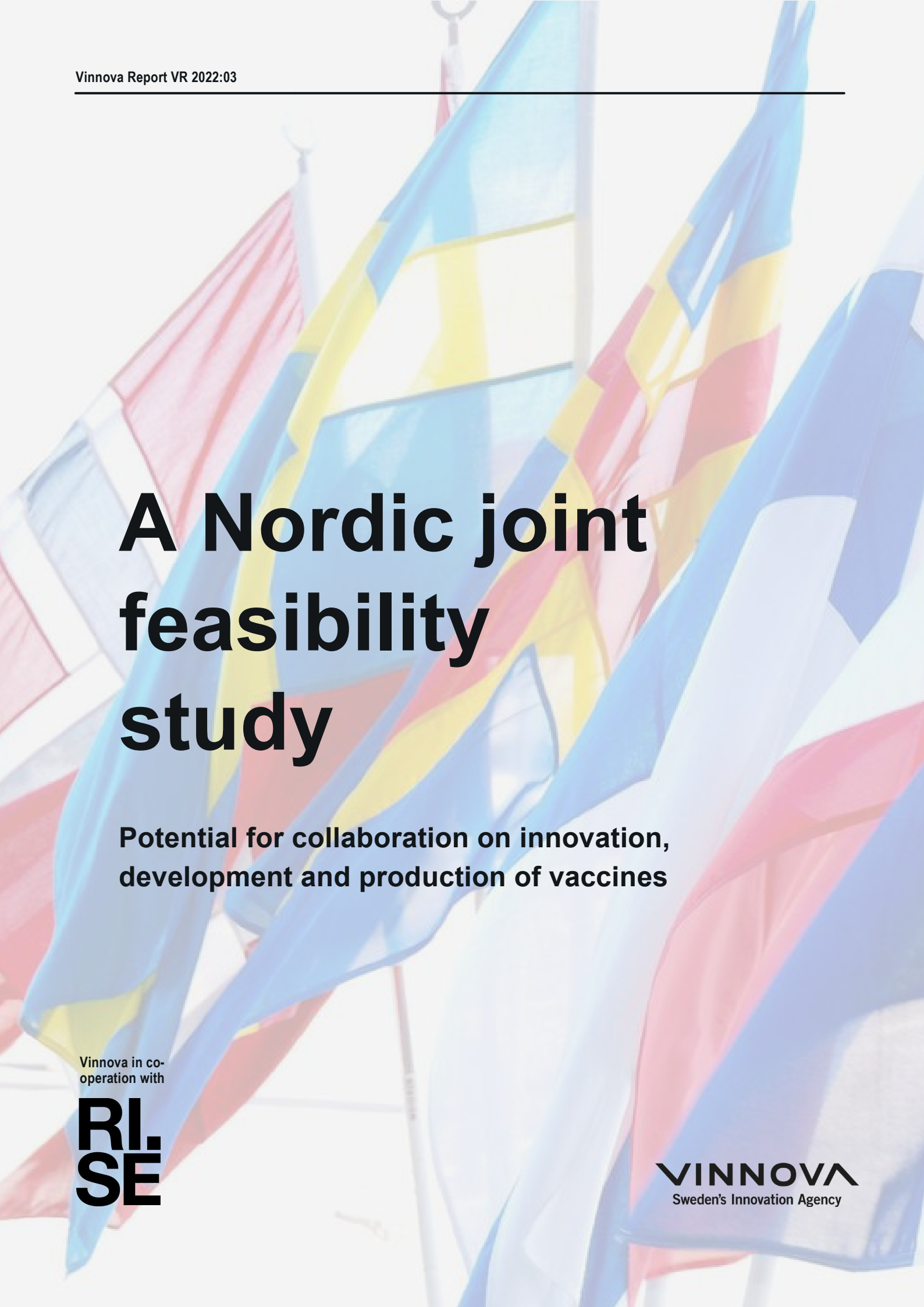
Vinnova Report VR 2022:03



A Nordic joint feasibility study

Potential for collaboration on innovation, development and production of vaccines

Vinnova in co-operation with

RI. SE

VINNOVA
Sweden's Innovation Agency

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Programme Manager: Anna Tegnesjö & Mats Jarekrans

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Preface

Vinnova is very grateful to everyone who, with great commitment, contributed to the production of this report. In particular the project team at RISE who coordinated and conducted the main part of the operational work.

The government assignment was carried out in dialogue with representatives of the Nordic countries who participated and contributed generously to the report's underlying data.

Representatives from Denmark were Charlotte Green Jensen (Statens Serum Institut) and Frank Follmann (Statens Serum Institut), from Finland Laura Mustaniemi (Business Finland) and Pertti Sormunen (National Emergency Supply), from Norway Catherine Capdeville (Innovasjon Norge) and from Iceland Stefán J. Sveinsson (Landás ehf).

Project managers for the assignment and representatives for Sweden were Anna Ridderstad Wollberg (RISE), Anna Tegnesjö (Vinnova) and Mats Jarekrans (Vinnova).

Vinnova May 2022

Lars Hammarström

Director, Health Division, Vinnova, Sweden

1. Introduction

1.1 The task

Statens Serum Institut (Denmark), Business Finland (Finland), Landas EHF (Iceland), Innovasjon Norge (Norway) and Vinnova (Sweden) have been commissioned to perform a joint study of the potential for Nordic collaboration within innovation, development and production of vaccines. The aim of the study was to achieve an increased level of shared insight into the national capacities available within each country, complementing the general Nordic and European preparedness work being laid out in several recent and upcoming initiatives from the Nordic Council of Ministers, the EU and nationally. Vinnova was appointed coordinator for the joint study and RISE, Research Institutes of Sweden, was engaged to provide project management, analysis and report editorial work. The report is based on national mappings performed in each country by respective participating national agency. The project spanned from the end of February to the beginning of May 2022, consequently there was a short timeline and limited scope.

As expressed in the task description, the Nordic countries have a long tradition of partnership and cooperation. This legacy in combination with geographical proximity and commonalities in terms of political and societal structures, renders the Nordic Region well suited for collaboration and coordination of resources for reinforced pandemic preparedness. However, further analysis of the prerequisites would be required to specify the scope and aims of such collaboration.

The aim of this report is to produce a summary that can support the assessment of the potential for deeper Nordic collaboration within vaccine development. The overarching goal of such potential collaboration is a stronger Nordic contribution to the resilience of Europe and the advancement of Nordic competitiveness within vaccine development and manufacturing.

It is important to note that the information and underlying data summarised in this joint report was compiled separately in each country, using different methods of data collection and with sparse opportunities for mutual alignment between countries. Consequently, the information presented here is not an exhaustive account of each national report, instead the material gathered has been summarised into a common format with the ambition of providing a balanced, objective overall representation of the current situation. Each national report is available in original format for review should there be a need to revisit this documentation.

1.2 Overview of the innovation and production landscape for vaccines in each Nordic country

1.2.1 Denmark

The life science industry in Denmark showed a turnover of just over EUR 33 billion in 2018, of which export accounted for more than half. A broad spectrum of organisations is involved in research and development. The life science industry focused on vaccines in Denmark (described in Section 2.1.2) includes private funds, public funds, associations and private companies within manufacturing, clinical trials and development. Key areas include vaccine manufacturers and an adjuvant production company.

Life science is a prioritised sector for the Danish government. A national life science office was established in 2018 within the Ministry of Business, Industry and Financial Affairs which publishes a yearly analysis of progress and development within the sector. The government also launched a National Life Science Strategy in May 2021, which included 38 initiatives to support the Danish life science industry and has as one of these initiatives created a National Life Science Council consisting of representatives of the entire sector. The Council will strengthen cooperation between public and private actors in the industry and in the health sector.

1.2.2 Finland

Finland's research and development expenditure was 2.8% of GDP in 2019 and one of the long-term goals of the Finnish Government is to increase this figure to 4% by 2030. Vaccine development research activities have been present in the Finnish innovation landscape for decades and the Finnish vaccine development ecosystem holds high expertise, particularly in specific parts of the development chain. Leading international vaccine manufacturers have conducted large scale clinical vaccine trials in Finland, motivated by the high-quality healthcare system, comprehensive healthcare records, national vaccination program and generally positive attitude towards vaccines within the population.

1.2.3 Iceland

Iceland is an innovative country according to global statistics. A highly educated workforce and attractive research systems along with widespread Internet access, provide a solid foundation for innovation and digital transformation in Iceland according to recent OECD economic surveys. Technological innovations are evident in the energy and fishing sectors, including cutting edge processes for carbon capture and sustainable fish farming, with strides in health technology and towards the development of high-tech solutions in the food industry. Iceland invests approximately 2.5% of GDP on R&D and governmental support of the research and innovation sector has increased extensively in recent years.

The Icelandic life science sector is relatively young and has emerged like in most countries from universities and spin-offs from international pharma companies. Today this sector mainly comprises biotechnology, biopharmaceutical, and pharmaceutical actors along with medical device, digital health, supply chain management and food supplement companies.

1.2.4 Norway

Norwegian vaccine innovation and production evolved around two key ecosystems: 1) academic research and university-based innovative companies and 2) the aquaculture industry.

Academic institutions such as the University of Oslo enjoy a solid infrastructure which together with Oslo University Hospital and funds from Norwegian Research Council and private investors has resulted in several successful drug discovery companies. There is also an academic ecosystem for research-based development and efficacy prediction of new vaccines, mainly in the oncology segment.

Norwegian aquaculture has seen formidable development in recent decades. Norwegian seafood exports summed nearly EUR 11 billion in 2020. One prerequisite for this positive development trend is an innovative pharmaceutical industry, which among other things has developed effective vaccines for fishes. Several companies within fish health have established all their research and development within fish vaccines and medicines in Norway due to the location of the largest fish farming companies and the correspondingly most extensive knowledge on this topic. The competencies, resources, and production facilities within the fish health industry are to a certain extent transferable to human health.

1.2.5 Sweden

Sweden possesses a long history as a life science nation, giving rise to global pharmaceutical companies and several groundbreaking innovations within drug discovery, biotech, medtech, diagnostics and clinical practice. Today, life science is a major research area at several Swedish internationally top ranked academic institutions, and a life science industry that in 2021 accounted for the second largest share of the country’s exports (over EUR 11 billion), with more than 3,000 companies employing more than 42,000 individuals in total.

Life science is a prioritised sector for the Swedish government, since 2019 there is a governmental life science office and a national life science strategy aimed at securing Sweden’s future as a leading life science nation.

The life science industry accounts for roughly 70% of life science R&D funding in Sweden. Advanced manufacturing of therapeutics has been an area of significant recent growth in Sweden, with specific investments in production totalling over EUR 2 billion over the past 2-3 years. Increased public funding of medical and vaccine research during the Covid-19 pandemic in combination with the overall growth of pharmaceutical industry capabilities in recent years have considerably advanced Sweden’s preconditions for vaccine development.

2. Nordic capabilities in the vaccine production value chain; from R&D to clinical studies

2.1 Development and manufacturing of vaccines in the Nordic Region

The development and production of vaccines is (as for all pharmaceuticals) a complex technological process that needs to maintain high quality and safety standards along the production chain. The rules governing manufacture of medicinal products in the European Union can be found in Eudralex Volume 4 where the principles of good manufacturing practices for medicinal products for human and veterinary use are described.

In order to evaluate the overall capabilities for development and production of vaccines in the Nordic countries, high-level mapping has been performed individually in each of the Nordic countries. This mapping has focused on the areas outlined in Figure 1. The purpose of this study has been to identify resources, competences and capabilities for vaccine production in each country. Organisations that could potentially contribute to the vaccine development value chain in the future have also been included to varying degrees.

Different technical platforms can be used for design, development and production of vaccines. In order to facilitate aggregated comparison between countries, mapping has focused on the six most common vaccine platforms (listed below).

2.1.1 Types of vaccines and technical platforms:

- Living attenuated vaccines
- Inactivated vaccines
- Recombinant protein vaccines
- mRNA vaccines
- DNA vaccines
- Viral vector vaccines

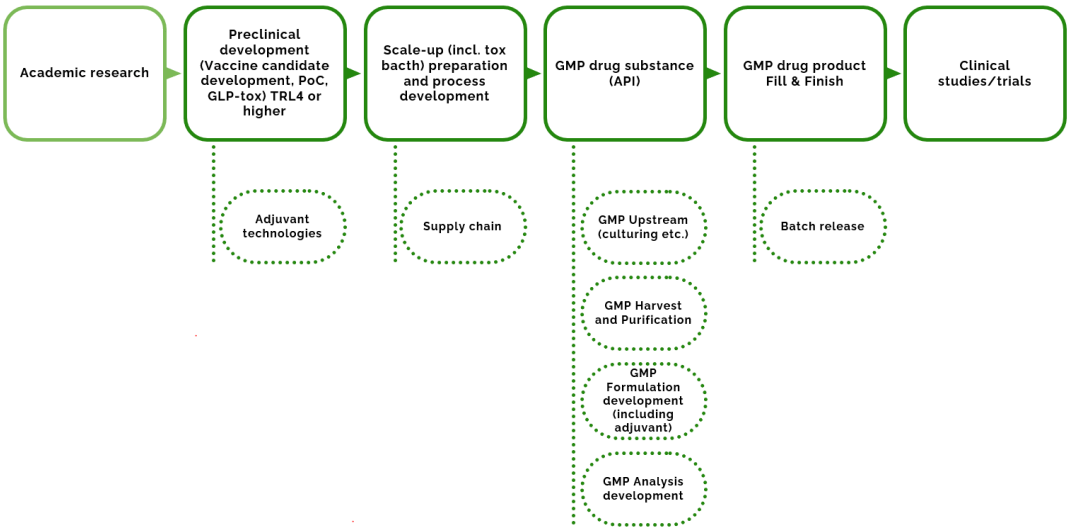

Figure 1

Overview of the vaccine development value chain and the elements addressed in this report. Academic research, below TRL4 (technology readiness level) is not included in mapping of capabilities.

Below follow short descriptions of capabilities in the Nordic countries relevant to vaccine development, complementing the heat map in Table 1. A summary of organisations identified in the mapping of each country can be found in Appendix 1.

2.1.2 Denmark

Denmark has a strong pharmaceutical industry with dedicated vaccine companies (i.e. AJ Vaccines and Bavarian Nordic) with capabilities from API to Fill & Finish. CRODA Denmark is a world-leading adjuvant specialist and produces both traditional (aluminium hydroxide) and novel adjuvants. Denmark has CMO/CDMO manufacturing capabilities for biological products for human health, including vaccines (AGC Biologics, FUJIFILM Diosynth Biotechnologies and Lonza). Scantox is a preclinical research organisation offering a broad range of services including regulatory toxicology.

There are several companies carrying out R&D in late preclinical stages (see Appendix 1) developing everything from new expression systems and live viral vaccine platforms to drug discovery tools. Statens Serum Institut has capabilities within research and development of vaccines and novel adjuvants and production of vaccines (drug substance) for clinical trials. Capabilities within all technical vaccine platforms are present in Denmark. For mRNA and DNA vaccines, activities are currently research based. Furthermore, Denmark hosts many pharma and biotech companies offering different elements of the production value chain.

2.1.3 Finland

Three companies in Finland (FinVector Oy, Biovian Oy and Paras Biopharmaceuticals Finland Oy) offer capabilities in many steps of the vaccine production value chain.

Relatively moderate investment could upscale these capabilities and make them a potential resource for vaccine manufacturing. Finland also has preclinical GLP-accredited facilities where research and safety studies prior to clinical trials could be performed, as well as bioanalysis.

On the vaccine research and development side, some early-stage SMEs focusing on vaccine development are present in the Finnish market, companies such as Rokote Laboratories Finland Oy. Additionally, several national centres and infrastructures concentrate on vaccine research (Meilahti Vaccine Research Center, Vaccine Research Center Finvac Ltd and many Finnish Universities that maintain high-class expertise in the field).

2.1.4 Iceland

There are very limited vaccine R&D activities in Iceland and no commercial manufacturing. Apart from a biotech start-up (Arterna Biosciences) working in the field of mRNA polymerase enzyme technology, vaccine R&D activity is limited to academic projects carried out at the University Hospital and the University of Iceland.

Controlant hf (based in Iceland) is a global provider in real-time supply chain monitoring and visibility technologies for regulated industries such as pharmaceutical industry.

2.1.5 Norway

Norway has a long history, competences, resources and production facilities within the fish health industry, which to a certain extent could be transferable to human health. PharmaQ (a vaccine and innovation company in aquaculture) possesses manufacturing capabilities for inactivated vaccines and GMP-accredited facilities across the entire value chain.

There are some manufacturing capabilities for biological products for human health (R&D and CMO/CDMO) in Norway. The strength within the vaccine field in Norway lies in academic research, resulting in start-ups and SMEs mainly in the therapeutic vaccine field primarily to develop cancer treatments. One such company is Nykode Therapeutics AS, working on a novel technical platform targeting antigen precenting cells aiming to improve potency of vaccines. As there are no large pharmaceutical companies developing vaccines (API) or other biological drugs in Norway, a shortage of relevant competences is noted in this field.

There are national centres and infrastructures with capabilities relevant for vaccine research and development such as the University of Oslo, Oslo University Hospital, the Viral Vector Core at Kavli Institute for Systems Neuroscience and SINTEF, a broad, multidisciplinary research organisation (CRO).

Cody AS holds GMP-accredited capabilities in custom tailored production equipment with solid expertise and a track record of delivering to pharmaceutical industries. Curida AS is a manufacturer of blow-fill-seal (BFS) products in nasal spray for many indications.

2.1.6 Sweden

Sweden hosts several companies and organisations covering the entire value chain for production of most types of vaccines. However, production of drug substance (DS) of new types of vaccines such as mRNA vaccines is currently in its early stages and remains small-scale.

Manufacturing of recombinant protein vaccines (DS and DP) can be carried out in Sweden. However, CDMOs with large scale GMP manufacturing of protein-DS is limited to a few companies only. Valneva Sweden AB has production facilities for several vaccine platforms and a new Fill & Finish facility in Solna in use for commercial manufacture of both their own and third-party products. Pfizer Health performs commercial vaccine production in Strängnäs in a multipurpose facility for production of protein-based biologicals and of an inactivated virus vaccine for the market. The recently formed CDMO NorthX Biologics (NorthX Bio) is a Swedish biomanufacturing company with GMP facilities, technical platforms (bacterial culture production) and BSL-2 facilities capable of producing DS of different types of vaccines. Finally, safety assessment studies for regulatory documentation can be performed by RISE, and on a smaller scale by Adlego.

Several companies in Sweden produce adjuvants. This includes companies producing more traditional adjuvants using, for example, aluminium salts as well as companies producing their own proprietary adjuvants (Novavax AB, Eurocine Vaccine AB and Scandinavian biopharmaceuticals AB).

In addition to private companies, there are national infrastructures supporting scale-up, process development and early manufacturing of vaccines (and other biologicals) i.e. Cytiva Testa Center, NorthX Bio Innovation hub, Pre-GMP facility at Karolinska Institutet and Vecura at Karolinska Hospital. RISE and APL are government-owned public companies that offer capabilities relevant to vaccine development.

2.2 Vaccine manufacture in the Nordic countries

The table below summarises current GMP capabilities for each country as concerns vaccine development and production.

The colour of each cell reflects number of organisations (white: no organisations, yellow: 1-3 organisations, green: >3 organisations), the letters in the cell correspond to the type of organisation (see figure legend for further information). Organisations with vaccine-research projects below TRL4 (technology readiness level) are not included in this mapping. Capabilities that produce other types of biologicals (GMP) are not included in Table 1, but if they are considered a potential resource for production of vaccines, they are included in Appendix 1. Other capabilities that are listed include some Fill & Finish capabilities that are more agnostic to type of drug product and CROs offering GMP-accredited services (for example analysis, formulation, or adjuvant development).

Table 1 Mapping of pharmaceutical vaccine development in the Nordic countries

Heat map of pharmaceutical vaccine development:
*– **Blank** no national organisations; Yellow ≤ 3 organisations; Green > 3 organisations.*

Number description of the type of organisation is as follows; A. Pharma (large), B. Pharma (SME), C. CMO/CDMO (manufacturing), D. National infrastructures (academic or private), E. Government-owned or public (companies, hospitals, academic), F. CRO (research and other services)/consultants, G. Other (e.g., Biotech, aquaculture and other areas).

Types of vaccines (technical platforms)	Scale-up (incl. tox batch and process development)	GMP Upstream (e.g. culture)	GMP Harvest & purification	GMP Analysis development	GMP Formulation development	GMP Fill & Finish
Denmark						
Living attenuated vaccines	A	A	A	A	A	-
Inactivated vaccines	A	A	A	A	A	A
Recombinant protein vaccines	A, C, F	A, C, F	A, C, E	A, C, E	A, E	A
mRNA vaccines	-	-	-	-	-	-
DNA vaccines	-	-	-	-	-	A
Viral vector vaccines	A	A	A	A	A	A
Finland						
Living attenuated vaccines	-	-	-	-	-	-
Inactivated vaccines	-	-	-	-	-	-
Recombinant protein vaccines						
mRNA vaccines						

Types of vaccines (technical platforms)	Scale-up (incl. tox batch and process development)	GMP Upstream (e.g. culture)	GMP Harvest & purification	GMP Analysis development	GMP Formulation development	GMP Fill & Finish
DNA vaccines	-	-	-	-	-	-
Viral vector vaccines	B, C	B, C	B, C	B, C	B, C	B, C
Iceland						
Living attenuated vaccines	-	-	-	-	-	-
Inactivated vaccines	-	-	-	-	-	-
Recombinant protein vaccines	-	-	-	-	-	-
mRNA vaccines	-	-	-	-	-	-
DNA vaccines	-	-	-	-	-	-
Viral vector vaccines	-	-	-	-	-	-
Norway						
Living attenuated vaccines						
Inactivated vaccines	F, G	G	G	G	A, G	G
Recombinant protein vaccines	B, F	B	B	B	-	B
mRNA vaccines	F	-	-	-	-	B
DNA vaccines	B, F	-	-	-	-	-
Viral vector vaccines	D	B	-	-	-	-
Sweden						
Living attenuated vaccines	C	C	C	B, C	C	A, C
Inactivated vaccines	A, B, C	A, C	A, C	A, B, C	A, C	A, C
Recombinant protein vaccines	A, B, C	A, C	A, C	A, B, C, F	A, C	A, C
mRNA vaccines	B, C	C	C	A, B, C, F	A, C	A, C
DNA vaccines	B, C	C	C	A, B, C, F	A, C	A, C
Viral vector vaccines	A, C	A, C	A, C	A, B, C	A, C	A, C

The summarised results in Table 1 show that capabilities for vaccine production are unevenly distributed throughout the Nordic countries and that recombinant protein vaccine is the technical platform showing the highest capacity level. Additionally,

the limited total capacity for mRNA/DNA vaccines is restricted to a smaller number of contract manufacturing organisations.

2.3 Supply and support for vaccine production in the Nordic countries

Manufacturing of vaccines requires a vast amount of chemicals, reagents, disposables, equipment and instruments. The principles of GMP demand specific accreditation or certification of items used as well as suppliers of these items. Moreover, the list of items varies for each technical platform and for each product. During the Covid-19 pandemic, shortage of supply chain items formed a major bottleneck for vaccine production globally, highlighting the importance of secure, resilient and sustainable supply chains globally for therapeutic manufacturing. In addition to supply of materials, service organisations (CROs and accredited labs holding GMP, GLP or ISO-certification) support manufacturing and are considered part of the supply chain in its entirety.

The brief time frame of the current study has not permitted a deeper analysis of supply chain limitations and thus a thorough mapping of supply industries in the Nordic Region has not been achieved. Below follows a summary of capabilities identified in the Region to supply and support the manufacturing of vaccines.

2.4 Supply chain industries identified in the Nordic countries

Chemicals and reagents

- Matrices and reagents for purification of proteins and vaccines (Cytiva, SE)
- Dry ice and liquid nitrogen (BirkaStorage, SE)
- Lectins and saponins for adjuvants (Medicago, SE)
- Blow-fill-seals (BFS), Fill & Finish for nasal spray products (Curida, NO)
- High purity ethanol and paper-based materials (FI)
- Syringes and needles (Ferrosan, DK)
- Plastics and consumables (BASF A/S, DK)

Production/Culturing

- Bioreactors (Getinge, Belach, SE)
- Cell culture media, buffers and filtration solutions for bioprocesses (Cytiva, SE)

Purification

- Chromatographic instruments used for purification of vaccines and biopharmaceuticals (Cytiva, SE)
- Columns for purification of proteins and vaccines (Cytiva, SE)

Sterilisation, storage and transportation

- Temperate storage solutions (Controlant hf., IC, ClinStorage, ClaraLABS, SE, DK, NO)
- Sterilisation (Sterillab A/S, Getinge, DK, SE)

Several companies provide instrumentation and supplies that are essential for production, purification, formulation or analysis of vaccines, such as Cytiva, Ferrosan, Medicago and Getinge. Climate-controlled storage solutions and production of ethanol and paper-based products are available in Sweden and Finland respectively, while Iceland possesses substantial know-how within cold chain transportation solutions.

It is important to note that essentially all companies listed above are also in turn dependent on imports of goods and materials from other companies outside the Nordic Region, thus adding to the complexity and vulnerability of the supply chain in its entirety.

2.5 Clinical studies of vaccines in the Nordic countries

Clinical development is a necessary step to achieving market authorization of new medicinal products, including vaccines.

The Nordic countries share strengths and challenges in the performance of clinical trials on vaccines. Strengths include strong public health care systems, well-established electronic health records, national vaccination programs and a general positive attitude towards scientific research and vaccines among the public. Challenges include limitations in financing, limited population sizes and a relatively low number of vaccine-naïve test subjects due to high levels of compliance to public vaccination programs. Recruitment of large patient cohorts may therefore be an issue.

The clinical vaccine studies performed in the Nordic countries between 2017-2022 are summarised in Table 2 and categorised as Covid-19 and non-Covid-related trials (data from clinicaltrials.gov, EU Clinical Trials Register and/or national registers).

The Nordic Trial Alliance (NTA) is an initiative that aims to facilitate clinical research cooperation in the Nordic Region and focuses on multi-centre clinical trials. All the Nordic countries are represented in NTA which is funded by the Nordic Council of Ministers and NordForsk.

In addition to NTA, national organisations aimed at supporting clinical trials for each country are described below. In addition, all Nordic countries host CRO companies specialised in clinical development services including regulatory submission and clinical operations for the pharmaceutical industry.

2.5.1 Denmark

Denmark has two national clinical trial infrastructures: Trial Nation and the Danish GCP units.

Trial Nation acts as a single, national point of entry for both commercial and non-commercial sponsors wishing to conduct clinical trials in Denmark. Trial Nation is funded by the Ministry of Business, Industry and Financial Affairs, the Ministry of Health, the five Danish Regions and several Danish life science companies.

The Danish GCP unit is a public partner that aims to assist non-commercial sponsors to comply with Good Clinical Practice (GCP) and Danish legislation when planning and performing clinical trials.

2.5.2 Finland

Finland has two recently established public clinical trial infrastructures: Finnish Vaccine Research Center Finvac Ltd and Meilahti Vaccine Research Center (MeVac). Finvac was

established early 2022 through a merger of Tampere University Vaccine Research Center and the THL (Finnish Institute for Health and Welfare) commercial vaccine research activities. Finvac conducts clinical studies of vaccines in all phases, as well as observational register studies and large phase III/IV trials in collaboration with healthcare organisations. MeVac is the joint vaccine research centre of Helsinki University Hospital and University of Helsinki that conducts clinical research commissioned by pharmaceutical companies as well as investigator-initiated studies. At their centre, they can conduct all types of studies except early phase I studies.

2.5.3 Iceland

There are several research groups at the University of Iceland and the University Hospital Iceland and the Children's Hospital involved in vaccine clinical trial activities. Trials are conducted at the hospitals and at trial sites abroad, the latter in collaboration with international researchers. deCODE contributed to patient observation studies on immune responses to influenza vaccination and biomarkers of inflammation in response to adjuvanted and non-adjuvanted influenza, hepatitis B, yellow fever and varicella zoster vaccines performed within ADITEC.

2.5.4 Norway

Norway has two national clinical trials infrastructures with different frameworks: NorCRIN and NorTrials. NorCRIN is a national research support network consisting of the country's six university hospitals. The goal is to increase the number and quality of national and international clinical studies. NorTrials is a partnership between the specialist health service and the business community on clinical studies and acts as a door to clinical studies for small and large companies in the business community, and for public actors who want to carry out such studies in Norway. Six centers are established in professional focus areas that are selected together with the business community.

2.5.5 Sweden

Today Sweden has one national clinical trial infrastructure: Clinical Studies Sweden which is a national collaboration between the six major health care regions of Sweden and is supported by the Swedish Research Council. Clinical Studies Sweden offers both researchers and industry a national single point of entry for support and advice in the implementation of clinical studies within Swedish healthcare.

ACTION Sweden (Alliance for Clinical Trials on acute Infections in Sweden) is a national network for collaboration between Sweden's infection clinics and other specialties. Their focus so far has been clinical trials of new antimicrobial treatments, but they intend to also include vaccines and have therefore initiated collaboration with Vaccelerate (described in Section 4.2.3) and the Danish Trial Nation (described above).

Table 2 Clinical studies for vaccines 2017-2022

**Number description of the type of organisation is as follows; A. Pharma (large), B. Pharma (SME), C. CMO/CDMO (manufacturing), D. National infrastructures (academic or private), E. Government-owned or public (companies, hospitals, academic), E. CRO (research and other services)/consultant*

Studies performed in Denmark

Covid-19 related	Sponsor country	Number of studies	Types of sponsors*	Clinical phase(s)
Covid-19 related	National	6	D	III, IV
	International	-	-	-
Covid-19 non-related	National	29	B, D, E	I, I/II, III, IV
	International	8	A	III

Studies performed in Finland

Covid-19 related	Sponsor country	Number of studies	Types of sponsors*	Clinical phase(s)
Covid-19 related	National	5	E	IV
	International	3	A	II
Covid-19 non-related	National	2	E	III, IV
	International	46	A	I, II, III

Studies performed on Iceland

Covid-19 related	Sponsor country	Number of studies	Types of sponsors*	Clinical phase(s)
Covid-19 related	National	-	-	-
	International	-	-	-
Covid-19 non-related	National	-	-	-
	International	1	E	IV

Studies performed in Norway

Covid-19 related	Sponsor country	Number of studies	Types of sponsors*	Clinical phase(s)
Covid-19 related	National	2	B, E	I, II
	International	1	B	III
Covid-19 non-related	National	45	A, B, E	I, II, III, IV
	International	20	A	II, III, IV

Studies performed in Sweden

Covid-19 related	Sponsor country	Number of studies	Types of sponsors*	Clinical phase(s)
Covid-19 related	National	11	E	IV
	International	-	-	-
Covid-19 non-related	National	14	A, B, E	I/II, II, III/IV, IV
	International	35	A, B, E	I, I/II, II, III

3. Investments and initiatives relevant to vaccine manufacturing in the Nordic countries

Below follows a summary of new and planned public and private investments identified in capacity building for vaccine development and production in each country.

3.1 Public-private and corporate investments into capacity of relevance for vaccine development

3.1.1 Denmark

The Danish Government is investing EUR 108 million in state aid for the development of a new Danish Covid-19 vaccine by Bavarian Nordic. The vaccine was originally developed by AdaptVac, which is a Danish joint venture between companies ExpreS2ion Biotechnologies and NextGen Vaccines. They originated from the research community at the University of Copenhagen.

Furthermore, the Danish government has invested approx. EUR 4 million in production and the first clinical trials of a Covid-19 DNA vaccine developed by Statens Serum Institut.

The Novo Nordisk Foundation has also recently begun developing plans for a new major vaccine research centre in Denmark. The ambition for this initiative is to establish a critical mass that conducts discovery, translational research and clinical trials on vaccines against diverse respiratory pathogens that have epidemic potential or promote the spread of anti-microbial resistance.

3.1.2 Finland

In 2022, public equity funding of EUR 8 million will be provided for the newly founded Vaccine Research Center Finvac Oy. FinVector Oy received funding in 2021 (a total of EUR 6,55 million from Etelä-Savo Centre for Economic Development, Transport and the Environment) for the construction of a new pharmaceutical manufacturing facility.

In 2021, a vaccine development project at Rokote Laboratories Finland Oy was funded by Business Finland in form of a EUR 5.5 million loan.

3.1.3 Iceland

There are currently no planned public or private investments in the vaccine development value chain in Iceland.

3.1.4 Norway

The Department of Pharmacy (University of Oslo) is planning a new technological centre for pharmaceutical development and production of medicines. Funding is however not yet secured.

3.1.5 Sweden

Several private and publicly funded initiatives relevant to vaccine production in Sweden have been launched or proposed.

The Cytiva Testa Center is a non-profit company (innovation hub) for pre-GMP process development of biologics established by Cytiva (then GE Healthcare) in 2017. The centre was launched with funding from the Swedish government (EUR 10 million) to support the growth and manufacturing capabilities of early-stage life science industry and academic projects.

NorthX Bio Innovation hub was launched in 2021 as a public-private-partnership between NorthX Biologics (EUR 9 million) and the Swedish government through Vinnova (EUR 5 million). It will function as a collaborative environment providing competence and capacity for process development, upscaling, analysis and large-scale production of advanced therapies and vaccines, aiming at strengthening the competitiveness of the Swedish life science sector.

The International Vaccine Institute (IVI) is an international vaccine development organisation founded in 1997 by the UN Development Program (UNDP) and consists of 36 member states. It is intended that the IVI European office will be established in Sweden by September 2022. The office is expected to provide new opportunities for collaboration with Swedish research and Swedish companies in life sciences and to strengthen Sweden's role as a leading life science hub. IVI has applied for EUR 24 million in public funding over five years (2022-2026) which is pending approval at the Ministry for Foreign Affairs. The Swedish Parliament is expected to take a decision in May 2022.

Recent corporate investments of relevance include the new Valneva 4000 m^2 Fill & Finish facility for vaccine production in Solna (EUR 29 million), the AstraZeneca Sweden Biomanufacturing Centre in Södertälje (EUR 240 million since 2015), Cytiva's production facility in Uppsala (EUR 65 million per year) and Novavax AB (continuous internal investments in Swedish adjuvant research and manufacturing capabilities). In addition, several SMEs implemented directed share issues in order to build capabilities in vaccine development.

4. Description of selected EU and international initiatives

4.1 Nordic initiatives

The Nordic countries have a long tradition of collaborations in many areas and several initiatives were mentioned in the task description, some are highlighted below.

4.1.1 Managing Competitive Interdependence in Northern Europe: Nordic Security of Supply in the Age of Disruption (NOSAD)

NOSAD, which is led by the Finnish Institute of International Affairs examines security of supply and crisis preparedness models in Nordic countries and reviews the existing and future potential of Nordic cooperation within the field. The project was launched in early autumn 2021 and is expected to deliver in June 2022.

4.1.2 Collaboration through the Nordic Council of Ministers

Recently (25 mars 2022) a joint declaration aimed at strengthening health crisis preparedness in the Nordic Region was signed. The aim is to intensify cooperation in several priority areas, this joint study being one of them. Another ongoing initiative is Nordic Production Mapping in which a cooperation intended to map production of pharmaceuticals has just been initiated. This mapping is expected to be reported at the end of 2023.

4.1.3 The Nordic Health Preparedness Group, the Svalbard Group

The aim is to facilitate broad cooperation in the field of health preparedness. The Group has prepared a strategic framework for 2018-2027, including a vision “to contribute to ensuring effective crisis management for health and social services in the Nordic Region”.

4.2 EU and other international initiatives

4.2.1 European Health and Emergency preparedness and Response Authority (HERA)

HERA[1] was launched in September 2021 and will be designed as a flexible structure which will ensure the development, production and distribution of medicines, vaccines and other medical countermeasures in response to emergencies. HERA will have EUR 6 billion at its disposal from the EU budget over a 6-year period, primarily building on the activities of EU4Health, Horizon Europe and Union Civil Protection Mechanism (UCPM). A total contribution of EUR 1.3 billion from the EU budget is allocated to HERA in 2022 for preparedness activities. The work plan considers ongoing or planned calls

[1] European Health and Emergency preparedness and Response Authority (HERA)

under Horizon Europe and rescEU in 2022. In 2022 the following subjects include those to be addressed:

- International supply chain bottlenecks, removing unnecessarily restrictions and expanding global production capacity.
- Scaling up national capacities for the detection and scientific assessment of variants.

4.2.2 Network of Ever-warm Production Capacities for Vaccines and Therapeutics manufacturing (EU FAB)

The aim of EU FAB is to award contracts to several commercial vaccine manufacturers in order to maintain part of their production capacity (single and/or multi technology sites) at the disposal of EU FAB in case of its activation.

The EU FAB contract notice[2] was published on 27 April 2022 and the call for participation will close on 3 June 2022. Procurement is divided into different lots based on platform technology. The bidders need to ensure the entire production chain of the finished product including Fill & Finish and packaging of vaccines, according to the specifications of the marketing authorisations and manufacturing authorisations. In addition, manufacturers must demonstrate access to sufficient quantities of all the necessary raw materials and consumables in order to produce the agreed number of doses of vaccines.

4.2.3 VACCELERATE

This project[3] was launched under the HERA Incubator framework, and it constitutes one single entry point to a network of actors involved in the development of vaccines against Covid-19 with the aim of facilitating the conducting of clinical trials. The project intends to create a network ready to face emerging pandemics and enhance vaccine development capacity in Europe. Partners from Sweden (KI, Region Stockholm), Denmark (Region Hovedstaden) and Norway (Bergen University) are participating in the project.

4.2.4 EU Vaccine Scale-up Task Force

Within the HERA incubator a Force for Industrial Scale-up of COVID-19 vaccines[4] was introduced in 2021 to facilitate the ramp-up of production capacity for Covid-19 vaccines and therapeutics in Europe. The task force's main activities included mapping EU vaccine production capabilities and identifying vaccine production bottlenecks. As preparation for the EU FAB project, the task force promoted industrial partnership through matchmaking events.

[2] EU FAB contract notice
[3] VACCELERATE
[4] Task Force for Industrial Scale-up of COVID-19 vaccines

4.2.5 Other international actors and initiatives

In addition to the above mentioned initiatives, several other actors and initiatives are of relevance to this report, those selected are listed below:

- Parallel to establishing HERA, a member state-led pandemic preparedness research and innovation partnership is being set up. The Pandemic Preparedness Partnership[5] should aim to improve EU preparedness to predict and respond to emerging infectious health threats by improved coordination of funding for research and innovation at EU, national (and regional) levels aimed at common objectives. The partnership will present a strategic research and innovation agenda at the beginning of 2023 that will guide the Commission and member states on needs and gaps.
- Important Projects of Common European Interest (IPCEI)[6] are EU Member State-led cross-border innovation and infrastructure projects that can contribute significantly to the achievement of EU strategies by allowing considerable levels of state aid support to areas of critical research and innovation marked by market failure. IPCEIs are funded from national budgets and partnering industries. There is work in progress towards a health IPCEI and, although the current content is not directed specifically towards vaccine development, topics discussed include "*innovation in antimicrobial resistance and rare diseases, as well as in emerging health threats where complementary to HERA; and developing cell and gene therapies, including production processes and technologies*".
- The Innovative Health Initiative Joint Undertaking (IHI JU)[7] aims to enable the cross-sectoral integration of technologies, know-how, products, services and workflows for people-centred healthcare. In their Strategic Research Agenda, development of improved vaccines and mRNA platforms are mentioned and may become topics for future calls.
- The new EU4Health[8] programme will go beyond crisis response to address healthcare system resilience. With EU4Health, the EU will invest EUR 5.3 billion in current prices in actions showing EU added value, complementing EU country policies and pursuing one or several of the EU4Health objectives. HERA and its actions are financed by this programme, and future calls with relevance to vaccine development can be expected in all pillars.

[5] Pandemic Preparedness Partnership
[6] Important Projects of Common European Interest (IPCEI)
[7] Innovative Health Initiative Joint Undertaking (IHI JU)
[8] EU4Health

- Joint action on vaccination (EU-JAV)[9] launched in 2018, aims to strengthen cooperation between European countries to fight vaccine-preventable diseases. The expert health agencies from four of the five Nordic countries (Norway, Denmark, Finland, and Sweden) are taking part in the action that is partly funded by the EU Health program.
- In EU, there is a centralised procedure for regulatory rapid approval of Covid-19 vaccines[10], after which the products receive Marketing Authorisation Approval for the entire EU area.
- Coalition for Epidemic Preparedness Innovations (CEPI)[11] is an innovative partnership between public, private, philanthropic and civil organisations launched in 2017 to develop vaccines against future epidemics. Their aim is to advance vaccines against known threats and establish investigational vaccine stockpiles before epidemics begin “just in case”. They will also fund new and innovative platform technologies with the potential to accelerate the development and manufacture of vaccines “just in time”. CEPI runs calls for proposals, invites research teams, vaccine developers and others from around the world to apply to their scientific programs. Their headquarters is in Norway.
- Global Research Collaboration for Infectious Disease Preparedness (GloPID-R)[12] is an alliance that brings together research funding organisations on a global scale to facilitate effective and rapid research into a significant outbreak of a new or re-emerging infectious disease with epidemic and pandemic potential. GloPID-R has 33 members worldwide, one is the European Commission – DG Research & Innovation. It is actively working on facilitating exchange of information and connecting research networks as well as involving developing countries.
- IVI International Vaccine Institute (IVI)[13] is an international organisation founded in 1997 by the UN Development Program (UNDP) and consists of 36 member states. The purpose of IVI is to “discover, develop and deliver safe, effective and affordable vaccines to enable the world's most vulnerable people to have full, productive lives”. The IVI European office is planned for establishment in Sweden by September this year. The office is expected to provide new opportunities for collaboration in Europe and in the region.

[9] Joint action on vaccination (EU-JAV)
[10] EMA: Covid-19 guidance
[11] Coalition for Epidemic Preparedness Innovations (CEPI)
[12] Global Research Collaboration for Infectious Disease Preparedness (GloPID-R)
[13] IVI International Vaccine Institute (IVI)

- There are several projects/networks, like the previously mentioned VACCELERATE[3] , arranging and coordinating clinical trials and infrastructure for vaccine development. Examples include EU COVID-19 TRIALS[14] that is an access point to and coordinator of the efforts in several European COVID-19 Adaptive Platform Trial (COVID-19 APT) projects, and ECRAID[15] that is a European clinical research network for infectious diseases. The TRANSVAC2[16] and TRANSVAC-DS[17] projects aim to further advance and consolidate the establishment of a Pan-European vaccine infrastructure. These networks collect together a broad range of expertise in the area of clinical research and development of vaccines.

4.3 Participation in EU/international initiatives on country level

All the Nordic countries participate in international and EU initiatives relevant to vaccine development and production. Some of these initiatives have been mentioned in the previous sections and other examples are found in Table 3. All the countries are to varying degrees represented in different networks, research projects or strategic initiatives/projects that aim to establish infrastructure or collaboration hubs to support new vaccines and vaccine development. Some of these initiatives include partners from several Nordic countries. Many of the EU-financed research projects are at relatively low TRL level and thus not within the scope of this mapping, but they still contribute to the competence build-up in the field and may generate new vaccine candidates in the future.

Table 3 below shows a selection of international initiatives classified into projects, networks and infrastructures/hubs and based on whether they are EU-related or involve other parts of the world. A link to the initiative website is included for further information.

Table 3 Examples of EU/international initiatives and the involvement of Nordic countries

(a) Type: I = Infrastructure/Hub, N = Network, P = Project.
(b) EU = European, G = Global

Initiative	Type (a)	Impact (b)	Link	DK	FI	IC	NO	SE
CEPI	I	G	https://cepi.net/	X	X		X	
EU COVID-19 trials	I	EU	https://covid19trials.eu/en				X	
DRIVE	P	EU	https://www.drive-eu.org/		X			
ECRAID	N	EU	https://www.ecraid.eu/					
EU-JAV	P	EU	https://eu-jav.com/	X	X		X	X

[14] EU COVID-19 TRIALS, https://covid19trials.eu/en
[15] ECRAID
[16] TRANSVAC2
[17] TRANSVAC-DS

Initiative	Type (a)	Impact (b)	Link	DK	FI	IC	NO	SE
EU Vaccine Scale up Task Force	N	EU	https://ec.europa.eu/growth/coronavirus-response/task-force-industrial-scale-covid-19-vaccines_en	X	X			
Global Vaccine and immunization research forum	N	G	https://www.who.int/teams/immunization-vaccines-and-biologicals/product-and-delivery-research/the-global-vaccine-and-immunization-research-forum-(gvirf)	X		X		
IUIS Vaccine Commitee	N	G	https://iuis.org/	X	X	X	X	X
TRANSVAC2	I	EU	https://www.transvac.org/transvac2	X				
TRANSVAC-DS	I	EU	https://www.transvac.org/transvac-ds	X				
VACCELERATE	I	EU	https://vaccelerate.eu/	X			X	X
Gavi	N	G	https://www.gavi.org/	X	X	X	X	X

5. Potential for Nordic collaboration and mutual benefits within innovation, development and production of vaccines

5.1 Current situation

From the mapping of national capabilities for development and production of vaccines performed in this study, it is evident that resources are unevenly distributed over the Nordic Region. Countries like Denmark and Sweden, with long histories of large pharmaceutical industries, have a more mature and industrialised vaccine production capacity than other Nordic countries. These capabilities are however not fully consolidated and are mainly based on capacities within the Biopharma and Biotech industries. When it comes to later stage development (industrial scale) and the production of new type of vaccines (for example mRNA/DNA), competences and capabilities are relatively scarce within the entire region.

Nordic countries today are heavily dependent on commercial vaccines that are developed and produced outside the region, and the parts of the vaccine development and production value chain that are present in the Nordic Region (see Section 2.3) are to a large extent dependent on numerous, globally distributed suppliers.

However, several areas of strength have been identified in the region that can be elaborated and built upon, including strong academic research on vaccines and immune therapies, national infrastructures for research, innovation and clinical trials and researchable patient records. Moreover, large global pharmaceutical companies and CMO/CDMOs have capabilities for vaccine development and production in the Nordic Region as can be seen in Table 1. Other areas of strength include formulation and adjuvant development, matrices and availability of specialised supply and support systems such as columns for purification of proteins and vaccines and temperature storage solutions as well as biotech and start-ups developing tools, expression systems, vaccine development platforms and other solutions supporting the progress of next-generation vaccines.

The number of vaccine-based clinical studies performed are also unevenly shared between Nordic countries, see Table 2. Most phase II and III studies are performed with large international pharmaceutical companies as sponsors, Finland being the country with the largest proportion of such studies. Covid-19 related studies in the Nordic Region have mainly one national sponsor. Most Nordic countries have national infrastructures to support and facilitate clinical studies. The mapping considers clinical studies with

vaccines, not distinguishing between vaccines aimed at preventing infectious pathogens and therapeutic vaccines.

Recent public-private and/or industrial investments in vaccine development capacity look very different in the Nordic countries (see Section 3.1). Many initiatives launched have aimed at building translational competence and capacity, supporting vaccine developers in early phases with industrial know-how and infrastructure.

Government-owned infrastructures, academic institutions, institutes or public companies that aim to develop vaccines or offer capabilities to support others developing vaccines are present in the Nordic Region as highlighted in Section 2.1. In general, these capabilities are of smaller scale, focused only on parts of the vaccine production value chain or on research.

Partners from all the Nordic countries are involved in EU projects and/or other international initiatives relevant to vaccine research and development (see Table 3 for examples). The scope of the initiatives ranges from basic research (not included in the mapping) to infrastructures to support vaccine development and clinical trials. In addition to EU initiatives, two global organisations have close connections in the region - CEPI that has its headquarters in Norway and IVI that is about to set up a European office in Sweden.

5.2 Areas with potential for Nordic collaboration

Given the complexities, high cost and extensive timelines required for vaccine development and production, there may be advantages in coordinating a joint vaccine development strategy between the Nordic countries. Reducing inefficiencies and redundancy, increasing robust supply and production chains, and making use of areas of complementary strength in a common Nordic context could support the overarching goal of a stronger Nordic contribution to the resilience of Europe. In addition, collaboration on competence development, infrastructure and development of favourable preconditions for performing clinical vaccine trials could improve the attraction of the region for international investment in vaccine production.

Below is a list of some areas with potential to be studied further as fields for collaboration and mutual development. It is important to note that the potential of any future collaboration within vaccine development and production can only properly be assessed if it provides a clear scope and objective for such collaboration.

5.2.1 Supply chain

There is a need to further investigate the full supply chain for vaccine development and production at the Nordic level in order to identify key areas of vulnerability. As the manufacturing of vaccines requires a vast number of items per drug product, it is challenging to grasp the full extent of this within the scope of this study. The present report lists the main suppliers that have been identified and gives an indication of areas with presence in the Nordic countries (see Section 2.3). The list is however not exhaustive and further study is required to gain deeper insight, involving expertise with extensive knowledge of the relevant production processes and the regulatory frameworks for different technical platforms.

5.2.2 New types of vaccines

New types of vaccines, such as mRNA/DNA vaccines and other novel vaccine platform technologies, are not readily established at commercial levels in any Nordic country. However, it is an area of intense research activity and many pharmaceutical companies and CMO/CDMOs are redirecting their focus towards these technologies. Despite the great promise these technologies hold for both prophylactic vaccines and vaccine therapies, there remain areas for potential improvement in the development and production of these products, including optimisation in process development and scaleup, stability and formulations and dependency of cold-chain shipping and storage.

Building competence and capacity in commercial manufacturing of new types of vaccines in the Nordic Region would make the region more competitive in attracting international investment and growth of new business. It would also contribute to European preparedness for potential future pandemics.

5.2.3 Competence build-up and skills supply

One theme common to many Nordic countries is the shortage of sufficient resources and competences necessary for industrial-scale manufacturing of vaccines, especially new types of vaccines. These are skills that are difficult to teach in theory and require exposure to the experience and infrastructure that only large-scale pharmaceutical and some commercial manufacturing organisations have access to. Countries with large pharmaceutical industries have some advantage as the national ecosystem is nurtured organically with industrial competence and experts stay in the country as there are more opportunities for employment.

Collaborative approaches to securing more sustainable skills development would be necessary if a more expansive vaccine production environment is envisioned for the Nordic Region. This would in turn also increase international attractivity as access to qualified personnel is one of the most critical factors in determining the suitability of a region for corporate investment in manufacturing.

5.2.4 Funding

Given that funding for vaccine research, development and production has been identified as an issue in several of the Nordic countries, this should be highlighted as an area that could be developed further in collaboration.

Increased public and private funding for basic research, innovation, clinical studies and commercialisation of vaccines would strengthen the overall pipeline of new fundamental discoveries in vaccine development, support long-term commercial development of new products within the region and attract more clinical trials to the Nordic countries.

5.2.5 Large-scale manufacturing and preparedness

One component of Nordic collaboration in vaccine production is to consider the availability and possible sharing of large-scale manufacturing facilities.

A vaccine GMP production plant or a plant with potential to produce vaccines can be converted to specific vaccines, but conversion requires time and resources. Also, an agreement on the conditions for conversion with the owner of the plant and a manufacturing license for the product intended to be produced after conversion will be necessary. The extent to which existing facilities and resources could be practically adjusted and made accessible to meet an identified need in e.g. a pandemic or other crisis will be dependent on the existence of such agreements and the type of technological platforms that are relevant.

For vaccines, production of drug substance and drug product/Fill & Finish are often separated geographically. The drug substance and the drug product steps constitute completely different parts of the production chain and differ considerably in terms of requirements for premises and equipment. The availability of large-scale production plants is unevenly distributed in the Nordic countries. There are numerous large-scale Fill & Finish facilities for production of biologicals, inactivated virus and protein vaccines in several locations. Facilities for production of drug substance on the other hand are limited and would today probably not suffice for supplying vaccine to the population in the Nordic countries (depending on technological platform used).

Vaccine production facilities intended solely for contingency purposes carry the challenge of maintaining a financial model that is sustainable over time as well as keeping the facility up to date regarding technology, competent and accredited personnel and quality systems. Keeping an empty facility "alive" is expensive and difficult.

Vaccine preparedness related to large-scale vaccine production for the Nordic Region should therefore probably be linked to the other EU initiatives on pandemic preparedness.

5.2.6 Joint Nordic participation in EU/international initiatives

During the Covid-19 pandemic, most countries in Europe have depended heavily on the strategies developed jointly within the European Union to secure vaccine for all member states. It is likely that the current pandemic preparedness initiatives under development within the EU will provide an even greater level of resilience and solidarity for Europe if, or more likely when, a health crisis strikes again. The Nordic countries are individually small but together form a critical mass of capacity and resources that are substantial on an international scale. In addition, the geographic location of the Nordic countries provides a complementary level of resilience to Europe in case of potential catastrophic developments on the central continent.

This speaks to the potential advantages of a more aligned Nordic strategy on participation in, and influence on, EU and international initiatives such as HERA and EU FAB. One example could be establishing joint Nordic working groups and infrastructure for engaging in EU/international initiatives relating to vaccine development (coordinating applications, legal aspects, contracting etc.). Nordic interests that are expressed mutually will have stronger impact than if each country presents their ideas separately. However, before engaging in such an endeavour, the countries would need to agree on more specific and substantiated goals shared by all the countries.

The opportunities that come with the establishment of the global organisations CEPI and IVI in the Nordic Region could open for joint Nordic collaboration within their framework. The experience within CEPI of supporting and coordinating competence and capability build up within vaccine production in developing countries, could also be of considerable use for capability build up in the Nordic Region. The presence of IVI will potentially intensify vaccine research in the region, and a joint approach could boost such development further.

6. Conclusions

Vaccines remain one of the most important medical technologies available to humanity, saving millions of lives annually. The global effort to rapidly develop safe and efficacious vaccines for SARS-CoV-2 in 2020 may be heralded as one of the greatest collaborative scientific achievements of our time. However, the need to rapidly develop and manufacture these vaccines also exposed vulnerabilities, including a global lack of coordinated production facilities and a complex international supply chain, that when stressed can result in shortages of raw materials and consumables.

The Covid-19 pandemic has highlighted the need for improved preparedness, more resilient supply chains and established collaboration processes prior to crises. Vaccines are complex therapeutics that are challenging to produce, requiring suitable expertise and facilities for process development, production, formulation and packaging. Today the Nordic countries are highly dependent on commercial vaccines that are primarily developed and produced outside the region, and the parts of the vaccine development and production value chain that are present in the Nordic Region are to a great extent dependent on global supplies.

While the EU has made significant efforts to increase European preparedness for pandemics and other health emergencies over the past two years, it is valid to further investigate the potential for collaboration, specifically between Denmark, Finland, Iceland, Norway and Sweden on strengthening vaccine production capabilities in the region. The Nordic countries are individually quite small but together provide a critical mass of capabilities and geographical proximity in Northern Europe that make the region strategically interesting for developing joint capacities within vaccine development, especially if catastrophic developments on continental Europe (health emergencies, natural disasters or military conflicts) should limit European production capacity.

This report is a result of a joint commission to Statens Serum Institut (Denmark), Business Finland (Finland), Landas EHF (Iceland), Innovasjon Norge (Norway) and Vinnova (Sweden) by the national ministers of business, industry and financial affairs. The aim has been to map the potential for Nordic collaboration within innovation, development and production of vaccines by providing an aggregated inventory of capacities available within vaccine production, clinical trials, supply chain and participation in European and international vaccine initiatives. The result of this material can be used as a basis for further analysis and for detailing common specific ambitions and goals for potential collaboration in the future.

Based on the aggregated material in this study it can be concluded that there may be advantages for coordinating joint efforts between the Nordic countries as outlined in Section 5.2. As stated previously, vaccines are complex and costly to produce, they require a broad range of skills, assets and infrastructure for development. Due to the

substantial but uneven distribution of expertise and capabilities in the Nordic countries, efforts to pool resources, funding, supply chains, skills development and clinical trials would provide added benefit to the region.

Specific joint investments in development of Nordic capabilities (research, skills and infrastructure for manufacturing) within new vaccine technology platforms (e.g. mRNA and DNA vaccines) where there are gaps across the Nordic Region (see Table 1), would not only increase the breadth and resilience of Nordic capabilities within vaccine development, but also potentially increase international investment, the number of clinical trials performed (Table 2), as well as strengthening the attractiveness of the Nordic countries as an internationally competitive life science region.

There are considerable efforts being made by the EU to strengthen overall European resilience and preparedness through initiatives such as EU FAB, VACCELERATE and HERA. Many Nordic countries are already involved in these efforts that will undoubtedly be of great benefit to improved response to future health emergencies. These initiatives are heavily influenced by Member States within the European Union. Joint efforts to increase Nordic influence and reap joint Nordic benefits from these initiatives is another area for potential collaboration.

An area requiring further analysis is the supply chains that provides the vaccine industry with the necessary raw materials, consumables, instrumentation and support functions required for successful vaccine development. The details and dependencies of these supply chains, and the extent to which sources are national, Nordic, European or international, has been very difficult to assess within the limited time frame of this report. Further investigation into the area would require expertise possessing extensive knowledge of the relevant production processes and the regulatory frameworks for different technical platforms.

In summary, the aggregated material provides a basis for assessing the comparative strengths of vaccine manufacturing and development in each of the Nordic countries, indicating that there are areas of strength and of potential improvement. However, in order to assess the full potential of collaboration between the Nordic countries in vaccine development, clear objectives and ambitions for collaboration must be formulated in order to place the Nordic capabilities into context.

7. Abbreviations

Found in main text or appendix

AI	Artificial Intelligence
API	Active pharmaceutical ingredient
ATMP	Advanced Therapy Medicinal Products
BFS	Blow Fill Seal
BSL	Biosafety Level
ca	circa
CCRM	Center for Commercialisation of Regenerative Medicine
CEPI	Coalition for Epidemic Preparedness Innovations
CMO	Contract Manufacturing Organisation
COVID	Coronavirus Disease
CDMO	Contract Development and Manufacturing Organisation
CRO	Contract Research Organisation
DG	Directorate General
DK	Denmark
DNA	Deoxyribonucleic Acid
DS	Drug substance
DP	Drug product
e.g.	for example
etc.	Et cetera
EU	European Union
EU FAB	Network of production capacities for vaccines and therapeutics manufacturing
GloPID-R	Global Research Collaboration for Infectious Disease Preparedness
FI	Finland
GCP	Good Clinical Practise
GDP	Good Distribution Practise
GLP	Good Laboratory Practise
GMP	Good Manufacturing Practise
HERA	European Health and Emergency preparedness and Response Authority
IC	Iceland
ICH	International Council for Harmonization of Technical Requirements for Registration of Pharmaceutical for Human Use
IEC	Import Export Code

IHI JU	Innovative Health Initiative Joint Undertaking
Incl.	Including
IoT	Internet of Things
IPCEI	Important Projects of Common European Interest
ISO	International Organization for Standardization
IVI	International Vaccine Institute
(m)RNA	(messenger) Ribonucleic Acid
NO	Norway
NOSAD	Nordic Security of Supply in the Age of Disruption
NTA	Nordic Trial Alliance
OECD	Organisation for Economic Cooperation and Development
PoC	Proof of Concept
QP	Qualified Person
R&D	Research and Development
RRF	Recovery and Resilience Facility
SE	Sweden
SME	Small and Medium Enterprises
TEM	Transmission electron microscopy
Tox	Toxicology
TRL	Technology Readiness Level
UCPM	Union Civil Protection Mechanism
US	United States
EUR	Euro

Appendix I

The tables listed below aim to describe current actors who could contribute to the research, development and/or manufacture of vaccines in the Nordic countries. These tables also include information relative to GMP facilities, Fill & Finish capabilities and potential resources from contracted organisations that could support the development of vaccines.

It is important to note that the information and underlying data was compiled separately in each country, using different methods of data collection and with sparse opportunities for mutual alignment between countries. The information presented here is extracted from each national report according to the criteria above. The information and organisations in this list have been summarised to a common format (including links to websites) with the ambition of serving as a basis of future studies.

Organisations playing a role in the process have been divided into eight categories from pharmaceutical companies based on their size to contracted organisations or government-owned institutions; this information is found in each table in the Type column (see associated legend under each table).

Organisations in Denmark

** Number description of the type of organisation is as follows; A. Pharma (large), B. Pharma (SME), C. CMO/CDMO (manufacturing), D. National infrastructures (academic or private), E. Government-owned or public (companies, hospitals, academic), F. CRO (research and other services)/consultants, G. Other (e.g. Biotech, aquaculture and other areas), H. Suppliers*

Organisation	Type*	Relevance	Location	Link
Adaptvac	B	Vaccine development against infectious diseases, cancer and immunological disorders.	Copenhagen	https://www.adaptvac.com
AGC Biologics	C	cGMP manufacture of protein-based therapeutics (mammalian and microbial production).	Copenhagen	https://www.agcbio.com
AJ Vaccines	A	Vaccine development. GMP-compliant production site.	Copenhagen	https://ajvaccines.com/
BASF A/S	A, H	Active within the industry for plastics, chemicals, construction and building as well as the automotive industry and in the human nutrition and agricultural sector. Listed as drug manufacturer for API.	Copenhagen, Ballerup, Vejle	https://www.basf.com/dk/en//who-we-are/BASF-in-Denmark.html
Bavarian Nordic	A	Vaccine developer with commercial-scale manufacturing. Fill & Finish.	Hellerup, Kvistgaard	https://www.bavarian-nordic.com
Biofac Group A/S	H	Supplier. Includes Pharmadan A/S and Orthana Kemisk Fabrik A/S.	Kastrup	https://biofac.dk
Bioneer	F, H	CRO, early drug candidates. Small, non-GMP recombinant protein expression manufacturing.	Hørsholm	https://bioneer.dk
Cytovac A/S	H	Immunotherapy. Phase I and II.	Hørsholm	https://cytovac.com
CRODA Denmark	F, H	Aseptic and cGMP manufacturing site for vaccine adjuvants.	Frederikssund	https://www.crodahealthcare.com/en-gb
DB Lab A/S	F, H	GMP certified analysis.	Odense	https://www.dblab.se

Organisation	Type*	Relevance	Location	Link
Evaxion Biotech	B	Drug discovery, in silico AI platform technologies. Bacterial and viral vaccines.	Hørsholm	https://www.evaxion-biotech.com
Expres2Ion	B	cGMP production, discovery to pre-clinical development. Recombinant protein expression system (ExpreS2 TM).	Hørsholm	https://expres2ionbio.com
Ferring Pharmaceuticals A/S	A	Drug manufacturer specialised towards API. Fill & Finish.	Kastrup	https://www.ferring.dk/
Ferrosan Medical Devices A/S	A, H	Strong capabilities within clinical insights, research and development, quality management and operations all the way to manufacturing the product. Particularly of relevance for syringes and needles.	Soeborg	https://www.ferrosanmedicaldevices.com/
Fertin	A, F	Formulation development, cGMP manufacturing and packaging. No vaccine development.	Vejle	https://fertin.com/
FUJIFILM Diosynth Biotechnologies	C	cGMP certified CDMO. Manufactures recombinant proteins, viral vaccines and gene therapies. Focus on cell culture, microbial fermentation.	Hillerød	https://fujifilmdiosynth.com
Genmab A/S	A	International biotech company specializing in the creation and development of differentiated antibody therapeutics for the treatment of cancer. Fill & Finish.	Copenhagen	https://www.genmab.com/
LEO Pharma	A	Research-based pharmaceutical company focusing on medical dermatology as therapeutical area. Fill & Finish.	Ballerup	https://www.leo-pharma.com/
Lonza	C	CDMO, custom manufacturing of biopharmaceuticals. Agreement with AstraZeneca about producing their own vaccine.	Copenhagen	https://www.lonza.com/
Lundbeck	A	Global pharmaceutical company. Research, development, manufacturing, marketing and sales of pharmaceuticals. Aseptic Fill & Finish.	Copenhagen (Valby)	https://www.lundbeck.com/global
MinerVax	B	Vaccine development, targeting pregnant women for the prevention of life-threatening infections in new-borns.	Copenhagen	http://minervax.com
Novo Nordisk	A	Global manufacturer. Research, development, manufacturing, marketing, and sales of pharmaceuticals. Fill & Finish.	Copenhagen, Bagsvaerd, Hilleroed, Koege, Soeborg, Måloev Hjoerring, Kalungborg.	https://www.novonordisk.com/
Pharmacosmos	G	Iron deficiency, GMP approval.	Holbæk	https://www.pharmacosmos.com/
Reponex Pharmaceuticals A/S	B	Drug Development, clinical stage.	Hørsholm	https://reponex.dk
Sterillab A/S	H	Supplier of sterilization solutions.	Gentofte	https://sterillab.com
Scantox A/S	F	Pre-clinical research organisation.	Lille Skensved	https://scantox.com
Statens Serum Institut	E	R&D of vaccines and adjuvants. GMP and animal testing facilities.	Copenhagen	https://en.ssi.dk/
Trial Nation Denmark	D	Clinical trials.	Copenhagen	https://trialnation.dk/
The Danish GCP units	D	Supports non-commercial researchers comply with good clinical practice (GCP) and Danish legislation.	Copenhagen, Aalbord, Aarhus, Odense	https://gcp-enhed.dk/english/
Xellia Pharmaceuticals (owned by Novo Holdings A/S)	A, F	Development and manufacturing of API. Focus on anti-infective treatments. Fill & Finish.	Copenhagen	https://www.xellia.com/
Y-mAbs Therapeutics A/S	B	Late-stage clinical biopharmaceutical company. Development and commercialisation of antibody-based therapeutic products for the treatment of cancer, including vaccines.	Hørsholm	https://ymabs.com/

Organisations in Finland

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Organisation	Type*	Relevance	Location	Link
Biovian Oy	C	GMP-authorised CDMO. From process development to production of finished products. Specialised in viral vectors for gene therapy and recombinant proteins.	Turku	https://biovian.com
FinVector Oy	B, C	R&D and GMP manufacturer of viral-based gene therapy products.	Kuopio	https://www.finvector.com/
Meilahti Vaccine Research Center	D, F	Government-owned CRO.	Helsinki	https://www.hus.fi/en/meilahti-vaccine-research-center-mevac
Paras Biopharmaceuticals Finland Oy	C	CDMO with recombinant biologics manufacturing.	Oulu	https://www.parasbiopharma.com
Vaccine Research Center Finvac Ltd.	E	CRO, conducts vaccine clinical studies.	Tampere	https://valtioneuvosto.fi
Rokote Laboratories Finland Oy	B	R&D, vaccine development.	Helsinki, Kuopio	https://rokote.com
Vactech Oy	B	R&D, vaccine development.	Tampere	http://www.vactech.fi/en/

Organisations in Iceland

** Number description of the type of organisation is as follows; A. Pharma (large), B. Pharma (SME), C. CMO/CDMO (manufacturing), D. National infrastructures (academic or private), E. Government-owned or public (companies, hospitals, academic), F. CRO (research and other services)/consultants, G. Other (e.g. Biotech, aquaculture and other areas), H. Suppliers*

Organisation	Type*	Relevance	Location	Link
Alvotech	A	Development and manufacturing of biosimilar medicines. Aseptic Fill & Finish.	Reykjavik	https://www.alvotech.com/
Arterna Biosciences	G	Biotech start-up (2021) selling enzymes required for RNA synthesis. Working with different polymerases and caspases.	Reykjavik	https://www.arternabio.com/
ArcticLAS	F	Preclinical research.		https://www.arcticlas.is/
Controlant hf	G	Global actor in real-time supply chain, monitors vaccines during shipping.	Kopavogur	https://controlant.com/
DeCODE Genetics	B	Analysing and understanding the human genome working also in vaccine responses.	Reykjavik	https://www.decode.com/
Institute for Experimental Veterinary Pathology at Keldur affiliated with the University of Iceland	E	Preclinical research.	Reykjavik	https://keldur.is/is/english-keldur
Sidekick Health		Gamification solution, that can be used in clinical trials.	Kopavogur	https://sidekickhealth.com/

Organisations in Norway

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Organisation	Type*	Relevance	Location	Link
Bionor Laboratories AS	G	Biotech company working on preclinical and clinical development for human and veterinarian use. Works on aquaculture.	Skien, Oslo	http://www.bionor.no/
Cody AS	H	High-tech equipment and automated solutions.	Skien	https://cody.no/en/
Curida AS	C	Formulation development and Fill & Finish. Aseptic manufacturing processes and terminal sterilisation.	Elverum	https://curida.no/
Diatec monoclonals AS	G	Two production sites of antibodies and specific APIs. One GMP, one ISO.	Oslo	https://diatec.com/
Lytix Biopharma		R&D and clinical-stage biotech company focusing on novel cancer immunotherapies.	Oslo	https://www.lytixbiopharma.com/
Nykode Therapeutics AS	B	Clinical-stage biopharmaceutical platform focusing on discovery and development of novel immunotherapies.	Oslo	https://nykode.com/
Pharma Q	G	Vaccine development for aquaculture. Research and manufacturing. GMP certification.	Overhalla, Oslo, Klöfta	https://pharmaq.com/en/
SINTEF	F	Early R&D partner.	Tondheim, Oslo	https://www.sintef.no/en/
Targovax ASA	B	Clinical stage immuno-oncology company developing immune activators for combination therapy in cancer.	Oslo	https://www.targovax.com/en/
The Viral Vector Core at Kavli Institet for Systems Neuroscience	E	R&D with expertise in high quality viruses for research purposes.	Trondheim	https://www.ntnu.edu/kavli/viral-vector-core
Ultimovacs ASA	B	Peptide-based vaccine platform with focus on immunotherapies towards cancer.	Oslo	https://ultimovacs.com/

Organisations in Sweden

** Number description of the type of organisation is as follows; A. Pharma (large), B. Pharma (SME), C. CMO/CDMO (manufacturing), D. National infrastructures (academic or private), E. Government-owned or public (companies, hospitals, academic), F. CRO (research and other services)/consultants, G. Other (e.g. Biotech, aquaculture and other areas), H. Suppliers*

Organisation	Type*	Relevance	Location	Link
Abera Biosciences AB	B	Vaccine development platform in late preclinical phase.	Uppsala	https://aberabio.com/
Adlego Biomedical AB	F	Early phase CRO with small GLP tox capacity.	Stockholm	https://adlego.se/
ALS MicroLab Stockholm AB	F	Swedish CRO for analytical support. ISO/IEC 170259 and GMP certified.	Sollentuna	https://www.alsglobal.se
Apotek Produktion & Laboratorier AB (APL)	C, E	Government owned. R&D, analysis, and formulation development. CDMO for biologicals, Fill & Finish.	Stockholm, Göteborg, Malmö, Umeå	https://www.apl.se/
AstraZeneca AB	A	Biologics manufacturing GMP, Fill & Finish. Own products.	Södertälje	https://www.astrazeneca.com/

Belach Bioteknik AB	H	Producers of Bioreactors and unique solutions for biotechnological systems. Decontamination solutions.	Stockholm, Skogås	https://www.new.belach.se
BioInvent International AB	C	Manufacturing GMP, protein-based biologicals.	Lund	https://www.bioinvent.com/
Birka BioStorage AB	H	Provides storage of samples from manufacturing, development, and clinical trials. Cell banks/Biobank, stability, GDP and GMP certified.	Lund	https://birkabiostorage.se
ClinStorage	E, H	GMP certified temperated storage solutions.	Solna	https://www.cleanstorage.se
Cytiva Testa Center AB	D, H	Testbed for biological products, process development. Non-GMP.	Uppsala	https://testacenter.com/
Diamyd Medical AB	B	Develop therapeutic vaccines. Preclinical production (GLP). Aim for GMP compliant by 2023.	Stockholm, Umeå	https://www.diamyd.com/
Eurocine Vaccines AB	B	Develops vaccine for Chlamydia. Own adjuvant (Endocine TM), available for customers.	Solna	https://www.eurocine-vaccines.com/
Eurofins BioPharma Product Testing Sweden AB	F	French global CRO, 6 sites in Sweden. GMP and Pharmacopeia.	Uppsala	https://www.eurofins.com
Galenica	C	CRO for process development and analysis. GMP certified.	Malmö	www.galenica.se
Getinge	H	Swedish supplier of sterilisation solutions in BSL 3 and 4 and handling of hazardous waste. Provides bioreactors.	Göteborg	https://www.getinge.com/
Medicago	H	Manufacturer of lectines and saponines.	Uppsala	www.medicago.se
NorthX Biologics Matfors AB	C, D	CDMO process development and manufacturing of biological drugs (drug substance) and forming an innovation hub.	Matfors	https://www.nxbio.com/
Novavax AB	A	US-based vaccine development company. Development, formulation, and manufacturing of own adjuvant (Matrix-M™) in Sweden.	Uppsala	https://www.novavax.com/
Octapharma Nordic AB	A	GMP Manufacturing (DS and DP). Blood-based protein products. Not vaccines.	Stockholm	https://www.octapharma.com/
Phase2Phase Biopharma AB	F	Consultants offering senior expertise and management in CMC of biologics.	Stockholm	https://phase2phase.com/
Pfizer Health AB	A	GMP manufacturing (including inactivated virus vaccine) and R&D for analytical and process formulation development.	Strängnäs	https://www.pfizer.com/
Pre-GMP facility at Karolinska Institutet	E	Preclinical research and process development facility.	Stockholm	https://staff.ki.se/core-facility-for-campus-flemingsberg-pre-gmp
Q&Q labs AB	E	GCP, GLP and GMP compliant facilities for analysis.	Mölndal	https://qandqlabs.se/en/
Rechon Life Science AB	C	GMP certified, Fill & Finish and storage capabilities for vaccines.	Malmö	https://www.rechon.com/
Recipharm AB	C	Formulation and Fill & Finish for R&D.	Solna	https://www.recipharm.com/
Research Institutes of Sweden (RISE) AB	E	Vaccine formulation and analytical development GLP tox facilities (in vivo and bioanalysis).	Stockholm, Södertälje	https://www.ri.se/en
Scandinavian Biopharma	B	Commercial R&D, specialised in global vaccine development, in-house scale-up and process development. Holds IP for own adjuvant.	Solna	https://scandinavianbiopharma.se/
Svenska vaccinfabriken AB (SVF)	B	Commercial R&D of DNA based vaccines combined with protein boosts.	Sollentuna	https://www.svenskavaccinfabriken.se/
Swedish Orphan Biovitrum AB	A	Middle-sized pharma company. R&D and manufacturing of biologicals.	Stockholm	https://www.sobi.com
TATAAA BioCenter AB	F	Swedish CRO. Bioanalysis. GLP certified.	Göteborg	https://tataa.com

Valneva Sweden AB	C	Production facilities for inactivated bacterial and viral vaccines, recombinant protein and virus vector vaccines. Fill & Finish.	Stockholm, Solna	https://www.valneva.se/en/general-public
Vecura and the Karolinska Cell Therapy Center (KCC)	E	Small-scale GMP manufacture of ATMP products.	Stockholm	https://ki.se/en/research/kcc-and-vecura
Vironova AB	F	Swedish CRO providing TEM and visual analysis of nanoparticles.	Stockholm	https://www.vironova.com
Ziccum AB	C	Vaccine formulation R&D.	Lund	https://ziccum.com/