January 2024

Vision 2030

A Resilient Submarine Cable System through the Arctic equipped with Sensing

The importance and the opportunities

NORDUnet
Nordic Gateway for Research & Education

Co-funded by the European Union

COLOFON

This report, "Vision 2030: A Resilient Submarine Cable System through the Arctic equipped with Sensing – The Importance and the Opportunities," was published in January 2024 by NORDUnet.

Co-funded by the European Union

The contents of this publication is the sole responsibility of NORDUnet and does not necessarily reflect the opinion of the European Union.

Written by:

NORDUnet, CSC, SUNET, DeiC

Endorsed by:

Sikt Kunnskapssektorens tenesteleverandør, RHnet

ISBN: 978-87-990712-3-4

DOI:10.5281/zenodo.10561009

Contact Information:

info@polarconnect.net

NORDUnet A/S

Kastruplundgade 22, 1st floor

DK-2770 Kastrup

DENMARK

January 2024 v1.1

PREFACE

This report presents a vision and the results of a viability study for creating a resilient submarine cable system across the high Arctic Region towards East Asia, with possible landfalls in North America. This severely adds to the strategic digital autonomy of the European Union and its close allies. Behind the report are the Nordic National Research & Education Networks (NRENs), collaborating within NORDUnet and continuously working to facilitate research and education. It is our ambition that this vision will have been realised by 2030 or soon thereafter, hence we call this our **Vision 2030**.

Collaboration among the five Nordic countries[1] is key and has shown huge results during the past many decades. History has shown that if the Nordics collaborate and harmonise their thinking and actions, great results can and will come from this.

The Vision 2030 was created by interviewing stakeholders from industry, science and research, government, and other areas in the Nordics, the rest of Europe, North America, and Asia. The Vision 2030 is an aspirational and ambitious trajectory for Europe to significantly contribute to its Digital Strategic Autonomy and to enhance Europe's Internet connectivity with the rest of the Northern Hemisphere.

The Vision 2030 is intended to bring action but also inspiration for a series of future projects, driven by the European Union and its Member States and their allies as well as from European carriers and the like.

The authors wish to thank all people that were graciously willing to be interviewed and bring their thoughts, concerns, solutions and inspiration forward. Most of all, the authors were inspired by the numerous pieces of encouragement we received while developing the Vision 2030.

This document was created by NORDUnet and the Nordic NRENs in the context of the Northern EU Gateways Project, co-funded by the European Commission with project acronym "21-EU-DIG-NORTHERN EU GATEWAYS[2]". The Northern EU Gateways project meets the objectives and the first call of the digital part of the Connecting Europe Facility 2 (CEF2) Digital.[3]

This Vision 2030 Report is also available online at: https://polarconnect.net/Vision2030

1 These are Finland, Sweden, Norway, Denmark, and Iceland. Together they rank 10th on the global scale of Nominal GDP and 7th with respect to geographical area worldwide.

2 More information on this project

3 Connecting Europe Facility - CEF Digital

Vision 2030

Table of Contents

PREFACE 3
EXECUTIVE SUMMARY 9
1. INTRODUCTION 10
- 1.1 European Digital Strategic Autonomy & Sovereignty 13
- 1.2 Alignment with European and Global Policies 14
- 1.3 Connecting Europe and Asia through the Arctic 17

2. THE APPROACH 19
- 2.1 Geographic Footprint 19
- 2.2 Possible route options 20
  - 2.2.1 Creating a resilient system 20
  - 2.2.2 Special route considerations for Polar Connect 21
- 2.3 Options for sensing 23
- 2.4 Societal and Economic Benefits 23
- 2.5 Green Aspects 25
- 2.6 Next Steps 26

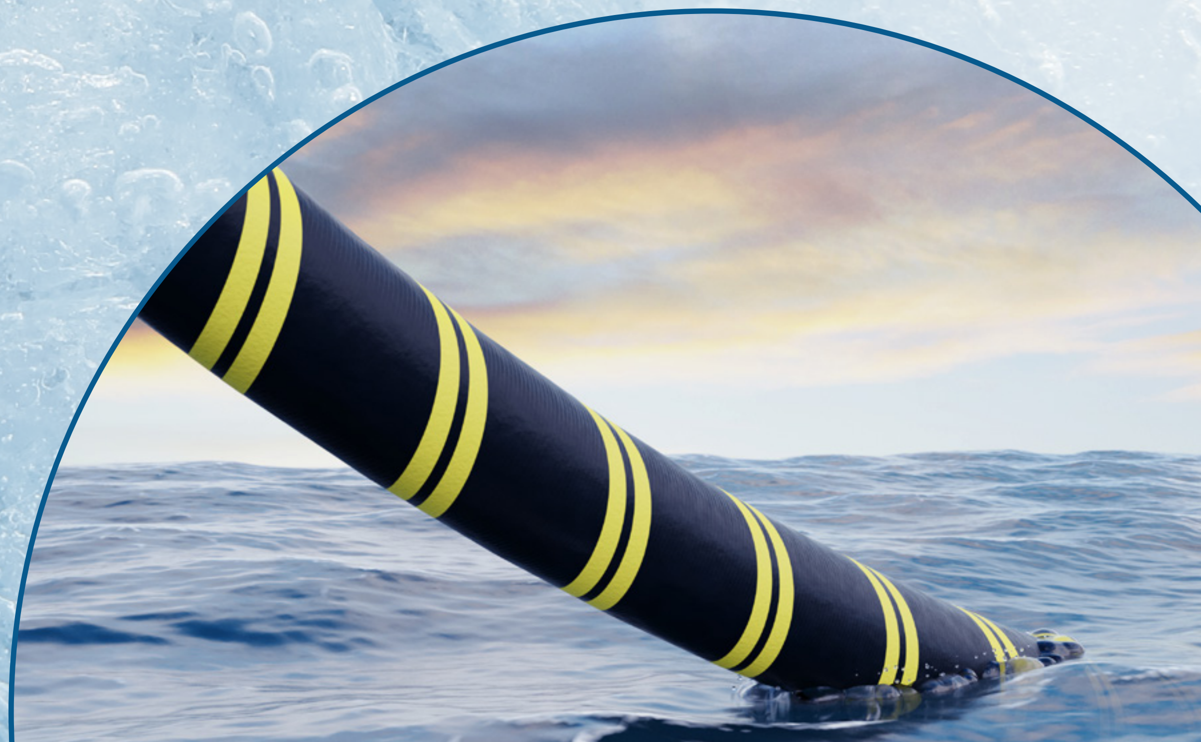
3. OPPORTUNITIES FOR ARCTIC ENVIRONMENTAL MONITORING AND RESEARCH 27
- 3.1 Key challenges for Arctic Research and environmental monitoring 27
  - 3.1.1 Climate research 28
  - 3.1.2 Impact from Arctic shipping 29
  - 3.1.3 Arctic marine geology and geophysics 30
  - 3.1.4 Very-long baseline interferometry and satellite orbit positioning 30
- 3.2 Sensing Opportunities and Science Collaborations 31
- 3.3 Key challenges for sustainable sensing in the Arctic Ocean 32

4. STAKEHOLDER ANALYSIS 34
- 4.1 Private and Commercial Stakeholders 34
  - 4.1.1 Carriers and OTTs 34
  - 4.1.2 Data Centre Market 36
  - 4.1.3 Other industry sectors 36
- 4.2 Public Stakeholders 37
  - 4.2.1 Governmental Bodies 37
  - 4.2.2 Research & Education Networks (NRENs) and HPC Centres 38
- 4.3 Scientific Stakeholders 39

5. RISK ANALYSIS AND MITIGATION 40
- 5.1 Risks during preparation phase 40
- 5.2 Risks during building phase 41
- 5.3 Risks during operations phase 42
- 5.4 Risks at end of life 44

APPENDIX A. SECURING CONNECTIVITY: THE ROLE OF SUBMARINE CABLE SYSTEMS AND OTHER TECHNOLOGIES 46
- A.1 Submarine cables – an overview 46
- A.2 Data Lakes and the increasing data transport needs 47
- A.3 Increasing Security and Resilience 47
- A.4 Other technologies, Satellites 50

APPENDIX B. FEASIBILITY STUDY REPORT ON ARCTIC ROUTE OPTIONS 51
APPENDIX C. SEABED PROPERTIES AND GEOHAZARDS ACROSS THE ARCTIC OCEAN 52
APPENDIX D. FEASIBILITY STUDY REPORT ON SENSING CABLE TECHNOLOGIES 53
APPENDIX E. SCIENCE OPPORTUNITIES ON POLAR CONNECT WORKSHOP REPORT 54
APPENDIX F. IMPLEMENTATION OF THE POLAR CONNECT SUBMARINE CABLE - PUBLIC FINANCING, DESIGN OPTIONS AND ECONOMIC REGULATORY IMPLICATIONS 55

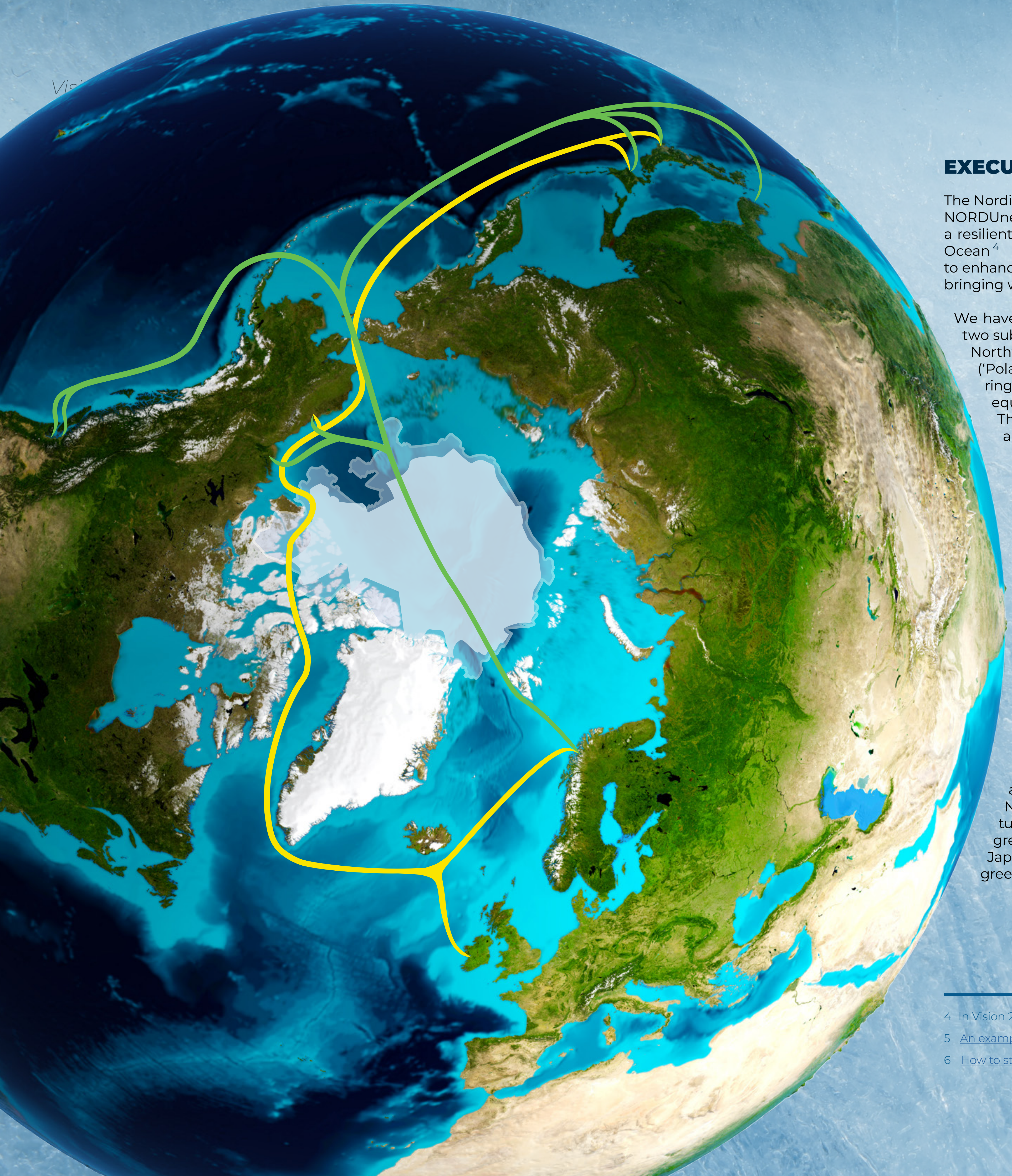


LIST OF ABBREVIATIONS

AMOC	Atlantic Meridional Overturning Circulation
ASN	Alcatel Submarine Networks
AUV	Autonomous Underwater Vehicle
CC	Climate Change
CEF2	Connecting Europe Facility 2
DAS	Distributed Acoustic Sensing
DTU	Danmarks Tekniske Universitet
ECMWF	European Centre for Medium-Range Weather Forecasts
EEZ	Exclusive Economic Zone
ENISA	European Union Agency for Cybersecurity
EU	European Union
FNF	Far North Fiber
FOSA	Fiber Optic Sensing Association
FWPA	Finnish Wind Power Association
GDP	Gross Domestic Product
GPS	Global Positioning System
IBCAO	International Bathymetric Chart of the Arctic Ocean
ICARP	International Conference on Arctic Research Planning
ICPC	International Cable Protection Committee
ICT	Information and Communication Technology
MOSAiC	Multidisciplinary drifting Observtry for the Study of Arctic Climate
NATO	North Atlantic Treaty Organisation
NREN	National Research & Education Network
OTT	Over The Top
PoP	Point of Presence
ROV	Remotely Operated Vehicle
SDG	Sustainable Development Goal
SMART	Science Monitoring and Reliable Telecommunications
SOP	State of Polarisation
SPRS	Swedish Polar Research Secretariat
SU	Stockholm University
TBF	Terrestrial Backbone Finland
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
VLBI	Very-Long Baseline Interferometry

LIST OF FIGURES

Figure 1.1 *Existing LONG, BAD, and UGLY data communications paths between Europe and Asia. (Source: NORDUnet)* 11
Figure 1.2 *Artist's impression of Far North Fiber and Polar Connect through the Arctic Ocean. (Source: NORDUnet)* 12
Figure 1.3 A schematic view of submarine cables in the Red Sea region, the **BAD** route as noted earlier (Image source: TeleGeography) 13
Figure 1.4 The European Data Gateway Platforms (Source: Declaration on European Data Gateways) 16
Figure 2.1 European part of Northern EU Gateways *(Source: NORDUnet based on data from Cinia 2023)* 19
Figure 2.2 *Potential interconnection points for Far North Fiber and Polar Connect. (Source: NORDUnet).* 20
Figure 2.3 *IODP ArcOP Expedition 302 in 2004 (Source: Swedish Polar Research Secretariat)* 21
Figure 2.4 *Icebreaker Oden (Source: Swedish Polar Research Secretariat)* 22
Figure 2.5 *Researchers on the ice during the research expedition Synoptic Arctic Survey 2021 (Source: Swedish Polar Rese arch Secretariat)* 24
Figure 2.6 *Examples of power plants for hydro, wind, and tidal wave. (Sources: Finnish Wind Power Association; © imaginima via Canva.com, SorbyPhoto/Shutterstock).* 25
Figure 3.1 *Polar bear in the Arctic Ocean during the research expedition Synoptic Arctic Survey (Source: Swedish Polar Research Secretariat)* 26
Figure 3.2 *CTD rosette - used for sampling water at different depths. Image from Synoptic Arctic Survey 2021 (Source: Swedish Polar Research Secretariat)* 27
Figure 3.3 *Observing the Earth's climate using meteorological stations on the ground or on ships, from drifting buoys, and from satellites (Source: NOAA).* 28
Figure 3.4 *Shipping across the North West Passage (Source: Traceready.ca)* 29
Figure 3.5 *Arctic Ocean seafloor map: Depth, Shelves, Basins and Ridges (Source: geology.com)* 30
Figure 3.6 *Map of VLBI stations in the Northern Hemisphere (Source: NORDUnet)* 31
Figure 3.7 *SUBMERSE Indicative site locations (Source: NORDUnet).* 32
Figure 3.8 *3D rendering of a subsea remotely operated vehicle (Source: Vismar UK/Shutterstock).* 33
Figure 4.1. *Share of used capacity on submarine cables (Source: NORDUnet, based on data from TeleGeography)* 35
Figure 4.2 *CERN's Data Centre (Source: Robert Hradil, Monika Majer/ProStudio22.ch)* 36
Figure 4.3 *EuroHPC supercomputer LUMI (top) and Japanese supercomputer Fugaku (bottom) (Sources: CSC, RIKEN)* 38
Figure 4.4 *Ny telescope at the geodetic observatory Rabben (Source: Olaf Schjelderup)* 39
Figure 5.1 *Arctic Administrative Areas map. (Source: Arctic Centre, University of Lapland)* 40
Figure 5.2 *Navigating in heavy ice cover, requires specialised vessels and careful planning (Source: Swedish Polar Research Secretariat)* 42
Figure 5.3 *Categorisation of cable faults (Source: ICPC report 2022)* 43
Figure 5.4 *There is* a small risk of icebergs grounding on the cable close to the landing point in Ny-Ålesund *(Source: Anna/NORDUnet)* 44
Figure 5.5 *Submarine cable loading to freighter vessel (Source: Korn Srirawan/Shutterstock)* 45
Figure A.1 The world's submarine cable systems (Source: Submarine Cable Map) 46
Figure A.2 *Data lake principle explanation with work cycle and stages outline diagram (Source: VectorMine/Shutterstock)* 47
Figure A.3 *Cable Innovator (C-Power) (Source: Hans Hillewaert)* 48
Figure A.4 *SpaceX, Falcon 9 rocket (Source: Public Domain)* 49



EXECUTIVE SUMMARY

The Nordic National Research and Education Networks (NRENs), collaborating within NORDUnet and continuously working to facilitate research and education, envision a resilient submarine cable system between Europe and Asia traversing the Arctic Ocean[4] by 2030. This system, equipped with advanced sensing capabilities, aims to enhance the strategic digital autonomy of the European Union and its close allies, bringing widespread benefits to the global community.

We have identified and created an ambitious, innovative, and realistic vision for two submarine cables between Northern Europe and East Asia, i.e. one across the Northwest Passage ('Far North Fiber') and one west of the Geographic North Pole ('Polar Connect'). In this vision, these two submarine cables will form a resilient ring on a new and unexploited route. It will create substantial added value by equipping Polar Connect with sensing technology, for Arctic research purposes. The Vision 2030 provides valuable and ambitious insights for future initiatives and projects that will enhance European Digital Autonomy.

With the implementation of this Vision 2030, high value will be created for society, significantly increasing resilience and security, pushing the green digital transition, and forming a unique contribution to science in critical areas such as climate research, marine biology, and natural disaster warning[5] and prediction. Moreover, the planning and execution of the Vision 2030 will build critical competence and tools, which in itself adds to European resilience in the Digital Age.

This vision is strategically taking into account the geopolitical tensions that have been rising recently, as the route through the high Arctic is a safe and sovereign route. Also, it is scientifically the most interesting route to take. Thus far, the Arctic has not been used for submarine cables, as we only now have the insight, technology, and knowledge to drive this.

By 2030, forecasts predict that Information and Communication Technology (ICT) will represent more than 20% of the global electricity demand, with one-third stemming from data centres alone.[6] As the demand for data storage and processing continues to grow, there is a big need for green data centres. With its abundance of green energy from hydro, thermal, and wind, and a climate that allows for carbon neutral and even natural cooling, the Nordics are an ideal place for building new, sustainable large data centres. In turn, this calls for high-performance connectivity between and to the so-called green giants of the World, i.e. the European Nordics, Canada's Northeast, and Japan's Hokkaido. Vision 2030 is spot on for this topic by interconnecting the green giants with high-bandwidth and low latency.

4 In Vision 2030, we speak about the Arctic Ocean, our ambition is to go through the High Arctic Region

5 An example of an earthquake warning system

6 How to stop data centres from gobbling up the world's electricity

1. INTRODUCTION

Society has become dependent on digital technologies and this development has only just begun. In order for these technologies to be ever-present, anywhere and all the time, stable interconnectivity between countries and continents is paramount. Digital has become the key to many areas of life and for businesses. Downtime is unacceptable, and can even be life-threatening, e.g. due to the lack of communication between emergency services.

Geopolitical tensions have been rising and non-European big-tech companies are taking the lead in connecting continents. At the moment, there is no attractive alternative for connectivity between Europe and Asia, as the three existing paths all have issues, i.e.:

- Transit through North America: A long route, controlled by non-European entities
- Through the Suez Canal region: A vulnerable and politically unsure route.
- Through Siberia: An expensive, unreliable, and geopolitically unuseful route.

The need for resilient, secure, and diverse submarine cable routes between Europe and Asia was also underlined in the first Japan – EU Digital Partnership Council meeting (July 2023).[7] Another critical factor is that some of the existing submarine cables directly connecting Europe to East Asia are approaching end of life.

Approximately 500 submarine cables transport more than 97% of the global Internet's intercontinental traffic. While wireless and satellite technologies are continuously developing, submarine cables remain the fastest, most efficient and least expensive way to send large amounts of digital information across the globe.[8] Almost all oceans are equipped with submarine cables, except for one: The Arctic Ocean. Our vision is for the world to benefit from having a completely new resilient submarine cable system across the Arctic Ocean as of 2030, that significantly adds to the strategic digital autonomy of the European Union and its close allies and that brings high-performance low latency connectivity between Europe and Asia.

> “ Approximately 500 submarine cables transport more than 97% of the global Internet's intercontinental traffic.

Given the context, there is quite some urgency and we have identified and created an ambitious, innovative, and realistic vision for two submarine cables between Northern Europe and East Asia (Figure 1.2), i.e. one across the Northwest Passage ('Far North Fiber') and one west of the Geographic North Pole ('Polar Connect'). These two submarine cables are planned to form a resilient system on a route that has never been used before. We plan to create added value for science and for the security of the cables, by equipping the cables with sensing technology.

7 Japan – EU Joint Statement of the 1st meeting of the Japan – EU Digital Partnership Council

8 Security threats to undersea communications cables and infrastructure – consequences for the EU

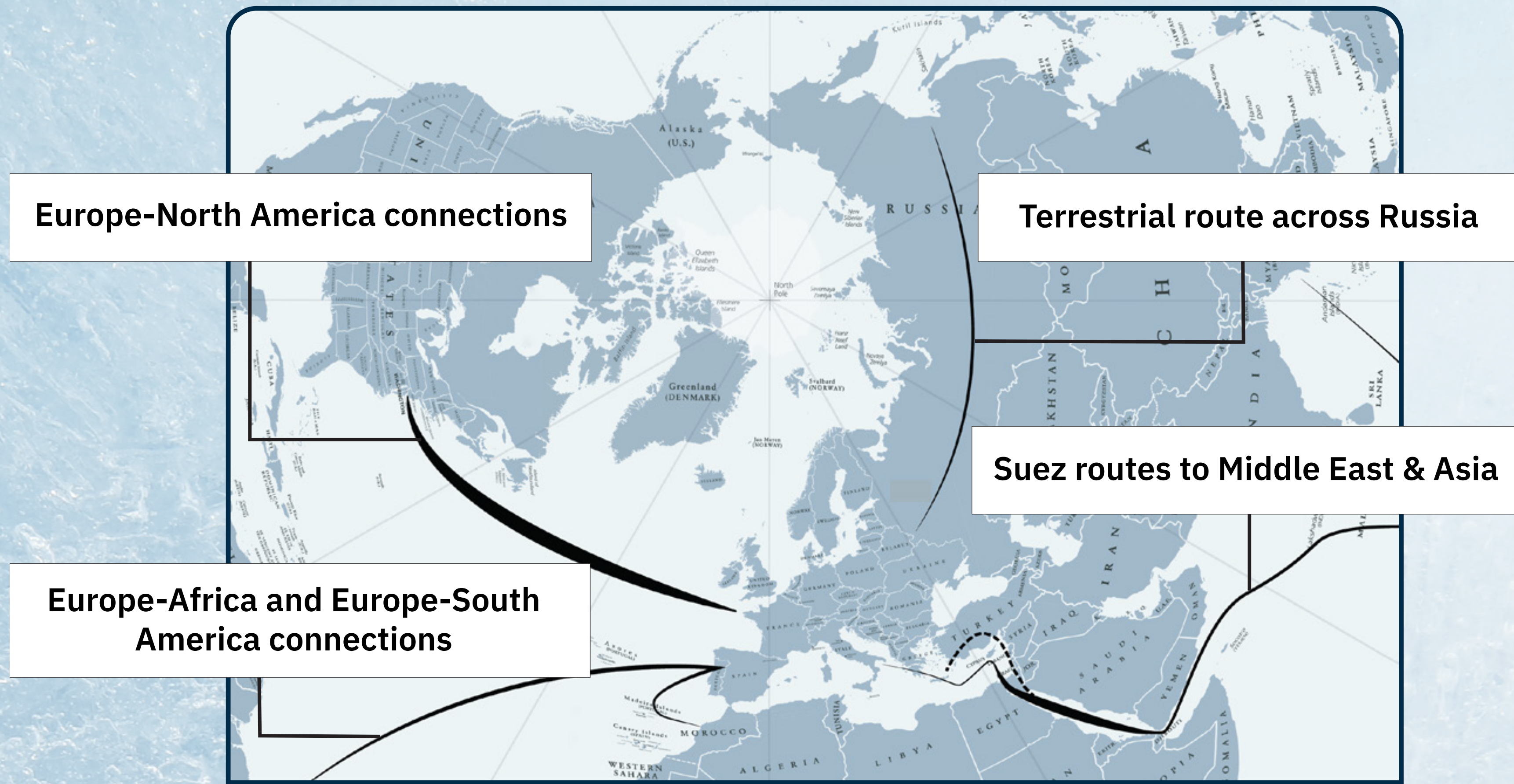


Figure 1.1 Existing LONG, BAD, and UGLY data communications paths between Europe and Asia. (Source: NORDUnet)

"The Long, the Bad, and the Ugly"

Historically, data transmission between Europe and Asia took the **LONG** route, traversing the North Atlantic Ocean, across North America (almost always through the USA), and traversing the Pacific Ocean , or occasionally a route around Africa. After the first modern cable systems at 100 Gbit/s and beyond were routed through the Suez Canal and the Red Sea area, more cables along exactly the same route emerged. This has now become a truly congested route with a high-risk factor, hence adding more cables in this region would not increase resilience substantially. That being said, it is a **BAD** route for new cables. Also, Russian operators started offering quite unstable and expensive services along the trans-Siberian railroad, and across the Sea of Japan / East Sea towards Japan. With the ongoing embargo on buying from Russian companies, this could be considered the **UGLY** route.

Building submarine cables through the Arctic creates huge potential for science and highly needed research because this enables the collecting of highly needed environmental monitoring data from the Arctic region. Equipping the submarine cable through the Arctic with sensors, i.e. the SMART[9] cable concept, we will not only be innovating the world's Internet routes, we also opening unique opportunities for science and industry, thus bringing Europe in the lead.

***Figure 1.2** Artist's impression of Far North Fiber and Polar Connect through the Arctic Ocean. (Source: NORDUnet)*

9 SMART stands for Science Monitoring and Reliable Telecommunications.

1.1 European Digital Strategic Autonomy & Sovereignty

Many aspects of society rely on the integrity and confidentiality of communication flows. Today, more than 90% of all communications traffic between Europe and Asia passes through a very narrow stretch of land in the Suez Canal and Red Sea areas and passes land stations under the control of authorities of Egypt. Moreover, many of the cable systems through the Red Sea rely on two cable landing stations in Djibouti, as can be seen in Figure 1.3.

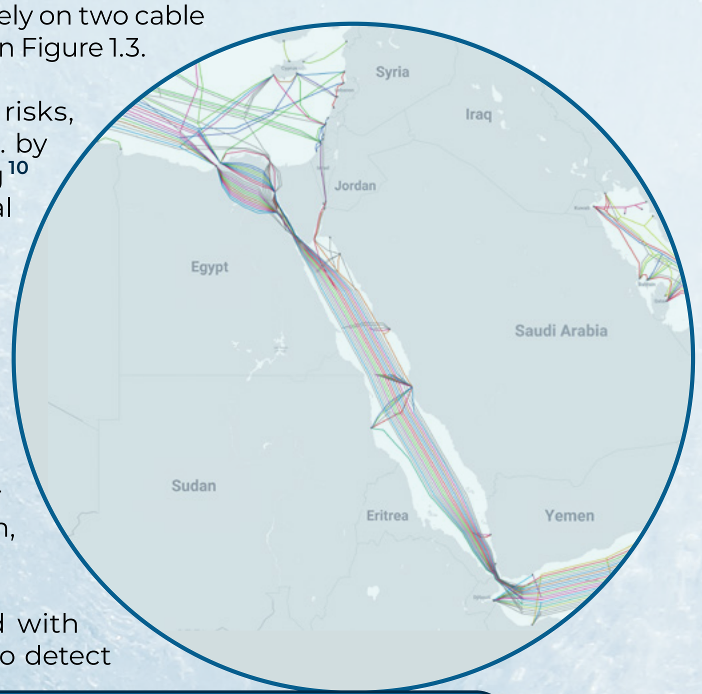


***Figure 1.3** A schematic view of submarine cables in the Red Sea region, the **BAD** route as noted earlier (Image source: TeleGeography)*

This obviously constitutes a number of risks, such as exercising control, severance (e.g. by trawling or anchoring), and eavesdropping[10] in a geographical region where political tensions have been high for decades and have further escalated in October 2023[11]. Moreover, this is a seismically active region, which poses a natural risk to the fibre optic cable systems. These risks and dependencies can best be mitigated by providing additional cable routes that pass through or close to the Exclusive Economic Zones (EEZs) of European countries, their allies, such as Canada, the USA, and Japan, and through international waters.

Furthermore, a cable system equipped with advanced sensing capabilities designed to detect activities threatening the security and integrity of the cable itself will ensure more secure communications. Fibre sensing is not a capability of existing long haul cable systems, but recent events[12] have shown that this is highly needed, according to a broad range of scientific and research communities. Therefore, Vision 2030 proposes a communication path between Northern Europe and East Asia, with a significantly higher security profile, unique from all other options available today.

This would greatly enhance Europe's digital strategic autonomy, which is about strengthening Europe's own digital capacities and reducing dependency on foreign technologies, critical infrastructures, digital services, and data control. In the era of digital transformation, where technology and geopolitics are more and more intertwined, European digital strategic autonomy is proven critical for Europe's long-term resilience, competitiveness, and ultimately freedom to act.

10 Encryption of the traffic can to a certain extent protect against eavesdropping, but the traffic can still be subject to traffic flow analysis.

11 World's Worst Internet Single Point of Failure Just Shifted to Bab-El-Mandeb

12 Examples include: 'Human activity' behind Svalbard cable disruption & Nord Stream gas 'sabotage': who's being blamed and why?

The geopolitical landscape is undergoing dramatic changes with fragmented and reorganised global structures and relationships. Russia's invasion of Ukraine and the serious conflict unfolding in the Middle East are crises with ripple effects across the world. Another factor, which has given rise to geopolitical tensions, is the complex USA-China strategic competition. European strategic autonomy has been part of the political debate for the past decade, but the recent geopolitical crises have brought it to the core of all policy areas. Europe needs to strengthen its capacity to act independently in a range of strategically important policy areas, while still forming reliable partnerships with like-minded actors outside of Europe. This is resonating well with similar statements from Japan and Canada. The implementation of Vision 2030 answers to this need by significantly strengthening Europe's critical digital infrastructure capabilities, with European-led activities.

1.2 Alignment with European and Global Policies

Vision 2030 is completely aligned with current European Commission policies and priorities[13] :

"A stronger Europe in the world": Vision 2030 provides Europe with a strategic role on the global stage with partner nations, providing a trusted critical digital infrastructure to strengthen communications security and integrity, and opening the way to closer scientific collaborations,

"A Europe fit for the Digital Age": Vision 2030 brings access to high speed and secured Internet in more remote areas and promotes digital inclusion,

"A European Green Deal": Vision 2030 offers unique opportunities for Arctic environmental monitoring and research, while new and resilient connectivity in Northern Europe will boost the Nordic region as a leading sustainable data centre destination with its cool climate and abundance of renewable energy. The construction of new submarine cables in the North will thoroughly take into account the environmental impact, and

"An economy that works for people": An ambitious new cable system will trigger investments, e.g. in new green data centres in the North, and will create value for local communities and benefit a large number of users in both Europe and Asia. It will also reduce the transfer cost of green energy from the Nordics to central Europe, as it is a lot cheaper to move data using fibre optic cables than moving energy in the power grid.

Even if the European elections in 2024 will bring changes to EU policies and priorities, it is very likely that strategic autonomy, EU competitiveness, the digital twin, and the green transition will remain high on the EU agenda in the coming years.

13 European Commision Priorities 2019-2024

Vision 2030

On a global scale, Vision 2030 matches with several of the United Nations (UN) Sustainable Development Goals (SDGs[14]):

"Industry, Innovation, Infrastructure" Vision 2030 is perfectly aligned with this goal and especially Targets 9.1[15] and 9.5, as the implementation of Vision 2030 will contribute to a sustainable and resilient infrastructure, bring innovation, and have impact on scientific research.

"Life below Water" The result of implementing Vision 2030 will not only be a telecommunications infrastructure but also a scientific instrument, equipped with environmental sensors on the ocean floor. Therefore, it will contribute to Target 14.a[16] with an "increase of scientific knowledge" in areas like earth observation, climate change, and marine biodiversity,.

"Partnerships for the goals" The implementation of Vision 2030 will bridge Northern Europe and East Asia and will provide opportunities for better resilience towards Canada and the USA, being a facilitator for new and further strengthening existing international science collaborations, contributing to Target 17.6.[17]

The European Union Agency for Cybersecurity, ENISA,[18] recently published the report 'Subsea cables - what is at stake?'[19] stating that "subsea cables are some of the most critical components of the global internet infrastructure". To increase the protection of subsea cables, this report highlights the need for a "geographic diversity of routes and landing of cables" in order to "avoid single point of failure". Vision 2030 fully anticipates and addresses this strategy.

The European Commission has made it a high-level priority through the Global Gateway[20] strategy to create sustainable and trusted connections that work for people and the planet. It is designated to help tackle the most pressing global challenges, from fighting climate change to improving health systems, boosting competitiveness, and security of global supply chains.

14 THE 17 GOALS | Sustainable Development

15 Goal 9 | Department of Economic and Social Affairs

16 Goal 14 | Department of Economic and Social Affairs

17 Goal 17 | Department of Economic and Social Affairs

18 ENISA - European Union Agency For Cybersecurity

19 Undersea cables — ENISA

20 European Commission's Global Gateway, fully aligned with the UN's Agenda 2030 and its Sustainable Development Goals as well as with the Paris Agreement.

Strong and secure internal and external connectivity networks are a fundamental part of Europe's digital autonomy. The objective of the Digital Data Gateway Platforms initiative from 2021 is part of the Digital Decade, the vision for Europe's digital transformation by 2030. All Member States of the European Union (EU) as well as Iceland and Norway signed the Declaration on European Data Gateway.[21] The aim is for Europe to reinforce connectivity with global partners through terrestrial and submarine cables, satellites, Internet exchange points, data centres, and other technologies. The 27 EU Member States have committed to align their national initiatives to strengthen international connectivity between Europe and its partners in Africa, Asia, the European Neighbourhood and Latin America.

The connectivity networks around the EU can be divided into four platforms, each with its own geopolitical significance (Figure 1.4):

- the EU-Atlantic Data Gateway Platform,
- the EU-Mediterranean Data Gateway Platform,
- the EU-North Sea & Arctic Data Gateway Platform, and
- the EU-Baltic-to-Black Sea Data Gateway Platform.

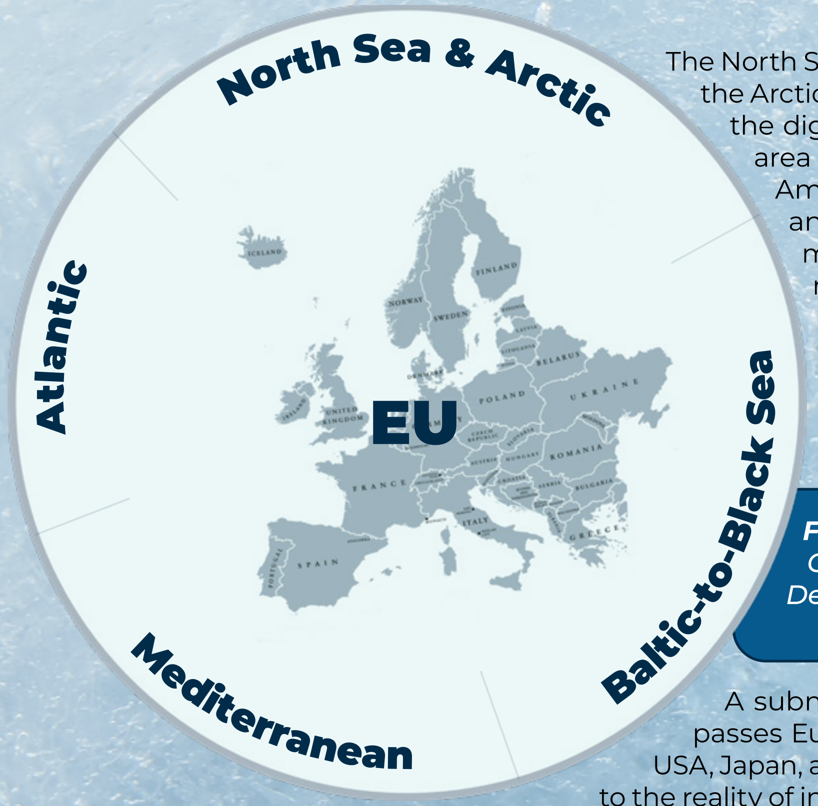
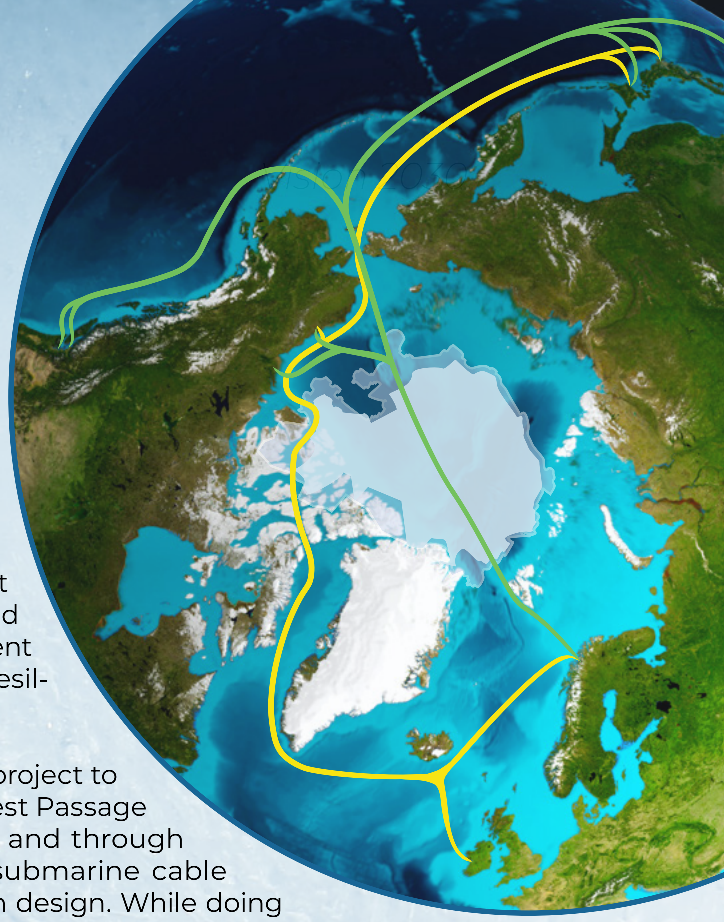


Figure 1.4 The European Data Gateway Platforms (Source: Declaration on European Data Gateways)

The North Sea and Arctic Data Gateway lifts the Arctic region as an important area for the digital shift for Europe. This is the area where Asia, Europe and North America are closer than they are at any other point on Earth, which means shorter and more efficient routes for data flows across these three continents. Resilience against geopolitical instability threats and vulnerability can be ensured by improved diversity via new cable routes.

A submarine cable system that only passes European Countries, Canada, the USA, Japan, and international waters answers to the reality of increased geopolitical risks using balanced and collaborative measures while staying clear of protectionism and extreme self-reliance. The aim is to sustain the exponential increase in internet traffic and to improve the security of critical communications infrastructure by complementing - not replacing - existing cable routes.

21 Digital Day 2021: Europe to reinforce internet connectivity with global partners



1.3 Connecting Europe and Asia through the Arctic

Vision 2030 entails a resilient submarine cable system across the Arctic Ocean between Northern Europe and East Asia. As part of this trans-Arctic connectivity initiative, two different Arctic route solutions are being investigated and planned for what will ultimately form a resilient system by providing backup solutions and resilience (see Figure 1.2).

Far North Fiber (FNF)[22] is the project to link Europe and Japan through the North-West Passage between Greenland and Northern Canada and through the Canadian Archipelago, using proven submarine cable construction techniques and creative system design. While doing so, it will also deliver broadband to Northern communities and will open up to opportunities for cleaner data centres. The anticipated Ready for Service date of FNF is scheduled to be in 2027. Cinia Oy[23] is the European driving force behind FNF.

Polar Connect[24] is a Northern European initiative to build secure and resilient connectivity passing under the ice cap of the North Pole in the Arctic Ocean, almost touching Svalbard, and from there on west of the Geographic North Pole and North of the Canadian Archipelago, towards North America and East Asia, on the shortest possible route. This initiative, driven by the Nordic NRENs and NORDUnet, was spurred to address the increasing needs of capacity to sustain the international collaborations, but also with the vision that it will create opportunities for scientific sensing, new innovative collaboration models, and support the rapid ongoing digital transformation. The envisioned Ready for Service date of Polar Connect is in 2030 or soon thereafter.

The Northern EU Gateways project,[25] funded by the European Commission within the framework of CEF Digital, is a collaboration between Cinia Oy and NORDUnet. This project is an important step in the development of Arctic connectivity and provides a boost to trans-Arctic connectivity between Europe and Japan by investigating the route options for submarine cables through the Arctic Ocean. The Project has contributed to creating this Vision 2030 for the North Sea and Arctic section of the Digital Gateway Platforms, fostering the Arctic region as the important area of the digital shift for Europe. Additionally, the Northern EU Gateways project is making an impact on the scientific value of the initiative by evaluating, together with researchers, Arctic opportunities and obstacles in the field of sensing technologies on submarine cables. The effort is considering the technical, commercial, and regulatory feasibility of using the fibre sensing and SMART cable

22 Far North Fiber

23 Cinia

24 Polar Connect

25 Northern EU Gateways | NORDUnet & Northern EU Gateways | Cinia

technology on the trans-Arctic submarine cable system, including evaluation of geopolitical and data management challenges in the area. The Northern EU Gateways project is paving the way for future initiatives and funding to deliver a trusted digital infrastructure to the benefit for Europe and the global community.

In Vision 2030, both Far North Fiber and Polar Connect are driven by consortiums of commercial carriers, of which at least one is based inside the European Union. This is already prominent for Far North Fiber, driven by Cinia from Finland, Far North Digital from the USA, and ARTERIA Networks from Japan. In the case of Polar Connect, many promising discussions have already taken place with a wide variety of carriers and other stakeholders, and these discussions are advancing.

In June 2023, Cinia and NORDUnet issued a joint statement with the title 'International connectivity between Europe and Asia will be strengthened and become more resilient through two complementing submarine cable systems – Far North Fiber and Polar Connect'.[26] This statement clearly demonstrates the desire of Cinia as well as NORDUnet and the Nordic National Research & Education Networks that Far North Fiber and Polar Connect will be submarine cable systems that are complementing each other to a great extent, especially through increased redundancy and route diversity, thus bringing a multitude of opportunities and benefits for increased collaboration between Europe, Asia, and North America.

Figure 2.1 *European part of Northern EU Gateways (Source: NORDUnet based on data from Cinia 2023)*

26 Joint communications statement Cinia Oy and NORDUnet

2. THE APPROACH

In order to realise the ambitious, innovative, and realistic Vision 2030, the plan is to create two independently routed submarine cables between the Northern part of the European Nordics and Japan, through the Arctic Ocean, that interconnect and can be configured as a backup for each other.

Therefore, NORDUnet and the Nordic NRENs[27], known for pioneering innovative solutions for decades, are looking into a number of initiatives to investigate and plan for the first submarine cable system straight across the Arctic Ocean connecting Europe, Asia, and North America and securing the shortest possible route, equipped with sensing technology. Today, the Arctic Ocean is without any submarine cable systems, hence it is offering this unique route that will dramatically increase the resilience and create redundancy for global connectivity, on the shortest possible route reducing latency.

2.1 Geographic Footprint

There are currently two projects underway that each address one of the two legs of the Vision 2030, as detailed in Chapter 1.3: Far North Fiber and Polar Connect.

From the Cable Landing Stations on both sides of the cable systems, it is relatively easy to ensure that the connectivity is brought onwards, into Europe and into Asia:

- From Japan, connectivity can be brought onwards into other parts of Asia, e.g. into South Korea and the Philippines. This can be done by branching one or both of the Arctic submarine cables into other countries in Asia or by relying on new or existing intra-Asia submarine cable systems. This opens up for more resilience in terms of connectivity as well as for powering the cable system.
- From the European Nordics, a project like the 'Northern EU Gateways'[28] with the sub-projects 'Terrestrial Backbone Finland' (TBF), 'C-Lion2' and existing terrestrial fibres within the Nordics will enable connectivity towards Western and Central Europe, hence reaching and benefitting the entire European Union. For Research & Education, the envisioned interconnection with the GÉANT[29] network will definitely enable the transport of huge scientific datasets to and from Europe.

27 About - NORDUnet

28 CEF Digital Call 1 co-funded project

29 GÉANT

2.2 Possible route options

Far North Fiber is planned to make landfall in Europe, i.e. in Northern Norway close to the Finnish border, and in Ireland. The route for Far North Fiber, as planned by Cinia and its partners, continues south of Iceland, south and west of Greenland, through the Canadian Archipelago, towards the Bering Strait and then onwards to Japan.

The Nordic NRENs, collaborating within NORDUnet, have taken the lead to promote Polar Connect, as the second leg of the resilient submarine cable system across the Arctic, on the shortest possible route between the EU and Japan, which will bring the shortest latency possible between Europe and East Asia.

2.2.1 Creating a resilient system

Having two separate routes across the Arctic is of great importance, as repair times in the Arctic Ocean can be longer than in places without ice conditions, especially in winter time. Ensuring that the two submarine cables can be each others' back-up greatly enhances the resilience of the entire system, providing reliable, direct, and high-performance connectivity between the EU and its like-minded partners in Asia.

In order for Far North Fiber and Polar Connect to form a resilient system, the two systems should interconnect in at least two or better in three places, such as (see Figure 2.2):

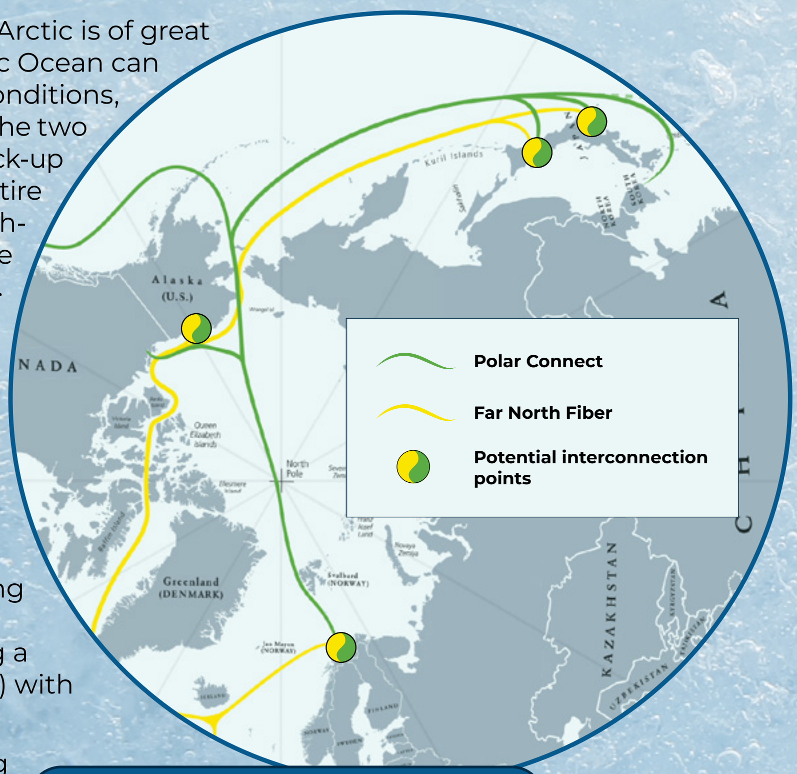


Figure 2.2 *Potential interconnection points for Far North Fiber and Polar Connect. (Source: NORDUnet)*

- In Europe, e.g. by interconnecting the two cable landing stations in Norway or by interconnecting a Swedish Point of Presence (PoP) with a Finnish PoP.
- In Japan, e.g. by interconnecting the two cable landing stations in Hokkaido or in Tokyo.
- In Alaska, e.g. by interconnecting the two cables in a cable landing station in Prudhoe Bay. As an alternative, outside Alaska the two cables could be equipped with submarine branching units interconnecting the two cables.

In addition, redundant power feeds to the cables' submarine amplifiers and sensors are important and could, in addition to the mandatory feed from the landfalls in Europe and Japan, also be done from Ny-Ålesund, Svalbard, potentially from a landfall in Canada, and from Prudhoe Bay in Alaska, enhancing the robustness of the Polar Connect cable.

The Bering Strait is an area to pay extra attention to for the design and route planning of both Far North Fiber and Polar Connect. The submarine cables will have to be routed between mainland Alaska and the Alaskan island, called Little Diomede,[30] to avoid any geopolitical issues. Resilience for mitigating the risk connected to the narrow part of Bering strait will be achieved by:

- Branching units the coast of Alaska, e.g. near Prudhoe Bay, where Far North Fiber and Polar Connect can interconnect.
- Seeking synergies with other initiatives such as Quintillion[31] and terrestrial fibres through Alaska towards Nome and Anchorage, and possibly onwards.

2.2.2 Special route considerations for Polar Connect

Figure 2.3 *IODP ArcOP Expedition 302 in 2004 (Source: Swedish Polar Research Secretariat)*

For the routing aspects of Polar Connect, logistics challenges, long term sustainability, security, and costs of the future Polar Connect cable need to be taken into account and sometimes also weighed against each other.

The logistic challenge is twofold, as both the deployment of the cable and the future access to the cable for repairs needs to be considered. The Northern EU Gateways project has commissioned a report from the Swedish Polar Research Secretariat (SPRS) on the topic of cable deployment and maintenance in the Arctic Ocean (see Appendix B) that has utilised expertise from decades of operation in the High Arctic Region as well as the design of ice-going vessels. The conclusion from the report is that deployment of Polar Connect across the Arctic Ocean, i.e. between Svalbard and the Alaskan coast, will require three ships. Two heavy icebreakers and an ice-strengthened cable laying ship, operating as shown in Figure 2.1, where the two icebreakers are doing advanced ice management to keep the cable laying ship safe. Sweden has become an expert in this field.

30 Little Diomede Island - Wikipedia

31 Quintillion Subsea Cable Network

Simulations and experience have shown that a route closer to the North Pole is shorter and less challenging due to lighter ice conditions than a route through the EEZ, north of Greenland. Compared to the route closer to the North Pole, the Greenland route would require more powerful icebreakers and a higher ice strengthened cable laying ship. The operation would also carry higher risks for the ships and the cable during the cable laying process.

A needed repair of the cable would be possible using a single heavy icebreaker fitted to host several kilometres of replacement cable and a Remotely Operated Vehicle (ROV) for underwater operations. As for the deployment, these repair operations would be less complicated at lighter ice conditions closer to the North Pole compared to north of Greenland.

The Swedish Government currently owns one icebreaker suitable for assisting a cable laying ship in the Arctic, i.e. the Oden[32] (Figure 2.4).Moreover, the Swedish Government is planning to commission a second heavy icebreaker with a design that will make it suitable for both assisting with the deployment of the cable as well as being fitted for cable repair. Currently, there is no cable laying ship suitable for autonomous use in heavy sea ice. The SPRS report suggests retrofitting an existing cable ship or reconfiguring a larger ice-class vessel for cable lying to meet the requirements for icebreaker assisted operations in the Arctic, since this will be significantly more cost-efficient than constructing a new ship.

Figure 2.4 *Icebreaker Oden (Source: Swedish Polar Research Secretariat)*

The report by Stockholm University (see Appendix C) addresses the seafloor properties along potential cable routes based on data from the International Bathymetric Chart of the Arctic Ocean (IBCAO[33]). The water depth along the route for Polar Connect is expected to be deep enough to make the cable safe from moving icebergs breaking away from glaciers in Northern Greenland, but the seafloor topography is more complex closer to the Greenland coast. Also, the route through the Greenland EEZ will be closer to the continental slope that has more complex and presumably less stable seafloor geology than the central Arctic Ocean basin closer to the Geographic North Pole, which with current knowledge is deemed to be the safer route.

32 Icebreaker Oden - Swedish polar research secretariat

33 The International Bathymetric Chart of the Arctic Ocean

Hence the northern route will have less risk of geological events disrupting the cable. More research and expeditions are needed to gather more data to draw conclusions from.

Contrary to the favourable conditions for deployment, repair, and geological setting, the route through the Greenland EEZ will offer better protection from deliberate interference with the cable. Though few entities have the capacity to do operations on the Arctic seafloor, the same existing technology needed to repair the cable can be used to access and interfere with it. Attempting unwarranted access in the EEZ of Greenland with its daunting ice conditions will be easily spotted since it would require having at least one large icebreaker stationed for an extensive period of time.

In future projects, the pros and cons of the different potential cable routes across the Arctic Ocean, including the EEZ of Greenland, will be studied, in order to deduce the best approach given the considerations above.

2.3 Options for sensing

Independent of the exact route, Polar Connect is envisioned to be equipped with sensing capabilities. An important driver for adding sensing capabilities to a submarine cable system is to guard the system itself and ensure quality and continuity of the connectivity. By adding sensing capabilities to the cable, the cable is able to send an alarm in case an event or a physical threat happens in the vicinity of the cable system. This can be a natural phenomenon, such as an earthquake or a volcanic eruption, or a human-caused event, such as a drifting anchor of a vessel or a fishing net in the neighbourhood of the cable.

Other key drivers for adding sensing capabilities to a submarine cable system are for environmental monitoring and research interests, as elaborated on in Chapter 3. The Arctic Ocean is of particular great interest to a wide variety of scientists, e.g. for climate researchers and marine biologists. Having real-time sensing data from this area would significantly enhance the conditions for their work, as this will greatly improve accuracy of their models and the scientific results derived from them.

2.4 Societal and Economic Benefits

Significant spill-over benefits for society are expected from a resilient submarine cable system across the Arctic between Europe and Asia, leading to a significant economic Gross Domestic Product (GDP) boost in the Nordics[34]. The placement of data centres in the North will create jobs and associated support services, thus creating an opportunity for remote areas to retain talented people and residents in the area. Putting data centres in the North will bring savings in power grid investments, for not having to transfer renewable energy for powering data centres in Central Europe.

34 The economic value of submarine cables in the Arctic.

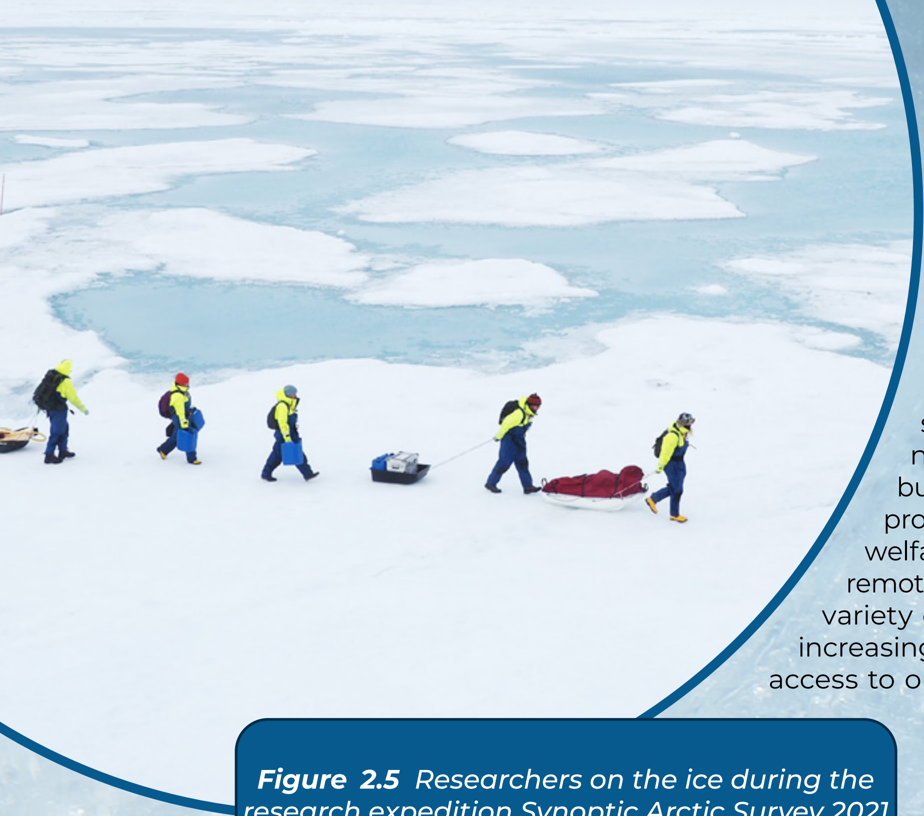


***Figure 2.5** Researchers on the ice during the research expedition Synoptic Arctic Survey 2021 (Source: Swedish Polar Rese arch Secretariat)*

Even more importantly, the improved connectivity will strengthen the Nordic regional networks, fostering new local business opportunities, increased productivity, and trade. Consumer welfare will also be improved, as the remote areas gain access to a broader variety of online goods and services, increasing the quality of life. Moreover, access to online tools can help remotely located people to be socially included with family, friends, and gain easier access to public services, like education and healthcare.

As for the economical benefits, faster broadband will enable remotely located people and businesses to participate in the global economy. While the region already has well developed mobile connectivity, the building of fibre resources in the Nordics will increase resilience and could further open up to competition for broadband provisioning, having a major impact on the market and on lower connectivity prices.

Last but not least, the datasets becoming available from the sensors on the submarine cable in the Arctic Ocean will certainly contribute to long term return on investments (see also Chapter 3), as the data will be immensely valuable for advances in many science disciplines and, hence, for addressing a number of the UN's Sustainable Development Goals.

2.5 Green Aspects

A resilient submarine cable system through the Arctic region will bring multi-layered benefits to Europe. Not only will it bring resilience to the Internet at large, it will also mitigate digital congestion for global connectivity as well as improve regional sustainability. It will induce more than 1 billion Euro worth of economic benefits to the Nordic region on an annual basis.[35]

The Nordic countries have access to vast renewable energy resources. Examples of currently harnessed energy resources in the Nordics are (see Figure 2.6):

- Hydro power (Norway, Sweden, Finland),
- Wind power (Denmark,Finland, Sweden, Norway),
- Tidal wave power (Norway).

***Figure 2.6** Examples of power plants for hydro, wind, and tidal wave. (Sources: Finnish Wind Power Association; © imaginima via Canva.com, SorbyPhoto/Shutterstock)*

For the future, the Nordic countries plan to further increase their green power supply. As an example, the Finnish Wind Power Association (FWPA) is expecting that Finland will have 100 TWh of annual offshore wind power production by the year 2040.[36] Shifting energy-intensive usage such as data centres towards regions with large local supply and even surpluses of renewable energy has a direct global impact on carbon emissions and cost. And this will call for new and resilient connectivity in the North.

The shift to the Green and Digital Transformation of the EU[37] creates a constantly growing demand in Europe for energy sources that are bcreates a constantly growing demand in Europe for energy sources that are both renewable and low-carbon.

35 The economic value of submarine cables in the Arctic.

36 Finnish Wind Power Association

37 European Green Digital Coalition

Figure 3.1 *Polar bear in the Arctic Ocean during the research expedition Synoptic Arctic Survey (Source: Swedish Polar Research Secretariat)*

It has been proven that it is always cheaper and more efficient to move as much consumption as possible closer towards the energy production sites. Following this efficiency trend, hosting data centres in Northern Europe is even more desirable, as it is more energy and cost efficient to move bits than to move energy.[38] This will allow for using the already constrained power grid in many areas in Europe more efficiently. However, this only makes sense if the local, regional, and global connectivity of data centres is very well developed.

2.6 Next Steps

To fully implement Vision 2030, important next steps need to be planned and taken soon. This could be realised in projects benefiting from EU (co-)funding, both with works and with studies, such as CEF Digital. This includes a strong engagement plan and continued activities with:

- Surveying of relevant parts of the seafloor of the Arctic Ocean,
- Nordic and European carriers, to bring commitments to the table and form a consortium for Polar Connect,
- Our partners in Asia and North America about harvesting collaborations and opportunities,
- The scientific community, to ensure the right choices on sensing are made to meet their needs and expectations and the appropriate funding channels are explored and used,
- The European Commission, Nordic Governments, and entities in East Asia, to ensure sustainable co-funding to bridge the funding gap for the challenging route through the Arctic, and
- The parties behind Far North Fiber and Polar Connect, to create a resilient system.

The Arctic Ocean provides unique new cable paths to connect continents. This area has not been utilised for global critical infrastructure before. A clear advantage of the submarine cable system passing close to the North Pole via or near the EEZs of Norway, Greenland (part of the Kingdom of Denmark), Canada, the USA, Japan, and South Korea is a much shorter distance between Northern Europe and East Asia than any other route can offer. However, this route is more complex in terms of technology readiness and availability of necessary resources to create it, thereby pushing the implementation further into the future, with the potential to innovate and lead for European companies and businesses.

38 A calculation can be found in Appendix A of the report The economic value of submarine cables in the Arctic.

3. OPPORTUNITIES FOR ARCTIC ENVIRONMENTAL MONITORING AND RESEARCH

In addition to providing telecommunications services, a state-of-the-art submarine cable system can also be instrumented for continuous harvesting and transfer of physical data such as temperature, salinity, pressure, and seismic and acoustic data. As the Arctic Ocean is the least explored area on the planet, the designated cable routes create highly demanded scientific opportunities that have never before been possible on a continuous, real-time, and permanent basis.

In addition, the high and unrestricted capacity that modern cables provide gives great opportunities for improving existing and developing new and highly distributed real-time observatory instruments in areas such as geodesy, climate, satellite operations, and for space research.

According to the Fibre Optic Sensing Association (FOSA),[39] the industry of submarine cable sensing is growing rapidly, as the market size was valued at 3 billion USD in 2021 and is projected to exceed 8 billion USD by 2030.[40] European research and industry are well positioned to benefit from these developments.

3.1 Key challenges for Arctic Research and environmental monitoring

Figure 3.2 *CTD rosette - used for sampling water at different depths. Image from Synoptic Arctic Survey 2021 (Source: Swedish Polar Research Secretariat)*

The Northern EU Gateways project explored scientific reports and science plans for Arctic research. We have also engaged directly with the scientific community to identify key issues that can be addressed using sensing on fibre optic cables in the Arctic. Mainly, the scientific challenges listed below have been deduced from the International Conference on Arctic Research Planning (ICARP))[41] and from the Northern EU Gateways' Science Opportunities workshop that took place in Oslo, Norway in October 2023 (see Appendix E).

The main conclusion is that there is an urgent need for continuous and long-term data from the high Arctic Region. Currently, nearly all direct observations from the Arctic Ocean are from ice-breaker expeditions that are only possible in summertime and do not provide the needed systematic and continuous observations.

39 Fiber Optic Sensing Association

40 Fiber Optic Sensing Assiciation (FOSA) post

41 Integrating Arctic Research - a Roadmap for the Future

Some additional information is provided from a few Arctic Argo floats [42] and from a few time-limited drifting stations on the Arctic ice, e.g. MOSAiC [43] . It is also possible to anchor instruments with data recorders to the sea bottoms for direct observations on the seafloor and limited sections of the water column. However, they have limited battery life and lack direct communication capabilities for data transfer and systems monitoring. Even if the deployment and operations are successful, the data is one or two years old when the data recorders (eventually) may be recovered.

Though these are ambitious efforts, they cannot provide the continuous and long-term data needed for reliably incorporating the Arctic Ocean in the Earth system models, like the EU Destination Earth initiative. [44] Permanent, consistent, and sustainable data collection in real-time is impossible or prohibitively expensive in the Arctic today. However, with a SMART cable, well equipped with several sensors in expedient locations, totally new opportunities for big leaps forward in various science disciplines will happen.

3.1.1 Climate research

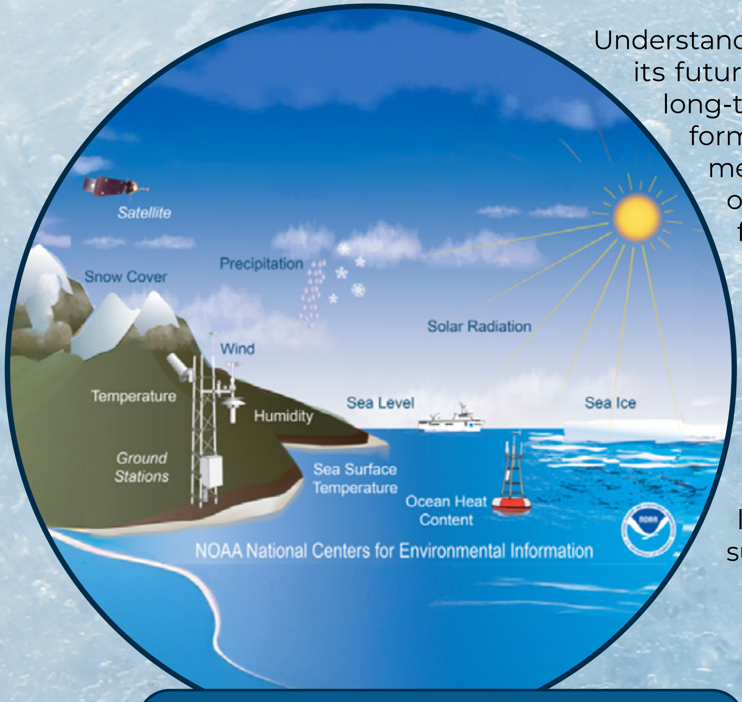


Figure 3.3 *Observing the Earth's climate using meteorological stations on the ground or on ships, from drifting buoys, and from satellites (Source: NOAA)*

Understanding the Earth's climate system and its future changes relies on the access to long-term and continuous data. This information is continuously sampled by meteorological stations on the ground or on ships, from drifting buoys, and from satellites (Figure 3.3). However, for the high Arctic Region, continuous data is only available from satellite measurements that, to a large extent, are obscured by sea ice. Data from direct measurements in the central Arctic Ccean is only available from occasional expeditions, all of which are nearly exclusively collected during the summertime and not in a systematic way.

Continuous collection of data from the Arctic Ocean is stated by the research community as key for a deeper and more accurate understanding of the currently ongoing and future climate changes.

42 Polar Argo

43 The MOSAiC expedition

44 Destination Earth | Shaping Europe's digital future

The Atlantic Meridional Overturning Circulation (AMOC) is key for transferring energy from the tropics to the Northern latitudes, i.e. Europe and the Arctic. [45]

This affects the climate and weather patterns throughout the Atlantic and the Arctic. The AMOC is driven by the difference in heat and salinity between its Northern extension into the Arctic and the warm water and saltier water in the tropics. Hence, to understand current climate and weather patterns as well as their future changes more deeply and extensively, there is an urgent need to acquire data from the Arctic Ocean and feed it to the models of the European Centre for Medium-Range Weather Forecasts (ECMWF [46]) and the Destination Earth. [47]

3.1.2 Impact from Arctic shipping

Due to the decrease in the Arctic Sea ice, shipping in the Northwest Passage has now been ongoing for a decade during the summertime. Given the rate of climate change, the NorthWest Passage is likely to be available during summers in the near future (Figure 3.4). Both these passages create new opportunities for efficient trade between countries and regions in the North Pacific and those in the North Atlantic.

The effects of opening these new shipping routes on the Arctic ecosystem are not well understood. Recent research by Prof. Landrø et. al. has shown the possibility to use submarine cables to monitor movement and behaviour of marine mammals. [48] Our current understanding of marine mammals in the Arctic is severely limited and a better knowledge of the migration, mating, and feeding patterns of marine mammals and their behaviour is key to limiting the impact of Arctic shipping on these key species in the Arctic ecosystem.

Figure 3.4 *Shipping across the North West Passage (Source: Traceready.ca)*

45 What is the Atlantic Meridional Overturning Circulation and its role for our planet?

46 ECMWF - European Centre for Medium-Range Weather Forecasts

47 Destination Earth | Shaping Europe's digital future

48 Simultaneous tracking of multiple whales using two fiber-optic cables in the Arctic

3.1.3 Arctic marine geology and geophysics

The Arctic Ocean is a complex and dynamic geological setting. The dynamics are driven by several interlinked processes. It is the only ocean with two parallel volcanic ridges and it is nearly completely surrounded by passive continental shelves and intersected by high rises (Figure 3.5).

Climate warming leads to the melting of glaciers and ice sheets surrounding the Arctic Ocean, resulting in uplift of the surrounding continents and release of gases from the thawing of the frozen reservoirs that are buried in the sediments. Together, these processes lead to large instabilities in the Arctic Ocean that trigger earthquakes and landslides. Cabled real-time sensors on the seafloor will act as near source seismometers for earthquakes and movements of the cable can be detected and used to detect landslides and uplifts.

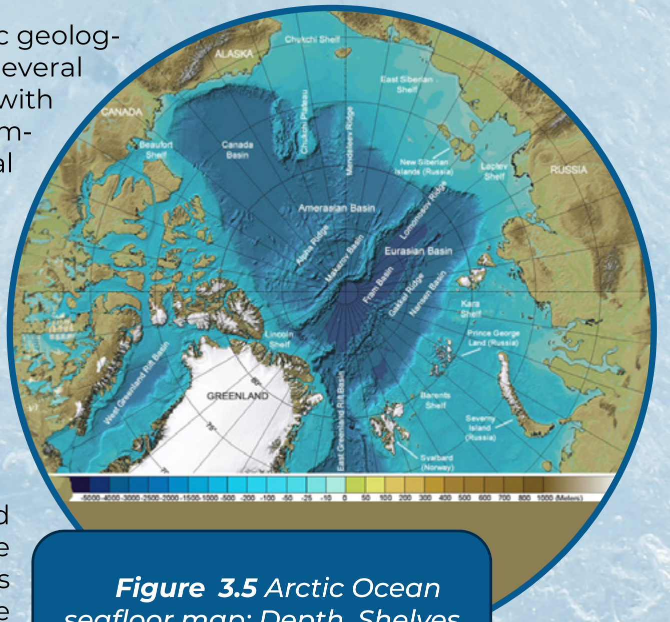


***Figure 3.5** Arctic Ocean seafloor map: Depth, Shelves, Basins and Ridges (Source: geology.com)*

3.1.4 Very-long baseline interferometry and satellite orbit positioning

Figure 3.6 shows the locations of the Very-Long Baseline Interferometry (VLBI[49]) stations in the Northern Hemisphere. These are primarily used for radio astronomy measurement and for geodesy. For both purposes, VLBI uses simultaneous observations from multiple sites and requires both extremely precise timing and transfer of large amounts of data to correlators that determine relative shifts between parameters recorded at each observatory.

Radio astronomy is key for advanced research in areas such as distant stars, supernovae, black holes, and the early development of the universe. VLBI geodesy is fundamental to all mapping of the Earth since the radio antennas are pointing towards the only fixed point, e.g. stars and quasars, whose relative positions on earth can be reliably established with high precision, down to the millimetre scale. It is also the only reliable way to establish changes in the Earth's rotations, the positions of the Earth's rotational axis, and the movement of tectonic plates relative to each other. These parameters are widely used by mapping authorities and satellite operators to position geographical features and to correct positioning systems such as the EU's Galileo System[50] and the USA's Global Positioning System (GPS). These parameters can also be used for determining increased risk of earthquakes by measuring tension build-ups between the tectonic plates. Furthermore, global ice melting and the sum of atmospheric pressures along the equator are also of interest to be observed as they influence the earth rotation.

Connecting VLBI stations in Europe, Asia, and the USA with fibre optic connections across the Arctic Ocean will significantly improve all aspects of this endeavour, including real-time observations. As the cable also can be instrumented with the high precision transfer of signals from next generation optical atomic clocks, laser cavities, and frequency combs, this can improve both quality and reliability of the VLBI data. Interconnected optical atomic clocks with ultra precision accuracy, expected to be commercially available as of 2024, also open up new ways to detect and record gravitational waves. It is envisioned that an infrastructure with these kinds of interconnected clocks may detect earthquakes and tsunami risks with the speed of light, which would make it possible, using instant warning systems, to save many lives close to seismically unstable areas.

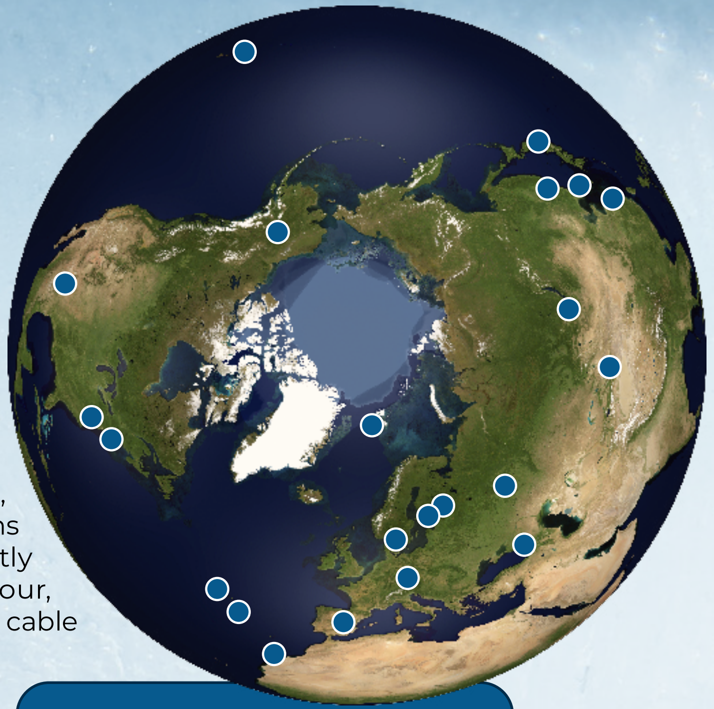


***Figure 3.6** Map of VLBI stations in the Northern Hemisphere (Source: NORDUnet)*

3.2 Sensing Opportunities and Science Collaborations

Many of the scientific opportunities mentioned in Section 3.1 are based on the possibility of equipping the cable system with various sensing technologies, some of which are already mature and some are in a very promising development. Examples include:

- Distributed Acoustic Sensing (DAS): Earthquakes are well recorded, even from far away continents. Tracking submarine mammals and distant storms. Micro seismology is also possible. Able to do recording and tracking of vessels and other human activities in proximity of the cable. A single DAS installation is currently limited to the first 150 km fibre segments, but provides real-time data.
- Cascading DAS. A cascading DAS system utilises specially crafted amplifier nodes, enabling to cover DAS sensing on the entire stretch of a submarine cable, e.g. all the way from Europe to Asia.
- State of Polarisation (SOP): Recording of the state of polarisation. Far less sensitive than DAS, but has a very long reach and could be applied on a regular optical communication channel in a legacy telecommunication system. However, localization of the recorded events demands a bidirectional setup and the use of interferometric or highly synchrinised clocks setup to calculate the distance to where events happen.
- Interferometric Phase Sensing: Sensing with extremely high stability laser cavities recording phase changes. Could be used on very long distances.

49 ESA - Observations: Very Long Baseline Interferometry (VLBI)

50 Galileo: European global satellite-based navigation system | EUSPA

Figure 3.7 *SUBMERSE Indicative site locations (Source: NORDUnet).*

- Bidirectional high-precision time transfer capability. Opens up for localization of SOP-events, comparison and transfer of atomic clock signals, and possible future detection of gravitational waves using next generation optical atomic clocks.
- Inductive coupling of sensors for data and power: One of the technology challenges or leaps we are working on with technology companies. With the help from AUVs, this enables dynamic and exchangeable branching to various external instruments from the cable's nodes such as repeaters and permanent sensors.

Already today, there are a number of science collaborations on using data collected from sensing equipment on submarine cable systems, and more can be expected to emerge in the near future, such as the EC co-funded project SUBMERSE,[51] paving the way for sharing sensing data and correlating events, including taking care of not disseminating sensitive data.

3.3 Key challenges for sustainable sensing in the Arctic Ocean

From the results of the Northern EU Gateway project, it has become clear that engagement with the scientific communities is paramount for a future SMART cable, as it must meet certain requirements in order for the scientific objectives to be fulfilled in a meaningful and cost-efficient way.

51 SUBMERSE project

Vision 2030

Most importantly, deployed sensors must demonstrate long-term reliability and control of eventual drift over the life-time of the cable. The target should be that sensors should be operational for 25 years since replacing faulty sensors on the ocean floor will be a complex and costly operation, especially if the faulty sensor was integrated into the submarine cable supporting life data traffic. Also, a sensor normally shows drift in the measured parameters and this must be addressed upfront. Either, the sensor should demonstrate long-term stability, i.e. no drift, or the drift should be known and constant for the sensor, or a means to continuously calibrate the sensor with high precision must be available.

The surrounding environment will have an effect on the sensors. In some areas, a high rate of sedimentation or biological activity can lead to a change in the sensors' contact with its surroundings, leading to drifting measurements. The cable can also be placed in an unstable area, leading to shifts in its position. A shift in the cable's position must be identified and there should be ways to deduce the location of each of the sensors.

Ideally, the integration of the sensor and cable should allow for easy replacement or upgrade of the sensors and the possibility to add branches. Adding branches, either to locations on the seafloor away from the cable or as floating devices in the water column above the cable will significantly increase the scientific potential of a SMART cable. To do this, the operator of the SMART cable sensors must have the technical and logistic capabilities to access the cable using Remotely Operated Vehicles (ROVs) and the sensor/cable interface should be designed to accommodate this.

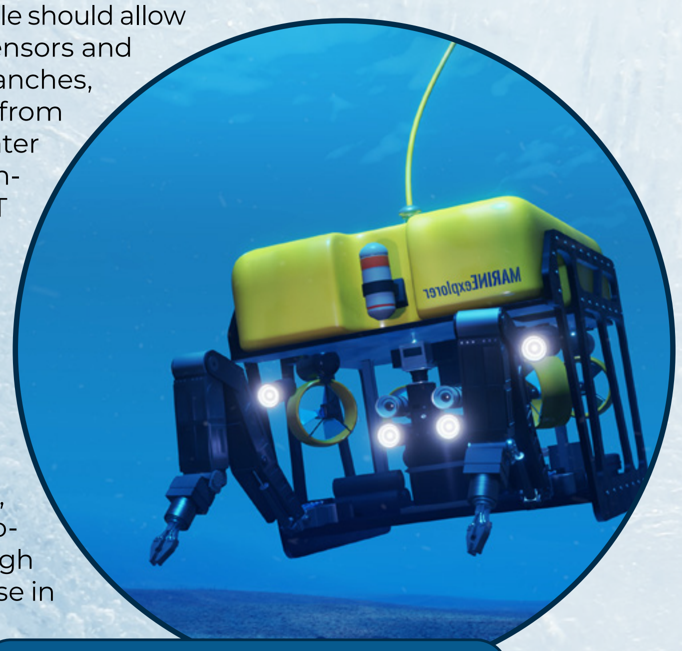


Figure 3.8 *3D rendering of a subsea remotely operated vehicle (Source: Vismar UK/Shutterstock)*

Modern oceanographic research is shifting towards unmanned sensor platforms, such as drifting buoys, gliders and Autonomous Underwater Vehicles (AUVs). Although already deployed in many settings, their use in ice covered areas has had a profound impact on our knowledge, since they can access water volumes otherwise out of reach.[52] These systems provide valuable information for science in general and for environmental monitoring in particular. They have two drawbacks, i.e. their position, when operating under water, is difficult to establish with high precision and they have limited capacity for transferring information or to receive instructions. Developing a SMART cable system that allows for positioning of an AUV and communications with an AUV would bring large benefits.

52 Pathways and modification of warm water flowing beneath Thwaites Ice Shelf, West Antarctica | Science Advances

4. STAKEHOLDER ANALYSIS

Any ambitious project heavily relies on having a vast number of different stakeholders who engage and make substantial contributions to the successful implementation of the project. The necessity to involve participation from many competent parties carries much higher importance in this project than in a regular submarine cable project along more traditional routes. This is due to the relatively higher costs of building the submarine cable systems across the Arctic region, the unique scientific and societal high value these cables represent, and the organisational and technical challenges associated. The global megatrend of digitalisation increases the global reliance on data and reliable data transfer, and is an important aspect for all stakeholders.

4.1 Private and Commercial Stakeholders

Similar to the majority of cable systems around the world, the vision for submarine cables through the Arctic is to be financed and operated as a commercially viable project by commercial operators.

4.1.1 Carriers and OTTs

The vast majority of submarine cable systems in operation today are owned and operated by consortiums of telecommunications carriers, e.g. Cinia, Orange, AquaComms, and Bulk, and by over-the-top providers (OTTs), e.g. Google, Meta, Amazon, and Microsoft. Also, for the submarine cables across the Arctic Ocean, it is foreseen to be the desirable type of set-up to have one or more carriers be leading the implementation and operations.

For quite a number of years, an observed tendency is for the OTTs to become full owners of new submarine cable systems rather than just tenants. This is witnessed with cables such as Dunant,[53] Grace Hopper,[54] Equiano,[55] and Topaz,[56] all four fully owned by Google. However, this does not exclude joint ownership between OTTs and carriers, as can be witnessed with cables such as MAREA[57], that has Meta, Microsoft, and Telxius as owners, and 2Africa,[58] that has Meta and others as owners. It is important to note that some NRENs have already become co-owners of a submarine cable systems, e.g. JGA-S[59] that has the Australian NREN AARNet plus Google and RTI as co-owners.

53 Dunant

54 Grace Hopper

55 Equiano

56 Topaz

57 Marea

58 2Africa

59 Japan-Guam-Australia South (JGA-S)

Moreover, Norwegian NREN Sikt[60] laid two submarine cables between the cities of Longyearbyen and Ny-Ålesund on Svalbard, that in addition to high data volume transfer capabilities also now are used for fibre optic sensing in a very scientifically interesting region of the planet. Figure 4.1 shows the used international bandwidth by source.

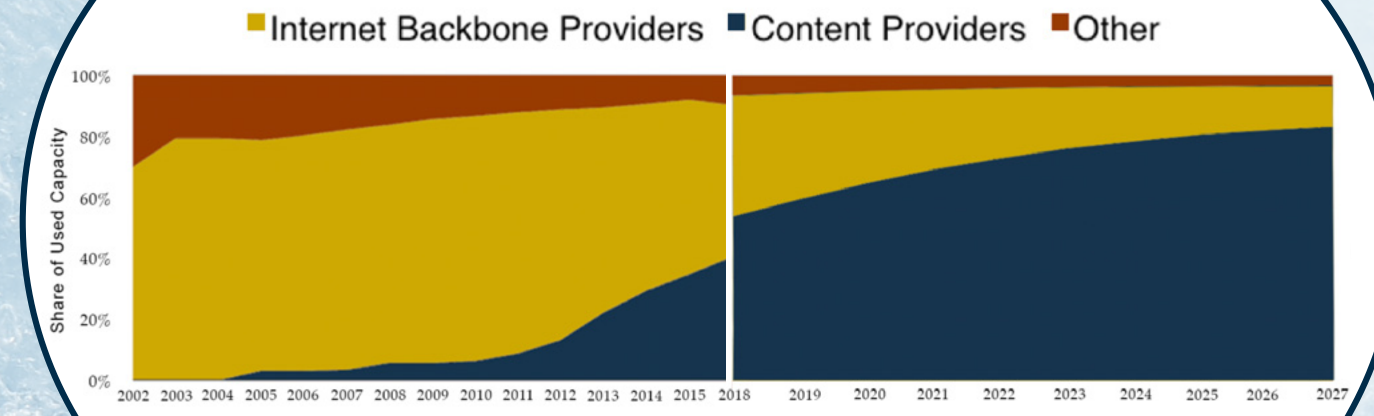


Figure 4.1. *Share of used capacity on submarine cables (Source: NORDUnet, based on data from TeleGeography)*

The implementation of the Vision 2030 is relying on having a larger number of involved participants or anchor tenants, due to the relatively higher initial cost of this project, compared to, for instance, a submarine cable system through the North Atlantic Ocean. On the other hand, it is also expected that it will raise the great interest of operators because of the relatively short path between Northern Europe and East Asia and the pioneering effect of the cable, which will be the first and, for a number of years, the only resilient cable system across the Arctic Ocean. Due to the unique geographic layout of the proposed cables, it is expected to substantially attract and supplement the increased need of intercontinental network capacity. Therefore, within the context of the Northern EU Gateways project a large effort has been made to engage with many telecom operators and some of the OTTs in the early stages, to create awareness and to listen to their input.

60 Sikt

4.1.2 Data Centre Market

Data centres rely on robust, resilient, and diverse network connections. The availability of the required network resources has a major influence on the placement of new data centres. Besides all the benefits highlighted in Vision 2030 of a submarine cable system crossing the Arctic region, the Green Digital initiative, supporting the placement of new large data centres in the High North regions of Europe, is an integral part of the Vision 2030. In the regions of Europe above the polar circle, power is less expensive [61] , has a much greener profile than in the rest of Europe, while cooling requires less energy due to the lower average ambient temperature, and is readily available. This makes Vision 2030 contribute to reducing the energy consumption and greenhouse gases emissions, compared to other possible locations of similar data centres in Europe. While data centres are not foreseen as members of the consortium owning the proposed cable, they and their tenants are certainly expected to be among the bigger users of a resilient submarine cable system through the Arctic Ocean.

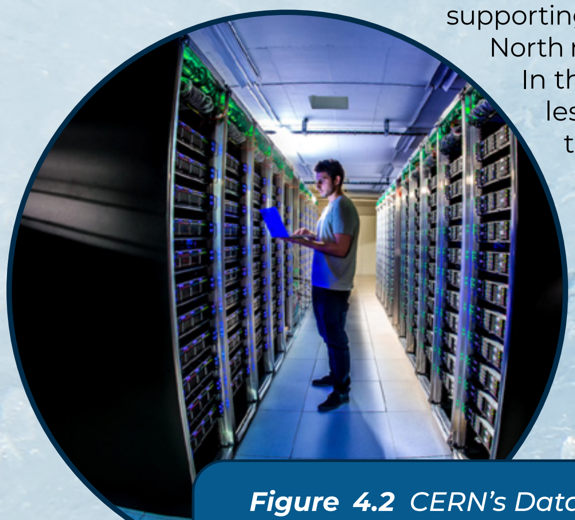


Figure 4.2 *CERN's Data Centre (Source: Robert Hradil, Monika Majer/ProStudio22.ch)*

4.1.3 Other industry sectors

Some cable systems, due to their low latency, are heavily used by the financial sector. An example of such a cable is EXA Express [62] between the UK and the USA, a cable system owned by EXA Infrastructure. [63] The efficiency of high-speed financial trading, also known as Algorithmic Trading or Algo Trading, is dependent on reduced delay between traders located in different parts of the world. [64] While there are a few initiatives to use short-wave based radio communications for this, notably the Shortwave Modernization Coalition [65] , all services in operation today in this field are based on cable systems. Therefore, the financial system can also be expected to become users of the submarine cable systems as a result of the implementation of Vision 2030, since it will provide the communication path of least delay between Europe and East Asia.

There are a range of other sectors that are foreseen to benefit from the Vision 2030 implementation, i.e. satellite operators, regular financial trading, emergency services, telemedicine, science and research, and users of high-precision time and frequency services on a global scale.

61 Due to capacity limits of the electricity transmission infrastructure, all the surplus capacity of the hydro power in the north can not be transmitted to the central European area, which is the reason for having a number of electricity price areas in the Nordic countries. Generally, the more northern the area, the lower is the average power price.

62 EXA Express

63 EXA Infrastructure

64 The Future of Subsea Cables

65 High-Frequency Traders Want Low-Frequency Radio Waves

Modern manufacturing industries generate increasing amounts of data. Data that, among other things, companies are using for quality control and are analysing to improve products and manufacturing efficiency. A combination of low-cost green energy with fast and reliable global data communication will produce a competitive setting in any region wanting to attract modern and high-value manufacturing facilities.

Revolutionising both telecoms and science

Vision 2030 has the huge potential to revolutionise both telecommunications and sciences. For telecommunications, implementing the Vision 2030 will add completely new routes to the world of submarine cables, through an ocean that does not have any submarine cables today, hence adding to the resilience of the Internet at large. For science, equipping the cable with scientific sensors will enable continuous data collection from an area that has only had sporadic measurement data, for many Arctic sciences improving their way of operations leading to new scientific insights, which is highly important for a better understanding of the threat and the impact of climate change.

4.2 Public Stakeholders

Public stakeholders themselves are big users of data communication and generate and transport large amounts of data. From this aspect, and from the aspect of them being able to help close the funding gap, they are important players in the implementation of Vision 2030.

4.2.1 Governmental Bodies

Various governmental bodies are interested, as this provides them with:

- A trusted and secure infrastructure, in particular for collaboration between governments. They must be able to rely on the integrity and confidentiality of communication flows. As outlined in section 1.1, the implementation of Vision 2030 offers a communications system with a security profile better than any other high-bandwidth facility available today between Europe and Asia, and
- Access to unique datasets generated from the fibre sensing capabilities

in the submarine cables over the Arctic Ocean. The most obvious uses of these unique datasets are:

- Contribution to keeping track of shipping and fishing activities,
- Helping search and rescue activities,
- Early warning systems for natural disasters, and
- Monitoring and assessing risk for the cable´s integrity.

4.2.2 Research & Education Networks (NRENs) and HPC Centres

In the early days of the Internet, NRENs helped the Internet deploy and grow. The Research & Education Networks were and are seen as experienced and neutral players in the area of Internet infrastructure expansion and technology growth, due to successfully solving and innovating advanced network solutions over many years for the demanding research community with extreme needs regarding traffic dynamics, functionality, and security. Moreover, Research & Education Networks are excellently positioned to bring together parties from different fields and to funnel co-funding to help create a sound business case. By working with the European NRENs, European digital sovereignty and European industrial development can be further stimulated and enhanced.

Figure 4.3 *EuroHPC supercomputer LUMI (top) and Japanese supercomputer Fugaku (bottom) (Sources: CSC, RIKEN)*

The NRENs are the carriers of traffic for the research and education sectors. The Nordic NREN community is a major driver behind the Vision 2030 and is looking to secure dedicated resources on the Arctic route. As NRENs are already paying for transmission capacity between Europe and Asia, the financial contributions from the NRENs can to a large extent be based on existing funding sources and, through this, help the business case.

Public entities, such as the NRENs, can be instrumental in creating the initial business case for a submarine cable project by being anchor tenants and committing to secure resources in advance, and thus playing an important part on the financial sustainability of such a project. Moreover, by their deep roots in the scientific communities, NRENs can be instrumental in pairing the scientific demands with the data transmission demands, and bring communities together to achieve this.

The scientific High Performance Computing (HPC) centres are a particular kind of data centre, usually purpose-built and owned by the higher education and research sector. The HPC centres will benefit from this project in the same ways as described for the commercial data centres and even more so, as an important number of research areas are expected to move petabyte sized datasets between such centres around the globe on a regular basis. An example of this is the collaboration between the EuroHPC[66] supercomputer LUMI,[67] located in Kajaani, Finland and the Japanese supercomputer Fugaku[68], located in the Riken Center for Computational Science[69] in Kobe, Japan. Given that Japan and the EU have established a partnership to support the digital transformation, more and closer collaborations in the data and computing domains are envisioned.

Data centres, for HPC and storage, are expected to gravitate more and more to locations that have a surplus of renewable and carbon-neutral energy supply with easy cooling and options to reuse waste heat. Also, they need inter-connectivity, and that drives trans-Arctic connectivity between Europe and Asia.

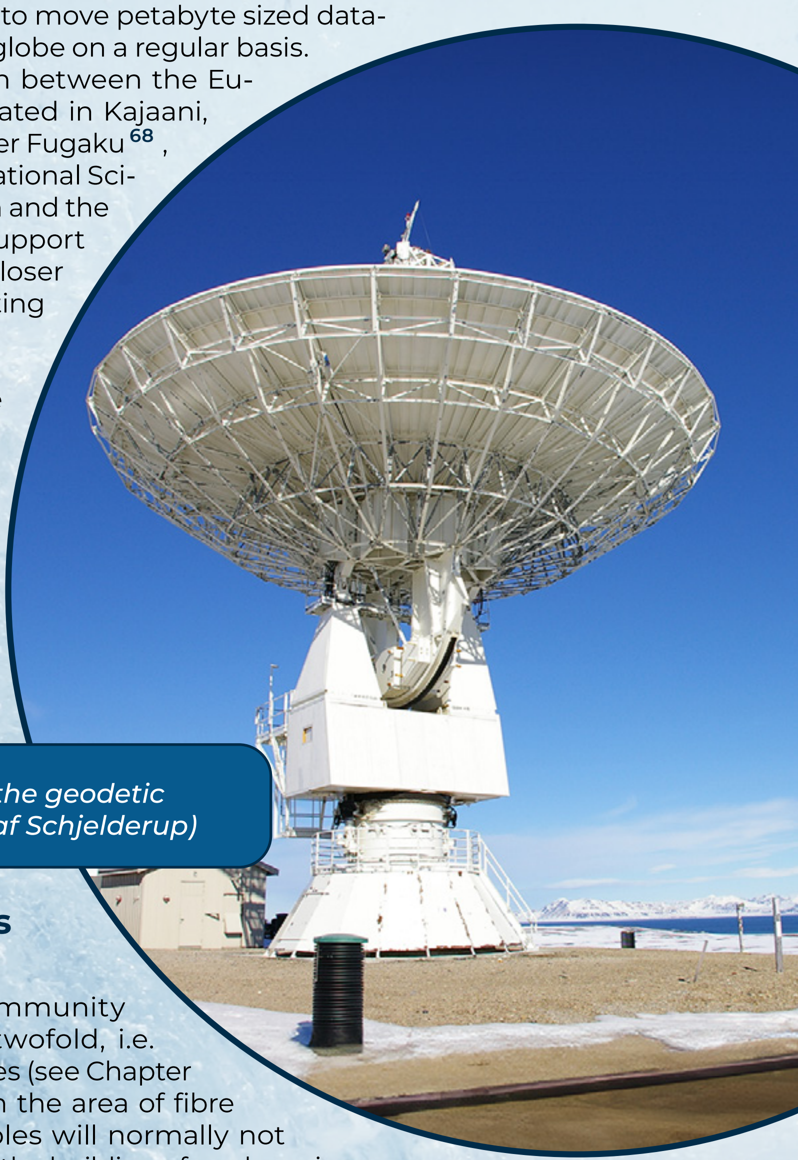


Figure 4.4 *Ny telescope at the geodetic observatory Rabben (Source: Olaf Schjelderup)*

4.3 Scientific Stakeholders

The interest from the scientific community in submarine cable in the Arctic is twofold, i.e. communications and sensing capabilities (see Chapter 3). Funding for the research projects in the area of fibre sensing technologies and SMART cables will normally not include direct contributions to financing the building of a submarine cable system itself. This part is usually under the responsibility of the NRENs.

66 EuroHPC JU

67 LUMI - Services for Research - CSC Company Site

68 Supercomputer Fugaku : Fujitsu Global

69 RIKEN

5. RISK ANALYSIS AND MITIGATION

Building a new submarine cable system always comes with risks. Building a submarine cable system through the Arctic Ocean comes with additional risks during deployment, due to the harsh conditions in the Polar region. These risks are known and so are their mitigations. However, when the cables are finally laid under the North Pole ice, they will be in one of the safest places on the planet, protected by both the deep waters and the ice cover. As mentioned before, the implementation of Vision 2030 is realistic, as proven by the works from the Swedish Polar Research Secretariat (see Appendix B).

To mitigate the risks, careful planning, risk assessment, project management, and collaboration among stakeholders are essential. Additionally, contingency plans, appropriate insurance coverage, and compliance with legal and regulatory requirements will help address all of the potential challenges associated with building a new submarine cable system through the Arctic Ocean between Northern Europe and East Asia.

5.1 Risks during preparation phase

The Arctic region is a subject of interest and competition among several countries due to its strategic location, vast natural resources, and growing opportunities for shipping and resource extraction as a result of climate change. Several countries have made claims to extend their Exclusive Economic Zones (EEZs) in the Arctic, but these claims do not influence the right to lay a submarine cable inside the EEZ according to international law. Freedoms established in UNCLOS[70] allow the laying, repairing, and maintaining of submarine cables, however some of the domestic regulations conflict with those freedoms. The state application process establishes requirements before exercising those activities. In light of this, a coastal state may require an application process to conduct activities in the EEZ.[71]

Figure 5.1 *Arctic Administrative Areas map. (Source: Arctic Centre, University of Lapland)*

This implies that careful route planning is more important than ever. While Arctic Connect[72] started out with route planning through the Northeast Passage and Far North Fiber is planning to go through the Northwest Passage, for Polar Connect we are aiming at a complementary route. The closer to the Geographic North Pole the route is planned, the more considerations have to be made. For Polar Connect, the envisioned route stays west of the Geographic North Pole, and aims to stay in or close to the EEZs of Norway (including Svalbard), Greenland (Denmark),

70 United Nations Convention on the law of the Sea

71 International regulation of Submarine cables. An analysis of the different States' practices.

72 Arctic-Connect

Canada, and the USA wherever possible. Detailed route studies will look into advantages and disadvantages of where to project the cables in our further studies. The sea floor of the Arctic Ocean is rich with localised volcanic activity and steep sub-sea slopes, as also is the case for the North Atlantic Ocean therefore special consideration must be taken into account in the planning of the routes crossing these areas.

Before the laying of a submarine cable can commence, research of the fishing regulations and dialogues with the fishery organisations relevant for the area needs to be conducted. While trawling is a hazard for a submarine cable, this can be mitigated by ploughing the cable into the seabed.

Before building a cable landing station in a region inhabited by indigenous people, e.g. in Northern Canada or in Alaska, it is crucial to engage in meaningful consultation and collaboration, to respect their rights and cultural heritage, to minimise any environmental impact, and to provide opportunities for economic and social development. The interests and concerns of indigenous communities should be at the forefront of the infrastructure project in their regions to ensure a mutually beneficial and respectful outcome. However, if these concerns would not be taken into account at an early stage of the project, it could result in risks, such as delays, extra expenditures, and in worst case - a sense of exclusion.

On Svalbard, the cultural heritage law of Svalbard is relevant for getting a permit for a landfall and to avoid shipwrecks in the surrounding waters.

Last but not least, for a submarine cable with sensing capabilities, the permitting process will have potentially longer lead times that have to be taken into account.

5.2 Risks during building phase

The laying of a submarine cable system in open water is a well-known technology.[73] Cable laying in areas with heavy ice cover, such as the North Pole region, or with floating icebergs requires special consideration. Navigating through an area with heavy ice cover does not only require the availability of a polar class cable laying vessel but also the availability of up to two ice breakers doing advanced ice management to make a free passage for the cable ship, which needs careful planning as there is only a limited number of such vessels that can do this.

At this time, such a vessel does not exist in Europe. The SPRS Report (Appendix B) shows that a regular cable laying vessel can relatively easily be converted into a polar class cable laying vessel or an existing large ice-class vessel can be refitted for cable deployment. Also, in heavy ice conditions, a polar class cable laying vessel needs to be accompanied by two polar class icebreakers, as explained in Chapter 2. However, the risks for deployment are higher for a route within the Greenland EEZ than for the shorter route directly across the Arctic Ocean closer to the Geographic North Pole. This is due to the difficult ice conditions north of Greenland. The close collaboration with the world´s most capable and experienced organisation on ice

73 The process of submarine cable laying (video)

management, the Swedish Polar Research Secretariat, adds confidence that the laying risks can and will be kept to a minimum.

Special care needs to be applied to the ecosystem impact by cable laying in the Arctic. E.g., environmentalists may raise concerns about the impact of cable installation on marine ecosystems. By working with marine ecosystem experts, the cable laying can be planned in a way that marine life will be protected and unharmed. Environmental topics should be in a key role of planning and implementation, because the region is in many ways fragile and untouched.

From an investors point of view, like with any submarine cable project, the construction costs can exceed the original budget. For a submarine cable system going through a new route this risk is higher. This risk can be mitigated by conducting a thorough feasibility and seafloor mapping studies, engaging experienced contractors, and having contingency plans for unforeseen expenses. Also, there can be delays in the project's completion. This can be mitigated by implementing strict project management practices, penalties for delays, and regular progress reporting.

5.3 Risks during operations phase

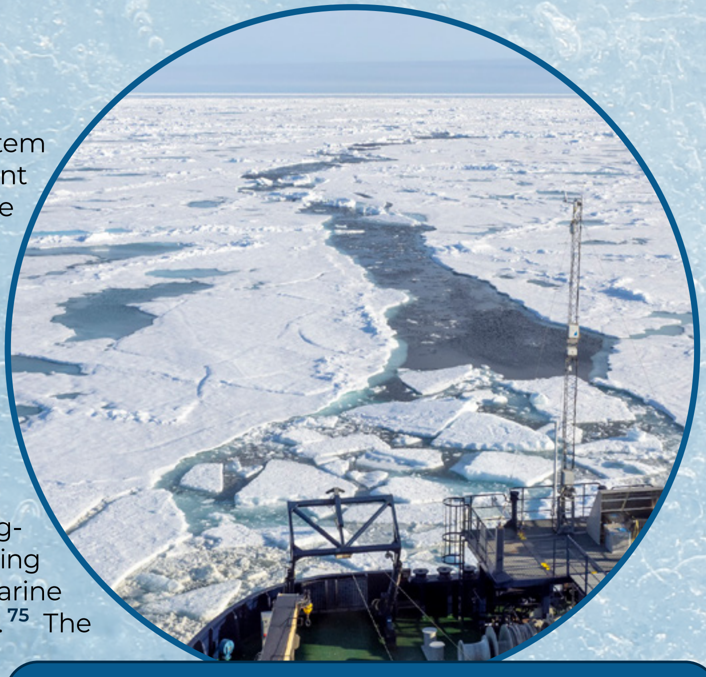


Figure 5.2 *Navigating in heavy ice cover, requires specialised vessels and careful planning (Source: Swedish Polar Research Secretariat)*

The operational phase of every submarine cable system requires preparation for cable breakage or equipment malfunction. This need is not special to submarine cable through the Arctic Ocean but to submarine systems in general, however this needs further investigations as the full path of Arctic submarine cables is currently not covered by any of the submarine cable maintenance zones. The Atlantic Cable Maintenance Agreement (ACMA) goes all the way North of Svalbard, but not across the North Pole and into the Canadian Archipelago.[74]

The most common causes of submarine cable breakages are fishing activities and vessel anchor drift. According to TeleGeography in 2017, more than 60% of all submarine cable outages were caused by these two root causes.[75] The July 2023 report from ENISA states, based on data from the International Cable Protection Committee (ICPC)[76] from 2022, that almost 40% of submarine cable faults are due to anchoring or fishing.[77] In the ice-covered areas of the Arctic Ocean, however, there is no fishing or shipping in general, so the chance of a breakage due to this is very limited. However, other causes of a submarine cable breakage such as a natural disaster, e.g. in an area of seismic or volcanic activity, or malicious treatment of the submarine cable system could still happen. This risk is mostly mitigated through careful route planning. The causes of harm to cable networks are addressed in the in-depth analysis "Security threats on undersea communications cables and infrastructure - consequences for the EU".[78]

74 Subsea Cable Maintenance

75 What happens when submarine cable breaks.

76 International Cable Protection Committee

77 Figure 5 from the ENISA Report ' Subsea Cable - What is at Stake'

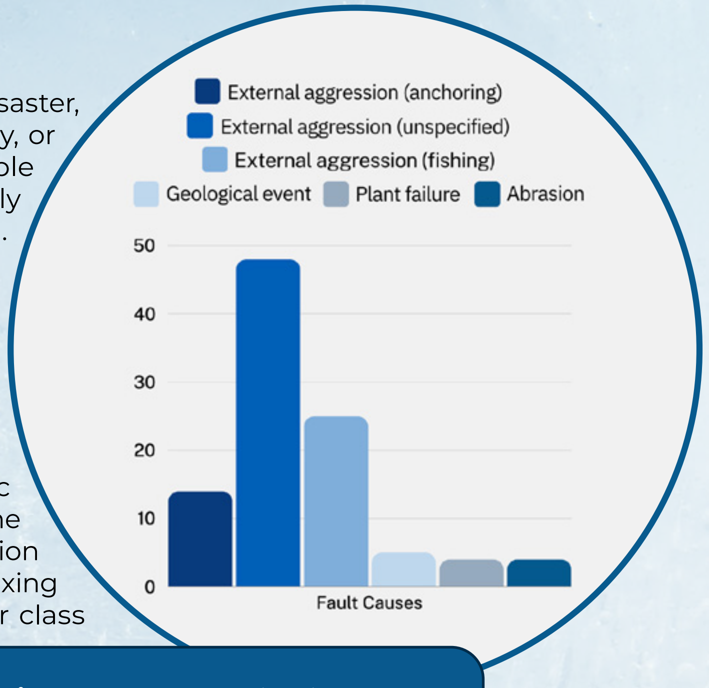


Figure 5.3 *Categorisation of cable faults (Source: ICPC report 2022)*

Fixing a cable breakage in the Arctic area has its special considerations, as the Arctic area waters are under ice for a large part of the year. If a cable break or equipment malfunction occurs under ice cover in the Arctic Ocean, fixing the issue requires ice breakers and a polar class cable repair vessel.[79]

In the unlikely event of a cable breakage under ice cover in the Arctic Ocean, as highlighted in Chapter 2 and Appendix B, it may take more time than a fixing cable in open waters. To mitigate this risk, the users of the cable system must have alternative routes available. This also highlights the importance of having more than one cable system in the Arctic, like proposed in the Vision 2030. Also, the costs of fixing an issue with a submarine cable under the ice may vary according to the season, which must be taken into account in the operational life cycle financial planning. This involves priority agreements with organisations with ice breakers, AUVs, and cable splicing capabilities. On the other hand, having a submarine cable under the ice, in the deep ocean, severely reduces the risks caused by typical marine traffic or fishing along the route where repairs are most challenging.

Environmental risks for a submarine cable across the Arctic Ocean are the same as for other submarine cables, e.g. slope instabilities, earthquakes, and submarine volcanic eruptions. Both routes along the Greenland EEZ and a northern route closer to the Geographic North Pole are deep enough to be safe from stranding icebergs. There is a small risk of icebergs grounding on the cable close to the landing point in Ny-Ålesund. This can successfully be mitigated with horizontal drilling technology, which moves the cable´s sea entry point to 30 metres below sea level. However, in that area the cable is easily accessible all year around and can be repaired using standard cable repair technology. Also, possible branching points on the North American coast towards the Arctic Ocean can be affected by stranding icebergs. Though this will have a local impact, it will not impair the communications between Europe and East Asia.

Sensing data from submarine cables can contain sensitive information that should not be shared openly. Sensing capabilities must and can be set up in a way that

78 Security threats to undersea comm. cables and infrastructure – consequences for the EU

79 Chapter 2 and Appendix B have further details.

sensitive data, especially regarding national security, is available for authorised personnel only. This includes ensuring alignment with governmental policies for keeping potentially sensitive data under relevant security measures and available for authorised personnel only. Current seafloor observatories therefore have the means to either scrub or filter the data from sensitive information prior to sharing or the ability for trusted external entities to turn off the sensing capabilities when deemed necessary. A SMART cable across the Arctic will pass through the EEZ of several countries. In order for the scientific community to access the collected data, there will be a need to establish relations with trusted entities in all these countries and to identify one or more suitable data holders that have the trust to manage the sensors and the raw sensing data. Contacts with partners in all relevant countries have been established and already exploring the possibility for a common solution is underway.

5.4 Risks at end of life

A submarine cable system is designed with a lifetime of at least 25 years in mind. This is due to a previously expected lifetime of 25 years of optical amplifiers on the ocean floor, but there is evidence that the expected lifetime can be longer. It may therefore happen that a cable system is in full production for more than 25 years, but inevitably there comes a time when the submarine cable is at its end of life.

Figure 5.4 *There is a small risk of icebergs grounding on the cable close to the landing point in Ny-Ålesund (Source: Anna/NORDUnet)*

The end-of-life management of a submarine cable involves several responsibilities for the owner(s). Key requirements typically include:

- Environmental Considerations: Owners are often required to adhere to environmental regulations and best practices when decommissioning a submarine cable. This includes minimising the impact on marine ecosystems.
- Cable Removal: In some cases, owners may be required to remove the entire submarine cable from the seabed. This can involve using specialised vessels and equipment to lift the cable and transport it to shore for proper disposal. Sometimes, the cable has become part of the marine environment and should for that reason be left alone.
- Communication with Authorities: Owners are usually obligated to inform relevant authorities and stakeholders about the decommissioning process. This ensures transparency and allows for coordination with other maritime activities.
- Risk Mitigation: Owners may need to take measures to mitigate any potential risks associated with the decommissioning process, such as avoiding damage to other cables, pipelines, or infrastructure in the vicinity.
- Legal and Regulatory Compliance: Compliance with national and international laws and regulations governing submarine cable operations and decommissioning is essential. This includes obtaining necessary permits and approvals from relevant authorities.
- Public Safety: Ensuring the safety of navigation and public safety during the decommissioning process is a critical requirement. This may involve marking the area to alert maritime traffic and taking precautions to prevent accidents.
- Financial Responsibility: Owners are typically responsible for covering the costs associated with the decommissioning process. This includes the removal of the cable, environmental remediation, and any other related expenses.
- Data Security and Confidentiality: If the submarine cable carries sensitive or confidential data, owners may need to take steps to ensure the secure and confidential disposal of any information stored or transmitted through the cable.

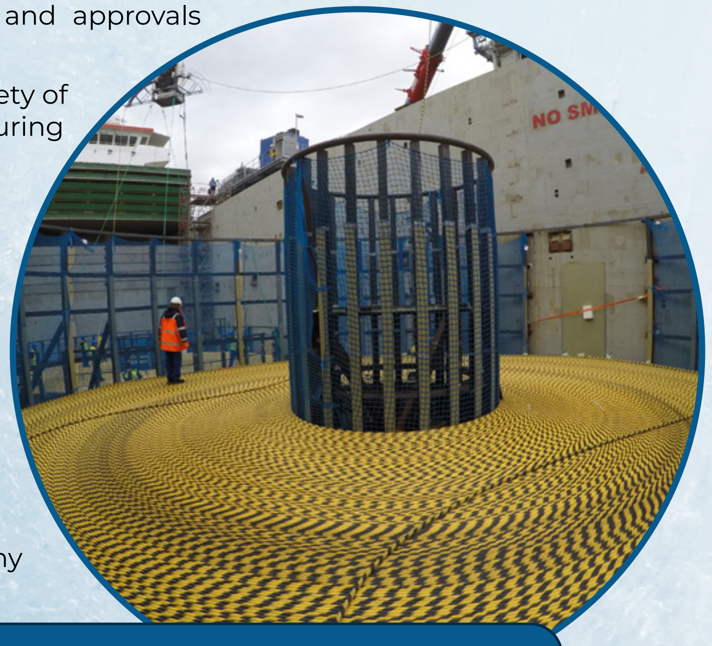


Figure 5.5 *Submarine cable loading to freighter vessel (Source: Korn Srirawan/ Shutterstock)*

It's important to note that specific requirements can vary based on the jurisdiction, the nature of the cable, and the agreements in place between the cable owners and relevant authorities. This will be further researched in due course, while the preparations for implementing Vision 2030 continue.

APPENDIX A. SECURING CONNECTIVITY: THE ROLE OF SUBMARINE CABLE SYSTEMS AND OTHER TECHNOLOGIES

Submarine cables play a crucial role in global telecommunications by facilitating the transfer of data across oceans and seas. Their role is often unknown or underestimated. In this Appendix, an overview is presented to increase the knowledge of submarine cables. Also, the role of satellites in data transmission is covered, by highlighting how they play an important role for data transmission, i.e. in the last mile.

A.1 Submarine cables – an overview

In June 2023, TeleGeography [80] counted 485 submarine cable systems in production, with another 70 being planned. [81] Figure A.1 shows the world's submarine cable systems as of November 2023. [82]

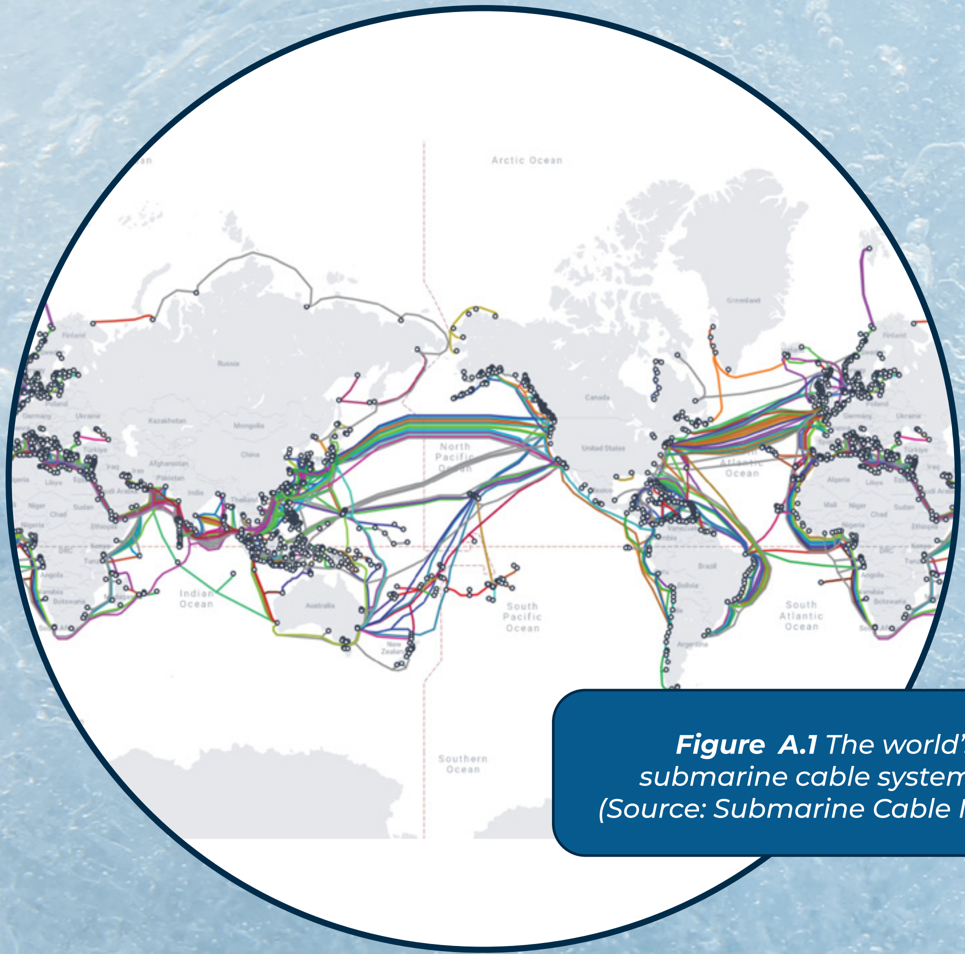


Figure A.1 *The world's submarine cable systems (Source: Submarine Cable Map)*

80 TeleGeography

81 How Many Submarine Cables Are There, Anyway?

82 Submarine Cable Map

Vision 2030

The Internet is built on these submarine cable systems, and on the terrestrial fibre infrastructures.

From Figure A.1 it is clear that the Arctic Ocean and the Southern Ocean are the only two oceans that have not been used for submarine cables until today. Hence, adding a submarine cable in these oceans increases the resilience of the overall data transport fabric.

A.2 Data Lakes and the increasing data transport needs

Data lakes [83] play a crucial role in managing and deriving value from the vast amounts of data generated across various industries. Compliance with data protection regulations, cloud adoption, integration with big data technologies, and a focus on security and governance are key considerations in the implementation and management of data lakes. Superb data communications facilities are extremely important for data lakes, as compute, storage, and data communications need to go hand in hand, in order to create a valuable and useful resource.

With the growing of data sets, the requirements on compute, storage, and data communications grow with it. Implementing Vision 2030 brings superb data communications facilities to Europe, to enable seamless, reliable, and secure data communications with partners in Asia and North America.

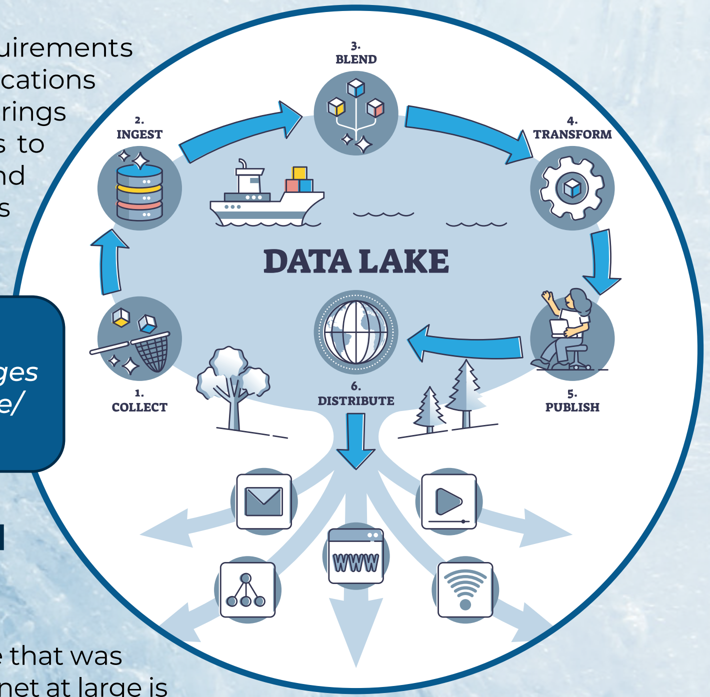


Figure A.2 *Data lake principle explanation with work cycle and stages outline diagram (Source: VectorMine/ Shutterstock)*

A.3 Increasing Security and Resilience

By building a submarine cable on a route that was not used before, the resilience of the Internet at large is hugely improved. Distributing cables along different routes helps minimise the risk of a single point of failure due to natural disasters, human activities, or accidents.

Both Far North Fiber and Polar Connect will bring added resilience, as the Arctic Ocean has not been used before for laying submarine cables. European-led projects increase the security of supply for European businesses, governments, and for research and education and they add to European digital strategic autonomy.

83 A data lake is a pool of data building on the federation of distributed data sources.

Submarine cable security, i.e. the securing of the cable itself, is of utmost importance. A combination of measures will protect the cable from damage, e.g.:

- Physical Protection: Reinforced cables and cables buried deeper under the seabed are less susceptible to damage from activities such as fishing, anchoring, or dragging equipment.
- Surveillance and Monitoring: Constant monitoring of the health and status of submarine cables, using sensing technology and other measures, helps to detect potential issues or disruptions early on, allowing for timely intervention, and implementing surveillance systems can help detect unauthorised activities around cable landing sites, such as anchor dragging or attempts to sabotage the cables.
- Security Protocols: Implementing strict security measures at cable landing stations, where submarine cables connect to terrestrial networks, helps prevent unauthorised access and tampering and implementing access control measures, both physical and digital, at various points along the cable route helps prevent unauthorised access and tampering.
- International Cooperation: Establishing international agreements and legal frameworks for the protection of submarine cables can deter malicious activities and provide a basis for cooperation in case of incidents.
- Deterrence Measures: Raising awareness about the importance of submarine cables and the severe consequences of tampering can act as a deterrent and enforcing strict legal consequences for intentional damage to submarine cables can discourage malicious activities.
- Repair Capabilities: Enhancing the capacity to quickly identify and repair cable faults ensures a faster restoration of services after a disruption.
- Cybersecurity Measures: Implementing robust cybersecurity measures to protect against cyber threats, such as hacking or denial-of-service attacks, helps ensure the integrity and availability of submarine cable networks.

Figure A.3 *Cable Innovator (C-Power) (Source: Hans Hillewaert)*

On 26 October 2023, a public hearing in the European Parliament hosted by the Subcommittee on Security and Defence (SEDE) titled 'Rising geopolitical tensions: the protection of subsea infrastructure, including communication cables and pipelines' took place[84] . The summary is presented here:

84 The recording of the hearing

"The Committee hearing on the protection of subsea infrastructure, hosted by the Subcommittee on Security and Defence, centreed on the escalating geopolitical concerns surrounding the safeguarding of critical subsea infrastructure, encompassing communication cables and pipelines. The meeting featured three key experts - Tobias Liebetrau, a researcher from the University of Copenhagen, Scott Spicer, leader of the Mass Casualty Commission Emergency Response Investigative Team, and James Appathurai, the Deputy Assistant Secretary General for Emerging Security Challenges at NATO - who provided valuable insights into these infrastructures, which are indispensable for secure supply chains and communication networks in the European Union. Notably, nearly 99% of global digital communications rely on subsea cables. Furthermore, the absence of comprehensive regulation and international legal safeguards has left them vulnerable to espionage and disruptions, posing a significant threat to European security and investments. Recent incidents, including damage to the Baltic connector gas pipeline and subsea telecommunications cables in the Finnish Gulf, have magnified these concerns, with Finland and Estonia suspecting acts of sabotage and seeking support from the EU and NATO, revealing the vulnerability of offshore critical infrastructure. Adding to the complexity is the management of subsea cables by the private sector, with Chinese companies having significant market share.

Figure A.4 *SpaceX, Falcon 9 rocket (Source: Public Domain)*

The hearing featured insight from Mr. Liebetrau, who emphasised the need for cross-sector integration, legal harmonization, information sharing, and the deployment of advanced technologies to enhance the resilience of subsea and maritime infrastructure in the face of evolving threats. He underscored the significance of understanding both the European and regional contexts and urged efforts to strengthen knowledge, legal harmonization, information sharing, and coordination at both EU and member state levels to ensure the resilience of subsea and maritime infrastructure. Mr. Spicer outlined potential threats and effective communication strategies, underlining the importance of timely and fact-based information sharing to prevent the escalation of uncontrolled narratives. His five targeted policies, covering intelligence sharing, improved coordination, information surveillance, multi-agency response and training, and the creation of a comprehensive working group involving diverse stakeholders, were recognised as essential steps to fortify the protection and preparedness of subsea infrastructure.

Mr. Appathurai addressed critical concerns related to the protection of cross-border subsea infrastructure within the NATO framework, highlighting the deteriorating global security environment and the deliberate targeting of energy infrastructure by Russia. He stressed the importance of collaboration with the European Union to enhance the resilience of critical infrastructure and adapt to evolving security challenges. Russia's comprehensive mapping of global energy infrastructure, coupled with the growing cyber threats, has resulted in clear and present risks to these vital assets. The presence of Chinese owned or affiliated telecom companies in cable consortiums and future challenges, such as increased data flows and the electrification of energy infrastructure, have further complicated the security landscape. To address these challenges, NATO has taken proactive measures, including the swift deployment of military assets for deterrence and enhanced presence, the establishment of an undersea infrastructure centre for better awareness and preparedness, and the creation of networks with industry partners for information sharing."

A.4 Other technologies, Satellites

Satellites have not played a significant role in the backbone of the Internet, due to relatively low capacity and high latencies. Recent developments in Low Earth Orbiting (LEO) satellites, with two companies now offering commercial services, i.e. OneWeb[85] and SpaceX[86] with their Starlink[87] product, and others such as Telesat[88] and Amazon with their Project Kuiper[89], this is not expected to change. Submarine cable systems, with their huge capacities and relatively low latencies, are expected to carry the majority of the world's global Internet traffic.

The LEO Satellite products, however, are well positioned to help in bringing connectivity to hard to reach places, e.g. a polar research station on Greenland or a rural community in the Arctic, or moving objects, e.g. a research vessel. With their low orbit around the earth, they typically have modest latencies and with modern transmission technologies their bandwidth for individual or relatively small groups of end users is sufficient.

85 OneWEb

86 SpaceX

87 Starlink

88 Telesat

89 Project Kuiper

Vision 2030

APPENDIX B. FEASIBILITY STUDY REPORT ON ARCTIC ROUTE OPTIONS

In the context of the Northern EU Gateways Project, the Swedish Polar Research Secretariat (SPRS) wrote the report titled 'Cable-laying project from Svalbard to the Bering Strait through the Arctic Ocean'. This report dives into the ice-breaking solution for this cable-laying project from Svalbard to Bering Strait.

For the operation to be carried out as safely and efficiently as possible, an Ice Management system must be prepared and in place. The intended Ice Management method is based on knowledge and experience gained in previous polar expeditions by SPRS.

The project is to include a cable-laying vessel Polar-class (PC) 3 or stronger, and two, possibly three, Polar-class icebreakers. Identified vessels that have the potential to act as the cable-laying vessel could be one of the Finnish icebreakers Fennica or Nordica, converted into a cable-laying vessel. The Swedish polar icebreaker Oden will be one of the required icebreakers, and the second Polar icebreaker should be the new Swedish Heavy Polar Research Vessel (hereinafter SHPRV).

Link to the report from the Swedish Polar Research Secretariat

APPENDIX C. SEABED PROPERTIES AND GEOHAZARDS ACROSS THE ARCTIC OCEAN

In the context of the Northern EU Gateways Project, the Department of Geological Sciences, part of Stockholm University (SU), wrote the report titled 'Seabed properties and geohazards across the Arctic Ocean' on the analysis of bathymetry and seafloor geology within the high Arctic EEZs of Norway, Greenland, Canada, and the USA as well as the central Arctic Ocean.

The desktop study focused on seabed properties and geohazards in the central Arctic Ocean, sea-ice covered segment of a potential route, which would connect Svalbard, the Bering Strait, Japan, and Korea (Fig. 1). The perennial Arctic Ocean sea-ice cover reaches its annual minimum extent around mid-September. A common long-term reference is the September median sea-ice extent from 1991 to 2010, which extends from north of Svalbard at about 80°N to approximately 73°N, north of the Bering Strait. Consequently, this study investigates seabed properties and viable cable routes from the continental shelf of Svalbard off Ny-Ålesund to north of the Bering Strait. As sea-ice conditions will greatly affect the logistical challenges of a cable installation on the seafloor, they were considered in addition to seabed properties and geohazards for two of the four optional routes in this study. In general, the sea-ice conditions pose more challenges for icebreaker operations on the northern Greenland and Canadian Arctic Archipelago side of the central Arctic Ocean compared to a route closer to the North Pole.

Link to the report from Stockholm University

Vision 2030

APPENDIX D. FEASIBILITY STUDY REPORT ON SENSING CABLE TECHNOLOGIES

Danmarks Tekniske Universitet (DTU), with input from Alcatel Submarine Networks (ASN), wrote a report on the technical aspects and developments in sensing on submarine cables. The title of the report is 'Feasibility Study on Sensing Applications of a Subsea Fibre Optic Cable in Arctic Oceans'.

In this deliverable, a feasibility study on sensing applications of subsea fibre optic cables is provided. This is done in relation to Work Package 5 Task 3 in the project "Northern EU Gateways". The study completes the task and is conducted in the period from April to December 2023.

The study is based on input from a submarine cable vendor, general research literature, other similar sensing projects, and consultations with relevant climate researchers and companies. As a vendor, Alcatel Submarine Networks (ASN) has been chosen, as ASN fulfils the initial requirements for consultancy and has relevant Climate Change SMART nodes in their product portfolio and roadmap.

Link to the report from DTU

APPENDIX E. SCIENCE OPPORTUNITIES ON POLAR CONNECT WORKSHOP REPORT

NORDUnet and the Nordic NRENs organised a Workshop on Arctic Sensing for researchers and scientists, in Oslo, Norway on 3-4 October 2023. With participants from the Nordics, the rest of Europe, Canada, and the USA, this workshop was well attended.

The NORDUnet organised workshop “Science Opportunities on Polar Connect” convened experts and stakeholders from both technical and scientific backgrounds to deliberate on an ambitious endeavour — creating opportunities for highly needed Arctic research using fibre sensing and SMART cable technologies in the Polar Connect submarine cable system. This initiative, supported by the European Union’s Connecting Europe Facility (CEF Digital) under the ‘Northern EU Gateways’ project, presented an unprecedented opportunity to address complex scientific challenges in the Arctic region while fostering collaboration between the fibre technology experts and international scientific communities in the field of Arctic research.

The focus of this workshop was a dialogue between researchers about application of fibre sensing capabilities and SMART cables equipped with sensors and branching points to enable real-time observations and data collection across the Arctic Ocean. This transformative approach offers profound opportunities for the science community, particularly in the context of Arctic exploration, where traditional methods often face logistical and technical limitations and, due to that, knowledge has been limited thus far.

Link to the report from the Science Workshop on Arctic Sensing

APPENDIX F. IMPLEMENTATION OF THE POLAR CONNECT SUBMARINE CABLE - PUBLIC FINANCING, DESIGN OPTIONS AND ECONOMIC REGULATORY IMPLICATIONS

NORDUnet asked Copenhagen Economics to perform a study on public financing design options and economic regulatory implications for the implementation of Polar Connect. During the study, input was gathered from over 30 industry experts and policy makers from different types of organisations (e.g. providers of cable connectivity, telecom operators, regulators, NRENs, and service providers) and with heterogeneous profiles (e.g. CEOs, CTOs, policy officers, and directors of research networks). This ensured a diverse set of commercial and policy viewpoints as well as a broad range of expertise, all in the interest of capturing important factual elements specific to this under-researched economic sector, namely the submarine cable industry and the role and mode of public intervention therein.

This study has led to a report, in which is explored and set out how public investment into Polar Connect could be implemented given the different financing and ownership options available, and how to secure economic regulatory consistency of such an investment.

First, the report states that there are three distinct financing and ownership models available in the submarine cable industry:

- The single (private) investor model, where a single owner is responsible for financing and for the risks of the cable,
- The consortium model, where multiple industry players collaborate to build a cable, pooling resources and sharing the risks, and
- The special purpose vehicle model, where multiple industry players come together and form an entity with a distinct legal status to finance and manage the cable.

Second, the report identifies 13 business functions that submarine cable project developers must perform and execute along the life cycle of the cable. These business functions include, but are not limited to, securing long-term anchor tenants, engaging with system suppliers and performing financial planning.

Third, the report explores the different remuneration models that cable owners can employ to sell capacity and finds that there exist three main options for selling capacity, namely through i) capacity leases; ii) fibre pair ownership sales; or iii) sales of a portion of spectrum of a fibre pair (spectrum sharing) solutions. These three solutions differ in terms of operational aspects and offer different degrees of control and management of the purchased capacity to the customers. The report also presents some of the features of the contractual agreements that entail long and short-term leases. Submarine cable owners must thus balance the need for ensuring pre-sales commitment from long-term users that allow them to lower the cable investment risk while permitting to charge lower rents and shorter leases to other customers, which are willing to pay a small premium.

Link to the Copenhagen Economics report

REFERENCES

1 These are Finland, Sweden, Norway, Denmark, and Iceland. Together they rank 10th on the global scale of Nominal GDP and 7th with respect to geographical area worldwide. . . . 3

2 More information on this project: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/projects-details/43251567/101089599/CEF?programmePeriod=2021-2027&programId=43251567&freeKeywords=101089599&order=DESC&page=1&pageSize=10 . . . 3

3 Connecting Europe Facility - CEF Digital: https://digital-strategy.ec.europa.eu/en/activities/cef-digital . . . 3

4 In Vision 2030, we speak about the Arctic Ocean, our ambition is to go through the High Arctic Region . . . 9

5 An example of an earthquake warning system: https://www.cbc.ca/player/play/2275781187752 . . . 9

6 How to stop data centres from gobbling up the world's electricity: https://www.nature.com/articles/d41586-018-06610-y . . . 9

7 Japan – EU Joint Statement of the 1st meeting of the Japan – EU Digital Partnership Council . . . 10

8 Security threats to undersea communications cables and infrastructure – consequences for the EU: https://www.europarl.europa.eu/RegData/etudes/IDAN/2022/702557/EXPO_IDA(2022)702557_EN.pdf . . . 10

9 SMART stands for Science Monitoring and Reliable Telecommunications. . . . 12

10 Encryption of the traffic can to a certain extent protect against eavesdropping, but the traffic can still be subject to traffic flow analysis. . . . 13

11 World's Worst Internet Single Point of Failure Just Shifted to Bab-El-Mandeb: https://www.linkedin.com/pulse/worlds-worst-internet-single-point-failure-just-shifted-sunil-tagare-80jje/?trackingId=T4bgGlAiSDiSjtxtIQxPAw%3D%3D . . . 13

12 Examples include: 'Human activity' behind Svalbard cable disruption: https://thebarentsobserver.com/en/security/2022/02/unknown-human-activity-behind-svalbard-cable-disruption &
Nord Stream gas 'sabotage': who's being blamed and why? https://www.reuters.com/world/europe/qa-nord-stream-gas-sabotage-whos-being-blamed-why-2022-09-30/ . . . 13

13 European Commision Priorities 2019-2024: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024_en . . . 14

14 THE 17 GOALS | Sustainable Development: https://sdgs.un.org/goals . . . 15

15 Goal 9 | Department of Economic and Social Affairs: https://sdgs.un.org/goals/goal9#targets_and_indicators . . . 15

16 Goal 14 | Department of Economic and Social Affairs: https://sdgs.un.org/goals/goal14#targets_and_indicators . . . 15

17 Goal 17 | Department of Economic and Social Affairs: https://sdgs.un.org/goals/goal17#targets_and_indicators . . . 15

18 ENISA - European Union Agency For Cybersecurity: https://www.enisa.europa.eu . . . 15

19 Undersea cables — ENISA: https://www.enisa.europa.eu/publications/undersea-cables . . . 15

20 European Commission's Global Gateway, fully aligned with the UN's Agenda 2030 and its Sustainable Development Goals as well as with the Paris Agreement: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/stronger-europe-world/global-gateway_en. . . . 15

21 Digital Day 2021: Europe to reinforce internet connectivity with global partners: https://digital-strategy.ec.europa.eu/en/news/digital-day-2021-europe-reinforce-internet-connectivity-global-partners. . . . 16

22 Far North Fiber: https://www.farnorthfiber.com . . . 17

23 Cinia: https://www.cinia.fi/en/ . . . 17

24 Polar Connect: https://nordu.net/polar-connect/. . . . 17

25 Northern EU Gateways | NORDUnet: https://northern-eu-gateways.nordu.net & Northern EU Gateways | Cinia: https://www.cinia.fi/en/solutions/international-connectivity/international-network-projects/northern-eu-gateways . . . 17

26 Joint communications statement Cinia Oy and NORDUnet: https://nordu.net/wp-content/uploads/2023/07/FNF-PC-Communications-by-Cinia_and_NORDUnet-20230629.pdf . . . 18

27 About - NORDUnet: https://nordu.net/about/ . . . 19

28 CEF Digital Call 1 co-funded project: https://northern-eu-gateways.nordu.net . . . 19

29 GÉANT: https://geant.org . . . 19

30 Little Diomede Island - Wikipedia: https://en.wikipedia.org/wiki/Little_Diomede_Island . . . 21

31 Quintillion Subsea Cable Network: https://www.submarinecablemap.com/submarine-cable/quintillion-subsea-cable-network . . . 21

32 Icebreaker Oden - Swedish polar research secretariat: https://www.polar.se/en/research-support/icebreaker-oden/22

33 The International Bathymetric Chart of the Arctic Ocean: https://www.gebco.net/about_us/committees_and_groups/scrum/ibcao/. . . . 22

34 The economic value of submarine cables in the Arctic: https://copenhageneconomics.com/publication/the-economic-value-of-submarine-cables-in-the-arctic/. . . . 23

35 The economic value of submarine cables in the Arctic: https://copenhageneconomics.com/publication/the-economic-value-of-submarine-cables-in-the-arctic/. . . . 25

36 Finnish Wind Power Association: https://tuulivoimayhdistys.fi/en/ajankohtaista/press-releases/the-offshore-wind-power-in-planning-will-bring-billions-in-tax-benefits-and-thousands-of-jobs-to-finland . . . 25

37 European Green Digital Coalition: https://digital-strategy.ec.europa.eu/en/policies/european-green-digital-coalition . . . 25

38 A calculation can be found in Appendix A of the report The economic value of submarine cables in the Arctic: https://copenhageneconomics.com/publication/the-economic-value-of-submarine-cables-in-the-arctic/. . . . 26

39 Fiber Optic Sensing Association: https://fiberopticsensing.org . . . 27

40 Fiber Optic Sensing Assiciation (FOSA) post: https://www.linkedin.com/posts/fiber-optic-sensing-association_fiberoptic-fiberoptics-infastructure-activity-7094718398135164929-47gg/. . . . 27

41 Integrating Arctic Research - a Roadmap for the Future: https://icarp.iasc.info/images/pdf/ICARP3/Downloads/ICARPIII_Final_Report.pdf . . . 27

42 Polar Argo: https://argo.ucsd.edu/expansion/polar-argo/ . . . 28

43 The MOSAIC expedition: https://mosaic-expedition.org/expedition/. . . . 28

44 Destination Earth | Shaping Europe's digital future: https://digital-strategy.ec.europa.eu/en/policies/destination-earth . . . 28

45 What is the Atlantic Meridional Overturning Circulation and its role for our planet?: https://ncas.ac.uk/what-is-the-atlantic-meridional-overturning-circulation-and-its-role-for-our-planet/ . . . 29

46 ECMWF - European Centre for Medium-Range Weather Forecasts: https://www.ecmwf.int . . . 29

47 Destination Earth | Shaping Europe's digital future: https://digital-strategy.ec.europa.eu/en/policies/destination-earth . . . 29

48 Simultaneous tracking of multiple whales using two fibre-optic cables in the Arctic: https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/3067975. . . . 29

49 ESA - Observations: Very Long Baseline Interferometry (VLBI): https://www.esa.int/Science_Exploration/Space_Science/Observations_Very_Long_Baseline_Interferometry_VLBI . . . 30

50 Galileo: European global satellite-based navigation system | EUSPA: https://www.euspa.europa.eu/european-space/galileo/What-Galileo. . . . 30

51 SUBMERSE project: https://submerse.eu . . . 32

52 Pathways and modification of warm water flowing beneath Thwaites Ice Shelf, West Antarctica | Science Advances: https://www.science.org/doi/10.1126/sciadv.abd7254 . . . 33

53 Dunant: https://www.submarinecablemap.com/submarine-cable/dunant . . . 34

54 Grace Hopper: https://www.submarinecablemap.com/submarine-cable/grace-hopper . . . 34

55 Equiano: https://www.submarinecablemap.com/submarine-cable/equiano . . . 34

56 Topaz: https://www.submarinecablemap.com/submarine-cable/topaz . . . 34

57 Marea: https://www.submarinecablemap.com/submarine-cable/marea . . . 34

58 2Africa: https://www.submarinecablemap.com/submarine-cable/2africa . . . 34

59 Japan-Guam-Australia South (JGA-S: https://www.submarinecablemap.com/submarine-cable/japan-guam-australia-south-jga-s) . . . 34

60 Sikt: https://sikt.no/en/home . . . 35

61 Due to capacity limits of the electricity transmission infrastructure, all the surplus capacity of the hydro power in the north can not be transmitted to the central European area, which is the reason for having a number of electricity price areas in the Nordic countries. Generally, the more northern the area, the lower is the average power price: https://nmbu.brage.unit.no/nmbu-xmlui/bitstream/handle/11250/2403175/Heien2016.pdf. . . . 36

62 EXA Express: https://www.submarinecablemap.com/submarine-cable/exa-express 36
63 EXA Infrastructure: https://exainfra.net 36
64 The Future of Subsea Cables: https://kis-orca.org/subsea-cables/the-future-of-subsea-cables/ 36
65 High-Frequency Traders Want Low-Frequency Radio Waves: https://www.bloomberg.com/opinion/articles/2023-09-25/high-frequency-traders-chase-low-frequency-radio-waves?embedded-checkout=true 36
66 EuroHPC JU: https://eurohpc-ju.europa.eu/index_en 39
67 LUMI - Services for Research - CSC Company Site: https://research.csc.fi/-/lumi 39
68 Supercomputer Fugaku : Fujitsu Globa: https://www.fujitsu.com/global/about/innovation/fugaku/ l 39
69 RIKEN: https://www.riken.jp/en/ 39
70 United Nations Convention on the law of the Sea: https://www.imo.org/en/OurWork/Legal/Pages/UnitedNationsConventionOnTheLawOfTheSea.aspx 40
71 International regulation of Submarine cables. An analysis of the different States' practices: https://munin.uit.no/bitstream/handle/10037/20068/thesis.pdf?sequence=2. 40
72 Arctic-Connect: https://www.submarinenetworks.com/en/systems/asia-europe-africa/arctic-connect 40
73 The process of submarine cable laying (video): https://www.youtube.com/watch?v=d0gs497KApU. 41
74 Subsea Cable Maintenance: https://globalmarine.co.uk/services/subsea-cable-maintenance/ 42
75 What happens when submarine cable breaks: https://blog.telegeography.com/what-happens-when-submarine-cables-break 42
76 International Cable Protection Committee: https://www.iscpc.org 42
77 Figure 5 from the ENISA Report ' Subsea Cable - What is at Stake': https://www.enisa.europa.eu/publications/undersea-cables 42
78 Security threats to undersea comm. cables and infrastructure – consequences for the EU: https://www.europarl.europa.eu/RegData/etudes/IDAN/2022/702557/EXPO_IDA(2022)702557_EN.pdf 43
79 Chapter 2 and Appendix B have further details. 43
80 TeleGeography: https://www2.telegeography.com 46
81 How Many Submarine Cables Are There, Anyway? : https://blog.telegeography.com/how-many-submarine-cables-are-there-anyway 46
82 Submarine Cable Map: https://www.submarinecablemap.com 46
83 A data lake is a pool of data building on the federation of distributed data sources. 47
84 The recording of the hearing: https://multimedia.europarl.europa.eu/en/webstreaming/sede-committee-meeting_20231026-1130-COMMITTEE-SEDE 48
85 OneWEb: https://oneweb.net 50
86 SpaceX: https://www.spacex.com. 50
87 Starlink: https://www.starlink.com 50
88 Telesat: https://www.telesat.com 50
89 Project Kuiper: https://www.aboutamazon.com/what-we-do/devices-services/project-kuiper. 50