In this section, we list some of these potential key stakeholders.

### 6.1.1. Priority mission area 1: Contribute to Norway's digital transformation by creating a diverse, digitally and soft-skilled workforce

<table>
<tr><td colspan="2">Key challenges that the mission aims to address</td></tr>
<tr><td colspan="2">• Ensuring that the education systems adapts to developments in the digital economy;<br>• Filling skills gaps in key industries, including (but not limited to) healthcare, financial services and retail;<br>• Ensuring the effective use of skills;<br>• Ensuring the active supply of skills;<br>• Contributing to the governance arrangements of Norway's skills system;<br>• Engaging stakeholders in the entire policy cycle; and<br>• Building integrated information systems.</td></tr>
<tr><td colspan="2">Exemplar targeted focus areas</td></tr>
<tr><td colspan="2">• Progressively reduce and eliminate the shortage in advanced digital and soft skills, training and competencies, to enable people to work in and adapt to the rapidly evolving digital economy in Norway and globally (including upskilling and reskilling workers); and<br>• Lead the way and demonstrate knowledge leadership in ensuring equal opportunities, eliminating disparities and overcoming bias and systemic barriers for all segments of the population working in the digital economy (e.g. women, minority ethnic communities, older people, the young workforce, disabled people).</td></tr>
<tr><td>Links to RCN Strategic Areas</td><td>Links to UN SDGs</td></tr>
<tr><td>• Technology and digitalisation (primary link)<br>• Cohesion and globalisation<br>• Health and welfare<br>• Oceans<br>• Green transition</td><td>• SDG 4: Quality Education<br>• SDG 5: Gender Equality<br>• SDG 8: Decent Work and Economic Growth<br>• SDG 9: Industry, Innovation and Infrastructure<br>• SDG 16: Peace, Justice and Strong Institutions</td></tr>
<tr><td>Links to clusters of Horizon Europe's Global Challenges pillar</td><td>Links to EU mission areas identified in Horizon Europe</td></tr>
<tr><td>• Culture, Creativity and Inclusive Society<br>• Digital, Industry and Space</td><td>• Conquering Cancer: Mission Possible<br>• A Climate Resilient Europe – Prepare Europe for Climate Disruptions and Accelerate the Transformation to a Climate Resilient and Just Europe by 2030<br>• Mission Starfish 2030: Restore our Ocean and Waters<br>• 100 Climate-Neutral Cities by 2030 – By and for the Citizens<br>• Caring for Soil Is Caring for Life</td></tr>
<tr><td colspan="2">Intersection with other priority mission(s) identified in this study</td></tr>
<tr><td colspan="2">All indicative priority missions</td></tr>
<tr><td colspan="2">Involvement of key stakeholders</td></tr>
<tr><td colspan="2">• All sectors<br>• Norwegian higher education institutions and research organisations<br>• Norwegian national agencies (e.g. Ministry of Labour and Social Affairs, Ministry of Local Government and Modernisation, Ministry of Education and Research, Sami Parliament, Industrial Development Corporation of Norway)<br>• International organisations (e.g. United Nations, World Bank, OECD, European Commission, World Economic Forum)<br>• Voluntary organisations (e.g. Frivillighet Norge, European Network of National Civil Society Associations)<br>• The Research Council of Norway and Innovation Norway</td></tr>
</table>

### 6.1.2. Priority mission area 2: Actively enable digital transformation at all levels of government in Norway

<table>
<tr><td colspan="2">Key challenges that the mission aims to address</td></tr>
<tr><td colspan="2">• Countering the fragmented implementation of digital technologies across the public sector;<br>• Providing key institutional actors with the means to promote the use of common guidelines, standards and digital solutions in different policy sectors;<br>• Responding to changing citizen and business needs and expectations;<br>• Strengthen coordination and synergies with local government;<br>• Increasing the priority assigned to the development of digital and data-related leadership and skills; and<br>• Simplifying and streamlining data-sharing practices.</td></tr>
<tr><td colspan="2">Exemplar targeted focus areas</td></tr>
<tr><td colspan="2">• Make better and more responsible use of a range of digital technologies, data and platforms as enablers of public services at both local and national level (to deliver more targeted, inclusive and user-centric services);<br>• Improve operations, work processes, productivity, user experience, accountability and transparency (and reduce risks);<br>• Promote activities and behaviours that involve the responsible use of data and evidence to inform decision making;<br>• Proactively focus on workforce development related to developing and maintaining skills (digital and soft); and<br>• Promote cooperation/collaboration within and across ministries/municipalities and with other stakeholders (including the private sector) (e.g. to share learnings, to share good practice, to build capacity).</td></tr>
<tr><td>Links to RCN Strategic Areas</td><td>Links to UN SDGs</td></tr>
<tr><td>• Technology and digitalisation (primary link)<br>• Cohesion and globalisation<br>• Health and welfare<br>• Oceans<br>• Green transition</td><td>• SDG 4: Quality Education<br>• SDG 9: Industry, Innovation and Infrastructure<br>• SDG 16: Peace, Justice and Strong Institutions</td></tr>
<tr><td>Links to clusters of Horizon Europe's Global Challenges pillar</td><td>Links to EU mission areas identified in Horizon Europe</td></tr>
<tr><td>• Culture, Creativity and Inclusive Society<br>• Digital, Industry and Space</td><td>• Conquering Cancer: Mission Possible<br>• A Climate Resilient Europe – Prepare Europe for Climate Disruptions and Accelerate the Transformation to a Climate Resilient and Just Europe by 2030<br>• Mission Starfish 2030: Restore our Ocean and Waters<br>• 100 Climate-Neutral Cities by 2030 – By and for the Citizens<br>• Caring for Soil Is Caring for Life</td></tr>
<tr><td colspan="2">Intersection with other priority mission(s) identified in this study</td></tr>
<tr><td colspan="2">All indicative priority missions</td></tr>
<tr><td colspan="2">Involvement of key stakeholders</td></tr>
<tr><td colspan="2">• All sectors<br>• Norwegian higher education institutions and research organisations<br>• Norwegian national agencies (e.g. Difi – Agency for Public Management and eGovernment, Norwegian Association of Local and Regional Authorities, Ministry of Local Government and Modernisation, Ministry of Finance, Ministry of Research and Education, Agency for Financial Management, Industrial Development Corporation of Norway)<br>• International organisations (e.g. United Nations, World Bank, OECD, European Commission, World Economic Forum)<br>• Voluntary organisations (e.g. Frivillighet Norge, European Network of National Civil Society Associations)<br>• The Research Council of Norway and Innovation Norway</td></tr>
</table>

### 6.1.3. Priority mission area 3: Play a leading role in Norway and internationally to substantially increase the use of renewable energy in a sustainable and long-lasting manner and accelerate R&I in this area

| Key challenges that the mission aims to address | |
|---|---|
| • Increasing the percentage of electricity production that comes from renewable energy sources;<br>• Making all new passenger cars and light vans zero-emissions vehicles and make buses and lorries emissions free;<br>• Improving reuse, recycle and repurpose strategies across different sectors;<br>• Improving and creating a fluctuating renewable energy supply;<br>• Increasing investment in (for example) solar panels, hydropower and wind parks;<br>• Improving tenant electricity models, car sharing, bicycle schemes and home storage systems; and<br>• Improving the smart grid and solutions for flexibility and integration of different power systems where renewables can dominate | |
| **Exemplar targeted focus areas** | |
| • Improve energy security by substituting fossil fuels with renewable sources across all sectors;<br>• Improve access to modern, reliable and cost-effective clean energy sources across all segments of the population; substantially improve energy efficiency (e.g. in the built environment);<br>• Accelerate R&I and increase public and private sector investment in renewable energy infrastructure and technology;<br>• Mobilise knowledge exchange and cross-sectoral/international collaboration (e.g. to share lessons, reduce duplication); and<br>• Provide thought leadership to help improve awareness and understanding. | |
| **Links to RCN Strategic Areas** | **Links to UN SDGs** |
| • Green transition (primary link)<br>• Cohesion and globalisation<br>• Technology and digitalisation | • SDG 7: Affordable and Clean Energy<br>• SDG 9: Industry, Innovation and Infrastructure<br>• SDG 13: Climate action |
| **Links to clusters of Horizon Europe's Global Challenges pillar** | **Links to EU mission areas identified in Horizon Europe** |
| • Climate, Energy and Mobility | • A Climate Resilient Europe – Prepare Europe for Climate Disruptions and Accelerate the Transformation to a Climate Resilient and Just Europe by 2030<br>• 100 Climate-Neutral Cities by 2030 – By and for the Citizens |
| **Intersection with other priority mission(s) identified in this study** | |
| • Establish a resilient and sustainable blue economy in Norway<br>• Significantly reduce Norway's transport-related emissions<br>• Establish Norway as a knowledge leader in global change processes, development and international relations<br>• Contribute to Norway's digital transformation by creating a diverse, digitally and soft-skilled workforce | |
| **Involvement of key stakeholders** | |
| • Sectors (e.g. energy, transport, development, technology, ocean, business, building, hospitality, retail)<br>• Norwegian higher education institutions and research organisations<br>• Norwegian national agencies (e.g. Ministry of Trade, Industry and Fisheries, Ministry of Transport, Ministry of Petroleum and Energy, Ministry of Local Government and Modernisation, Waste Norway, Bane Nor, Industrial Development Corporation of Norway)<br>• International organisations (e.g. United Nations Environment Programme, International Water Association, United Nations Development Programme, European Commission)<br>• Voluntary organisations (e.g. Frivillighet Norge, European Network of National Civil Society Associations, Miljøagentene, Norges Naturvernforbund, Norsk Friluftsliv, Natur og Ungdom)<br>• The Research Council of Norway and Innovation Norway | |

### 6.1.4. Priority mission area 4: Enhance Norway's world-leading capabilities and expertise in future maritime technologies

| Key challenges that the mission aims to address | |
|---|---|
| • Ensuring effective surveillance and monitoring of the oceans;<br>• Reducing some of the challenges associated with large-scale fishing that have an impact on climate change;<br>• Ensuring sustainable offshore aquaculture;<br>• Ensuring innovative modes of transport, such as autonomous or electric ferries;<br>• Developing green shipping solutions;<br>• Developing new wave and wind technologies;<br>• Supporting communities that are dependent on the marine ecosystem; and<br>• Improving Norway's position as a global leader in relation to the ocean ecosystem. | |
| Exemplar targeted focus areas | |
| • Put Norway at the forefront of successfully developing, deploying and scaling up a range of innovative, clean technology solutions applicable to the marine environment around Norway;<br>• Responsibly use data to inform ocean management–related decision making;<br>• Strengthen Norway's position as an international leader in green shipping;<br>• Position Norway as a global leader in leveraging the opportunities offered by maritime technologies while addressing the risks and challenges associated with deploying these technologies; and<br>• Actively promote cooperation (regional and international) between relevant stakeholders in this area. | |
| Links to RCN Strategic Areas | Links to UN SDGs |
| • Oceans (primary link)<br>• Technology and digitalisation<br>• Green transition | • SDG 7: Affordable and Clean energy<br>• SDG 13: Climate Action<br>• SDG 14: Life Below Water |
| Links to clusters of Horizon Europe's Global Challenges pillar | Links to EU mission areas identified in Horizon Europe |
| • Digital, Industry and Space<br>• Climate, Energy and Mobility<br>• Food, Bioeconomy, Natural Resources, Agriculture and Environment | • Mission Starfish 2030: Restore our Ocean and Waters by 2030 |
| Intersection with other priority mission(s) identified in this study | |
| • Establish a resilient and sustainable blue economy in Norway<br>• Position Norway as a global leader in combating marine pollution and establish Norwegian ocean ecosystems free of marine pollution<br>• Significantly reduce Norway's transport-related emissions<br>• Contribute to Norway's digital transformation by creating a diverse, digitally and soft-skilled workforce<br>• Actively enable digital transformation at all levels of government in Norway | |
| Involvement of key stakeholders | |
| • Sectors (e.g. energy, aquaculture, development, shipping, petroleum, seafood, technology, chemical industry, biotech)<br>• Norwegian higher education institutions and research organisations<br>• Norwegian national agencies (e.g. Ministry of Trade, Industry and Fisheries, Ministry of Transport, Ministry of Petroleum and Energy, Norwegian Petroleum Directorate, Ministry of Local Government and Modernisation, Ministry of Foreign Affairs)<br>• International organisations (e.g. United Nations Environmental Assembly, International Maritime Organisation, International Water Association, Food and Agricultural Organization of the United Nations, World Bank, United Nations Development Programme, European Commission, Industrial Development Corporation of Norway)<br>• Voluntary organisations (e.g. Frivillighet Norge, European Network of National Civil Society Associations, Miljøagentene, Norges Naturvernforbund, Norsk Friluftsliv, Natur og Ungdom)<br>• Research Council of Norway and Innovation Norway | |

### 6.1.5. Priority mission area 5: Accelerate people-centred, data-driven strategies to digitally transform and improve Norway's health and welfare system

| Key challenges that the mission aims to address | |
|---|---|
| • Improving telehealth and welfare offerings across Norway[66];<br>• Improving data and image sharing among healthcare and welfare providers in Norway; and<br>• Contributing to new data models, increased collaboration, and transformation towards a preventative approach. | |
| **Exemplar targeted focus areas** | |
| • Further leverage Norway's research and innovation strengths in data-driven technologies (e.g. AI, machine learning, nanotechnology, biotechnology, etc.) and the translation of these into practice to improve the prevention, diagnosis and treatment of diseases and illnesses[67];<br>• Actively address the potential ethical, societal and legal challenges involved in development and adoption; and<br>• Ensure that all segments of the population in Norway are positively impacted. | |
| **Links to RCN Strategic Areas** | **Links to UN SDGs** |
| • Health and welfare (primary link)<br>• Technology and digitalisation | • SDG 3: Good Health and Well-being |
| **Links to clusters of Horizon Europe's Global Challenges Pillar II** | **Links to EU mission areas identified in Horizon Europe** |
| • Health<br>• Digital, Industry and Space | • Conquering Cancer: Mission Possible |
| **Intersection with other indicative priority mission(s) identified in this study** | |
| • Actively address the impacts of non-communicable diseases in Norway<br>• Substantially reduce the prevalence and impact of mental illness in Norway<br>• Establish Norway as a global knowledge leader in personalised medicine and healthcare<br>• Improve the quality of life and health of an ageing society in Norway<br>• Contribute to Norway's digital transformation by creating a diverse, digitally and soft-skilled workforce<br>• Actively enable digital transformation at all levels of government in Norway | |
| **Involvement of key stakeholders** | |
| • Sectors (e.g. health, social care, life sciences, pharmaceuticals, education and learning, technology, environment, climate)<br>• Norwegian higher education institutions and research organisations<br>• International organisations (e.g. World Health Organization, OECD, European Commission, United Nations)<br>• National and regional government health agencies (e.g. Ministry of Health and Care Services, Norwegian Institute of Public Health, Norwegian Medicines Agency, Norwegian Directorate of Health, Norwegian Association of General Medicine, Norwegian Data Protection Authority, Central Norway Pharmaceutical Trust, Northern Norway Regional Health Authority, Southern and Eastern Norway Regional Health Authority, Western Norway Regional Health Authority, National Centre for eHealth Research, Industrial Development Corporation of Norway)<br>• Voluntary organisations (e.g. Frivillighet Norge, European Network of National Civil Society Associations, Aurora, Barnekreftforeningen, Blå Kors Norge, Internasjonal helse- og sosialgruppe, Kreftforeningen, Nasjonalforeningen for folkehelsen, Mat&Atferd, Norsk Helse- og Avholdsforbund)<br>• Research Council of Norway and Innovation Norway | |

[66] See, for example Department for Business, Energy & Industrial Strategy (2021), European Cluster Collaboration Platform (2021) and Nordic Health 2030 (2018).

[67] Norway can also further leverage data-driven strategies and data spaces for technologies related to cloud, data and artificial intelligence, to create registries that can benefit research and innovation in other sectors where Norway has competitive advantages (i.e. health, earth observation and the Arctic, maritime through BarentsWatch, and energy).

### 6.1.6. Priority mission area 6: Establish Norway as a global knowledge leader in personalised medicine and healthcare

| Key challenges that the mission aims to address | |
|---|---|
| • Improving the prediction and prevention of disease, precision diagnostics, tailored interventions and a more active role for participants in managing their own healthcare needs;<br>• Furthering Norway's strong position in personalised medicine, with population–based healthcare administrative registers, biobanks, and the potential for collaboration with other Nordic countries given similarities between health systems; and<br>• Improving the links between digitalisation targets and patient treatment targets, strengthening teams-based and multidisciplinary care provision, rolling out personalised medicine across Norway's regions, and contributing to developing population-oriented information. | |
| Exemplar targeted focus areas | |
| • Put Norway at the forefront of developing cutting-edge and responsible personalised medicine approaches and patient-centred care;<br>• Translate these into practice to improve patient care and outcomes and to avoid unnecessary health costs; roll these out across all segments of the population in Norway; and<br>• Actively address the potential ethical, societal and legal challenges involved in development and adoption. | |
| Links to RCN Strategic Areas | Links to UN SDGs |
| • Health and welfare (primary link)<br>• Technology and digitalisation | • SDG 3: Good Health and Well-being |
| Links to clusters of Horizon Europe's Global Challenges Pillar II | Links to EU mission areas identified in Horizon Europe |
| • Health<br>• Digital, Industry and Space | • Conquering Cancer: Mission Possible |
| Intersection with other priority mission(s) identified in this study | |
| • Actively address the impacts of non-communicable diseases in Norway<br>• Substantially reduce the prevalence and impact of mental illness in Norway<br>• Accelerate people-centred data-driven strategies to digitally transform and improve Norway's health and welfare system<br>• Improve the quality of life and health of an ageing society in Norway<br>• Contribute to Norway's digital transformation by creating a diverse, digitally and soft-skilled workforce<br>• Actively enable digital transformation at all levels of government in Norway | |
| Involvement of key stakeholders | |
| • Sectors (e.g. health, social care, life sciences and pharmaceuticals, technology)<br>• International organisations (e.g. World Health Organization, OECD, European Commission, United Nations)<br>• National and regional government health agencies (e.g. Ministry of Health and Care Services, Norwegian Institute of Public Health, Norwegian Medicines Agency, Norwegian Directorate of Health, Norwegian Association of General Medicine, Norwegian Data Protection Authority, Central Norway Pharmaceutical Trust, Northern Norway Regional Health Authority, Southern and Eastern Norway Regional Health Authority, Western Norway Regional Health Authority, National Centre for eHealth Research, Industrial Development Corporation of Norway)<br>• Voluntary organisations (e.g. Frivillighet Norge, European Network of National Civil Society Associations, Aurora, Barnekreftforeningen, Blå Kors Norge, Internasjonal helse- og sosialgruppe, Kreftforeningen, Nasjonalforeningen for folkehelsen, Mat&Atferd, Norsk Helse- og Avholdsforbund)<br>• Research Council of Norway and Innovation Norway | |

### 6.1.7. Priority mission area 7: Make Norway's (largest) cities climate neutral

| Key challenges that the mission aims to address[68] | |
|---|---|
| • Reducing greenhouse gas (GHG) emissions through urban planning and housing development;<br>• Improving urban environments;<br>• Counteracting the negative effects of climate change;<br>• Improving land use and energy efficiency in buildings;<br>• Improving consumption and waste practices; and<br>• Improving adaptation to climate change. | |
| **Exemplar targeted focus areas** | |
| • Further reduce (X% reduction in) greenhouse gas emissions in key sectors across Norway's (largest) cities, aimed at ultimately achieving carbon neutrality; and<br>• Implement sustainable, greener, resource-efficient and inclusive measures (for example, in relation to land use and transport, energy use in the built environment, consumption and waste, and adaptation to climate change). | |
| **Links to RCN Strategic Areas** | **Links to UN SDGs** |
| • Green transition (primary link)<br>• Cohesion and globalisation<br>• Technology and digitalisation | • SDG 7: Affordable and Clean energy<br>• SDG 11: Sustainable Cities and Communities<br>• SDG 13: Climate Action |
| **Links to clusters of Horizon Europe's Global Challenges Pillar II** | **Links to EU mission areas identified in Horizon Europe** |
| • Climate, Energy and Mobility | • A Climate Resilient Europe – Prepare Europe for Climate Disruptions and Accelerate the Transformation to a Climate Resilient and Just Europe by 2030<br>• 100 Climate-Neutral Cities by 2030 – By and for the Citizens |
| **Intersection with other priority mission(s) identified in this study** | |
| • Accelerate the transition to a sustainable and circular economy in Norway<br>• Significantly reduce Norway's transport-related emissions<br>• Play a leading role in Norway and internationally to substantially increase the use of renewable energy in a sustainable and long-lasting manner and accelerate R&I in this area<br>• Contribute to Norway's digital transformation by creating a diverse, digitally and soft-skilled workforce<br>• Actively enable digital transformation at all levels of government in Norway | |
| **Involvement of key stakeholders** | |
| • Sectors (e.g. energy, transport, food, environment, technology, building, construction, hospitality, retail)<br>• Norwegian national agencies (e.g. Ministry of Trade, Industry and Fisheries, Ministry of Transport, Ministry of Climate and Environment, Ministry of Petroleum and Energy, Ministry of Finance, Ministry of Local Government and Modernisation, Waste Norway, Bane Nor, Norwegian Climate and Pollution Agency, Norwegian Association of Local and Regional Authorities, Industrial Development Corporation of Norway)<br>• International organisations (e.g. United Nations Environmental Assembly, World Bank, OECD, European Commission, World Economic Forum)<br>• Voluntary organisations (e.g. Frivillighet Norge, European Network of National Civil Society Associations, Miljøagentene, Norges Naturvernforbund, Norsk Friluftsliv, Natur og Ungdom)<br>• The Research Council of Norway and Innovation Norway | |

[68] Although the focus of this mission is on factors related to the green transition (and incorporates aspects of technology and digitalisation and cohesion and globalisation), the mission could be designed and implemented in such a way that it would also encompass key issues related to the urban–rural divide and to connectivity and cohesion among Norway's (largest) cities and rural areas.

### 6.1.8. Priority mission area 8: Significantly reduce Norway's transport-related emissions

| Key challenges that the mission aims to address | |
|---|---|
| • Establishing low-emissions pathways in the transport sector, including in fisheries and machinery, passenger cars and aviation;<br>• Sustainably meeting Norwegian transport demand;<br>• Fully phasing in biogas, hydrogas and electric vehicles;<br>• Reducing traffic congestion;<br>• Increasing Norway's share of worldwide light vehicles; and<br>• Introducing innovative mobility solutions. | |
| **Exemplar targeted focus areas** | |
| • Considerably reduce (X% reduction in) greenhouse gas emissions from the entire transport sector in Norway (including terrestrial and maritime transport) and make it fully sustainable;<br>• Promote and invest in R&I activities to develop and adopt climate-friendly technologies, innovations and infrastructure at scale across all segments of the transport value chain (e.g. including but not limited to making shipping and maritime passenger transport greener); and<br>• Play a leading role in developing collaborations, improving education, understanding behavioural patterns, raising awareness and enhancing capacity-building measures related to climate change mitigation, adaptation and impact reduction. | |
| **Links to RCN Strategic Areas** | **Links to UN SDGs** |
| • Green transition (primary link)<br>• Technology and digitalisation<br>• Oceans | • SDG 7: Affordable and Clean energy<br>• SDG 9: Industry, Innovation and Infrastructure<br>• SDG 13: Climate Action |
| **Links to clusters of Horizon Europe's Global Challenges pillar** | **Links to EU mission areas identified in Horizon Europe** |
| • Climate, Energy and Mobility<br>• Food, Bioeconomy, Natural Resources, Agriculture and Environment | • Prepare Europe for Climate Disruptions and Accelerate the Transformation to a Climate Resilient and Just Europe by 2030<br>• 100 Climate-Neutral Cities by 2030 – By and for the Citizens |
| **Intersection with other priority mission(s) identified in this study** | |
| • Make Norway's (largest) cities climate neutral<br>• Enhance Norway's world-leading capabilities and expertise in future maritime technologies<br>• Play a leading role in Norway and internationally to substantially increase the use of renewable energy in a sustainable and long-lasting manner and accelerate R&I in this area<br>• Contribute to Norway's digital transformation by creating a diverse, digitally and soft-skilled workforce<br>• Actively enable digital transformation at all levels of government in Norway | |
| **Involvement of key stakeholders** | |
| • Sectors (e.g. energy, transport, logistics, food, environment, technology, building, construction, hospitality, retail)<br>• Norwegian national and regional agencies (e.g. Norwegian regional authorities, Norwegian Ministry of Climate and Environment, Norwegian Ministry of Finance, Ministry of Petroleum and Energy, Norwegian Climate and Pollution Agency, Ministry of Local Government and Modernisation, Ministry of Transport Norwegian Ministry of Health and Care Services, Railway Directorate, Industrial Development Corporation of Norway)<br>• International organisations (e.g. United Nations Environmental Assembly, World Bank, OECD (e.g. International Transport Forum), European Commission, World Economic Forum)<br>• Voluntary organisations (e.g. Frivillighet Norge, European Network of National Civil Society Associations, Miljøagentene, Norges Naturvernforbund, Norsk Friluftsliv, Natur og Ungdom)<br>• The Research Council of Norway and Innovation Norway | |

### 6.1.9. Priority mission area 9: Actively contribute to healthy, safe and sustainable food systems

| Key challenges that the mission aims to address |
|---|
| • Improving ecological farming;<br>• Improving sustainable food movements;<br>• Increasing the number of innovative solutions (e.g. local food systems, producer cooperatives, calculators of food footprints);<br>• Improving the sustainability of fish farming;<br>• Improving knowledge among consumers and the food retail sectors;<br>• Improving the safeguarding of water, soil and air quality, while minimising greenhouse gas emissions; and<br>• Reducing food loss and waste. |
| **Exemplar targeted focus areas** |
| • Increase sustainable, climate-resilient food production – nationally and globally;<br>• Increase access to safe and healthy food while reducing food waste and loss<br>• Ensure that food production systems can provide food to improve quality of life and health;<br>• Stimulate innovations/technology development and adoption to accelerate the transformation of food systems (e.g. in relation to improving productivity, supply chain efficiency and transparency);<br>• Actively position Norway as an international thought and knowledge leader with regard to effective food systems governance; and<br>• Promote international cooperation (e.g. in relation to R&D, agricultural practices) between stakeholders to stimulate the creation of economically, socially and environmentally sustainable food systems. |

| Links to RCN Strategic Areas | • Links to UN SDGs |
|---|---|
| • Green transition (primary link)<br>• Health and welfare<br>• Technology and digitalisation | • SDG 2: Zero Hunger<br>• SDG 3: Good Health and Well-being<br>• SDG 6: Clean Water and Sanitation<br>• SDG 12: Responsible Consumption and Production<br>• SDG 13: Climate Action |
| **Links to clusters of Horizon Europe's Global Challenges pillar** | **Links to EU mission areas identified in Horizon Europe** |
| • Health<br>• Food, Bioeconomy, Natural Resources, Agriculture and Environment | • Caring for Soil Is Caring for Life |

| Intersection with other priority mission(s) identified in this study |
|---|
| • Actively address the impacts of non-communicable diseases in Norway<br>• Protect, value and restore Norwegian biodiversity and reduce its degradation and loss<br>• Play a leading role in tackling antimicrobial resistance (in Norway and globally) and actively share expertise<br>• Contribute to Norway's digital transformation by creating a diverse, digitally and soft-skilled workforce<br>• Actively enable digital transformation at all levels of government in Norway |
| **Involvement of key stakeholders** |
| • Sectors (e.g. retailers, farmers, fish farming, seafood, health, environment, public, leisure)<br>• Norwegian higher education institutions and research organisations<br>• International organisations (e.g. Food and Agricultural Organization of the United Nations, International Fund for Agricultural Development, World Food Programme, World Health Organisation, OECD)<br>• National government agencies (Norwegian Farmer's Union, Ministry of Agriculture and Food, Norwegian Food Safety Authority, Ministry of Climate and Environment, Ministry of Foreign Affairs, Ministry of Justice and Public Security, Industrial Development Corporation of Norway)<br>• Voluntary organisations (e.g. Frivillighet Norge, European Network of National Civil Society Associations, Miljøagentene, Norges Naturvernforbund, Norsk Friluftsliv, Natur og Ungdom)<br>• The Research Council of Norway and Innovation Norway |

### 6.1.10. Priority mission area 10: Ensure decent work for all people in Norway

| Key challenges that the mission aims to address | |
|---|---|
| • Increasing youth employment;<br>• Improving integration of immigrants into the labour market;<br>• Improving aspects of work, such as quality of work, working conditions, job satisfaction;<br>• Improving equal access to the employment market; and<br>• Improving productive employment. | |
| **Exemplar targeted focus areas** | |
| • Promote and accelerate inclusive, diverse and decent work for all people in Norway across all segments of the population (including integration of immigrants into the labour market);<br>• Increase youth employment;<br>• Improve quality of work, working conditions, job satisfaction, etc.;<br>• Ensure equal access; and<br>• Achieve productive employment for the Norwegian workforce that can adapt to digitalisation/automation. | |
| **Links to RCN Strategic Areas** | **Links to UN SDGs** |
| • Cohesion and globalisation (primary link)<br>• Health and welfare<br>• Oceans<br>• Green transition<br>• Technology and digitalisation | • SDG 4: Quality Education<br>• SDG 8: Decent Work and Economic Growth |
| **Links to clusters of Horizon Europe's Global Challenges pillar** | **Links to EU mission areas identified in Horizon Europe** |
| • Culture, Creativity, and Inclusive Society | • A Climate Resilient Europe – Prepare Europe for Climate Disruptions and Accelerate the Transformation to a Climate Resilient and Just Europe by 2030 |
| **Intersection with other priority mission(s) identified in this study** | |
| • Contribute to Norway's digital transformation by creating a diverse, digitally and soft-skilled workforce | |
| **Involvement of key stakeholders** | |
| • All sectors<br>• Norwegian higher education institutions and research organisations<br>• International organisations (e.g. World Bank, International Labour Organisation, European Commission, OECD, United Nations Development Programme, International Organisation of Employers)<br>• National government agencies (Ministry of Research and Education, Ministry of Labour and Social Affairs, Norwegian Labour and Welfare Administration, Ministry of Children and Families, Industrial Development Corporation of Norway)<br>• Voluntary organisations (e.g. Frivillighet Norge, European Network of National Civil Society Associations)<br>• Research Council of Norway and Innovation Norway | |

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# Annex A. Future scenario narratives used in the study

In this annex, we present the comprehensive versions of the future scenario narratives across both scenario sets (i.e. Norway in a national context and Norway in a global context). The scenarios were used in the foresight workshops as a tool to examine and debate a set of potential priority missions and discuss ideas for wider structural measures. The narratives were shared with the workshop participants in advance of the workshops. Because of their cross-cutting nature, the cohesion and globalisation and the technology and digitalisation strategic areas (and to some extent green transition as well), were covered by both scenario sets. To aid the reader, before presenting the detailed scenario narratives, we again outline the two broad scenario sets:

- **Scenario set 1 (*Norway in a national context*):** The first scenario set, consisting of four future scenarios, broadly focuses on Norway in a national context, largely relating to the Norwegian domestic agenda. This scenario set encompasses such themes as health, welfare, education, work and skills, cohesion, and relevant aspects of technology and digitalisation, and it also covers some aspects related to green transition (for example, in relation to the circular economy).
- **Scenario set 2 (*Norway in a global context*):** The second scenario set, consisting of four future scenarios, focuses on Norway in an international or global context, primarily relating to Norway's outward-facing role. It broadly covers themes related to climate, oceans, energy, transport, food, biodiversity and globalisation, as well as relevant aspects of technology and digitalisation.

Alongside each scenario narrative, we also outline the associated key characteristics and underpinning factors of the scenarios.[69]

[69] The arrows in the scenario narratives signify as follows: An upwards-facing arrow indicates an increase in the projection/future direction of travel for the factor, a downwards-facing arrow indicates a decrease in the projection/future direction of travel for the factor, and an arrow that goes in both directions horizontally indicates that the projection/future direction of travel for the factor remains the same as the current situation.

# A.1. Future scenario narratives for the scenario set pertaining to 'Norway in a national context'

## Scenario 1: Protectionist decline

### Global developments

Shifts in geopolitical power in the 2020s led to a period of political instability over the next decade with serious implications for global trade. Struggling to maintain supply chains, countries increasingly put pressure on locally based companies to serve their needs first. Many countries have adopted a protectionist approach, increasingly looking inwards to protect their own populations. As a result, Norway has become increasingly dependent on primary exports. Even within the EU, which initially sought to maintain a united front, there are divergent views on how to tackle current problems of climate change and stagnant economic growth.

### Health and welfare in Norway

The delivery of health and welfare in Norway has also been affected by protectionism. Unable to make proper use of collaboration and imports of medical equipment from other countries, the Norwegian government has struggled to use technology and innovation to meet the complex health needs of the Norwegian population. However, there has been increased national spending on the healthcare sector in terms of research and training, as well as frontline delivery, although medical and care services have not been linked up. Approaches to complex health needs related to an overall increase in life expectancy, population ageing and immigration are largely reactive, with limited capability in preventative strategies. Protectionism presents a significant impediment to pharma and life sciences, hindering the development of industries that thrive on collaboration and sharing.

### Societal and economic development

With the slowdown in sovereign wealth fund growth and unpredictability in global markets, Norwegian business and consumer confidence is low. At the same time, the ageing population in Norway has increased spending on social services and pensions. Norway has continued to accept some migrants from countries affected by instability or the effects of climate change, from a pragmatic perspective – to not make the current international situation worse – and to meet some of its labour shortages. However, reduced cooperation with the EU means that skilled labour is generally in short supply. Despite increased growth in some sectors, such as domestic food production, overall productivity growth and labour force participation are low and trust in public institutions is declining. Stagnant economic growth has also reduced much-needed investment in a digital infrastructure that facilitates data sharing, adequately deals with cyber and privacy protection threats, and helps increase the digital skills of the Norwegian population. There is a lack of transnational cooperation of social media, and social media continues to be used extensively to influence public debate on immigrants, spread hate speech and polarise Norwegian society.

### The location of jobs and housing and greening initiatives

With limited employment opportunities in urban areas, where the effect of increasing temperatures is also more apparent, Norwegians are dispersing across smaller cities and towns. However, this dispersal is limited by a lack of investment in public transport and digital connectivity. The decrease in urbanisation has positive impacts on health outcomes of populations, with less traffic and pollution. Recent investments have also improved access to health and welfare services across different geographical locations in Norway, although research and training still tends to be city based. There have been some successes in greening domestic energy and linking up waste and energy across the public sector, but the circular economy is not seen as the way forward by politicians or citizens.

### Research and innovation

Overall, funding in the R&I sector has reduced, and it is fragmented due to general mistrust of the government and international actors. Norwegian actors are finding it difficult to compete in the world market. These issues are further amplified by the absence of coordination and collaboration across stakeholders in the R&I system in a national and international arena, as well as limited data sharing. Furthermore, the lack of relevant competencies in the labour market required for meeting current and future demands of the sector has created longer-term challenges. In Norway, the absence of infrastructure and funding to support partnerships, combined with restrictions on data access and sharing, has prevented Norway from leveraging and capitalising on the data economy and on the digitalisation trends in the health, pharma and life sciences.

| | |
|---|---|
| Health and welfare | Demand and access to health and welfare services ↔<br>Collaboration and interdisciplinarity ↓<br>Development and adoption of telemedicine and telecare ↔ |
| Economy and society | Discrimination and hate speech ↑<br>Use of social media to spread disinformation – increasingly used with impact on the spread of misinformation<br>Trust in public administration ↓<br>Net immigration ↔<br>Natural resource wealth – slow growth or stagnation in the economy |
| Location of jobs and housing and greening initiatives | Skilled labour availability to match employment demand ↓<br>Location of jobs and housing – more dispersion with mixed transport links<br>Ability of Norway to adapt to climate change ↔<br>Circular infrastructure for energy, water and waste supply – focussed on current approaches. |
| Technology, digital skils and digital threats | Digital skills – digital divide increases ↓<br>Digital security and cyber protection – Norway is unable to respond, and threats increase, demanding increasing protection<br>Data sharing<br>Technology convergence and use of enabling technologies ↓ |
| Research and innovation | Globalisation of research and innovation and data sharing – decrease in international data sharing and collaboration<br>Funding for research and innovation – decreases |

# Scenario 2: Going green together

## Global developments

During the 2020s there was a realisation across governments, industry leaders and populations that the relationship with the planet is key and resources and time are finite. This led to efforts at the international level and activism at the local level to build a green agenda. Norway, already a leader in renewable energy and decarbonised transport, has focused on further reducing its environmental and climate impact.

## Health and welfare in Norway

Norway has undergone significant demographic changes, with a shift towards a higher number of senior citizens. This has created pressure for the healthcare system due to increased demand for services. On the other hand, there is increased access to health and welfare services as a result of policies promoting decentralisation towards municipalities and increasing digitalisation of the healthcare sector. Telehealth has become the default option, allowing for a more targeted and less resource-intensive provision of services, reducing unnecessary travel. Access to healthcare has also improved through strategies focused on reducing and preventing social inequalities in health, such as prevalence of risk factors in population sectors with lower income and education. Alongside these changes, there has been an increase in digital skills across the Norwegian population due to efforts from the government to build digital competence by adapting the education curricula and providing adequate training across all age groups and sectors. These educational programmes have also sought to develop other relevant employment skills as the economy continues to move from a consumption to a green approach.

## Societal and economic development

Norway has seen a decline in hate speech and discrimination, partly as a result of interventions, such as the increased capacity of authority to tackle these issues, especially in the online environment. Internet and smartphone use remain high in Norway. With the higher level of digital competence across all demographics and improved data security and ethics standards, social media is generally seen as a reliable source, used to facilitate a range of peer-to-peer activities and communications, from grassroots to government. Pockets of misinformation remain, however, and attract a vocal minority. Data security standards have also created tensions given the overregulation perceived by the Norwegian population.

## The location of jobs and housing and greening initiatives

The success of Norway's approach is reflected in the level of trust in Norway's public administration, which continues to grow. This has been important in fostering green transition initiatives through the interconnection between citizens, local governments and local businesses. Cross-sectoral cooperation and cooperation across different governance levels have promoted a circular economy at national, regional and local levels. The Government Pension Fund of Norway has managed to adequately manage climate risks by investing in climate change policy and new technology. This is particularly the case within regions with higher population density, such as cities, where the adaptation of the built environment has been an important priority for the green transition, and green initiatives, such as urban farming and 'green builds' that are fully carbon neutral, have become more widespread. Additionally, citizens have a more prominent role in the green transition through higher levels of engagement in innovation and green entrepreneurship, as well as through local activism. There are, however, challenges in fostering behavioural change; older generations show more reluctance to adapting to new social norms, while younger generations feel they are being asked to pay too much of the price for climate change.

## Research and innovation

Open science and increased data sharing have made research more accessible to citizens and policy makers, which has been particularly beneficial in supporting evidence-based policy for the green transition. Increased data availability has also allowed researchers to better evaluate the effectiveness and acceptability of initiatives, and to determine how Norway can best leverage and adapt to these. Aligned with the focus on cybersecurity in the EU Framework Programme, Norway has made a key priority to embed data protection and information security in its information and communications technology policy strategy, which has allowed for a better response to digital and cyber security threats, which have now decreased. Additionally, the green transition has led to a redistribution of jobs, away from jobs in a fossil-fuelled industry towards jobs in a green economy.


| | |
|---|---|
| Health and welfare | Demand and access to health and welfare services ↑ |
| | Collaboration and interdisciplinarity ↑ |
| | Development and adoption of telemedicine and telecare ↑ |
| Economy and society | Discrimination and hate speech ↓ |
| | Use of social media to spread disinformation – increasingly used, but little impact on the spread of disinformation |
| | Trust in public administration ↑ |
| | Net immigration ↓ |
| | Natural resource wealth – steady growth in the economy, greater share of wealth from sustainable sources |
| Location of jobs and housing and greening initiatives | Skilled labour availability to match employment demand ↑ |
| | Location of jobs and housing – located in big cities and transport-friendly locations |
| | Ability of Norway to adapt to climate change ↑ |
| | Circular infrastructure for energy, water and waste supply – develop rapidly and are implemented at national, regional and local levels |
| Technology, digital skills and digital threats | Digital skills – decrease, digital divide increases |
| | Digital security and cyber protection – Norway is better able to respond, decreasing threats |
| | Data sharing ↑ |
| | Technology convergence and use of enabling technologies ↑ |
| Research and innovation | Globalisation of research and innovation and data sharing – increasing international data sharing and collaboration (open and distributed) |
| | Funding for research and innovation – sufficient and continuous |

# Scenario 3: Slowly changing society

## Global developments

The mid- to late 2020s saw a return to business as usual for most of the world and Norway. Strategic alliances have largely remained the same, and there is a slow but steady drift of economic power and influence away from Western powers. Although there have been periods of strong support for environmental activism, particularly in Europe, this has not been sustained, and internationally there has not been a real impetus for change. There has been some progress towards reducing emissions, but without a clear vision at the international level, this progress has not been sufficient, and the impacts of climate warming are starting to be felt.

## Health and welfare in Norway

Trends towards technological innovation and digitalisation in the healthcare system in Norway have continued, and there are areas of Norway where there is strong technological innovation. However, these are not widely rolled out across different regions in Norway, and there are challenges with collaboration between the private and public sectors. Some private initiatives exist in the healthcare sector, but the Norwegian system continues to rely heavily on public funds, and measures to improve care coordination have been only partly successful. The healthcare workforce has been only partly able to meet the growing health and long-term care needs that have resulted from Norway's ageing population, increased immigration, and the effects of climate change. There is also a reluctance to address the underlying issues of social inequalities in life expectancy, disparities among income groups, and behavioural risk factors.

## Societal and economic development

Regional conflicts and climate change have created increased pressure on immigration globally, but Norway has always had strong measures in place to ensure education and employment for migrants. Despite this, tensions still exist, particularly with regard to cultural integration. With only incremental changes in the make-up of the Norwegian welfare provision and labour markets, trust in public institutions remains relatively high, but there is concern about Norway's strategy for ensuring it has the necessary digital and employment skills to deal with changes in the national and global landscape. Although there is good digital provision in Norway, lack of appropriate regulation of the digital space means that social media continues to be a source of misinformation, feeding potential social divisions.

## The location of jobs and housing and greening initiatives

There has been an increasing concentration of the Norwegian population in urban areas, as a thicker labour market in the cities has been better able to meet the demand of workers with specific qualifications. At the same time, commercial activity has opened up in the Arctic following the lack of impetus to deal with climate change internationally, which has accelerated the melting of the sea ice in the Arctic. This has accelerated economic growth in counties in northern Norway, but challenges persist with ensuring that there is access to labour with the necessary skills and expertise to make use of an improved knowledge base and value creation in the North. Regional development initiatives also remain weakly connected and do not really support the Sami community and their employment and business opportunities. Because Norwegians are concentrated in cities, it has been easy to join together energy and waste initiatives across hospitals and public sector buildings. This has also facilitated the creation of city-led initiatives, but their wider take-up has not been incentivised. Many Norwegians feel that they are already playing their part with renewable energy and electric vehicle use. Although people have greater access to services in urban areas, the concentration of people in cities also means that there are increased pressures of mass marketing, availability of unhealthy food choices and access to transport, which all have an effect on lifestyles and negative health outcomes.

## Research and innovation

National and international collaboration for R&I continues to increase, but researchers continue to voice concerns about data sharing, and funding for interdisciplinary research is limited. The lack of collaboration between industry and the higher education sectors also poses key challenges for Norway. The skills that Norwegians obtain through higher education are not fully aligned with the skills needed in the labour market, particularly as new areas of innovation open up and automation, the application of artificial intelligence and broader technology convergence start to change the nature of employment. There is a fragmented funding landscape that is largely focused on excellent science, while the translation into innovation outputs is limited. In health, Norway concentrates health R&D in university research, and there is weak coordination between the different key actors in the R&D health system, which has had resulted in a lack of cost-effectiveness in the development of pharmaceuticals in Norway.

| | |
|---|---|
| Health and welfare | Demand and access to health and welfare services ↔ |
| | Collaboration and interdisciplinarity ↔ |
| | Development and adoption of telemedicine and telecare ↔ |
| Economy and society | Discrimination and hate speech ↔ |
| | Use of social media to spread disinformation – increasingly used, with impact on the spread of disinformation |
| | Trust in public administration ↔ |
| | Net immigration ↔ |
| | Natural resource wealth – steady growth in the economy, no change in share of wealth from sustainable sources |
| Location of jobs and housing and greening initiatives | Skilled labour availability to match employment demand ↔ |
| | Location of jobs and housing – located in big cities and transport-friendly locations |
| | Ability of Norway to adapt to climate change ↔ |
| | Circular infrastructure for energy, water and waste supply – rapid development, but implementation localised |
| Technology, digital skills and digital threats | Digital skills – remains as now |
| | Digital security and cyber protection – Norway is unable to respond, demanding increased protection |
| | Data sharing ↑ |
| | Technology convergence and use of enabling technologies ↔ |
| Research and innovation | Globalisation of research and innovation and data sharing – increase in international data sharing and collaboration |
| | Funding for research and innovation – fragmentation |

# Scenario 4: Technological trajectory

## Global developments

In line with the prevailing international view, Norway has focused on technological advances to promote economic growth and support its sustainability goals. Technology and the knowledge-based economy have been the main tenets of the Norwegian R&I agenda, from both an international and a domestic perspective, with new technologies and their convergence having brought about significant advances in health and welfare. However, changes in employment have created new social inequalities.

## Health and welfare in Norway

Many digital solutions have been integrated into health and welfare services, which has helped to address the continued demand and pressure for these services. Automation and artificial intelligence are commonplace in healthcare, and telehealth has become the default option for health and welfare. Digital technology, such as robotics, is used to help support the autonomy of older people. Thanks to its comprehensive health databases and its ability to exploit large amounts of patient data, Norway was able to rapidly digitalise the health sector. In addition, health data; an improved focus on funding; and developments in and convergence of bioinformatics, genetic engineering, biotechnology and nanotechnology have enabled Norway to move towards personalised medicine, which has made great strides since the 2020s. Overall, this has led to a more patient-centred health system. However, there are concerns that the health system is becoming 'twin-track', because users have to be digitally competent and willing to share personal data to access it and because some advanced treatments are only available privately.

## Societal and economic developments

Although a substantial part of the Norwegian population now has access to Internet and service industries, such as banking, finance and tourism, have achieved efficiency gains and improved their business processes, some people are being left behind in terms of their digital skills even though the economy is doing well. Technology convergence and development has been led by Norwegian industry, and central and local government and other public sectors have not fully integrated common systems for user-friendly digital services. There is acceptance from the public that data generally has to be shared to access services and participate in society, and the Norwegian population continues to have a relatively stable level of trust in its public institutions. However, trust in government has, at the same time, not increased, and the perceived lack of control around data privacy and security issues threatens to reduce it further. The application of advanced technologies has contributed to efficiencies in transport, health, agriculture and food, and manufacturing industries, at the same time transforming employment in these industries. Norway has actively addressed these changing employment needs through education and training policies. Although overall immigration to Norway has remained stable, there has been a shift in the type of immigrant, to higher-skilled, wealthier immigrants. However, the need for some low-skilled labour remains, and political tensions around the role of immigrants in the Norwegian economy and society persist.

## The location of jobs and housing and greening initiatives

Remote working has been the norm since the 2020s. Investment in digital infrastructure has continued, and many Norwegians have moved out of urban centres to smaller cities and towns, where the impacts of climate change are currently more supportable. The Internet and social media are key elements of this lifestyle, with vast amounts of data changing hands and control of platforms still in the hands of Big Tech companies that actively resist regulation. Norway is not alone in struggling to police misinformation, and it has invested heavily with partners in cyber security prevention.

## Research and innovation

The increased use of artificial intelligence, big data and genomics in Norwegian society has been associated with a steadily rising demand for data and data sharing both nationally and internationally. Norway has been able to widely deploy technologies across sectors due to increasing collaboration and funding for collaboration across sectors. However, R&I initiatives for developments in technology tend to be geared towards developments in the natural sciences. There is a lack of recognition of the human, ethical and legal challenges that emerge with increased data sharing and resulting privacy and cyber security threats, which contributes to a growing distrust of pervasive technology in Norway.

**Health and welfare**
- Demand and access to health and welfare services
- Collaboration and interdisciplinarity
- Development and adoption of telemedicine and telecare

**Economy and society**
- Discrimination and hate speech
- Use of social media to spread disinformation – increasingly used, with impact on the spread of disinformation
- Trust in public administration
- Net immigration
- Natural resource wealth – steady growth in the economy, no change in share of wealth from sustainable sources

**Location of jobs and housing and greening initiatives**
- Skilled labour availability to match employment demand
- Location of jobs and housing – more disperse with mixed transport links
- Ability of Norway to adapt to climate change
- Circular infrastructure for energy, water and waste supply – rapid development, but implementation localised

**Technology, digital skills and digital threats**
- Digital divide increases
- Digital security and cyber protection – Norway is better able to respond, decreasing digital and cyber security threats
- Data sharing
- Technology convergence and use of enabling technologies

**Research and innovation**
- Globalisation of research and innovation and data sharing – increase in international data sharing and collaboration
- Funding for research and innovation – sufficient and continuous

# A.2. Future scenario narratives for the scenario set pertaining to 'Norway in a global context'

## Scenario 1: Protectionist decline

### Global landscape

Shifts in geopolitical power that came to the fore in the 2020s led to a period of political instability over the next decade, with serious implications for global trade. Struggling to maintain supply chains, countries increasingly put pressure on locally based companies to serve their needs first. By 2040, this has led to mistrust even among former close allies. Many countries have adopted a protectionist approach, increasingly looking inwards to protect their own populations. Even within the EU, which initially sought to maintain a united front, member states have divergent views on how to tackle current problems of climate change and stagnant economic growth. At the international level, cooperation on climate goals has plummeted and targets agreed at the last United Nations Climate Change Conference, five years ago, look increasingly unattainable. The negative impacts of climate change have been limited only by the poorly performing global economy.

### Trade and availability of skilled labour

The uncertainty in global trade has seen countries re-shore food production and manufacturing. In Norway, as elsewhere, there has been investment in automation and additive manufacturing to support this move. Although there has been an increase in immigration from countries affected by instability or climate effects, reduced cooperation with the EU means that skilled labour is in short supply. Norway remains a trusted partner for energy, but export demand for the industry has fallen, and some countries have chosen to invest in home-grown renewable energy to secure their supply. Demand for Norwegian seafood products and shipping in global markets is also down, and Norway's imports of manufactured items have also declined.

### Circular initiatives

Despite Norway's success in greening its domestic energy and transport sectors, successive governments have found it increasingly difficult to encourage further behavioural change through circular economy initiatives when consumption is down and many in the population are worrying about how to pay their bills. Stagnant economic growth has meant that much-needed investment in digital infrastructure has also stalled. Compounding this, the levels of public trust in science and technology are at an all-time low, and a few high-profile cyber-attacks have dominated the headlines.

### Research and innovation

Research and innovation in Norway has been affected by reduced funding and the loss of some external collaborators, as mistrust also pervades this sector; long-term investment in research loses out to short-term policy needs as both governments and industry tighten their belts. Most funding now comes from national bodies and aims at least to facilitate collaboration between public and private sectors domestically. Opportunities are seen to develop the ocean and onshore environments for food and energy production. There is also an ambition to develop new applications using skills and innovations from the petroleum sector that could boost the economy.

| | |
|---|---|
| Green transition | Demand and support for circular initiatives ↓ |
| | Circular infrastructure for energy, water and waste supply – remains focussed on current approaches |
| | Investments/innovations to reduce emissions from oil ↓ |
| | Ability of Norway to adapt to climate change ↓ |
| | Food security and supply – Norway maintains security of food supply with higher share of domestic production |
| | Low-carbon business models (international) – no change in emergence |
| Oceans | Sustainable aquaculture – little expansion in the aquaculture sector |
| | Norwegian shipping industry – greening of international shipping industry remains as now |
| Globalisation and society | Norway's trade linkages with other countries ↓ |
| | Norwegian cooperation with EU/EEA ↓ |
| | Natural resource wealth – slow growth or stagnation |
| | Make up of geopolitical landscape – the geopolitical landscape becomes less stable with a shift in global power |
| | Skilled labour availability (to match employment demand) ↓ |
| | Teechnology convergence and the use of enabling technologies ↓ |
| Research and innovation | Globalisation of research and innovation and data sharing – decrease in international data sharing and collaboration |
| | Funding for research and innovation – decreases |

# Scenario 2: Global greening

## Global developments

During the 2020s, there was a further realisation across governments, industry leaders and populations that their relationship with the planet is key and resources and time are finite. This led to efforts at the international level and activism at the local level to build a green agenda. The EU sees the benefits not only of greater internal cooperation, but also of building external relations and leading by example. Relations between major powers have improved as these countries see value in pursuing a 'green economy' approach, focusing on innovative solutions for all sectors, rather than securing ownership of rapidly depleting resources. Regions like Africa and South America are now recognised for their valuable resources, but regional disparities still remain. The impacts of climate change are happening at a slower rate, but the longer-term focus is on adaptation, as the current trajectory, tracking close to a 2°C increase, looks hard to maintain.

## Circular economy

The top-down approach means that low-carbon business models have developed across many sectors where there are international trade sectors, and this is matched by a demand within Norway, in Europe, and internationally for products and services that have a low impact on the environment and climate. A circular economy approach has been central to this. Some change has been industry led, some has been driven by international agreements and legislation; Norway has worked hard within supra-national institutions to further this agenda and support regional change through overseas aid. But changing consumer attitudes has also been key, and top-down approaches are balanced against initiatives driven by communities and government at the local level, where quality of life is displacing consumption as a measure of success and there is a focus on local production and consumption. Yet tensions persist among different stakeholder groups, with some advocating a more relaxed approach to the environment given the gains made in recent years.

## Renewable energy

There has been a rapid move away from fossil fuel dependence to electricity from renewables, linked to expanding regional grids. The Government Pension Fund of Norway has managed to adequately manage climate risks by investing in climate change policy and new technology. International travel and transport of goods have not returned to levels seen in the 2010s. Norway has invested heavily in offshore renewables and is a key proponent of greener and smarter shipping – one area where hydrogen has taken off.

## Circular initiatives and technology in Norway

In Norway, circular initiatives have been introduced in relation to key sectors of energy, waste and water by the government, but there is also a supportive environment for local solutions, resulting in a boom in green entrepreneurship that enjoys easy access to European markets. Technology and data are seen as key to sustainable solutions, from food to retail, with many of these starting at a small scale, seizing supply chain opportunities offered by a move to low-carbon business models by bigger companies at the national and international level and the public sector. However, technology is seen as the means and not the end. Norway has also seen its aquaculture exports expand, although for fresh products these have focused on EU markets, and the domestic share of food production has also increased.

## Research and innovation

There has been investment in research, which is seen as key to a green future, both within the EU and in Norway. This has been accompanied by greater collaboration between these partners and internationally. To facilitate openness in research and innovation, the EU has also worked together with industry and national governments to develop protocols for data sharing, improved data security and authentication. While there has been action to re-align education and training to better match skills to the changing employment opportunities in Norway, these systems are still seen as being slow to respond. Collaborative research in social sciences has also been important to maintain momentum towards climate goals and global stability, keeping citizens educated and engaged.


**Green transition**

- Demand and support for circular initiatives ↑
- Circular infrastructure for energy, water and waste supply – develop rapidly and implement at national, regional and national levels
- Investments/innovations to reduce emissions from oil ↓
- Ability of Norway to adapt to climate change ↑
- Food security and supply – Norway maintains security of food supply with higher share of domestic production
- Low-carbon business models (international) – rapid emergence

**Oceans**

- Sustainable aquaculture – expanded aquaculture sector with expanded share of sustainable farming
- Norwegian shipping industry – greening of international shipping industry is extensive

**Globalisation and society**

- Norway's trade linkages with other countries ↑
- Norwegian cooperation with EU/EEA ↑
- Natural resource wealth – steady growth, with greater share from sustainable sources
- Make-up of geopolitical landscape – more stable, with greater cooperation and stability in Norway's partner countries
- Skilled labour availability (to match employment demand) ↑
- Technology convergence and the use of enabling technologies ↑

**Research and innovation**

- Globalisation of research and innovation and data sharing – increase in international data sharing and collaboration (open and distributed)
- Funding for research and innovation – sufficient and continuous

# Scenario 3: Slowly shifting power

## Global developments

The mid- to late 2020s saw a return to business much as usual for most of the world. Although Britain's exit from the European Union did result in a small shift in trading patterns, strategic alliances have largely remained unchanged, and the slow but steady drift of economic power and influence away from Western powers has continued. Regional conflicts rumble on, but wider geopolitical tensions, for a while the focus of global attention, have now largely eased. The intervening years have seen the usual rounds of climate and trade summits, but existing supra-national structures are losing their relevance. Although there have been periods of strong support for environmental activism, particularly in Europe, this had not been sustained, and internationally, it has not led to impetus for real change. There has been some steady progress towards reducing carbon emissions, but, as foreseen, without a clear vision at the international level, this has not been sufficient, and the impacts of climate warming are starting to be felt.

## Economic trends

Economic trends towards increasing supply chain efficiencies through automation, artificial intelligence, and distributed ledger technologies have continued, as have efforts to decarbonise the transport and energy sectors. Electric cars are now increasingly widespread, but there is a lack of consensus on greening international shipping and aviation. Progress in other sectors, which depend on commercial incentives for citizens and businesses, is more limited. The circular economy is still seen as a key solution by the EU, but it has not gained much traction across member states, especially when other problems seem more pressing.

## Oceans

The ocean has become an important focus for the Norwegian economy. There is continued demand for sustainable gas from Norway's key partners as they transition towards net-zero, and Norway has expanded its ocean-bed carbon storage capability to decarbonise its gas exports. Other offshore technologies, such as solar panels and wave energy convertors, are being explored to supplement its hydropower and offshore wind farms. As a knowledge leader in the oceans sector, Norway has exported these solutions, often as part of its efforts to support developing countries. At the same time, Norway has seen increased demand for seafood, leading to an expansion in that sector. However, by 2040, the ability of the ocean to sustain all this activity is not clear. The impacts of climate change are particularly felt in the High North, and these changes have accelerated changes in Arctic ecosystems and the loss of sustainable habitats for Arctic species. Norway is increasingly looking to Europe and the Nordics for collaboration to solve some of these challenges. The rapid melting of the sea ice in the Arctic in recent years has reduced some of the natural ice borders between countries, creating a renewed focus on opportunities for commercial activity in the region but also tensions with other nations.

## The circular economy in Norway

Norway has opted for a government-led approach to the circular economy, mainly focusing on its energy and waste sectors as areas where these approaches could be the most beneficial. Local initiatives aimed at reducing consumption through reuse, repairing and recycling are encouraged but currently not incentivised, and many Norwegians feel that by leading on renewable energy and electric vehicle use, they are already playing their part. Green shipping is one area where Norway is leading the way again, having introduced electric batteries and carbon capture technologies into its domestic fleet.

## Research and innovation

Funding for research and development has remained fragmented both within Norway and externally. Norway has continued to co-operate closely with its EU/EEA partners. Substantial funding has been available in some areas, but the closed nature of collaboration between institutions and the lack of focus on monitoring and data sharing have meant that resources have not been targeted appropriately; there has been a lack of investment in interdisciplinary collaboration; and challenges remain with the translation of excellent science into innovations. Norwegian efforts in technology convergence have remained broad, covering energy, electronics and optics, the environment, and health. But because much research is still undertaken by the private sector and because the humanities, social science and legal perspectives on technology have not been systematically addressed, this has so far not led to the expected transformational change.

**Green transition**

- Demand and support for circular initiatives ↓
- Circular infrastructure for energy, water and waste supply – focussed on current approaches to water/energy/waste
- Investments/innovations to reduce emissions from oil ↔
- Ability of Norway to adapt to climate change ↓
- Food security and supply – maintains food supply with same share of production as now
- Low-carbon business models (international) – no change in emergence

**Oceans**

- Sustainable aquaculture – expanded aquaculture sector, with expanded share of sustainable farming
- Norwegian shipping industry – greening of international shipping industry remains as now

**Globalisation and society**

- Norway's trade linkages with other countries ↔
- Norwegian cooperation with EU/EEA ↔
- Natural resource wealth – steady growth, but no change in share from sustainable sources
- Make-up of geopolitical landscape – no change in the stability of the geopolitical landscape
- Skilled labour availability (to match employment demand) ↔
- Technology convergence and the use of enabling technologies ↔

**Research and innovation**

- Globalisation of research and innovation and data sharing – increase in international data sharing and collaboration (closed) ↑
- Funding for research and innovation – fragmentation

# Scenario 4: Technological trajectory

## Global developments

After some turbulence at the start of the 2020s, the focus has been on revitalising the global economy, which is seen as a key driver for reducing global inequalities and achieving inter-regional stability. As economic and geopolitical power has continued to shift towards the BRIC (Brazil, Russia, India and China) countries, Western democracies have looked to establish new regional relationships that have opened up opportunities for Norway for trade, investment and R&I collaboration. Norway has continued to play an active role in international institutions, but the prevailing international view has been that climate change goals can be achieved through digitalisation and technological advances. Consumption is still regarded as an important driver of economic growth, and the green agenda has somewhat taken a back seat. This is reflected in the current pace of environmental change, with the result that by 2040, there is a growing clamour for more action

## The use of technology

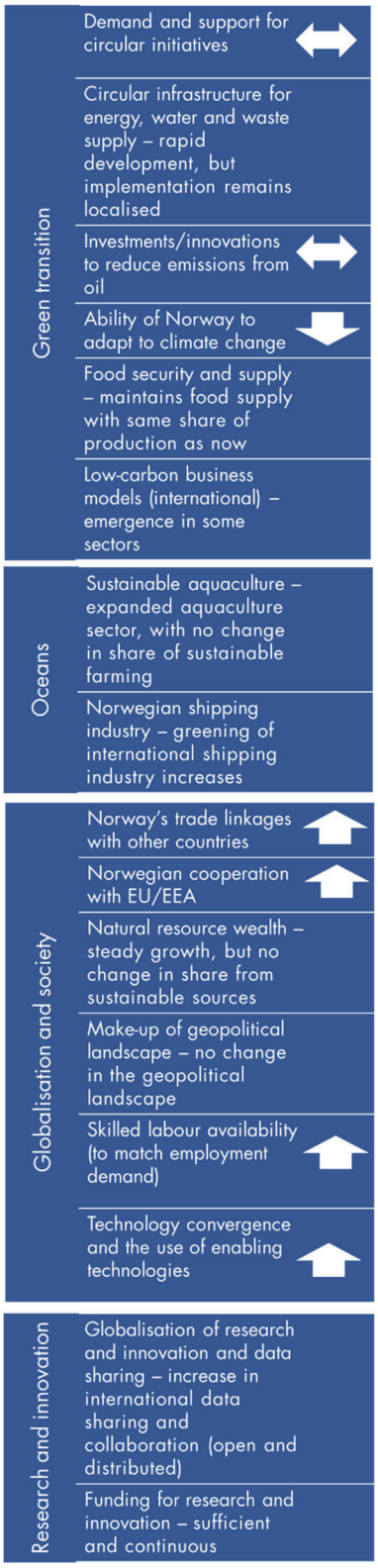
Technology has played a key in role in recent economic growth, impacting on many areas of daily life as using the Internet for entertainment, socialising shopping, working, accessing services and education has become the norm. Automation and AI are commonplace across a range of sectors, and technology convergence has led to a re-alignment in the transport, health, agriculture, food and manufacturing industries, resulting in new players and new business models. Although the perception is that power remains in the hands of a few, rapid regional expansions have created new firms. Technology has contributed to reducing carbon emissions, from large-scale carbon capture and storage and green hydrogen generation, to small-scale urban farming. Innovative technological solutions have also been implemented to both reduce and remove marine biowaste and plastics. But technology is now seen by some as a problem too in terms of resource and energy use. The past decade has also seen considerable movement of goods and people across the planet, as well as continued urbanisation. And, while changes in employment brought about by technological advances have been accommodated in some countries through forward-looking skills and education strategies, this is by no means the norm, potentially introducing new inequalities.

## The Norwegian economy

The Norwegian economy has also shown strong growth, fuelled by a continued close relationship with Europe but also by new trade links, providing technology partners and new markets for seafood products and energy solutions. Norway has invested in integrating energy and waste systems at a national level, collaborating closely with European neighbours on these and exporting this expertise. It has also continued to expand its carbon capture and storage capability, but hydrogen from sea-splitting, first trialled as part of shipping, is a potential new export. There has also been rapid growth in green initiatives in other areas that are often technology led. There is demand for sustainable solutions at the European level, but without real cross-sectoral synergies, it remains difficult for new green companies to expand outside Norway.

## Research and innovation

Technology and the knowledge-based economy have been the main tenets of the Norwegian R&I agenda both from an international and from a domestic perspective, with technology seen to underpin many sustainability objectives. To promote openness and transparency in international data sharing and collaboration, public funding from national bodies and the EU has been supplemented by the development of new relationships with universities and research institutes, including in South-east Asia and South America. This has resulted in a rapid expansion in the research base, without having to be overly dependent on a small number of foreign economies and the private sector. A key part of the agenda has also been developing a base of highly skilled workers, both through an open-door policy for overseas researchers and an agile, responsive higher education sector. But less focus has been placed on training for those who have seen their jobs displaced.



# Annex B. Set of indicative priority missions related to the RCN's five strategic areas

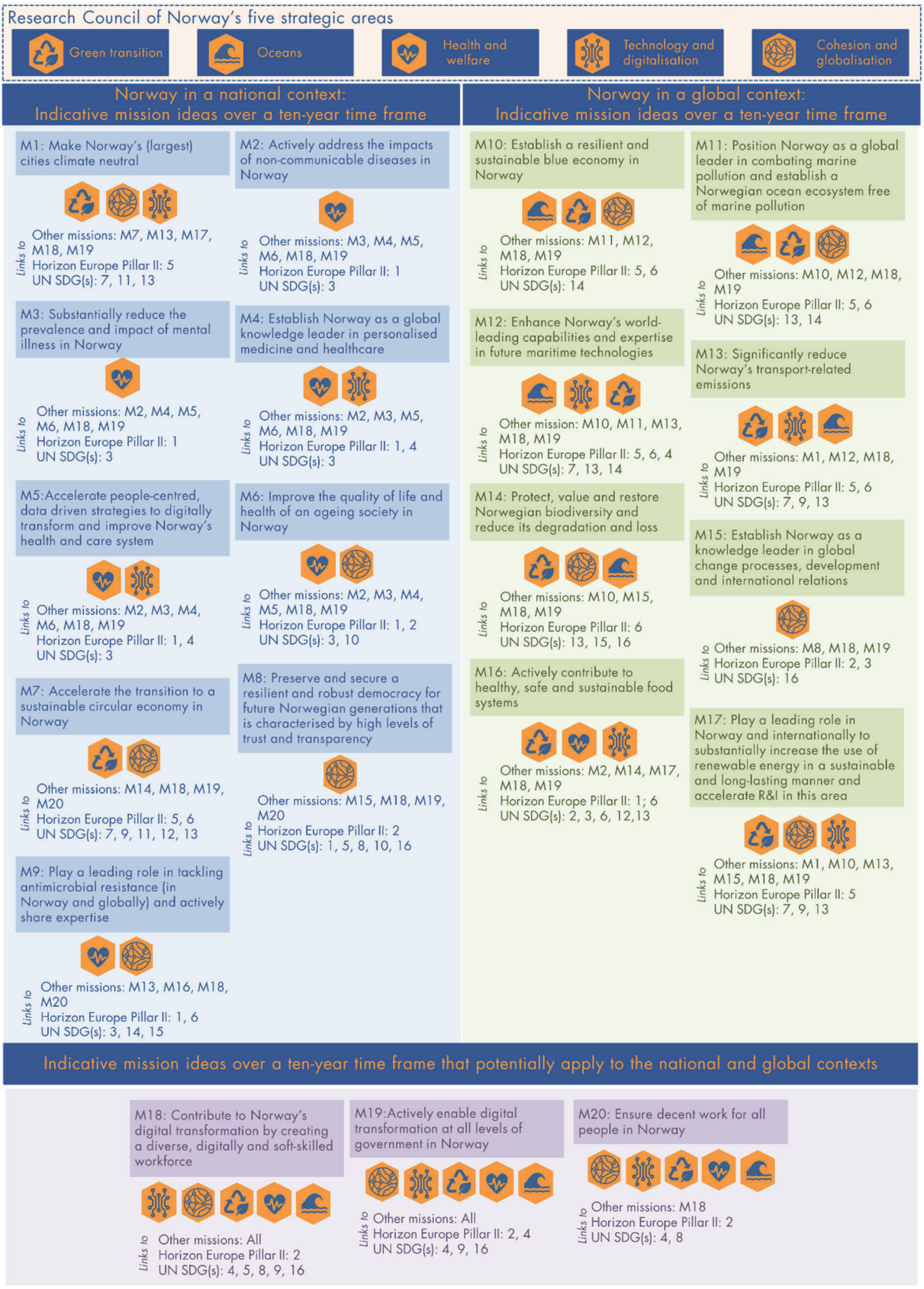
In the infographic below, we provide an overview of indicative mission ideas that have been articulated within, across and outside the RCN's five strategic areas (oceans; green transition; health and welfare; technology and digitalisation; and cohesion and globalisation).[70] The priority missions have been structured according to the two high-level scenario sets discussed in Chapter 5 and Annex A. As highlighted previously, all the missions are cross-cutting in terms of potential sectors and disciplines involved and will need a multi-stakeholder approach to be implemented. The spectrum of target focus areas for each mission will need to be specified with distinct, measurable and timebound goals that decided by the stakeholders involved in selecting and implementing the missions. Furthermore, their implementation will also require social sciences, humanities, legal and ethical perspectives to be effectively incorporated. Finally, the missions must engage the public regularly and in a meaningful manner, and also be evaluated against a set of clearly defined criteria that are set out upfront.

[70] In the infographic, we highlight the broad links between the priority missions and the United Nations Sustainable Development Goals (UN SDGs) and the clusters under Pillar II of Horizon Europe.

The UN SDGs are: SDG1: No poverty; SDG2: Zero hunger; SDG3: Good health and well-being; SDG4: Quality education; SDG5: Gender equality; SDG6: Clean water and sanitation; SDG7: Affordable and clean energy; SDG8: Decent work and economic growth; SDG9: Industry, innovation and infrastructure; SDG10: Reduced inequalities; SDG11: Sustainable cities and communities; SDG12: Responsible consumption and production; SDG13: Climate action; SDG14: Life below water; SDG15: Life on land; SDG16: Peace, justice and strong institutions; and SDG17: Partnerships for the goals.

The Horizon Europe Clusters under Pillar II includes: (1): Health; (2): Culture, Creativity and Inclusive Society; (3): Civil Security for Society; (4): Digital, Industry and Space; (5): Climate, Energy and Mobility; and (6): Food, Bioeconomy, Natural Resources, Agriculture and Environment.

**Figure B.1 Indicative priority missions proposed within and across the five strategic areas**




Source: Study team analysis