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NordForsk

Improving research capabilities

An evaluation of the possibilities for increased Nordic cooperation on research infrastructures

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Executive Summary

Scientific progress has become more dependent upon advanced infrastructures and facilities, and research infrastructures have over the last few years received increased attention in science policy. With the use of utterly complex and ground-breaking technologies, research infrastructures have in turn become increasingly expensive and complex to build. There is thus a drive for investigating the possibilities for increasing international cooperation for construction and operation of infrastructures.

Scientific endeavour is in principle without borders, and international cooperation on infrastructures has a long tradition. This tradition is visible in very large infrastructures like the European Organization for Nuclear Research (CERN), and on a smaller scale as cooperation between countries and institutions. With the initiation of the processes in the European Strategy Forum on Research Infrastructures (ESFRI) the EU has reinforced European cooperation, while Nordic cooperation has recently been vitalised through several initiatives.

The emerging national roadmaps for infrastructures have high cost-estimates for new infrastructures. Besides the scientific advances made possible, cost-sharing is probably the best argument for cooperation. Flexible and innovative models for cost-sharing might be necessary for realising infrastructures.

Several general models for Nordic cooperation and actions are available, making it possible to choose between future strategies ranging from micro to macro level actions. Several

single and combined strategies are thus open for consideration: support to shared access to national facilities, establishing joint Nordic facilities or working together for realising and hosting large scale European facilities of common interest.

This policy brief focuses on the possibilities for further increasing Nordic cooperation on research infrastructures. This is done through analysis of current policies and positions, and through a discussion of contextual factors.

THE CHALLENGE: POLICIES FOR REALISING NORDIC COOPERATION

Efforts to realise closer Nordic cooperation are well under way. Still, given the complexities of the international processes for research infrastructures, the large investment required as well as other elements to be discussed in this report, the room for improved coordination and joint initiatives is large.

Among recent developments, the programme *Joint Nordic Use of Research Infrastructure* has been implemented by NordForsk and the first grants were distributed in 2007. On the policy side, several conferences and meetings have been organised, aimed at optimising joint Nordic participation in the planning and implementation of European and international infrastructure projects, to optimise joint Nordic use of research infrastructures and to increase the interaction between existing infrastructures.

All of the Nordic countries are also well

under way in formulating their own strategies for infrastructures, the so-called roadmaps. From these processes emerge consolidated priorities at national level that provide the input for discussing cooperation. It is however realistic to expect the final outcome of priorities at national level to show some discrepancies between countries regarding what types of infrastructure to realise and in what order, making coordinating efforts across countries a challenge.

Another concern is that realising the relatively long lists of prioritised infrastructures emerging from the national processes will require considerable resources over a long time, and the battles for getting funds will probably be hard for all of the suggested facilities. The final outcomes of the processes are thus dependent on the political level and the budgetary processes, and may face the risk of being subject to concerns other than what has underpinned the priorities from scientists and their organisations. In the overall struggle for public funding, the cost of research infrastructures will of course have to be measured against the costs of health, communications, education and all the other good causes. The economic benefits of cross-border cooperation might make it easier to overcome these challenges.

The Nordic coordinated effort and the individual national efforts are however part of a larger endeavour in the European and global arena. The Nordic countries are already members of global and European initiatives. The European Strategy Forum on Research Infrastructures (ESFRI) process is the dominant context for most large infrastructure developments these days. The ESFRI process is likely to result in an extensive strategy for new infrastructures which will set the agenda for many stakeholders in the years to come. Keeping in focus the possibilities for Nordic cooperation in this context is thus a challenge, but represents also a possibility for increasing the influence on the process. This requires involvement at the higher levels of policy making. The main challenge is to convince stakeholders that cooperation actually can result in some expectations being met.

THE POSITION OF THE NORDIC COUNTRIES

The Nordic countries are not only putting together roadmaps for which infrastructures to build at national level, but strategies for participation and priorities in international processes, foremost the European level ESFRI process, forms an integrated part of the national processes. Strategies and priorities are thus about to emerge both for national and international level development.

Nordic cooperation on research infrastructures will be about alignment of national priorities, and finding the relevant measures to bring this alignment forward.

Denmark conducted in 2005 a survey on the needs for infrastructures, and a strategy has been implemented in the years since. Currently the strategy is being updated, expected to be finalised by the end of 2008. As a roadmap already exists, the update is expected to move more in the direction of a strategy for the funding of infrastructures.

Denmark has expressed interest in participating in 12 of the shortlisted ESFRI projects, and has expressed interest in co-hosting the European Spallation Source (ESS) with Sweden in Lund. Denmark is currently negotiating membership in the X-ray Free-Electron Laser (XFEL) in Hamburg and for The Institut Laue-Langevin (ILL) in Grenoble. To date no final decisions have been taken, but a contract for the XFEL is expected to be signed in the near future.

Interviews show that Denmark finds the existing Nordic collaboration on research infrastructures very valuable. It estimates that for the future, joint access and funding for very expensive facilities especially could be valuable from a Nordic perspective, even though it should be acknowledged that Nordic collaboration is not always relevant. Denmark is thus positive about further developing Nordic collaboration for research infrastructures, and NordForsk is identified as the possible driving force and point of departure in the further process.

Finland started a process towards a roadmap when the Research Infrastructure Committee of the Ministry of Education proposed a national review of research infrastructures in 2007. At the beginning of 2008 the *Federation of Finnish Learned Societies* made a survey on the needs for national level research infrastructures and participation in international research infrastructures via existing inter-governmental agreements or memberships. The process will go on during 2008 with expert evaluations, before the final report will be presented by the end of the year.

Among the ESFRI projects, Finland is involved in the construction of the Facility for Antiprotons and Ion Research (FAIR) facility and Technical Research Centre of Finland (VTT) is involved in the construction of the Jules Horowitz Reactor (JHR). Finland is currently discussing its participation in the Swedish National Electron Accelerator Laboratory (MAX IV).

Interviews show that from a Finnish perspective, the distinction between Nordic and other European countries for infrastructure cooperation is not very important, but there are research topics like environmental and Arctic research that are considered particularly suited to Nordic cooperation. In a Nordic perspective Finland also wishes to see a closer cooperation with the countries in the Baltic Sea region.

Iceland recently started a process towards mapping existing facilities and needs for national and international research facilities. Preparation of the roadmap started September 2008, and the final report is expected to be presented to the Ministry of Education in December 2008.

The general view among Icelandic stakeholders seems to be that there is a great potential for improvement regarding Iceland's participation in international research facilities, and awareness of the importance of increased participation. Nordic cooperation is a very important part of this.

Currently Iceland is involved in two ESFRI projects; the bioinformatics and the bio-banks projects.

Norway collected in 2007 viewpoints from research institutions on the need for research infrastructures at the expected costs of NOK >30 mill, as well as which ESFRI projects to participate in. Based on the survey, an infrastructure strategy was published in 2008, including the proposal for a funding mechanism. The roadmap is currently being considered by the relevant ministries.

The strategy lists 12 out of the 35 proposed ESFRI projects as interesting for Norwegian participation. In June 2008 the Research Council of Norway recommended that Norway support the location of ESS in Sweden, and enter into negotiation with Sweden regarding possible Norwegian participation. Norway has suggested three new projects to be included in the ESFRI update:

- European Carbon dioxide Capture and Storage Laboratory Infrastructure (ECCSEL).
- Svalbard Integrated Arctic Earth Observing System (SIAEOS)
- Advanced Sustainable Sea-based Aquaculture (ASSA)

Decisions on future action regarding ESFRI currently rest with the government.

Interviews show that from a Norwegian point of view, actions at Nordic level need to be balanced against the European arena. The ESFRI process is at the moment high on the agenda, drawing the focus somewhat away from the Nordic arena, but there are fields of research that are considered very well suited for Nordic cooperation, such as climate and polar research and databanks.

Sweden updates its roadmap for infrastructures annually. In the 2008 update the Swedish Research Council recommends investing in a number of national and international infrastructure projects that are of strategic importance in strengthening Swedish research in the long term. A new government research bill is expected during autumn 2008, which is expected to stress the usefulness of research infrastructures.

Swedish infrastructure policies are currently focusing on making Sweden the host country for ESS and the Max IV. Besides ESS, Sweden participates in the preparatory phase of about 15 of the ESFRI projects (including XFEL and FAIR).

Interviews show that Sweden considers Nordic collaboration to be strategically important for increasing quality and attracting large international research facilities. A number of research areas have been identified where Nordic collaboration could be of particular value, such as climate and the environment, polar research, demographic studies, language technology, biobanking, databases etc. The Swedish Research Council has suggested that future Nordic collaboration could involve the establishment of large international infrastructures in the Nordic region (such as the ESS, the MAX IV, EISCAT-3D and eInfrastructures).

SCENARIOS FOR THE FUTURE

The Nordic countries are somewhat asynchronous regarding the point in time their strategies for infrastructures will be completed and their policies and priorities show some variations. Discrepancies are however in no way overwhelming, and when priorities from all the countries emerge in the course of 2009 a very favourable window for improved Nordic cooperation and coordination will open. This is a point in time when the ESFRI update process has also moved a considerable step forward, with the results of the update process expected to be published in December 2008. The Nordic countries will thus be in a position to judge what possibilities there are for joining forces for realising infrastructures of common interest among themselves and for judging the possibilities for joining forces for realising European infrastructures.

Forces can of course be joined in many ways and for the realisation of a varied spectrum of goals. To facilitate the discussion on which direction Nordic cooperation can go, we propose four scenarios singling out some main directions open. They should be considered as signposts for possible roads to follow towards the same end, not as the definitive route.

Scenario A

“The Global Research Platform”

The Nordic countries join forces to establish the region as a preferred location for internationally operated large infrastructures, with the aim of having several large international infrastructures in place in relatively few years. This scenario will be part of an ambition to strengthen the region as a centre for advanced science and of enhancing the region's position in the knowledge economy by drawing on the positive effects from infrastructures for industrial and societal development.

Scenario B

“The Nordic ESFRI initiative”

The Nordic countries coordinate their opinions and actions towards the ESFRI process more strongly and systematically, with the ambition of realising those infrastructures with highest priority among the Nordic countries. The countries have a common interest in realising several of the ESFRI projects, and through intensified coordination and commitment this interest can be realised.

Scenario C

“The Nordic Research Technology Initiative”

The Nordic countries get more involved in international research infrastructures through development of crucial technologies for infrastructures. Development, construction, testing and installation of advanced technologies form a gateway for increased involvement in large-scale facilities. It requires a dedicated effort for improvement and development of existing infrastructures in the Nordic countries, including cooperation with industries capable of delivering the required technologies.

Scenario D

“Nordic excellence”

The Nordic countries develop further the existing cooperation on Nordic Centres of Excellence and the initiative *Joint Nordic Use of Research Infrastructure*. This scenario can imply both development of new joint facilities and increasing shared access to facilities, constructing an integrated approach for excellent research and technological innovation in fields of high importance.

IMPROVING COORDINATION

Increased ambitions and activities necessary for their realisation also require improvements in coordination and interaction with the political level. Considering the possible scientific and economic impacts of large research infrastructures, as well as the technically and politically complex processes preceding their realisation, we suggested a three-level structure where the top level endorses the processes at policy level, the intermediate level has a day-to-day operative responsibility for ongoing processes, and the basic level has the responsibility for making infrastructures meet the needs of science.

The Infrastructures High Level Group

The mandate of the group is to negotiate and prepare propositions at government level necessary for the implementation and funding of joint Nordic infrastructures and joint positions towards international infrastructures. The group consists of representatives of ministries from each country, or other bodies with the necessary authority.

The Infrastructures Standing Committee

The mandate of the committee is to prepare and prioritise joint actions. The committee will seek out the potential for cooperation through interaction with ad hoc scientific committees, investigate the possibilities for joint actions and make the preparations necessary for the high level group. The group consists of officials from research councils, academies of science and other relevant bodies at the operative level.

Ad hoc Scientific Committees

The mandate of these committees is to seek out potential cooperative actions and the provisional specifications for joint/shared facilities or for joint actions towards international initiatives. Committees will be set up ad hoc with a mandate from the standing committee.



Increased ambitions and a strengthened coordinating structure will also require a reinforcement of administrative resources. NordForsk is the obvious choice for undertaking these functions, and should be given the resources necessary for maintaining the permanent secretary functions as well as for seeing plans and preparatory actions realised.

Assessment of which infrastructures that might meet future needs for knowledge and how research infrastructures can play a part in industrial and economic development in the Nordic region can be improved. To meet these needs we suggest the implementation of a foresight study. Foresight studies have already been successfully implemented in science and innovation policy in the Nordic countries. Technology foresight might be seen as one of several inputs available to politicians and businesses when making decisions concerning investments in the future and in strengthening the dialogue between business and the research communities. Combined with the emerging national roadmaps and analysis of regional scientific strongholds and the extra-scientific effects of infrastructures, this will lay the foundation for well informed choice.

Sammendrag

Vitenskapelig utstyr og infrastruktur har blitt en viktig forutsetning for å frembringe nye vitenskapelige resultater, og forskningsinfrastruktur har de senere årene fått økt oppmerksomhet i forskningspolitikken. Med bruken av svært kompliserte og banebrytende teknologier, har forskningsinfrastruktur i sin tur blitt stadig mer kostnads-krevende og komplisert å utvikle. Dette har skapt et behov for å styrke det internasjonale samarbeidet om bygging og drift av infrastruktur.

Vitenskap er i prinsippet en aktivitet uten grenser og det er en lang tradisjon for internasjonalt samarbeid om infrastruktur. Denne tradisjonen er synlig i de store infrastrukturene som European Organization for Nuclear Research (CERN), men også innenfor samarbeid i mindre skala mellom land og institusjoner. Gjennom opprettelsen av European Strategy Forum on Research Infrastructures (ESFRI) og de prosesser som forumet har tatt initiativ til har EU forsterket det europeiske samarbeidet, samtidig som nordisk samarbeid også har blitt forsterket gjennom en rekke initiativ.

De nasjonale veikartene for infrastruktur som er under utarbeidelse omfatter ny infrastruktur med betydelige kostnader. I tillegg til at samarbeid øker mulighetene for vitenskapelige gjennombrudd, er kostnadsdeling sannsynligvis det viktigste argumentet for samarbeid om infrastruktur. Innovative og fleksible modeller for kostnadsdeling kan derfor være nødvendig for å få realisert ny infrastruktur.

Flere modeller for nordisk samarbeid og

samhandling finnes, noe som gjør det mulig å iverksette tiltak på mange plan, fra mikro- til makronivå. Strategier kan derfor utvikles som enkelttiltak eller som en kombinasjon av ulike tiltak, for eksempel støtte til bruk av infrastruktur på tvers av landegrensene, etablering av fellesnordiske fasiliteter eller samarbeid for å få realisert store europeiske fasiliteter og få dem lokalisert til Norden.

Denne rapporten fokuserer på mulighetene for å forsterke det nordiske samarbeidet om forskningsinfrastruktur. Dette gjøres gjennom en analyse av politikk og ståsteder, og gjennom en drøfting av faktorer som danner konteksten for politikken på området.

UTFORDRINGEN: POLITIKK FOR NORDISK SAMARBEID

Man har kommet godt i gang med tiltak for økt nordisk samarbeid om forskningsinfrastruktur. Til tross for dette gjør kompleksiteten i de internasjonale prosessene, de store investeringene som er nødvendige og en del andre faktorer som drøftes i denne rapporten at rommet for forbedret koordinering og fellestiltak er stort.

Et av samarbeidstiltakene som nylig er satt i verk av NordForsk er programmet *Joint Nordic Use of Research Infrastructure*, der de første tildelingene ble gjort i 2007. Flere konferanser og møter har blitt organisert for å diskutere behovet og mulighetene for økt nordisk samarbeid om planlegging og implementering av europeiske og internasjonale infrastrukturer, og for å optima-

lisere bruken av eksisterende nordiske infrastrukturer og øke samhandlingen dem imellom.

Alle de nordiske landene har kommet godt i gang med utarbeidelsen av egne strategier for infrastruktur, de såkalte «veikartene for infrastruktur». Gjennom disse prosessene er det utviklet konsoliderte nasjonale prioriteringer som danner et godt utgangspunkt for å drøfte samarbeid. Realistisk må man likevel forvente at de nasjonale prioriteringene går i ulik retning både når det gjelder hvilke typer infrastruktur som prioriteres og i hvilken rekkefølge de skal implementeres. Dette gjør koordinering mellom landene til en utfordring.

En annen utfordring ligger i det at realisering av de forholdsvis mange kostnadskrevende infrastrukturene som blir prioritert på nasjonalt nivå krever store investeringer over lang tid. Å få sikkerhet for at de nødvendige økonomiske ressursene stilles til rådighet vil derfor bli krevende. Det endelige utfallet av prosessene vil være avhengig av politiske beslutninger og budsjetter. Dette kan medføre at andre hensyn og prioriteringer enn de rent vitenskapelige behovene blir lagt til grunn når de endelige beslutninger foretas. I kampen om offentlige bevilgninger vil ressurser til forskningsinfrastruktur måtte vurderes i forhold til investeringer i helse, samferdsel, utdanning og mange andre gode tiltak. Økt samarbeid mellom landene kan gjøre det enklere å overvinne slike utfordringer.

Nordisk samarbeid og nasjonale tiltak i de nordiske landene inngår i mer omfattende prosesser på den europeiske og den globale arena der de nordiske landene allerede deltar. Prosessene iverksatt av ESFRI er for øyeblikket den dominerende konteksten for utvikling av infrastruktur. ESFRI-prosessen vil sannsynligvis resultere i en omfattende strategi for ny infrastruktur og denne strategien må forventes å sette dagsorden for mange av aktørene i de nærmeste årene. Å sette fokus på nordisk samarbeid kan være krevende i denne sammenhengen, men nordisk samarbeid innebærer også betydelige muligheter for økt innflytelse. Dette krever engasjement og involvering av aktører på høyt nivå i politikken. Utfordringen her ligger i å overbevise interessentene om at et samarbeid faktisk kan føre til at forventninger innfris.

DE NORDISKE LANDENES STÅSTED

De nordiske landene er ikke bare i ferd med å utvikle veikart for utvikling av nasjonale infrastruktur, men også strategier for deltakelse og prioriteringer i de internasjonale prosessene, først og fremst knyttet til den europeiske ESFRI-prosessen. Strategier og prioriteringer er derfor i ferd med å materialisere seg for utvikling av infrastruktur både på nasjonalt og internasjonalt nivå.

Nordisk samarbeid om infrastruktur vil derfor dreie seg om å finne felles ståsteder med utgangspunkt i de nasjonale strategiene, og om å finne strategier for å realisere de felles prioriteringene.

Danmark gjennomførte i 2005 en undersøkelse for å kartlegge behovet for ny infrastruktur, og en strategi har blitt implementert i årene etter dette. Strategien blir nå oppdatert og er forventet ferdigstilt innen utgangen av 2008. Siden man allerede har et veikart, forventes det at oppdateringen i større grad vil fokusere på strategier for finansiering av infrastruktur enn på hvilke infrastrukturer som behøves.

Danmark har uttrykt interesse for å delta i 12 av de prosjektene som er på ESFRIs prioriterte liste, og har uttrykt interesse for å være vertskap for European Spallation Source (ESS) i samarbeid med Sverige. Danmark forhandler også om medlemskap i X-ray Free-Electron Laser (XFEL) i Hamburg og i Institut Laue-Langevin (ILL) i Grenoble. Så langt har man ikke nådd frem til endelige beslutninger, men det forventes at en kontrakt om medlemskap i XFEL vil undertegnes i løpet av den nærmeste fremtid.

Intervjuer viser at Danmark finner det nordiske samarbeidet om infrastruktur verdifullt og at felles tilgang til og felles investeringer i svært kostbar infrastruktur vil være verdifullt i et nordisk perspektiv, selv om man må innse at nordisk samarbeid ikke alltid er like relevant. Danmark er således positivt innstilt til å videreutvikle det nordiske samarbeidet, og NordForsk anses som et naturlig utgangspunkt og drivkraft for det videre arbeidet.

Finland startet prosessen mot et veikart med at Komiteen for forskningsinfrastruktur i Under-

visningsministeriet i 2007 foreslo en gjennomgang av infrastrukturen. I begynnelsen av 2008 gjennomførte Vetenskapliga Samfundens Delegation en undersøkelse angående behovet for forskningsinfrastruktur på nasjonalt nivå og angående behovet for deltakelse i internasjonale infrastrukturer gjennom eksisterende avtaler og medlemskap. Prosessen vil fortsette i 2008 med ekspertevalueringer, før en endelig rapport forventes å bli lagt frem ved utgangen av 2008.

Blant ESFRI-prosjektene er Finland involvert i oppbyggingen av Facility for Antiprotons and Ion Research (FAIR), og Finlands Tekniske Forskningscenter (VTT) er involvert i konstruksjonen av Jules Horowitz Reactor (JHR). Finland drøfter også deltakelse i Sveriges nasjonale elektronakselerator-laboratorium (MAX IV).

Intervjuer viser at fra finsk perspektiv er ikke skillet mellom nordisk samarbeid og samarbeid med andre europeiske land så fremtredende, men forskningsområder som miljøforskning og arktisk forskning oppfattes som spesielt godt egnet for nordisk samarbeid. I et nordisk perspektiv ønsker Finland også å ivareta et forsterket samarbeid med landene i den baltiske region.

Island påbegynte nylig en kartlegging av eksisterende fasiliteter og behovet for nasjonale og internasjonale forskningsfasiliteter. Forberedelsene for å få utarbeidet et veikart startet i september 2008, og den endelige rapporten forventes å bli forelagt Ministeriet for Undervisning, Forskning og Kultur i desember 2008.

Det islandske ståsted synes å være at det er et stort potensiale for å forbedre Islands deltakelse i internasjonale forskningsfasiliteter, samt for å øke oppmerksomheten i forhold til slik deltakelse. Nordisk samarbeid er en svært viktig del av dette.

Island er involvert i to ESFRI-prosjekter, innenfor bioinformatikk og biobanker.

Norge samlet i 2007 inn synspunkter fra forskningsinstitusjonene angående behovet for ny større infrastruktur og angående deltakelse i ESFRI-prosjekter. Basert på undersøkelsen ble en infrastruktur-strategi som også omhandlet finansiering lagt frem i 2008. Strategien er for tiden til behandling i de relevante departementer.

Strategien lister opp 12 ESFRI-prosjekter som er av interesse for Norge. Norges forskningsråd anbefalte i juni 2008 at Norge burde støtte lokalisering av ESS til Lund og at man burde innlede forhandlinger med Sverige om mulig norsk deltakelse i prosjektet. I forbindelse med ESFRI-oppdateringen har Norge foreslått tre nye prosjekter:

- European Carbon dioxide Capture and Storage Laboratory Infrastructure (ECCSEL).
- Svalbard Integrated Arctic Earth Observing System (SIAEOS)
- Advanced Sustainable Sea-based Aquaculture (ASSA)

Beslutninger angående norsk deltakelse i ESFRI-prosjekter er til behandling i regjeringen.

Intervjuer viser at fra et norsk ståsted bør nordisk samarbeid balanseres mot samarbeid på europeisk nivå. Den store oppmerksomheten rettet mot ESFRI trekker i noen grad oppmerksomheten bort fra det nordiske samarbeidet, men det er også forskningsområder som vurderes som særlig godt egnet for nordisk samarbeid, for eksempel klimaforskning, polarforskning og databanker.

Sverige oppdaterer sitt veikart for forskningsinfrastruktur årlig. I oppdateringen gjort i 2008 anbefaler Vetenskapsrådet investeringer i et antall nasjonale og internasjonale infrastrukturer som er av strategisk betydning for svensk forskning. En ny proposisjon om forskning er forventet høsten 2008, og den forventes å understreke behovet for infrastruktur.

Svensk politikk for infrastruktur er fokusert på å få ESS lokalisert til Sverige, samt på realiseringen av MAX IV. I tillegg til ESS, deltar Sverige i forberedelsesfasen til 15 ESFRI-prosjekter, inkludert XFEL og FAIR.

Intervjuene viser at Sverige ser på nordisk samarbeid som strategisk viktig for å øke forskningskvaliteten og for å tiltrekke seg store internasjonale fasiliteter. Et antall forskningsområder er identifisert der nordisk samarbeid kan være særlig verdifullt, for eksempel klima

og miljø, polarforskning, demografiske studier, språkteknologi, biobanker og databaser. Vetenskapsrådet har foreslått at fremtidig nordisk samarbeid kan omfatte etablering av store internasjonale infrastrukturer i den nordiske regionen, for eksempel ESS, MAX IV, EISCAT-3D og eInfrastruktur.

SCENARIOER FOR FREMTIDEN

De nordiske landene er ikke helt i samme fase når det gjelder ferdigstillelse av nasjonale strategier for infrastruktur, og deres politikk og prioriteringer er noe ulike. Forskjellene er likevel på ingen måte overveldende, og når alle landene får gjort sine prioriteringer i løpet av 2009 kan det oppstå en svært gunstig anledning for å forsterke det nordiske samarbeidet og koordineringen. Dette er også et tidspunkt da ESFRI-prosessen er forventet å ha kommet et langt stykke videre ettersom resultatene fra oppdateringsprosessen forventes å foreligge i siste del av 2008. De nordiske landene vil derfor være i posisjon til å bedømme hvilke muligheter som foreligger for å forene kreftene med henblikk både på virkeliggjøring av infrastruktur der de har felles interesser og på felles opptreden på den europeiske arena.

Kreftene kan selvfølgelig forenes på mange måter og for å realisere flere mål. Som et bidrag til diskusjonen om mulige retninger for det nordiske samarbeidet foreslås fire scenarioer som antyder mulige hovedretninger. Scenarioene bør betraktes som retningsvisere for flere mulige veier til samme mål snarere enn som definitive veivalg.

Scenario A

"Den globale forskningsplattformen"

De nordiske landene forener krefter for å etablere Norden som den foretrukne region for store internasjonale infrastrukturer, med det mål å ha flere store internasjonale infrastrukturer lokalisert i regionen i løpet av relativt få år. Dette scenarioet vil være ledd i en ambisjon om å styrke regionen som et senter for avansert forskning og om å styrke regionens posisjon i kunnskapsøkonomien ved å utnytte de positive effektene av infrastruktur til industriell og samfunnsmessig utvikling.

Scenario B

«Det nordiske ESFRI-initiativet»

Med ambisjoner om å få realisert de ESFRI-prosjektene som er høyest prioritert av de nordiske landene, koordinerer landene sterkere og mer systematisk sine standpunkter og handlinger i forhold til ESFRI-prosessen. De nordiske landene har en felles interesse i å få realisert flere av prosjektene, og ved hjelp av forsterket deltakelse og koordinering kan denne interessen bli virkeliggjort.

Scenario C

«Det nordiske initiativet for forskningsteknologi»

De nordiske landene øker sin deltagelse i internasjonale forskningsinfrastrukturer ved å utvikle sentral teknologi til infrastrukturene. Utvikling, konstruksjon, testing og installasjon av teknologi kan åpne en port for økt deltagelse i stor-skala fasiliteter. Det vil kreve en dedikert innsats for å forbedre og videreutvikle eksisterende fasiliteter i de nordiske landene, inkludert forsterket samarbeid med den industrien som er i stand til å levere denne typen teknologi.

Scenario D

«Fremragende nordisk infrastruktur»

De nordiske landene videreutvikler samarbeidet omkring "Nordic Centres of Excellence" og initiativet for felles nordisk bruk av infrastruktur. Scenarioet kan medføre utvikling av nye fellesnordiske fasiliteter og større adgang til fasiliteter på tvers av landene. Samlet vil det innebære en integrert tilnærming til fremragende forskning og teknologisk innovasjon på strategisk viktige områder.

FORBEDRET KOORDINERING

Økte ambisjoner og et økt aktivitetsnivå for å realisere ambisjonene krever forbedret koordinering og integrering på det politiske nivå. Tar man de potensielle vitenskapelige og økonomiske effektene av stor infrastruktur, samt de kompliserte tekniske og politiske prosessene som må gå forut for en eventuell realisering, i betraktning, er det hensiktsmessig å foreslå en struktur med tre nivåer. Det øverste nivået forankrer prosessene på det

politiske nivå, et mellomnivå har det operative ansvaret for igangsatte prosesser, og et basisnivå har ansvaret for at infrastrukturen samsvarer med forskningens behov.

Den nordiske embetsmannsgruppen for infrastruktur

Gruppens mandat vil være å forberede og fremforhandle de forslag som er nødvendige på regjeringnivå for å implementere og finansiere fellesnordiske infrastrukturer og felles nordiske posisjoner i forhold til internasjonale infrastrukturer. Gruppen settes sammen av representanter for de relevante ministeriene eller for andre organer med den nødvendige autoritet.

Den permanente komité for infrastruktur

Komiteens mandat er å forberede og prioritere fellesnordiske tiltak. Komiteen vil undersøke mulighetene for samarbeid gjennom samhandling med de vitenskapelige komiteene, undersøke mulighetene for felles tiltak og gjøre de nødvendige forberedelser i forhold til embetsmannsgruppen. Komiteen settes sammen av representanter for forskningsrådene, vitenskapsakademiene og andre relevante organer på operativt nivå.

Ad hoc vitenskapelige komiteer

Mandatet til disse komiteene er å undersøke mulighetene for samarbeid og å utarbeide spesifikasjoner for felles eller delte infrastrukturer, samt for felles ståsted i forhold til internasjonale prosesser. Komiteene vil bli etablert ad hoc med mandat fra den permanente komiteen.

Økte ambisjoner og en forsterket koordineringsstruktur vil også kreve forsterkede administrative ressurser. NordForsk er det opplagte valg til å utføre disse funksjonene, og bør bli tildelt de nødvendige ressursene for å utføre permanente sekretæroppgaver og for å sikre at forberedelsesfaser og planer blir gjennomført.

Vurderinger av hvilke infrastrukturer som kan bidra til å møte fremtidige behov for kunnskap og hvordan forskningsinfrastruktur kan bidra til økonomisk og industriell utvikling i Norden kan forbedres. For å imøte-

komme disse behovene foreslås en fremsynsstudie. Fremsynsstudier har blitt gjennomført med suksess som grunnlag for forsknings- og innovasjonspolitikken i flere av de nordiske landene. Teknologiske fremsynsstudier kan sees som en av flere typer informasjonskilder tilgjengelige for politikere og næringsliv når beslutninger om fremtidige investeringer skal gjøres og når dialogen mellom forskere og næringsliv ønskes forsterket. I kombinasjon med nasjonale veikart, analyser av regionens vitenskapelig sterke områder og de utenomvitenskapelige effektene av infrastruktur, vil en fremsynsstudie legge et godt fundament for beslutninger.

RU

The image features a large, bold, orange-colored text 'RU' that dominates the foreground. The background is a vibrant blue with a dynamic, radial pattern of lines emanating from the center, creating a sense of motion and depth. In the center of the image, a person is visible, appearing to be running or moving quickly towards the viewer. The person is slightly out of focus, emphasizing the sense of speed and movement. The overall composition is energetic and visually striking.

uc

1. Current policies and strategies

Policies and strategies for research infrastructures are under development in all of the Nordic countries as well as at European level. This section reports current status of policies and initiatives at national level in each of the Nordic countries and at Nordic and European level. Descriptions of emerging policies are partly compiled from official strategy documents and partly from interviews. Since descriptions largely depict what can be characterised as “work in progress”, they should not be interpreted as official policies or statements.

1.1 NATIONAL STRATEGIES FOR RESEARCH INFRASTRUCTURE IN THE NORDIC REGION

The Nordic countries have started a process for realising a closer cooperation towards research infrastructures. On the operative side, the programme *Joint Nordic Use of Research Infrastructure* has already been implemented by NordForsk and the first grants were distributed in 2007. On the policy side, the aims are to optimise joint Nordic participation in the planning and implementation of European and international infrastructure projects, to optimise joint Nordic use of research infrastructures and to increase the interaction between existing infrastructures. The possible realisation of these aims was discussed by a group of national experts at a workshop arranged by NordForsk in 2007, while a larger conference addressing the topic will be arranged in November 2008. Efforts to realise closer cooperation are thus well under way. Still, given the complexities of the international processes for research infrastructures, the large investments required, as well as other elements to be discussed in this report, the room for improved coordination and joint initiatives is large.

All of the Nordic countries are also well under way in formulating their own strategies for infrastructures, the so-called road-

maps. These processes provide a very favourable point in time for coordinating actions. Not only have these processes without doubt increased the attention of policy makers towards the need for infrastructures and thus the possibilities for active involvement. From these processes emerge consolidated priorities at national level that provide the input for discussing cooperation. The national processes are however not fully synchronous and while Denmark, Norway and Sweden will have their priorities updated in 2008, Finland and Iceland have only recently started their processes and priorities might not emerge before 2009. There may be some risk of losing momentum and influence towards international processes if potential coordinating actions are not initiated before these countries have finished their national processes. It is also realistic to expect the final outcome of priorities at national level to show some discrepancies between countries regarding what types of infrastructure to realise and in what order, making coordinating efforts across borders a challenge.

Another concern is that realising the relatively long lists of prioritised infrastructures emerging from the processes will require considerable resources over a long time, and the battles for getting funds will probably be hard for all of the suggested facilities. The final outcomes of the processes are thus dependent on the political level and the budgetary processes and may face the risk of being subject to concerns other than what has underpinned the priorities from scientists and their organisations. For example, concessions to a “fair distribution” of resources between fields of science, institutions and geographic locations may affect the original priorities. In the overall struggle for public funding, the cost of research infrastructures will of course have to be measured against the costs of health, communications, education and all the other good

causes. The economic benefits of cross-border cooperation might however make it easier to overcome these challenges.

The Nordic coordinated effort and the efforts of each of the countries is however part of a larger endeavour in the European and global arena. The Nordic countries are already members of global and European initiatives like CERN, EMBL, ESO, ESRF etc, and have to pay attention to the future development of these. Membership fees, expansion and modernisation of facilities, like the Large Hadron Collider at CERN for example, require substantial budget allocations that might have consequences for available resources for other facilities. Further, the pan-European ESFRI process is the dominant context for most large infrastructures development these days. The ESFRI process is likely to result in an extensive strategy for new infrastructures which will set the agenda for many stake-holders in the years to come. The process represents a unique opportunity for realising many infrastructures that would not have been possible without the systematic cooperation of many countries, and the Nordic countries too have a considerable stake in this. The process thus opens large possibilities for the Nordic countries of seeing their priority infrastructures realised, while the scope of the process and the involvement necessary make participation demanding. Keeping in focus the possibilities for Nordic cooperation in this context is thus a challenge, but represents also a possibility for increasing influence on the process. This requires involvement at the higher levels of policy making.

To summarise the challenges:

- There is currently no formally established system for coordinating policies and initiatives between the Nordic countries, and coordination is largely done ad hoc.
 - Central parts of the future development of large infrastructures are coordinated at European level. Promoting national interests in these processes leaves little room for other initiatives and may take focus away from the Nordic arena.
 - The Nordic countries are somewhat asynchronous in their development of national roadmaps for infrastructures, with the risk of coordinating actions to be implemented too late for ongoing European processes.
 - Membership fees for membership in existing global and European infrastructures, commitment to new European infrastructures and the overall costs of infrastructures, may make it difficult to find budgetary resources for new initiatives.
 - The budgeting system for infrastructures varies between the Nordic countries, causing some uncertainties over possibilities for long-term planning and commitment.
- The above sections may lead the reader into thinking that collaboration on infrastructures is too complicated and difficult to be a realistic option. The intention has however been to create some awareness about challenges and concerns that sooner or later will have to be taken into account.
- The main challenge is to convince stakeholders that cooperation actually can result in some expectations being met. If the challenges discussed above are overcome and cooperative efforts are realised, this can in fact play a role in the realisation of some policy goals:
- Building on existing Nordic strengths in science, new scientific breakthroughs can be obtained.
 - The Nordic countries might play a stronger role in European and global action towards infrastructures.
 - The Nordic countries might become an attractive location for research infrastructures and for research and knowledge intensive businesses.

1.1.1 Denmark

Denmark is currently developing a strategy based on the results of a survey conducted in 2005 by the Danish Council for Strategic research. The strategy is being developed by the *Danish Agency for Science, Technology and Innovation*. Considerable external consultations are foreseen. The strategy is not expected to be a roadmap but more of a policy document identifying the problems related to funding large infrastructures. The strategy is expected to be presented in December 2008.

The main needs and relative costs that were identified on the basis of a survey conducted in 2005 were:

- An immediate upgrade of existing infrastructure (DKK 300 million)
- Investment in new national infrastructures (DKK 2 billion) over eight to ten years
- Participation in new international infrastructures¹

The survey was conducted through an open process. Public research institutions, the GTS institutes and large companies as well as researchers were given the opportunity to provide input through a special website. Specific projects mentioned as being highly relevant within a short timeframe were:

- The establishment of the synchrotron radiation facility ASTRID 2000
- Increased investment in supercomputing and grid computing, including expansion of the research network (with special reference to the Danish Centre for Grid Computing, DCGC)
- Establishment of a particle therapy facility for cancer research
- Investigations: registers and databases

The survey also pointed out international projects of great interest for Danish researchers. Three examples are mentioned in the report:

- The European Research Observatory for the Humanities and Social Sciences (EROHS)

What is a research infrastructure?

A research infrastructure is in principle anything that facilitates research, but in this context we are discussing research equipment and facilities of considerable physical size or requiring considerable investment. Due to the differences of a technical nature, an exact definition of a research infrastructure is however difficult to obtain. Infrastructures can be concentrated (e.g. a telescope) or distributed (e.g. a network of computers), and are found in many scientific disciplines or they can be inter-disciplinary. Other examples of research infrastructures are ocean exploration vessels, ship model tanks, databases and repositories, clean rooms, cyclotrons, Arctic observatories, high power lasers, etc. The roadmap of the European Strategy Forum on Research Infrastructure (ESFRI) *"...deal[s] with facilities, resources or services of a unique nature... including the associated human resources, covers major equipment or sets of instruments, as well as knowledge-containing resources such as collections, archives and databases. Research Infrastructures may be 'single-sited', 'distributed', or 'virtual' (the service being provided electronically). They often require structured information systems related to data management, enabling information and communication"*. The estimated costs are often part of the definition, since many of the infrastructures require substantial investment for their realisation; the facilities included in the ESFRI roadmap for example require investments in the range of 9 – 1.186 million Euros for their completion.

- The European X-ray Free Electron Laser (XFEL) and
- The European Spallation Source (ESS)

The needs identified in the survey led to the creation of a national programme for investment in research infrastructure at national and international level. As part of the political agreement of November 2006, a decision was made to establish the national programme for research infrastructure for the period 2007–2009. The idea to set up a special programme for research infrastructures was also one of the key initiatives on public research presented in the Danish government's Globalisation Strategy 2006.² The total funds allocated to the programme are DKK 600 million. It is not yet decided if the programme will continue after 2009 but results so far indicate that it has

been a successful programme, which points to a possible continuation after this period.

The infrastructure programme supports investments that are of national strategic importance and that are, due to their large scale, generally utilised by several institutions jointly. In 2008 the programme has a budget of DKK 200 million for the purpose of establishing major national research infrastructures and to fund Danish membership or participation in major international research facilities.

The Danish Ministry for Science, Technology and Innovation allocates funding from the programme to major research infrastructures on the advice of the Danish Research Coordination Committee (DRCC), which is assisted by an international committee of experts.³

Unlike the other Nordic countries Denmark has in this phase chosen not to make a new large-scale survey; neither is a formal consultation process expected to take place. Through the national programme for research infrastructure the Danish Agency for Science, Technology and Innovation is in continuous contact with universities and therefore receives valuable information about future needs.

With regard to ESFRI, 13 out of the 35 projects⁴ have so far officially been identified as interesting for the Danish research community. This does however not exclude universities from taking part in other ESFRI projects on their own initiative. The national research infrastructure programme has so far been funding one ESFRI project in the social science field.

Negotiations underway

Denmark is currently negotiating membership in XFEL in Hamburg and for ILL in Grenoble. To date no final decisions have been taken, but a contract for XFEL is expected to be signed in the near future.

With regard to ESS there are ongoing negotiations with Sweden to determine the Danish role in relation to the facility in the event that ESS will be located in Lund. Denmark has already expressed interest in co-hosting the facility.

Regarding involvement in MAX IV, no decisions have yet been made. The research com-

munity has expressed an interest, but attention has so far mainly been directed towards ESS.

1.1.2 Finland

Since Finland has only recently started the process towards a roadmap it is somewhat behind the other Nordic countries in research infrastructure planning. The first step has been to make a survey and an evaluation of existing and future needs for research infrastructures. Only when this step is completed will the Finnish priorities emerge.

There are currently no larger research infrastructures in Finland. Researchers nevertheless have access to several important international infrastructures through membership in CERN, ESO, EMBL and EMBO. The Academy of Finland and The Finnish Funding Agency for Technology and Innovation (Tekes) are funding membership fees for participation in international research infrastructures.

Neither is there any specific budget line for research infrastructures and decisions are traditionally made on an *ad hoc* basis (to some extent unlike in Sweden, Norway and Denmark).

The Academy of Finland works to support an active infrastructure policy in Finland. According to its International Strategy 2007 the Academy's international infrastructure policy has two main aims: 1) "to make sure the Academy and Finnish researchers are involved in international infrastructures that are important to Finnish research and to make the best possible use of those infrastructures, and 2) to get one or more internationally significant infrastructures that have international funding to set up base in Finland in fields of research where we have strong expertise".⁵

The process to set up a national strategy for research infrastructure started in June 2005 with the appointment of a working group within the Science and Technology Policy Council (STPC). The STPC is an advisory body led by the Prime Minister, with significant influence over decisions concerning research and infrastructure. The suggestions of the working group pointed to the need for reviewing major national research infrastructures, for giving attention to Finnish participation in

international research infrastructures and for identifying future needs.⁶

A second step in the process was taken by the Research Infrastructure Committee of the Ministry of Education, which proposed a national review of research infrastructures in its report published in 2007. The Committee suggested that Finland should establish mechanisms for competitive funding of research infrastructures and equipment and called for more centralised planning of and increased financial investment in research infrastructures, long term solutions and permanent structures for funding.

Furthermore, the Committee proposed that Finland should set up a permanent body to outline infrastructure policies and strategies. The permanent body should regularly review the current state of infrastructures and assess the long term needs (10–15 years) of different research fields in terms of infrastructures, including participation in international research infrastructures. The Committee also suggested setting up a supplementary infrastructure appropriation to be financed with income from the sale of state-owned companies and used for updating the national research infrastructure, improving services and for Finnish participation in advanced international research infrastructure projects.⁷

The roadmap process started at the beginning of 2008. Commissioned by the Ministry of Education, the work is undertaken by the *Federation of Finnish Learned Societies*. The input and suggestions of national stakeholders, universities, university hospitals, research institutes and archives have been collected through open online questionnaires. The survey has taken into account only proposals for national-level research infrastructures or participation in international research infrastructures via existing inter-governmental agreements or memberships. The universities and research institutes have also given information about new facilities, facilities being planned, major upgrades needed and new ideas for joining new projects in ESFRI. Even if it is too early to assess the results and conclusions of the survey, there has been an overwhelming response to the questionnaires and the pro-

posals show that the research infrastructures are scattered and that a substantial increase of funding is needed.

After a pre-evaluation of the synthesis templates of national research infrastructures and proposals for a national roadmap, the results of the survey will be assessed by international expert panels in September 2008. According to the time schedule, a broad and open hearing process is expected to take place in October and the proposals for a national roadmap are expected to be finalised by the end of the year. A steering group composed of representatives from several ministries and industry will make the final report, which will be presented to the Ministry of Education and the STPC in December 2008.

The roadmap report is expected to be a 10–20 year plan for national needs or possible emerging national needs of different research fields. The roadmap will also be submitted to the Science and Technology Policy Council.

Negotiations underway

Finland is currently discussing its participation in MAX IV. Among the ESFRI projects, Finland is participating in the FAIR facility. VTT is funding the construction of the Jules Horowitz Reactor (JHR), a new materials and fuel test reactor at the Cadarache Centre in France. Finland has decided not to participate in XFEL or in ESS, the reason being that Finland does not have significant research activities on neutrons. Finland is nevertheless supporting the eventual location of the ESS in Lund as it might prove valuable for Finnish researchers in the future. From a Finnish perspective, the distinction between Nordic and other European countries for infrastructure cooperation is not very important. In a Nordic perspective, Finland also wishes to see a closer cooperation with the countries in the Baltic Sea region.

1.1.3 Iceland

As in Finland, Iceland has only recently started a process towards mapping the needs for national as well as international research facilities and the work towards developing a roadmap for research infrastructures. An important step in the process towards a roadmap was the

decision taken by the The Icelandic Science and Technology Policy Council (STPC)⁸ at their spring meeting in June 2008 that the generation of a roadmap for research infrastructures should a priority in 2008. A working group has been formed, with three representatives from the STPC, one from the Ministry of Education, Science and Culture and one from The Icelandic Centre for Research (RANNIS). The working group has been asked to have the first draft ready by December 2008. The STPC has identified areas of strengths that are considered to be of strategic importance for Icelandic research, and these areas will be important in determining domestic research infrastructure needs.

RANNIS reports to the Ministry of Education, Science and Culture and provides operational support and advice to the STPC and its committees, in addition to managing the governmental funding system for research and technological development. Under the auspices of RANNIS, a process of mapping Icelandic research infrastructures was started in 2007. The work is estimated to be finalised by October 2008. The mapping started with a collection of information on databanks and the identification of crucial areas of research, and will be an important platform for the roadmap work.

The general view among Icelandic stakeholders seems to be that there is a great potential for improvement regarding Iceland's participation in international research facilities, and awareness of the importance of increased participation. Nordic cooperation is a very important part of this. Apart from the participation in research facilities such as CERN and EMBL, Iceland overall has a relatively low participation in international research infrastructures. Currently Iceland is involved in four ESFRI projects: CLARIN, ELIXIR, EUROPEAN SOCIAL SURVEY and EUROPEAN BIOBANKING. Iceland has traditionally had a high participation rate in the EU framework programmes, however recently there have been concerns, with a falling Icelandic participation in general. Iceland participates in an ERA-net; ERA-Instruments that was kicked off in April 2008.

1.1.4 Norway

The Norwegian government has identified the priority directions for the development of Norwegian science and technology. In the latest white paper on research (St.meld.nr. 20 (2004–2005) *Vilje til forskning*) the selected research areas are: energy and environment, food, health and sea. Prioritised technology fields are ICT, new material technology and nano- and biotechnology. The national strategic priorities for investing in new or existing research infrastructure are selected with regard to these thematic areas. Decisions regarding international research collaboration with long term investment commitments and national large scale facilities (with costs over NOK 200 million) are taken at ministerial level with the Research Council of Norway as strategic adviser. In other words, Norway has a multi-layer structure of decision making for research infrastructures. In some cases, decisions might be at the institutional level of research institutions. In other cases decisions rest with the deciding bodies of the research council, while decisions requiring substantial funds will be prepared by ministries and finally approved by parliament. This implies that there is no single procedure for establishing new infrastructures.

The Norwegian process on research infrastructures is essentially based on a bottom-upward approach. Roadmaps and shortlists are developed from the suggestions of scientists and their institutions, and priority setting is handled by the Research Council of Norway. This also implies that as a rule international cooperation on research infrastructures has to be endorsed within the research community, i.e. from the bottom up.

Norway's engagement in the ESFRI process is expressed in the 2008 government strategy document for cooperation with the EU on research and development⁹. The document states that the Ministry of Education and Research, in coordination with other ministries and the Research Council, will clarify and decide upon Norwegian priorities for infrastructures in a national and European context.

In the Research Council's recently launched strategy, *Tools for Research – National strategy*

for research infrastructure, an increase in infrastructure investment of NOK 800 million annually over a ten-year period is being proposed. To ensure reliable and long-term financing, the strategy suggests the establishment of a government fund with a start capital of NOK 20 billion, from which the entire yield (approximately NOK 800 million) would be reserved for investment in new and existing research infrastructure and associated operational expenditures.

The strategy recommends that 75 per cent of the annual return is channelled through the Research Council, while the remaining 25 per cent is distributed as earmarked allocations among the budgets of the universities, university colleges and independent research institutes. The Research Council would be responsible for funding the components of nationally-oriented infrastructure that fall within a cost framework of NOK 2–200 million. Investments that exceed NOK 200 million would be dealt with by the government ministries.¹⁰

The strategy also gives an overview of Norwegian participation in ESFRI projects. Currently Norway is interested in participating in 12 out of the 35 proposed ESFRI projects that will receive EU funding in the “Preparatory Phase”. In addition, the strategy document says that Norway will in future consider participation in these ESFRI projects: ESRF upgrade (European Synchrotron Radiation Facility), ESS (European Spallation Source), XFEL, ILL, IRUVX-FEL, ELT (The European Extremely Large Telescope), FAIR (Facility for antiproton and ion research), and SPIRAL2 – Rare isotope radioactive beams (EURISOL).

The roadmap is currently being considered by the relevant ministries. Decisions regarding the construction of new infrastructures are part of the budgetary process within government and parliament, and so far no conclusions have been drawn.

Norway participates in several international research infrastructure projects, the major ones being CERN, EMBL and EMBC, the two organisations for molecular biology, the ESRF and the Integrated Ocean Drilling Program (IODP).

At a Nordic level, Norway also participates in research infrastructure projects such as the Nordic Optical Telescope (NOT), NORDSYNC Consortium and the Nordic DataGrid Facility (NDGF).

Negotiations underway

More specific to the European Spallation Source, the Research Council of Norway recommended in June 2008, after consulting the relevant research milieus, that Norway supports the location of ESS in Sweden, and enters into negotiation with Sweden regarding possible Norwegian participation. Decisions on future action currently rest with the government, but talks are expected to take place during autumn 2008. In the strategy, the Research Council suggests that Norway should consider future membership in the Nordic synchrotron facility MAX IV in Lund, in the European Southern Observatory (ESO) in Chile and Deutsches Elektronen-Synchrotron (DESY) in Hamburg. Norway wishes to promote and to host three of the new projects in the ESFRI Roadmap. The suggested projects are currently considered as part of the ESFRI update process are:

- European Carbon dioxide Capture and Storage Laboratory Infrastructure (ECCSEL).
- Svalbard Integrated Arctic Earth Observing System (SIAEOS)
- Advanced Sustainable Sea-based Aquaculture (ASSA)

1.1.5 Sweden

The Swedish Research Council is the main public authority in Sweden supporting the development and utilisation of research facilities. The Research Council is responsible for drawing up the long term guideline (roadmap) which is updated every year. The directions of the research priorities, also with regards to research infrastructure, are included in the government’s research bill, which is presented to the parliament each term of office (i.e. every four years). The latest bill, with the title “Research for a better life” (prop. 2004/05:80) indicates the priority directions of Swedish research policy for 2005–2008 including pol-

ity priorities with regard to research infrastructure. A new research bill is expected during autumn 2008. However, the bill is not expected to discuss details of research infrastructures, rather to express more general statements on the importance of building research infrastructures for Sweden.¹¹

The Swedish Research Council is also one of the largest funding agencies for research infrastructures together with the Knut and Alice Wallenberg Foundation. Parts of the funding for the Swedish Research Council are earmarked for infrastructures, while some of the non-earmarked funding can also be used for this purpose. Other funding bodies are:

- The Swedish Research Council for Working Life and Social Research (FAS)
- The Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning (Formas)
- Swedish Governmental Agency for Innovation Systems (VINNOVA)
- The Swedish National Space Board
- The Bank of Sweden Tercentenary Foundation

Since 2005 a dedicated Committee for Research Infrastructure (KFI), appointed by the Board of the Swedish Research Council, has supported the development and utilisation of infrastructure in Sweden. The Committee has an annual funding of SEK 650 million and collaborates with other research financers to develop long term strategic planning within all research fields. The KFI also represents Sweden in the European Strategy Forum for Research Infrastructure (ESFRI).

The first roadmap for research infrastructure was published in October 2006 and a second revised version came in December 2007, the suggestions of which will feed in to the 2008 research bill. The planning covers a time perspective of 10–20 years. The aspects covered by the Committee are infrastructure planning, development and operation and phase out of research infrastructure. The Swedish Research Council's Guide to Research Infrastructure provides an overview of the long term needs for research infrastructure and participation in

joint international infrastructures. The guide has been prepared in cooperation with FAS, Formas and VINNOVA.

In the latest updated edition of 2008 the Swedish Research Council recommends investing in a number of national and international infrastructure projects that are of strategic importance in strengthening Swedish research in the long term. The update has been made with regard to the ESFRI roadmap. The main recommendations include priorities and strategies for an active Swedish participation in the development of common international infrastructures – primarily by contributing to the 15 projects from the ESFRI Roadmap for Research Infrastructures that have been given highest priority by Swedish researchers. The Research Council is participating in the planning of seven projects judged to be of particular interest.¹² A decision on Swedish participation in XFEL and FAIR is expected from parliament during this autumn. Sweden also has a positive standpoint on a possible enlargement of ESO, the European Space Observatory in Chile.

The coordination of research infrastructures at national level is highlighted as important to increase the quality of research and utilise resources more efficiently. Current examples include systems for managing environmental and climate data and the coordination of biobanks. Other recommendations point to the creation of national nodes to collaborate with international infrastructures.

Some of the core international infrastructures that Sweden has offered to host are the ESS, the MAX IV synchrotron radiation facility and the upgrading of EISCAT. Advancements in eScience and the development of eInfrastructures for large-scale computing, communication and storage are also high on the Swedish agenda.¹³

With regard to the ESS, there are two other candidates competing to host the facility: Bilbao in Spain and Debrecen in Hungary. The proposal to locate ESS in Sweden – near Lund in the south-west of the country – has been put forward by a consortium known as ESS-Scandinavia (ESS-S). This consortium includes around 20 universities, laboratories, institutes, regional authorities and transnational organi-

sations as members. A final decision on where to build ESS will be made official at the end of 2008. Denmark, Poland and Estonia have officially announced support for the Swedish candidacy.

In Europe there are currently several synchrotron facilities under construction. One of them is MAX IV, which will be the next generation facility after Max lab located in Sweden, in proximity to the University of Lund. Sweden has proposed to make MAX IV a Nordic synchrotron facility.¹⁴

Interviews show that Nordic collaboration is considered to be strategically important to attract large international research facilities and a number of research areas have been identified where Nordic collaboration could be of particular value, such as climate and the environment, polar research, demographic research, language technology, biobanking, databases etc. The Swedish Research Council has suggested that future Nordic collaboration could involve the establishment of large international infrastructures in the Nordic region (such as the ESS, the MAX IV, EISCAT-3D and eInfrastructures).

Swedish researchers participate in several international research infrastructure projects, such as CERN, the European Organization for

Nuclear Research, EMBL and EMBC, the two organisations for molecular biology, the European University Institute (EUI), the European Southern Observatory (ESO), the European Synchrotron Radiation Facility (ESRF) and the Integrated Ocean Drilling Program (IODP). Major national laboratories that receive financial support from the Swedish Research Council are the Max-lab and the Onsala space observation centre.

The Committee for research infrastructure has proposed new types of infrastructure funding: a long-range investment framework for large infrastructures and a type of grant for education addressing the use of infrastructures. The first type applies mainly to participation in the development of larger international or national research infrastructures, e.g. those included in the ESFRI roadmap, etc. Currently, there are no specific grants for long range construction of extensive infrastructures in Sweden. The second one recommends that major investment in infrastructure should be combined with targeted project grants for a limited time, in conjunction with the start up of infrastructures to achieve efficiency in investment and to assure broad use among research groups.¹⁵

TABLE 1. ESTIMATED NEEDS, ABOVE CURRENT BUDGETS, FOR NEW SWEDISH INVESTMENT IN RESEARCH INFRASTRUCTURES

Area	Need for investments in joint infrastructures up to the year 2012 (Billion SEK)
Astronomy, astro-, nuclear-, and particle physics	160
eScience	180
Earth and environmental sciences	180
Humanities and social sciences	50
Materials science	220
Medicine and life sciences	400
MAX IV*	1610
TOTAL	2800

* MAX IV is presented separately in the table since it is interdisciplinary (involves all other areas in the table) and because the investment need is significantly greater than for any of the individual areas. A property management corporation is presumed to invest in the buildings.

Source: The Swedish Research Council's Guide to Infrastructure (2008). English Summary.

Negotiations underway

As mentioned earlier, Swedish infrastructure policies are currently focusing on making Sweden the host country for ESS and the Max IV. The possible participation of the other Nordic countries is currently under negotiation. All Nordic countries have been invited to become members or co-host ESS. So far only Denmark has declared its support. The Research Council of Norway recommends in its recently presented roadmap for research infrastructure a Norwegian membership in ESS. The Norwegian government has so far however shown a negative standpoint, mainly because of environmental concerns, but the decision remains to be taken. In Finland the official line is not to participate in ESS, the reason being a lack of significant neutron research in the country.

The Research Council is also investigating the interest of other countries in the EU for MAX IV. In a Nordic context, Norway is showing interest in participating. Finland is already participating in Max Lab and is expected to be part of MAX IV as well.

1.2 NORDIC COOPERATION ON RESEARCH INFRASTRUCTURES

The Nordic countries have for many years had extensive collaboration on research and research infrastructures. Some of the Nordic Research Infrastructures in this framework are well established, but have during the last decade been subject to changes in policy. From having an independent institutional status and being jointly funded by Nordic governments, these institutions has largely been “re-nationalised” and become an integral part of universities and funded through their budgets.

1.2.1 Nordic policy cooperation

Several initiatives are taking place and are being suggested for strengthening Nordic policy cooperation on research infrastructure. The issue of research infrastructure is high on the agenda of the current Swedish presidency of the Nordic Council of Ministers. In this context a conference on how research infrastructure can support Nordic competitiveness is planned for November 2008. Important themes that

Examples of joint Nordic infrastructures

The Nordic Optical Telescope (NOT)

NOT was founded in 1984 to construct and operate a Nordic telescope for observations at optical and infrared wavelengths. The Nordic Optical Telescope (NOT) is a modern 2.5 m telescope located at the Spanish Observatorio del Roque de los Muchachos on the island of La Palma, Canaries, Spain. It is operated for the benefit of Nordic astronomy by the Nordic Optical Telescope Scientific Association (NOTSA), established by the national Research Councils of Denmark, Finland, Norway, and Sweden, and the University of Iceland.

Nordic Institute for Theoretical Physics (NORDITA)

aims at carrying out research and strengthens Nordic collaboration within the basic areas of theoretical physics. The institute is run jointly by Royal Institute of Technology (KTH) and Stockholm University and is located on the premises of AlbaNova University Centre in Stockholm. Until 2006, Nordita was funded by the five Nordic countries Denmark, Finland, Iceland, Norway and Sweden through the Nordic Council of Ministers. Today the funding is shared between the Council, KTH and Stockholm University.

European Incoherent Scatter Facility (EISCAT)

uses radar waves to study the influence of solar wind on the earth's atmosphere and magnetic field. The organisation operates radar stations in Sweden, Norway, Finland and Svalbard.

Nordic Secondary Ion Mass Spectrometer (NORDSIM)

is placed in Sweden, but runs jointly with Norway, Finland, and Denmark to measure elements and isotopes that are found only in very low concentrations. A pan-Nordic resource for geological research, located at the Swedish Museum of Natural History in Stockholm.

Nordic Datagrid Facility (NDGF) is a production grid facility that leverages existing, national computational resources and grid infrastructures. The motivation for NDGF is to ensure that researchers in the Nordic countries can create and participate in computational challenges of scope and size unreachable for the national research groups alone.

NORDUnet – Nordic Infrastructure for Research and Education is a collaborative organisation involving the university data networks in the Nordic countries.

will be discussed are infrastructure needs and prospects in the fields of energy, climate and environment as well as in the fields of welfare and health. National strategies and solutions related to research infrastructure will also be discussed.

NordForsk has helped facilitate the coordination of Nordic stakeholders within the ESFRI process and several meetings have been organised with regard to strengthening Nordic collaboration within this framework.

The Nordic Research Council Directors (NordHorcs) has proposed establishing a common Nordic platform to discuss national infrastructure priorities. The initiative has been taken based on the assumption that cooperation is an essential element if the Nordic countries are to take a leading role vis-a-vis both the ESFRI process and in preparation of infrastructure in general.

1.2.2 Nordic funding instruments for infrastructure cooperation

Numerous funding opportunities for infrastructure projects exist at Nordic level.

The NordForsk initiative *Joint Nordic Use of Research Infrastructure* was launched in 2007 and the aims of the programme are to:

- a) Optimise joint Nordic use of research infrastructures
- b) Increase the interaction between existing infrastructures
- c) Share best practices in operations by making these more available to interested parties and
- d) Optimize joint Nordic participation in the planning and implementation of European and international infrastructure projects

A total of 19 infrastructure projects that received NordForsk funding in 2007 are listed in Appendix C. The infrastructure collaborations include participants from all the Nordic countries, and from Russia and the Baltic states.

The Nordic Centres of Excellence in Research Programme (NCoE) is based on existing

research groups in the Nordic countries. Basic funding of the NCoEs is expected to come from national sources and the Nordic support should thus supplement this national funding. Several of the centres are networks of research teams working in the Nordic countries, and a few of these provide facilities and infrastructure support to Nordic researchers.

The Nordic Centres of Excellence¹⁶ are selected for a five-year period based on open competition. The most important selection criterion is excellent scientific quality (in an international context) of the research of the NCoE candidate in its own field, and the potential to further develop it on the Nordic arena.

Networks of National CoE. Increased collaboration between the best research environments in the Nordic countries is an important contribution to keeping and developing the role of the Nordic countries as one of the most dynamic regions in the world in research and innovation. This is the background of NordForsk's call for collaboration between national Centres of Excellence or corresponding environments in the Nordic region. The networks receive up to NOK 400 000 for up to three years¹⁷. There are currently nine Networks of National CoE.

1.3 EUROPEAN COOPERATION ON RESEARCH INFRASTRUCTURE

The processes driven by European Strategy Forum for Research Infrastructures (ESFRI) are at the core of the European transnational processes towards new research infrastructures. In addition there are several intergovernmental infrastructures that already have a long operational history, as well as infrastructures under the EU Joint Research Centres. These processes and existing structures will be briefly described in this section along with the track record of cooperative infrastructures among Nordic countries.

1.3.1 European policy cooperation on research infrastructure

The European Strategy Forum for Research Infrastructures (ESFRI) was set up in 2002

after Commissioner Busquin asked the research ministers of EU15 to nominate representatives¹⁸. In 2004 ESFRI decided to prepare a roadmap for research infrastructures in Europe, for the next 10 to 20 years, in order to provide an overview of the need for research infrastructures of pan-European interest and to facilitate decision making by Member States and the European Union. ESFRI Roadmap Working Groups and several hundred high-level experts supported the strategy forum in the preparation of the roadmap. In September 2006 ESFRI agreed upon the roadmap¹⁹ which describes and suggests 35 projects for new large-scale research infrastructures based upon peer review, considered to be “crucial pillars to strengthen the European Research Era, particular for capacity building”²⁰. The expected expenditure for the construction of each project ranges from €10 million (Digital Research Infrastructures for the Arts and Humanities) to €1,200 million (Facility for Antiproton and Ion Research or SKA radio telescope). Some 20 additional projects are also mentioned as “emerging proposals that may constitute a base for future upgrades of the roadmap itself”²¹. ESFRI estimated that over 200 proposals were originally prepared by about 800 scientists and managers.

Implementation issues

The ERA expert group has recently delivered its report on research infrastructures²², which recommends member states to develop their national/regional infrastructure planning to improve synergy with ESFRI activities. Also, the expert group suggests the EU should “establish a ‘strategic coordination mechanism’ at EU level to ensure the implementation of the Roadmap projects and a coherent ERA policy for research infrastructures”. Another suggested measure is to ensure the efficiency of funding through evaluation and also for the research infrastructure consortia to explore various other existing financing sources: Structural Funds, Risk-Sharing Finance Facility and Public-Private Partnerships. The expert group also furthermore recommends measures on the legal framework, the management and the access to research infrastructures as well as on eInfrastructure.

Examples of European Research Infrastructures

Europe’s Intergovernmental Research Organisations and the EIROforum

The EIRO forum established in 2002 is a partnership between the following seven existing European intergovernmental scientific research organizations:

- European Organisation for Nuclear Research, CERN
- European Fusion Development Agreement, EFDA
- European Molecular Biology Laboratory, EMBL
- European Space Agency, ESA
- European Southern Observatory, ESO
- European Synchrotron Radiation Facility, ESRF
- Institut Laue–Langevin, ILL

The EIROforum’s primary goal is to play an active and constructive role in promoting the quality and impact of European Research, as well as to coordinate between member organisations. The forum has been engaged with the ESFRI and EU ongoing initiatives on infrastructures.

EU Joint Research Centres

The Joint Research Centre was originally established under the Euratom treaty in 1957. Euratom’s role is to promote nuclear safety and security in Europe and the JRC has been contributing to this aim with its research activities ever since. Today, the seven JRC institutes are located in Belgium, Germany, Italy, the Netherlands and Spain. Some examples on research facilities are: European Laboratory for Structural Assessment, High Flux Reactor, GELINA neutron time-of-flight facility and the Van de Graaff accelerator.

The Joint Research Centre Institutes are:

- The Institute for Reference Materials and Measurements (IRMM)
- The Institute for Transuranium Elements (ITU)
- The Institute for Energy (IE)
- The Institute for the Protection and the Security of the Citizen (IPSC)
- The Institute for Environment and Sustainability (IES)
- The Institute for Health and Consumer Protection (IHCP)
- The Institute for Prospective Technological Studies (IPTS)

ESFRI on the other hand, has initiated meetings and workshops to support the implementation process of the 2006 roadmap through clarification of legal aspects of new research infrastructures, their regional impacts, needs for satellite facilities or the use of structural funds. The ESFRI roadmap update process started in 2007 and is expected to be completed by December 2008.

On 15 July 2008 the European Commission proposed a legal framework for a European Research Infrastructure to make it easier to set up European infrastructures. "This new tailor-made legal framework would provide a legal personality recognised in all Member States and could provide some of the advantages of international organisations, such as VAT exemptions. It also offers the opportunity to cut down significantly the time necessary for setting up such European Research Infrastructures, allowing them to become operational as soon as possible, which is important in the quickly evolving world of science" according to an EU Commission Press Release. The legal framework is expected to become effective in mid 2009.

1.3.2. European funding instruments for research infrastructure cooperation

The seventh Framework Programme for the European Community for Research, Technological Development and Demonstration (2007–2013) addresses needs for Infrastructure in its specific programme 'Capacities' – Optimising the use and development of research infrastructures.

The activities to be supported are identified under three main lines of action:

1. Optimising the utilisation of existing research infrastructures and improving their performance as well as strengthening research eInfrastructures.
2. Support to new research infrastructures (or major upgrades of existing ones)
3. Support measures for policy development and programme implementation, including support for emerging needs.

In May 2008 a new call for FP7-INFRA-STRUCTURES programme was published, focusing on support to existing ICT research infrastructures with a €20 million indicative budget. The prior program call was focused on "Support to policy development and programme implementation" Planned Calls for 2009/2010 will, according to the Capacities work programme, also address design studies for research infrastructures in all S&T fields as well as support to the preparatory phase for construction of research infrastructures.

1.3.3 Nordic participation in European research infrastructure cooperation

The Nordic countries have long participated in European cooperation on research infrastructures. All Nordic countries are members of the European Molecular Biology Laboratory (EMBL) and organisations from all countries are members of the European Science Foundation (ESF). All countries are also represented in the European Strategy Forum on Research Infrastructures (ESFRI), and through the association agreements Iceland and Norway are also integrated into other EU initiatives on research infrastructures. Further, all countries except Iceland are members of the European Organisation for Nuclear Research (CERN) and the European Space Agency (ESA). The Nordic countries are thus very well integrated into the larger European initiatives.

Membership of European organisations plays an important role in the strategies for infrastructures in the Nordic countries. It is here sufficient to state that the membership fees for European cooperative research facilities make up for a considerable part of national R&D expenditures and that EU initiatives will probably to a large extent form the future of national infrastructures. The Norwegian membership fee for CERN participation in 2008 is for example estimated at NOK 122 million, while the total cost of realising the 35 infrastructures on the 2006 ESFRI shortlist is estimated at € 13.5 billion. The decisions concerning participation in existing European facilities and the realisation of future ones thus set some limitations on what it is possible to realise in other contexts and to what will be useful to prioritise in the Nordic context.

1.4 INTERNATIONAL CO-OPERATION ON RESEARCH INFRASTRUCTURE

The scientific endeavour is in principle without borders, and international cooperation on infrastructures has a long tradition. In order to illustrate the broad participation of Nordic countries in international research facilities we present a few examples from different research fields.

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of Europe, Japan and North America in cooperation with the Republic of Chile to be completed in 2010. Danish, Swedish and Finnish researchers are participating in the facility. In 2007 a collaborative agreement was launched also involving the University of Chile and the University of Copenhagen (Denmark). The newly established cooperation aims at contributing to the promotion of teaching, scientific research, and the expansion of altitude physiology and medicine or other related areas considered appropriate.

Integrated Ocean Drilling Programme (IODP) is an international marine research program that explores Earth’s history and structure recorded in seafloor sediments and rocks, and monitors subsea floor environment. Sweden, Norway and Finland are member nations in the programme.

The **OECD Halden Reactor Project** is a joint project under the Nuclear Energy Agency. It brings together an important international technical network in the areas of nuclear fuel reliability, integrity of reactor internals, plant control/monitoring and human factors. The project is mainly based on experiments, product developments and analyses carried out at the Halden establishment in Norway. The programme is supported by 130 organisations in 17 countries.

International Agency for Research on Cancer – IARC, is a centre for international cancer epidemiology, cancer toxicology research and cancer statistics and education. Today, IARC’s

memberships include 21 countries. All Nordic countries (Iceland excluded) are members of IARC along with Australia, Belgium, Canada, India, Ireland, Japan, the Netherlands, Republic of Korea, Russian Federation, Spain, Switzerland and Austria.

Organisations in Finland, Norway and Sweden are members of the **International Institute for Applied Systems Analysis (IIASA)**, an international research organisation located near Vienna, Austria. It conducts inter-disciplinary scientific studies on environmental, economic, technological, and social issues in the context of human dimensions of global change.

1.5 SUMMARY

The efforts to develop roadmaps for research infrastructures are under way in all Nordic countries, and by 2009 most countries can be expected to have developed their priorities in a more explicit way. At present, each country has identified or is in the process of identifying a substantial number of facilities to be further developed (in cases where a facility already exists) or considered for construction. From these “long lists” more definite priorities will be emerging in the form of shortlists and action plans. **When shortlists have emerged, an examination of priorities and the scientific aim of infrastructures could reveal overlaps in priorities and potential for coordinated actions.**

Considerable Nordic cooperation already exists. The programme *Joint Nordic Use of Research Infrastructure* has already been implemented by NordForsk and the first grants were distributed in 2007. At policy level, the objectives are to optimise joint Nordic

Status of Roadmap exercises

Denmark	Revised list of priorities expected late 2008.
Finland	Proposal expected December 2008.
Iceland	Final report in December 2008.
Norway	Strategy formulated early 2008, currently for government processing.
Sweden	Road map updated 2008.

participation in the planning and implementation of European and international infrastructure projects, to optimise joint Nordic use of research infrastructures and to increase the interaction between existing infrastructures. In this context, conferences and meetings with national and Nordic stakeholders are organised.

The processes in the Nordic countries, as well as the processes of Nordic cooperation, cannot be considered in isolation from the ESFRI process, initiatives from EIRO-forum²³ and the outcome of other EU and national processes. When the outcome of these processes, and primarily the ESFRI process, emerges, a matrix for possible action will open. The final outcome will however be dependent upon the decisions of many countries, not only the Nordic ones.

Table 2 lists the infrastructures suggested during the ESFRI process in which the Nordic countries have expressed their interest in participation. As should be obvious from the sections above, the Nordic countries are in various phases of considering their engagement in the ESFRI shortlisted projects, as well as of suggesting new infrastructures as part of the ESFRI update. For this reason the list should be considered as “expressions of interest” rather than as a list of confirmed participations.

**BUILDING ON EXISTING
NORDIC STRENGTHS
IN SCIENCE, NEW
SCIENTIFIC
BREAKTHROUGHS
ARE POSSIBLE.**

TABLE 2. SUGGESTED ESFRI FACILITIES IN WHICH NORDIC COUNTRIES HAVE EXPRESSED AN INTEREST AS OF AUGUST 2008. SOURCE: INTERVIEWS WITH EXPERTS²⁴

	Denmark	Norway	Sweden	Finland	Iceland
AURORA BOREALIS		X		X	
CESSDA	X	X	X	X	
CLARIN	X	X	X	X	X
DARIAH	X				
EATRIS	X	X	X	X	
ECRIN	X			X	
ELIXIR	X		X	X	X
ELT				X	
EMSO		X	X		
ESRF UPGRADE				X	
EUFAR				X	
EUROPEAN SPALLATION SOURCE (ESS)	X	X	X		
EUROPEAN SOCIAL SURVEY (ESS)	X	X	X	X	X
EURO-ARGO		X			
EUROPEAN BIOBANKING AND BIOMOLECULAR RESOURCES		X	X	X	X
FAIR			X	X	
ICOS	X	X	X	X	
INSTRUCT	X			X	
INTRAFRONTIER			X	X	
IRUVX-FEL			X		
JULES HOROWITZ REACTOR				X	
LIFEWATCH	X	X	X	X	
PRACE (EU-HPC)		X	X	X	
SHARE	X				
X-FEL	X		X		

In addition, several new infrastructures have been suggested by the Nordic countries during the ESFRI 2008 update process:

- **Advanced Sustainable Sea-based Aquaculture (ASSA).** Proposed by Norway.
- **EISCAT-3d.** Proposed by Sweden, with the expressed interest of Norway and Finland.
- **European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECC-SEL).** Proposed by Norway.

- **Svalbard International Arctic Earth Observing System (SIAEOS).** Proposed by Norway.

Even if the table and the list of new proposals are considered as provisional expressions of interest, it is evident that the Nordic countries will be likely to have a common interest in realising some of the suggested infrastructures. In other words, **ESFRI is likely to be the arena where coordination may increase greatly the chances for realising the infrastructures prioritised by the Nordic countries.**

2. Assessing the options

An intensified Nordic cooperation on infrastructures in the future depends very much on the possibility of finding workable models for how to realise the cooperation. To facilitate the discussion on possible models and action, this section first discusses some contextual issues of importance. Among them are the scientific and industrial strongholds of the Nordic countries, their commitment to existing international infrastructures, priorities of other countries etc (2.1). Second, extracted from interviews with experts on research infrastructures in the Nordic countries, some challenges and opportunities from a national perspective are put forward (2.2). From this background we develop three principal models for how reinforced Nordic cooperation can be structured (2.3), before we finally give some comments on the capacities for coordination and analysis (2.4).

2.1 THE CONTEXT FOR COLLABORATION ON RESEARCH INFRASTRUCTURES

Cooperation strategies for research infrastructures yielding an added value are developed in complex settings and dependent on many criteria. Research infrastructures are thus not developed in a vacuum apart from other policy domains, nor from developments in other countries and regions. This section focuses on some of the contextual issues.

2.1.1 Scientific strongholds and priorities

Emerging from a long history of science, its results and national priorities, each country will have its own distinct scientific profile in respect of research fields, institutional setting and existing infrastructures. Specific national science bases have thus emerged over the years. Examples are Norway's position in arctic research, Sweden's in pharmaceuticals etc. On one hand, the national priorities for infrastructures will obviously be coupled to what are regarded as strong fields and the needs of these. A much used strategy of science policy is to reinforce already strong fields. On the other hand, another strategy can be to use investments in infrastruc-

tures to strengthen fields considered as weak or to support promising areas. The national strategies about to emerge will obviously seek out priorities that pay attention to these possibilities. The future development of Nordic cooperation will similarly have to pay attention to the national priorities, as well as to the strategic choice of which fields to support on the Nordic level. **One obvious possibility for future action is to identify regional scientific strongholds and/or emerging fields, and use these as guiding lines for fields suitable for infrastructure cooperation.**

An approach already used, is to identify scientific strongholds by the use of data on scientific publications (bibliometrics). A study commissioned by NordForsk used bibliometric techniques with the aim of identifying areas of research excellence in the Nordic area (Cadiou et al 2007). This study does not refer to infrastructures, but it can still be used as a point of departure for identifying potential fields for cooperation. The study identified three fields of science that have an established strength across the Nordic countries:

- Applied biology – ecology
- Earth and space sciences
- Fundamental biology

In addition, three fields were identified that showed an improving and accelerating tendency:

- Mathematics
- Engineering and technology
- Physics

The study also identified the ten strongest sub-fields of Nordic science. The fields that emerged were:

- Fisheries
- Obstetrics and gynaecology

INFRASTRUCTURES’
USEFULNESS FOR
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- Anaesthesiology
- Marine and freshwater biology
- Ecology
- Sports sciences
- Dentistry, oral surgery and medicine
- Rheumatology
- Public, environmental and occupational health
- Environmental sciences

Bibliometric methods involve some methodological limitations, which is also acknowledged by this study; such as the very limited number of bibliometric indicators outside the English language and the “hard sciences” and the fact that bibliometrics is a limited tool for picking up how scientific fields develop. Still, the fields identified can be used as a starting point for more sophisticated analysis of scientific development.

Development of research infrastructures is however only partly defined from the need for research alone. As important as science might be, the future needs of industry and society at large and research and innovation strategies are developed with attention to the existing industrial base, industries’ need for research, development and testing and the directions industries are expected to develop in. Priorities for research infrastructures have thus to consider also the benefits they might have for industry, and these will vary with the industrial structure as well as the interactional pattern between industry and science.

A systematic approach to scientific and technological specialisation at country level was the ERAWATCH specialisation study, which investigated how R&D activities in the public R&D base related to R&D, technological and economic specialisation in European countries. Based on several indicators, the study tried to identify what fields of specialisation were to be found within public and business R&D, as well as what field of technology the countries specialised in. The findings for the Nordic countries are summarised in Table 3 (in alphabetical order per country and sector).

TABLE 3. SPECIALISATION OF NATIONAL R&D AND TECHNOLOGY 2003²⁵

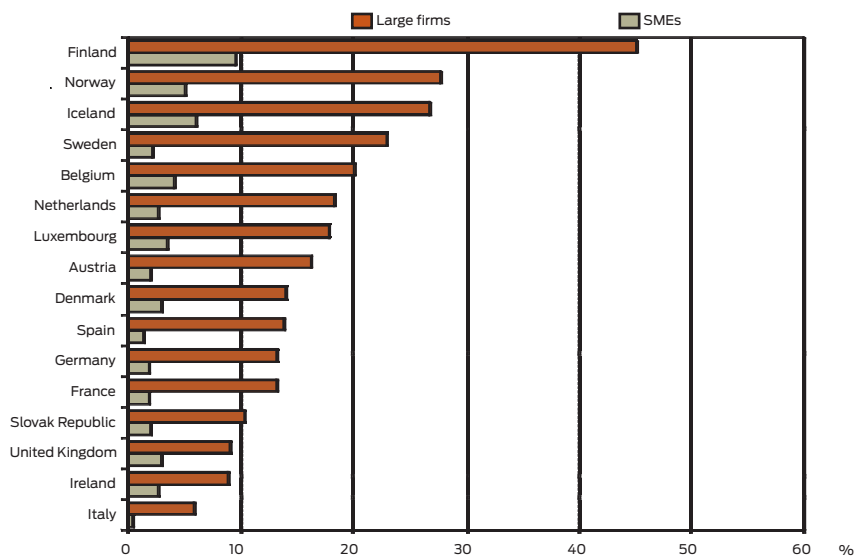
	Public R&D	Business R&D	Technology
Denmark	Clinical medicine Immunology Microbiology Pharmacology	Financial intermediation Food Instruments IT services Machinery Pharmaceuticals Telecommunication	Chemicals Food Instruments Pharmaceuticals
Finland	Agriculture Biology Biochemistry Computer science Clinical Medicine Environment Neuroscience Pharmacology Physiology Social sciences and Education	Construction Electrical machinery Electrical equipment Wood and printing	Electronic equipment Office machinery Telecommunication equipment Wood & publishing
Iceland	n.a.	n.a.	n.a.
Norway	Agriculture Earth sciences Marine research Petroleum and gas Social sciences	Agriculture Basic metals manufacturing Fisheries Food Petroleum and gas Printing and publishing Ship building	Chemicals Machinery Furniture and other manufacturing Pharmaceuticals
Sweden	Biology Biochemistry Clinical medicine Environment Immunology Pharmacology Neurosciences Social sciences	Financial intermediation Office machinery Wood and publishing	Community services Electronic equipment Instruments IT services Machinery Motor vehicles Pharmaceuticals

This study was not done with the aim of identifying arenas for infrastructure cooperation, but it illustrates the fact that the Nordic countries to some extent have commonalities in their industrial structure and also to some extent different points of departure for their priority setting for research infrastructures. While there should be some common ground, for example for infrastructures related to the pulp and paper industry in some of the countries²⁶, some other industries are to a larger degree country-specific and will require country-

specific developments or cooperation outside the Nordic countries.

In addition to the industrial structure itself, the structure of the relationship between the scientific community and industry also plays a part in the realisation of infrastructures. Not least how the public parts of science interact with industry, and how public policies and investments are developed to encourage this interaction. In the Nordic countries there is in general a well developed cooperation between public research institutions and firms.

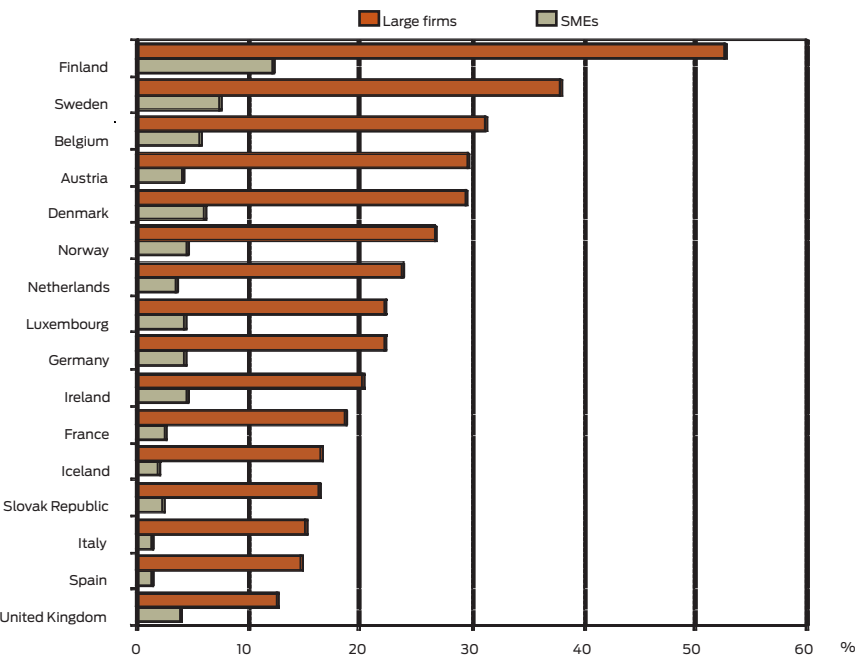
FIGURE 1. FIRMS COLLABORATING IN INNOVATION WITH GOVERNMENT INSTITUTIONS, BY SIZE, 2002-04. AS A PERCENTAGE OF ALL FIRMS. SELECTED COUNTRIES



Source: OECD Science, Technology and Industry Scoreboard 2007

Among European countries, firms in the Nordic countries have among the highest rates of collaboration with government institutions (research centres and institutes) in their innovation activities (Figure 1). Especially larger firms (> 250 employees) have considerable collaboration. Similarly, firms in the Nordic countries also have considerable collaboration with higher education institutions in their innovative activities (Figure 2).

FIGURE 2. FIRMS COLLABORATING IN INNOVATION WITH HIGHER EDUCATION INSTITUTIONS. BY SIZE, 2002-04. AS A PERCENTAGE OF ALL FIRMS. SELECTED COUNTRIES



Source: OECD Science, Technology and Industry Scoreboard 2007

The collaborative patterns are, among other factors, related to how research-intensive industries are and to what extent they have developed their own research capacities. Some industries have sufficient in-house R&D capacity to answer their own needs, while others rely heavily on public resources. Regarding the public-private relationship, Norway and Denmark have for example a tradition of a relatively large sector of research institutes serving industry, while this function to a larger degree has been undertaken by universities in Sweden. Even if many Danish institutes have recently been merged into the universities, the tradition of cooperation with industry will probably prevail. In Finland, government funded institutes have also played a considerable role in industrial development.

Even if collaboration between firms and public research institutions are not dependent on research infrastructures, infrastructures at public institutions can be an asset also for industry relevant research. **For some types of infrastructures the potential trade-offs with industry and their usefulness for industrial and business development should be considered.**

2.1.2 Priorities for industrial and societal investments

National priorities and policies in other policy domains are also expected to play a role for research infrastructures. For example, infrastructures for medical research will be of importance for health care, while facilities for the surveillance of oceans, the atmosphere or the Arctic might give important input for policies related to climate change. Furthermore, registers and databases from social science surveys might be of importance for the development of the Nordic welfare model.

The industrial structure of the Nordic countries is, put very simply, partly the result of their geographical location and partly of innovations and subsequent path dependencies. The geographical location of these countries required the development of an agriculture adapted to the sub-Arctic situation, while large forests have encouraged the growth of a large wood, pulp and paper industry in three of the countries. The geographical location also

drives the fishery-related industries in some of the countries, as well as the extensive energy-related industries. We find examples of industries emerging not so much from geographical location as from the capability to innovate and develop innovations into industrial products in the large consumer electronics industries and automotive as well as in the pharmaceutical industries.

The complexities of the industrial and societal considerations behind priorities for infrastructures are not to be analysed here, but it is necessary to bear these in mind when approaching Nordic collaboration. The commonalities and discrepancies between the countries form a backdrop for the considerations that might at one hand point to great advantages of cooperation, while on the other hand also give reason for various national trajectories.

2.1.3 Priorities of non-Nordic countries

Research infrastructures are essentially part of the global efforts for extracting new knowledge for the benefit of mankind. This enterprise leads on one side to large international cooperative projects like CERN and EMBL, and on the other hand to competition to be first with ground-breaking scientific insights or with results of promising economic or strategic advantage. **Nordic efforts for research infrastructures thus need to address not only international cooperative efforts, but also other countries' strongholds and priorities.** This leads to a situation with several possible lines of action.

In some cases it will be obvious that the priorities and excellence of other countries will be hard to match without extreme efforts. In such cases the best option might be to leave the field of science to those already best equipped to handle it. Such an action will of course also have an economic rationale: duplicating costly infrastructures would call for very strong justification. The best line of action in such cases will be one of non-engagement or cooperation towards existing facilities.

However, in some cases such duplication of infrastructures or the creation of infrastructures that to some extent resemble existing or planned ones might be deemed necessary

for strategic reasons. Reasons for this might be that facilities are necessary for keeping in touch with the research front or that they have large externalities for several fields of science. In some cases slight diversities from an existing facility might be the tipping point for new discoveries. In other cases it will be strategically wise to duplicate an effort, since the knowledge gained might be of strategic interest. In such cases, Nordic cooperation can be one line of action, while national efforts might be another.

2.1.4 Budgetary constrictions

From the above sections it should be obvious that the availability of funds is a severe constraint for the realisation of research infrastructures. Since many of the infrastructures require considerable investment, such requirements are also the main driver for international cooperation. What is beyond the limits of one nation can be realised through the combined forces of several.

Even if potential cost reductions through joint efforts may be large, there might understandably be some reluctance towards engaging in cooperation over infrastructures because of the investment necessary. Some of them require a substantial part of a research budget for their construction, and after the construction phase costs for operations, maintenance and improvements will accrue²⁷. Long term commitment is thus often necessary, which national treasuries are often reluctant to engage in since it reduces flexibility towards other policy goals. Realising larger infrastructures is thus sometimes not only about having success within the science budget, but also of enlarging the science budget towards other priorities of government as well as safeguarding long-term commitment.

Collaboration should probably be reserved for facilities where investment and operational costs are higher than a set threshold. What this threshold should be will be subject to variations between fields of science and the availability of funding. In fields of science where good quality facilities already exist at national level, the threshold might be higher, since new collaborative facilities will require sub-

stantial investment to pass the already existing ones in quality and usefulness. In fields of science where there are no existing facilities, the threshold might be lower, as establishing a collaborative facility might be the only way forward to get a facility into operation. Available funding is of course the most critical factor, and from an economic perspective the added value of collaborative facilities will increase in periods with decreasing science budgets. In other words, the threshold for profitable collaborative investment will vary with the potential added scientific and economic value likely to emerge from the investment. The points where the two criteria coincide should thus be the points most likely to gain from Nordic collaboration.

2.1.5 Summary

At the risk of over-simplification, the discussion in this section (2.1) can be summed up in a few lines:

- The Nordic countries have different scientific strongholds, differences which are likely to affect priorities for infrastructures.
- The Nordic countries have different industrial strongholds and have variations in ways of integrating between industry and public science, and these variations are also likely to influence priorities regarding research infrastructures.
- The priorities of countries outside the Nordic regions will be co-decisive for what facilities to prioritise within the region.
- The Nordic countries are well integrated in international processes, but these processes will also set limitations for actions open for the Nordic countries.
- Large costs make long-term commitment necessary, but also call for flexible models for cost sharing.

2.2 CHALLENGES AND OPPORTUNITIES FROM A NATIONAL PERSPECTIVE

To explore Nordic challenges and opportunities with regard to research infrastructures, several interviews were conducted with key experts in the Nordic countries²⁸. Analysis of the respondents' comments shows that generally there is a very positive attitude in all Nordic countries for joint action on research infrastructures where common interests coincide. Some of the benefits mentioned were advantages of sharing costs, higher combined expertise and better use of and competition for resources. Joining Nordic forces is also considered as strategically important in larger international infrastructures initiatives in order to increase influence, expertise and resources. There are several Nordic initiatives that are considered as exemplar for cooperation on infrastructures. As policies for research infrastructures are increasingly set in an international context, there is an increased awareness of the possibilities and potential benefits of international cooperation, a potential that will be more extensively investigated in the years to come. On the other hand, it is also evident and probably inevitable that decisions regarding infrastructures will be taken case by case, and that this will result in various cooperative models depending on their usefulness in each case.

Barriers to cooperation

The experts pointed to several challenges and obstacles that may hamper cooperation. The Nordic countries have different mechanisms for deciding their priorities and they are also in fact setting different priorities for their research infrastructure needs. Such discrepancies in priorities might explain the apparent difficulties in identifying common areas of interest upon which to build common Nordic infrastructure initiatives. In addition, decisions have to be taken at several levels and negotiations might be time consuming. From the experts' point of view, more could be done by the Nordic institutions, with NordForsk as the seemingly most obvious arena to proactively coordinate the efforts being made at national level. So far, initiatives and alliances

have mostly been made on an ad hoc basis and have taken different directions depending on the agenda. This is not necessarily negative but NordForsk could be an arena for discussing and coordinating initiatives to a greater degree. At the same time, parallel discussions at national level are necessary and for larger projects the political level must be involved.

Variations in the countries decision making processes might further hamper joint action. While some countries have multi-year research budgets allowing for long-term investment planning, others depend on annual budgets. This can be a constraint when opting for long-term engagements, but in practice it has been proved that it is of no major importance.

Prospects for cooperation – from the very small to the very big

Regarding the potential for cooperation within the ESFRI framework, some of the interviewed experts refer to this process as primarily belonging to the European arena and a process where scientific aspects are at the forefront. This implies that positions and interests should be expressed first and foremost at European level, and that infrastructures' usefulness for advancing scientific quality and knowledge should be the main criteria for decision. Despite this however, Nordic cooperation and joint positions are considered a possibility if beneficial. For example, coordinated or common Nordic consortia for the construction of large ESFRI infrastructures could be valuable. In general, the advice is to increase the awareness of potential mutual Nordic interests in the realisation of infrastructures emerging from the ESFRI process.

Nordic strategies could also focus more on the micro level by identifying and supporting good researchers at university level for common Nordic collaboration endeavours, as well as identifying research needs in areas of common Nordic interest. Numerous areas of research have a potential for Nordic collaboration, but databanks and databases are pointed out as especially promising. In these fields there are already good examples of joint projects. Additional fields which are suggested include: collaboration in eInfrastructure (also with regard

to eInfrastructure initiatives in ESFRI), polar and sub-Arctic research, Nordic forestry and ecology, climate and the environment.

Furthermore, joint access and funding of very expensive Nordic facilities is identified as a potentially promising field of cooperation. Experts suggest that a common Nordic strategy for access policy towards research infrastructures be developed. In particular, the possibility of using other countries' facilities on a pay-as-you-go model should be explored. If a joint interest for such models emerges, interviewees estimate that NordForsk could play a role as facilitator for the cooperation.

2.2.1 Summary: Key elements

Some viewpoints emerge from the expert interviews that will be central to future strategies for Nordic cooperation:

- Cooperation is in general beneficial for cost reduction and increasing quality.
- Currently focus is on ESFRI processes and awareness of the mutual benefits of joint ESFRI positions should be increased.
- Decisions regarding new infrastructures have to be made ad hoc, but processes towards decisions should be more actively coordinated, preferably by NordForsk.
- Several strategies for increased Nordic cooperation should be considered, ranging from micro-level funding initiatives to large scale facilities.

2.3 MODELS FOR NORDIC COOPERATIVE INFRA-STRUCTURES

On the basis of the contextual considerations and the ongoing processes, as well as the input from experts, we discuss in this section three models for Nordic cooperation on infrastructures:

- Model A** Joining forces for international participation
- Model B** Nordic joint facilities
- Model C** Shared access to national facilities

These generalised models are presented to facilitate the discussion on possible future action, and some pros and cons of each are discussed. Cooperation has the general advantages of cost sharing, increasing the possibilities of realising infrastructures and from this increasing research quality and the likelihood of scientific breakthroughs. Disadvantages might be a time consuming need for deliberations and formal agreements and increased bureaucracy in the operational phase. These general pros and cons should be borne in mind when considering the models.

The models represent in principle three different strategic levels of action, and as such invite a choice of which strategic level to put future emphasis on. However, since research facilities are of many types and require various approaches, a mixed strategy will probably have an equal or better chance of success. There is thus no need to insist on one model or level of action being selected. All models presuppose some kind of overarching cooperative arrangements at Nordic level. Cooperative infrastructures emerging from the institutional level and developed outside of national priorities or roadmaps are not considered here.

2.3.1 Model A Joining forces for international participation

This model is one for promoting the coordination of possible common interests between the Nordic countries towards priorities of support for and location of joint international facilities. The ongoing efforts for joint European and other facilities described above might call for coordinated Nordic initiatives. In some situ-

ations, the Nordic countries, all or just some of them, might find it beneficial to coordinate their positions towards international decisional processes, within the ESFRI initiative or within other international cooperative efforts. Nordic cooperation depends of course on the countries involved having a common perception of the situation and a mutual interest in consolidating their position. This will probably by no means be an obvious situation for all international actions and cases, and calls for clarification of positions and deliberations ahead of the international processes. Such deliberations would thus have to be organised in any case.

The most obvious benefit of such coordination is increasing the strength of positions, as joint or common positions might be more likely to succeed in the overall setting of priorities than separate positions. The ESFRI process has considerable momentum and attention at present, which probably increases the possibility of getting budgets within the scheme realised. Similarly, the start-up of the Large Hadron Collider at CERN created considerable attention, which may have positive effects on the realisation of other large scale facilities. It should however be acknowledged that international deliberation and priority setting is a delicate matter, and the formation of blocks of countries or joint positions is not always beneficial. Given the circumstances, separate and individual positions between the Nordic countries can also be favourable. Coordinated Nordic policies thus definitely depend on prior analysis of the possibilities for success and on the mutual interest of the countries in promoting a joint stand.

2.3.2 Model B Nordic joint facilities

The Nordic countries already have a considerable track record in operating joint research centres and infrastructures. This model is a continuation of this tradition, and includes the construction and operation of new joint facilities. Compared to joint facilities at the global or European level, an obvious advantage of operational cooperation at the Nordic level is the reduced complexity of negotiations required prior to construction and administrative structures for operations. The long-term

experiences of Nordic cooperation have built mutual confidence between partners, preparing a favourable climate for increased cooperation, also increasing the likelihood of success. Another advantage of joint Nordic facilities is that, with some very few possible exceptions, they will be located in the region and thus create positive economic side effects within the region. Within ESFRI most of the infrastructures will be built outside of the Nordic region, implying a transfer of resources to other countries and regions.

As mentioned several times above, it is definitely the ESFRI actions that are currently given attention. This can make it more difficult to win attention for Nordic initiatives outside of ESFRI. Also the as yet unknown budgetary consequences of future ESFRI-initiated infrastructures might make policy makers unwilling to engage in other kinds of joint infrastructures.

Joint facilities can be of various kinds depending on what type of research they are serving. We can discern between localised/centralised and distributed facilities, and also between facilities being strictly Nordic and facilities being Nordic nodes in a wider grid or otherwise coordinated set of facilities. There are thus several possible configurations of joint facilities:

■ Infrastructures distributed among the Nordic countries

These can be joint infrastructures that have nodes in (some of) the Nordic countries. Typically such facilities can be databases, measurement/observation networks, linked databases or high power computing facilities (for example the Nordic DataGrid Facility) and are usually found within social sciences and humanities, medicine and research on the climate and environment. Such facilities often have large operating costs, require a long-term perspective on data collection and availability, and also require a networking operational organisation.

■ Joint infrastructures located in one of the Nordic countries (or outside)

These can be infrastructures where (some of) the Nordic countries have agreed to construct an infrastructure at a dedicated site. Typical centralised infrastructures are synchrotrons, telescopes, accelerators etc. requiring large investment or a special location due to their nature (for example in polar environment, close to the ocean or at a specific location as for The Nordic Optical Telescope). Such facilities are most common within the natural sciences and technology, and require an organisation taking care of long-term funding for operation, maintenance and upgrading, as well as the service functions necessary. They also are in need of a review system to ensure that the projects given access are utilising the facility optimally.

■ Joint Nordic nodes in internationally located or distributed facilities

This model will be useful when participation in European or global facilities requires too many resources for one country, but where a joint initiative might provide the necessary resources. Examples might be global observation networks, super-computing grids or the Nordic consortium NORDSYNC for participation in the European Synchrotron Radiation Facility (ESRF).

From the many years of Nordic experience with various cooperative models, as far as we know no evidence for one model being superior to another has emerged. The usefulness of the specific models will depend on the context of the infrastructure in question, and it is difficult to promote one model as suiting Nordic collaboration best. However, there should be no doubt that there is a potential for reusing the models and experiences in the future, making the way forward considerably easier than if starting from scratch.

2.3.3 Model C Shared access to national facilities

There are already many facilities in the Nordic countries of outstanding quality that are attractive to scientists from other countries. We are primarily thinking here of facilities for experimental sciences that are operated on regular basis by a university or other research organisation, which scientists from other countries will have an interest in using because of their qualities or uniqueness. A model for sharing such facilities will imply that researchers from the Nordic countries are given access to existing or future facilities if they meet certain criteria. A possible approach is thus to agree on principles for intra-Nordic access to facilities, implying introduction of some rules for sharing the costs, for assessing the project quality and usefulness, for allotting time etc. Using this model as a strategy requires however that shared access is implemented at some scale, and that new facilities are planned and constructed with this aim in mind. If new facilities are constructed with the aim of serving the needs of researchers at the hosting institution only, sharing will obviously be difficult to implement.

The benefit of this model is the avoidance of duplicating investment in the Nordic countries, and for the hosting institution to get the maximum research out of the facility. It will further facilitate the transfer of knowledge and the pursuit of parallel research tracks between research groups. We should however not underestimate the fact that an institution hosting a good facility will probably be strongly inclined to utilise the facility for its own research, implying a scarcity of available time slots for others. Sharing of access thus presupposes some interest within the hosting institution in letting others have access, and this is probably best obtained through scientific or economic benefits. By scientific benefits we mean the potential for the hosting institution learning from letting colleagues use the facility. Bringing in new researchers with other possible perspectives or problems for investigation might result in transfer of knowledge or development of mutual understanding at higher levels.

We might think of this model in two ways. First, use of facilities might function on a simple “hiring of capacity” principle, e.g. external researchers come in to do their experiments while the hosts are operating the equipment and providing the necessary services. Such a model is probably best suited for well defined experiments and testing, and in situations where the scientific uncertainties are not too large and where the scientific results might be obtained within well defined periods of time.

Second, sharing of facilities might be done through joint projects where scientists from the host institution and from other institutions work together to solve scientific problems. In such cases the project is defined from the outset as a joint project including use of the facility. This method of cooperation is probably already the most common and productive way of sharing facilities, as many international projects are built around complementary resources and capacities, e.g. most EU funded projects are of this kind.

Sharing facilities will also normally require some assessment from the hosting institution’s side regarding the scientific merit of the experiment planned and the scientists involved. Such assessment will include determining the potential usefulness of the facility for the experiment, the experimental setup and any necessary changes etc. In situations where demand for use of the facility is in greater than the time slots available, priorities must be set.

2.3.4 Models for cost sharing

Construction of joint facilities and sharing of facilities must depend on some predefined principles for cost sharing. Construction of new facilities is costly and use of the facility also generates operational costs for materials, technicians, maintenance etc. Cooperative funding models can be developed in several ways. Cooperation does not necessarily entail equal contributions from the partners, and variations can be thought of depending on the capabilities and interests of each country. If constructing/sharing access to a facility is the overall goal, flexible and innovative models of funding might be the key to open the lock.

Costs for joint initiatives can be shared in

different ways according to the circumstances, but there are some general models possible:

■ **Investments shared between partners**

Initial costs can be shared equally, or at a predefined rate. Unequal contributions could be related to access rates, i.e. scientists from a country are given access to the facility in proportion to that country’s investment.

■ **Payment by use**

Another model for cost sharing is to let the users pay according to how much they use the facility. This means that investments are covered by one country, while users from other countries contribute according to actual use. This can be done based on actual use or in advance based on expected use. The first is to the benefit of the users since their use might vary over time, and they will be charged only for the actual use. The second is to the benefit of the operator since contribution from other countries will be guaranteed irrespective of the actual use. A combination of the two might be preferable, since there will be advantages for both parties.

■ **Sharing operating, maintenance and upgrading costs**

It is well known that the operation and further development of research facilities can be expensive. Another way of cost sharing might be to distribute such costs between countries, even if the initial costs are covered by one country.

These models can of course be combined in various ways, and it is difficult to recommend one over another. Other factors such as for how long commitments are agreed or contracted, the number of partners, etc., will also be part of the deliberations.

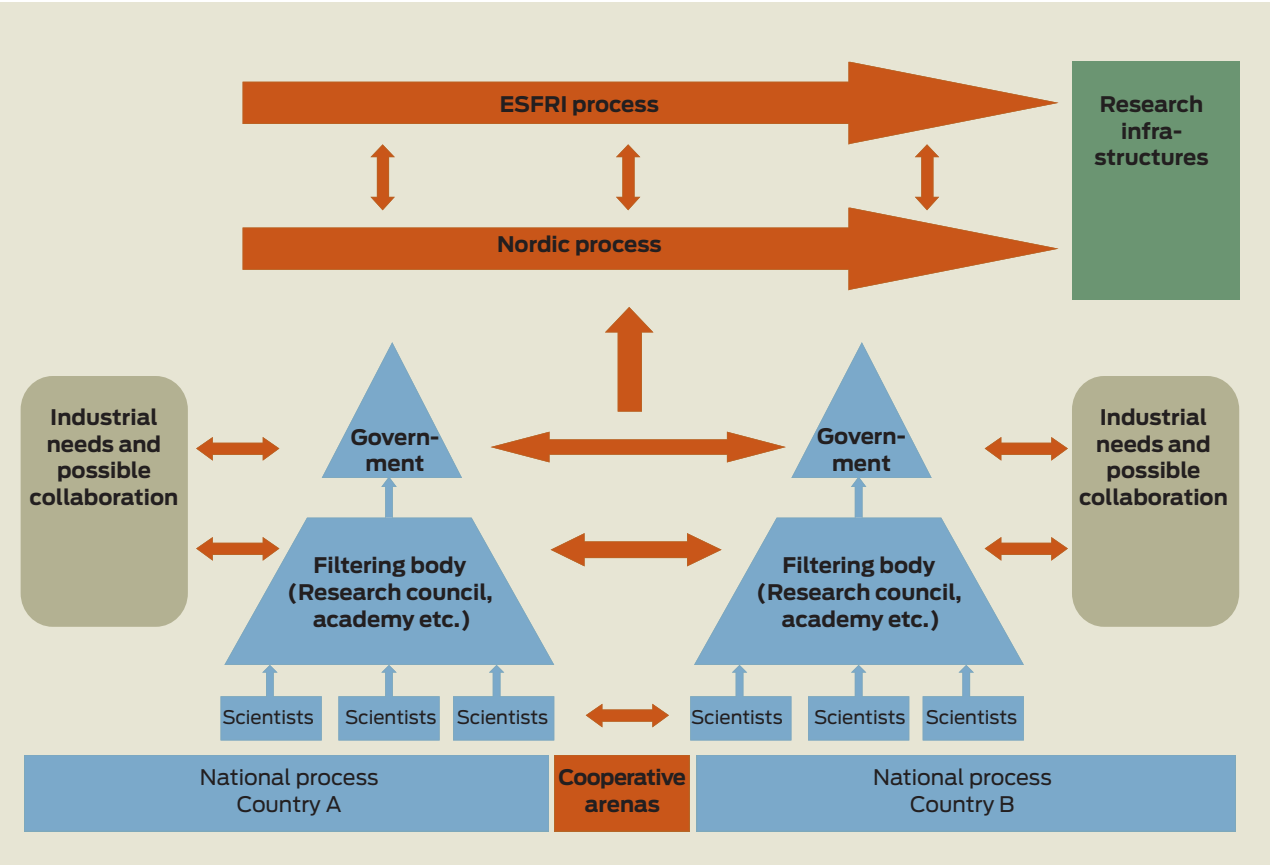
2.4 NEEDS FOR IMPROVED COORDINATION AND ANALYSIS OF FUTURE NEEDS

The essential criterion for joint initiatives and actions is of course a joint interest among the partners. The foregoing analysis has demonstrated that a good starting point exists; the challenge is to design processes creating joint understanding and actions. The current national process towards roadmaps and the ESFRI process are in general bottom-upward and multi-level, with consulting interactions in cooperative arenas (Figure 3 gives an illustration).

Usually, processes start at the level of scientists as they express their opinions on needs and requirements as individuals or through their departments or institutions. The sec-

ond level is a filtering of suggestions done by research councils or other equivalent intermediaries (for example an academy, ad hoc group of experts etc). The third level, often reserved for the larger investments or long-term commitments, is the government level that makes the final decisions on which infrastructures to support. Of course, government decisions also need to be approved by parliament, but for reasons of simplicity we consider this a part of the government process. Introducing international cooperation, be it at Nordic, European or global level, introduces an additional fourth level on top of these three levels. In addition, to a varying extent industry might be involved as stakeholders and possible partners.

FIGURE 3. PROCESS OVERVIEW



Essentially, all processes for collaboration on research infrastructures need to have a bottom-upward approach. From the perspective of how scientific progress evolves, this is quite natural because the scientific usefulness of advanced scientific infrastructure is difficult to assess outside of science itself. Making decisions on the priorities of infrastructures without the explicit involvement of scientists is hazardous in terms of increasing the risks for failure. However, since we are here discussing issues with potentially large financial and scientific implications, as well as in some areas also with large social and economic implications, processes will have to be a mix of bottom-upward and top-downward, in the sense that scientific priorities must come from scientists, while the implications of their priorities have to be interpreted and developed in a policy context by policy makers. National interests might in some cases be at stake, and call for decisional outcomes other than the top priorities of scientists. **Nordic processes have therefore to be horizontally and vertically integrated at multiple levels.**

Identifying and defining joint interests can thus be complicated, since consensus has to be sought at all levels, and will be more likely to succeed if begun at the level of scientists. Such processes are exemplified through ESFRI, where scientists are involved in propositions, evaluation and in defining the priorities. For potentially increased Nordic cooperation this means that consensus on priorities among scientists in the Nordic countries on what infrastructures to construct will also be an important criterion for decisions at higher levels. Given the various scientific strongholds, consensus among scientists in all countries might be difficult to obtain. Consensus among scientists in some of the countries might thus be an option. On the other hand, the greater the portion of the science system a consensus includes, the greater will be the probable chance of realising an infrastructure.

As discussed in section 4.1.2, realising infrastructures is not only about scientific priorities. It is also about priorities for industry and societal development. To some surprise, little attention has been directed towards the pos-

THE NORDIC
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sible positive effects from infrastructures on innovative capacities and for economic development. After all, large-scale infrastructures often require new high-tech solutions that in some cases might be directly applicable in the market or are useful in other arenas. The criteria for common interests thus also have to include political and economic relevance of the infrastructure. To put it bluntly, the larger the spin-off effects of an infrastructure is expected to be, the larger is its chance of being realised. Analysing the possible externalities of joint investments in infrastructures should thus be included in the preparations towards decisions. **The Nordic countries are thus in need of improved coordination of processes as well as of improved analysis of future needs and the potential effects of infrastructures.**

2.5 CONCLUSIONS

The current focus of the Nordic countries is towards the outcomes of the ESFRI process and the national roadmaps. As capacities are limited, this has to some extent reduced attention towards Nordic cooperation. As the outcome of these processes is soon to emerge, a very favourable time window for Nordic cooperation is about to open. Adequately exploited, this window can create a very favourable climate for realising cooperative efforts.

Developed as it is from a long history of cooperation, the climate for Nordic cooperation is favourable, probably making it far easier to increase cooperation in this region than in others. Several general models for Nordic cooperation and actions are available, making it possible to choose between future strategies ranging from micro to macro level. In particular, the possible advantages of cooperation towards ESFRI should be explored.

Choosing which specific infrastructures to prioritise for Nordic cooperation is complex, and needs further and more detailed preparation. First, strategic plans need to be developed. Second, plans at the operational level specifying the infrastructure design, operational modes, funding models etc should be put forward. To increase knowledge of future needs, combining the emerging national roadmaps with foresight exercises in combination with

analysis of regional scientific strongholds and the extra-scientific effects of infrastructures will be a contribution in the right direction. This will also put infrastructures into a wider context and increase attention on the usefulness of infrastructures. At the same time, awareness towards priorities of other countries and the EU is necessary.

The roadmaps that have so far emerged have high cost estimates for new infrastructures. Besides the scientific advances made possible, cost sharing is probably the best argument for cooperation. Flexible and innovative models for cost sharing might be necessary for realising infrastructures.

The ongoing processes are complex and multi-level, and to some extent fragmented and ad hoc. Considering the large investment and long planning horizons required, better coordination of processes is desirable. Improved coordination is likely to speed up processes, as well as creating the momentum necessary for getting the attention of policy makers.

3. The way forward

Developing further the Nordic joint policies for research infrastructures is challenging, given the complexities and as yet undetermined results of the ongoing global, European and national processes. This section answers the challenge by suggesting four scenarios for how Nordic cooperation can be intensified, and discusses also how coordination and the knowledge base can be improved.

The previous analysis has demonstrated that there are on the one hand considerable assets from the long tradition of cooperation between Nordic countries and that a favourable window for increased cooperation is about to open. In addition, the recent joint Nordic initiatives put into operation by NordForsk and the overlapping interests between the Nordic countries for many of the ESFRI projects are building blocks on which a stronger cooperation can be built.

On the other hand, there are also some obstacles to be passed. Even if there are overlaps between the Nordic countries in their priorities, there are also some diverging opinions about what fields of science to prioritise and the will to prioritise research infrastructures varies between governments. The analysis has further demonstrated that decisional processes are multi-level and complex, and could benefit from improved coordination. This issue, together with the need for including broader economic and industrial perspectives, will be pertinent if the Nordic countries are to increase their ambitions. A combination of conflicting and overlapping opinions and priorities is however the normal setting for international cooperation. What are required to bring cooperation forward are visions of where to go and some suitable mechanisms to ensure forward movement.

3.1 INCREASING THE AMBITIONS – FOUR SCENARIOS

In the landscape of emerging international and national priorities, what could be the scenarios for future Nordic cooperation? There are of course several possible lines of action available, of which keeping the status quo is the least ambitious. The analysis has, despite some variations in intensity, demonstrated that there is a substantial momentum towards increasing the ambitions. Four “stylised” or generalised scenarios are thus put forward, scenarios that are all to a varying degree an intensification of the cooperation. The scenarios and lines of action behind their realisation can also be combined to fit a variety of types of infrastructures and cooperative structures, and both centralised and distributed infrastructures. We thus do not speculate about what specific infrastructures will fit Nordic cooperation best. That issue needs detailed and qualified input from scientists, universities and other research organisations.

The scenarios should be understood as suggestions to foster further discussion on ambitions and actions, rather than as policies ready to be implemented. Implementation will as always be subject to negotiations and available budgets. However, without some ambitions to fulfil, there will no policies at all.

Scenario A

“The Global Research Platform”

The Nordic countries agree on the joint ambition to establish the region as a preferred location for internationally operated large infrastructures and implement a joint action plan for this purpose. The Nordic countries are already well known for their commitment to R&D and further investment in infrastructure will reinforce the region’s position in the knowledge economy. The ambition will thus be to get several large infrastructures located in Nordic countries, and thereby to strengthen the region as a centre for advanced science.

Compared to the models from section 2.3, this scenario will be the strong version of the “Joining forces for international participation model” (Model A), with the explicit aim of not only participating in international infrastructures, but actually having them located in the Nordic region.

The realisation of such an ambition requires commitment at government level for the planning and investment, as well as the willingness of the countries to take responsibility for fronting the actions for the realisation of specific infrastructures. It also requires well prepared processes at government level if it is likely to succeed.

The infrastructures to be realised as part of the scenario can be developed from new plans emerging at global level, from infrastructures already suggested as part of the ESFRI process, from priorities of the national roadmaps, as well as from further development of existing scientific strongholds, for example:

- European Spallation Source
- EISCAT-3d
- The Svalbard infrastructures
- Polar and sub-Arctic research
- Register-based social science studies
- Forestry and ecology
- Telecommunications
- Climate and the environment
- Energy related research (renewable, oil and gas, nuclear)

Scenario B

“The Nordic ESFRI initiative”

The Nordic countries more strongly and systematically coordinate their opinions and actions towards the ESFRI process with the ambition of realising those infrastructures with highest priority among the Nordic countries. As was evident above, there are several of the ESFRI projects that the countries have a common interest in realising. The ambition can be developed from the already existing coordination efforts, but should be intensified and implemented more rigorously. There is of course an extra impetus towards better coordinating the effort towards those projects with some chance of obtaining a Nordic loca-

tion. This will be the weaker version of Model A from above. A less ambitious version of this strategy will be to develop mutual and reciprocal support for those ESFRI projects prioritised by only one or a few of the Nordic countries.

Scenario C

“The Nordic Research Technology Initiative”

The Nordic countries develop an alternative strategy for getting more involved in international research infrastructures, namely to develop crucial technologies for infrastructures. Most infrastructures are dependent on specialised technologies and instruments, often developed on a one-of-a-kind basis from science-based specifications, and the development, construction, testing and installation of such technologies can be a gateway for increased involvement. Scientists involved will have hands-on experience with equipment later to be used in large-scale facilities, making them more attractive for cooperation as well increasing their possibilities for scientific breakthroughs. This scenario requires a dedicated effort for improvement and development of existing infrastructures in the Nordic countries, including cooperation with industries capable of delivering the required technologies. High-tech equipment developed can later be exploited in the market.

This scenario builds on the “Nordic joint facilities model” (Model B) from above, but is to some extent a specialised version since it explicitly pays attention to potential industrial involvement. Developing new technologies and instruments at the scientific front requires a considerable high-tech industrial base to be feasible, but will also provide considerable pay-back to the same industries if successful. The Nordic countries probably have the industries necessary, at least in some domains, but not all are as included in science-based technology development as they could be. This scenario might thus offer them an opportunity.

Scenario D

“Nordic excellence”

The Nordic countries develop further the existing cooperation on Nordic Centres of Excellence and the initiative for joint Nordic use

of research infrastructures. This scenario can imply both development of new joint facilities (Model B “Nordic joint facilities”) and increasing shared access to facilities (Model C “Shared access to national facilities”). Emphasis should be put on increasing the available resources and the possibility of treating the two existing initiatives as a total, i.e. reinforcing support for research infrastructures as part of the support for Centres of Excellence. Further consolidation could be done with the research and innovation programme on energy, climate and the environment (“Research Excellence initiative”)²⁹, as well as including development of relevant technologies (similar to “the Nordic Research Technology Initiative” scenario above). If implemented, this scenario could realise an integrated approach for excellent research and technological innovation in fields of high importance.

3.2 IMPROVING COORDINATION – A THREE-LEVEL NORDIC STRUCTURE

The analysis above also showed that the Nordic countries to some extent follow their own paths towards new infrastructures, paths that are dependent upon the perceived scientific, industrial and social needs of each country. Analyses of the scientific needs are well maintained at national level through the bottom-upward priority process, and NordForsk is well on the way towards coordinating the processes at regional level. Still, there is room for better assessing the common interests in new infrastructures, as well as improved and more formalised coordination in the cases where a common interest exists. If the Nordic countries in addition should agree on fulfilling at least some of the ambitions outlined in the scenarios above, the need for coordination and knowledge-based decisions will increase.

We suggest a three-level Nordic structure:

■ The Infrastructures High Level Group

The mandate of the group is to negotiate and prepare propositions at government level necessary for implementation and funding of joint Nordic infrastructures and joint positions towards international infrastructures. The group con-

sists of representatives from each country of ministries or other bodies with the necessary authority³⁰.

■ The Infrastructures

Standing Committee

The mandate of the committee is to prepare and prioritise joint actions. The committee will seek out the potential for cooperation through interaction with ad hoc scientific committees, investigate the possibilities for joint actions and make the preparations necessary for the high level group. The group consists of officials from research councils, academies of science and other relevant bodies at the operative level.

■ Ad hoc Scientific Committees

The mandate of these committees is to seek out potential cooperative actions and the provisional specifications for joint facilities or for joint actions towards international initiatives. Committees will be set up ad hoc with a mandate from the standing committee.

A structure like this is of course in danger of increasing the bureaucracy. Considering the possible scientific and economic impacts of large research infrastructures, as well as the technically and politically complex processes preceding their realisation, the suggested structure is not exaggerated and maintains connections to the various levels already involved. The high level group will endorse the processes at policy level, ensuring that steps are not taken that are disconnected from political priorities. The standing committee will be the main coordinating body, having the day-to-day operative overview of ongoing processes and keeping liaisons with both policy makers and scientists. Scientific committees are necessary to ensure that infrastructures meet the needs of science.

The suggested structure will also require the administrative resources to be reinforced, and NordForsk should be given the resources necessary for maintaining the permanent sec-

retary functions as well as for seeing plans and preparatory actions realised. At national level, the ministries and intermediate bodies involved in the development of infrastructures should consider the set-up of task forces for the realisation of infrastructures. Such groups of dedicated experts can ensure knowledge and experience from one infrastructure is transferred into the next.

3.3 IMPROVING KNOWLEDGE THROUGH FORESIGHT

The national roadmaps and the ESFRI process convey considerable knowledge on the needs and potential design of new infrastructures. Assessment of which infrastructure can meet future needs for knowledge and how infrastructures can play a part in industrial and economic development in the Nordic region can however be improved. To meet these needs we suggest a foresight study to be implemented. Carefully designed, such a study can lay the foundations for a policy integrating the development of research infrastructures with development of high-tech industries and capacities for innovation.

Foresight studies have already been successfully implemented in science and innovation policy in the Nordic countries, and can inform policy makers on anticipated near future developments in science, technology and industry.

The Swedish innovation agency VINNOVA has used foresight for identifying strategic areas and in developing joint strategic visions among various players – both industrial and academic – while the Finnish Ministry of Employment and the Economy has used foresight for understanding the changes and developments taking place in the innovation environment and their implications. Technology foresight might be seen as one of several inputs available to politicians and businesses when making decisions concerning future investment and as strengthening the dialogue between business and the research communities.

Examples on foresight activities in the Nordic countries:

- The Swedish Technology Foresight programme (Teknisk Framsyn) was initiated by VINNOVA, with a budget of € 1.6 million, and was concluded in March 2004.
- The Finnish Ministry of Employment and the Economy in cooperation with TEKES operated in 2002–2005 a major research programme in the field of technology studies (The Research Programme for Advanced Technology Policy – ProAct). The four-year budget of ProAct amounts to € 10 million.
- In Denmark the Ministry of Science, Technology and Innovation (VUT) is responsible for Denmark's Foresight Programme. In 2001–2004 the Ministry funded a Technology Foresight (TF) project.
- The Research Council of Norway and the Norwegian innovation agency, Innovation Norway, actively utilise foresight approaches.
- In Iceland the Science and Technology Policy Council and RANNIS, the Icelandic Centre for Research, have expressed the need to make foresight studies over the coming years.
- Recently the Nordic Innovation Centre (NICe) recommended using foresight to strengthen the Nordic Research and Innovation Area.



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ABBREVIATIONS

ALMA	The Atacama Large Millimeter/submillimeter Array
ASSA	Advanced Sustainable Sea-based Aquaculture
ASTRID	Aarhus Storage Ring in Denmark (synchrotron radiation facility)
CERN	The European Organization for Nuclear Research
CLARIN	Common Language Resources and technology Initiative (see CLARIN in Annex B for a short description)
DCGC	Danish Centre for Grid Computing
DESY	Deutsches Elektronen-Synchrotron
DRCC	Danish Research Coordination Committee
ECCSEL	European Carbon dioxide Capture and Storage Laboratory Infrastructure
EFDA	European Fusion Development Agreement
EIRO-forum	The co-ordination and collaboration organisation of the Council of the European Intergovernmental Research Organisations
EISCAT	European Incoherent Scattter
EISCAT-3D	Planned expansion of the European Incoherent Scattter
ELIXIR	European Life Sciences Infrastructure for Biological Information (see Upgrade of European Bioinformatics Infrastructure in Annex B for a short description)
EMBL	European Molecular Biology Laboratory
EMBO	The European Molecular Biology Organization
ERA-NET	Funding scheme within EU Framework Programmes with the objective of developing and strengthen the coordination of national and regional research programmes
ERAWATCH	Online information platform on research systems and policies within the European Union
EROHS	The European Research Observatory for the Humanities and Social Sciences (see EROHS in Annex B for a short description)
ESA	European Space Agency
ESO	European Southern Observatory (see ELT in Appendix B for a short description of the planned expansion of ESO)
ESRF	European Synchrotron Facility (see ESRF UPGRADE in Annex B for a short description)
ESFRI	The European Strategy Forum on Research Infrastructures
ESS	The European Spallation Source (see the European Spallation Source for Producing Neutrons in Appendix B for a short description)
ESS-S	ESS-Scandinavia Consortium (initiative to support ESS located to Scandinavia)
EUI	European University Institute
FAIR	Facility for Antiprotons and Ion Research (see FAIR in Annex B for a short description)
FAS	The Swedish Research Council for Working Life and Social Research
FORMAS	The Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning
IARC	International Agency for Research on Cancer
IIASA	The International Institute for Applied Systems Analysis
ILL	The Institut Laue-Langevin (see ILL 20/20 Upgrade in Annex B for a short description)
IODP	Integrated Ocean Drilling Program
JHR	Jules Horowitz Reactor (see Jules Horowitz Reactor in Annex B for a short description)
KFI	Committee for Research Infrastructure, Sweden
MAX IV	Planned expansion of the National Electron Accelerator Laboratory, Lund
NCoE	The Nordic Centres of Excellence in Research Programme
NDGF	The Nordic DataGrid Facility
NORDITA	Nordic Institute for Theoretical Physics
NORDSIM	Nordic Secondary Ion Mass Spectrometer
NORDSYNC	Membership consortium to ESRF of Denmark, Finland, Norway and Sweden
NORDUnet	Nordic Infrastructure for Research and Education
NOT	Nordic Optical Telescope
NOTSA	Nordic Optical Telescope Scientific Association
PRACE	Partnership for Advanced Computing in Europe
RANNIS	The Icelandic Centre for Research
SIAEOS	Svalbard Integrated Arctic Earth Observing System
SPTC	The Icelandic Science and Technology Policy Council
STPC	The Science and Technology Policy Council of Finland
TEKES	The Finnish Funding Agency for Technology and Innovation
VINNOVA	Swedish Governmental Agency for Innovation Systems
VTT	Technical Research Centre of Finland
XFEL	The X-ray Free-Electron Laser (see EUROPEAN XFEL in Appendix B for a short description)

Appendix A

EXPERTS INTERVIEWED

Mika Aalto, Tekes, Finland

Mirja Arajärvi, Ministry of Education, Finland

Lars Börjesson, Swedish Research Council

Tord Ekelöf, Uppsala University

Ole Henrik Ellestad, Research Council of Norway

Odd Ivar Eriksen, Research Council of Norway

Fridrika Hardardóttir, Ministry of Education, Iceland

Eeva Ikonen, Academy of Finland

Mats Johnsson, Ministry of Education, Sweden

Oddný Ósk Sverrisdóttir, Rannís – The Icelandic Centre for Research

Anders Ødegaard, Danish Agency for Science, Technology and Innovation

Kari Balke Øiseth, Ministry of Education and Research, Norway

Appendix B

ESFRI ROADMAP 2006 – THE 35 PEER-REVIEWED PROJECTS³¹

Social Science & Humanities

CESSDA (Council of European Social Science Data Archives) is a distributed research infrastructure that provides and facilitates access of researchers to high quality data and supports their use. The CESSDA network of organisations currently extends across 21 countries in Europe. It holds some 15,000 data collections and provides access to over 20,000 researchers.

The upgrade costs for CESSDA are € 30 million, covering the upgrading of the existing technical infrastructure (common standards, tools, instruments and services through the creation of middleware); capacity building (a hub for strategic development, maintenance and coordination); supporting less developed and less-resourced organisations; and extending and deepening the CESSDA network to new and associated CESSDA-Members.

www.nsd.uib.no/cessda

CLARIN (Common LAnguage Resources and technology INitiative) is a large scale pan-European coordinated infrastructure effort to make language resources and technology available and useful to scholars of all disciplines, in particular the humanities and social sciences. It will overcome the present fragmented situation by harmonising structural and terminological differences, based on a Grid-type of infrastructure and by using Semantic Web technology.

The CLARIN infrastructure is scheduled to reach its full functionality based on fully operational resource and service centres in 2012. The total costs for the five-year period will amount to around € 120 million, based on an estimate of about 20 distributed resource and service centres in Europe.

www.mpi.nl/clarin

DARIAH (Digital Research Infrastructure for the Arts and Humanities) will be based upon an existing network of Data Centres and Services based in Germany (Max Planck Society), France (CNRS), the Netherlands (DANS) and the United Kingdom (AHDS). The model is however open and will be able to embrace new fields. It will also profit from European Cultural Heritage Online (ECHO), an Open Access Infrastructure to bring essential cultural heritage online.

DARIAH will be based on partner organisations that have national infrastructures in place and are already collaborating. A core group of national institutions will directly contribute to DARIAH by offering their existing infrastructures (thus ensuring a quick take-up within three years at most). Preparatory cost is estimated at € 6 million and construction cost at € 10 million. Operational cost is estimated at € 4 million per year.

www.dariah.eu

EROHS (European Resource Observatory for the Humanities and Social sciences) will operate as both a central and distributed facility with a strong physical hub working in close conjunction with a number of spokes across Europe, harnessing European expertise through a coordinated yet decentralised network. It will be organised to promote and ensure cooperation and integration of data, technologies and policies. EROHS will gradually become active in more and more areas. The costs will therefore increase year by year during the first five years of EROHS life time, from € 5 million for the first year to € 12 million for the fifth year.

www.erohs.org

THE EUROPEAN SOCIAL SURVEY (ESS) was set up in 2001 to monitor long term changes in social values throughout Europe and produce data relevant to academic debate, policy analysis and better governance. It now covers 27 European countries. A long term pan-European instrument such as the ESS requires long term funding commitments. A major upgrade is now sought to “ll debilitating gaps in the present programme”.

The total annualised cost of the ESS infrastructure at present, combining all sources of finance amounts to around € 6 million per year. The major upgrade proposed would bring the total annual costs to around € 9 million per year (a 50% overall increase). If the ESS were to assure funding for three further rounds, including its infrastructure responsibilities, the overall commitment would be around € 54 million over 6 years.

www.europeansocialsurvey.org

SHARE (Survey of Health, Ageing and Retirement in Europe) provides data infrastructure for fact-based economic and social science analyses of the on-going changes in Europe due to population ageing. The original 8-country survey has already been expanded to cover two new Member States; ideally SHARE will be expanded to all 25 Member States of the EU.

Costs are roughly proportional to the number of participating countries and the number of waves. Preparatory costs amount to approximately € 250,000 per country and wave (=€ 3.75 million for 15 countries). Construction costs (i.e. data collection) amount to about € 400,000 per country/per wave (=€ 6 million for 15 countries). Annual operating costs for the entire SHARE infrastructure (data distribution and documentation) amount to some € 300,000 per year. Hence, one wave of the biannual data collection in 15 countries thus costs about € 10.5 million. Three waves in all 25 Member States cost about € 51 million. Current funding is from EU, NIA (National Institute on Ageing) and national sources, and such cost sharing is also expected in the future.

www.share-project.org

Environmental Sciences

AURORA BOREALIS (European Polar Research Icebreaker) will be a powerful research icebreaker vessel (31,000 tonnes displacement 196 metres long) with 50 megawatt azimuth propulsion systems and deep drilling capability for use in extreme conditions in excess of 4,000 m water depth. It will have high ice performance to penetrate autonomously into the central Arctic Ocean with 2.5 metres of ice cover, during all seasons.

Estimated costs: Preparatory phase: 2006–2008 (€ 6 million). Construction phase: 2008–2010 (€ 360 million). Operation: 2010 onwards (€ 17.5 million/year).

www.europolar.org

EUROPEAN MULTIDISCIPLINARY SEAFLOOR OBSERVATION (EMSO). Deep sea-floor observatories are deployed on specific sites offshore European coastline to allow continuous monitoring for environment and security. They will be organised in a unique management structure at European level (and part of a global endeavour in sea-floor observatories), for long term monitoring of environmental processes related to ecosystem life and evolution, global changes and geo-hazards. EMSO will be a key component of GMES and GEOSS.

Surveys, Cables, junction boxes and boreholes in 5 different places will be gradually implemented from 2007 to 2011. Preparatory costs: € 50 million, Construction Costs ~€ 100 million for 5 sites, Operational costs € 20 million/year.

www.ifremer.fr/esonet/emso

EUFAR (European Fleet of Airborne Research) will be a Heavy-Payload fleet of airborne research in Environmental and Geo-Sciences. Two main aircraft alternatives are being considered and the time table depends on the choice. If a C130 is selected the plans for research modifications of the frame have already been validated by the NSF and NASA in the US and they can be finalised within a year. If an A400M is selected, the prototype will not be available before the year 2009, and modifications for research will have to be adapted to the frame of the A400M, significantly different from that of a C130. As already demonstrated, the life time of such an infrastructure is ~25 years, with a potential of 15,000 flight hours. Preparatory cost ~€ 1 million. Acquisition and implementation cost ~€ 50 million (C130) or ~€ 100 million (A400M). Operation Cost ~€ 2 million/year.

www.eufar.net

EURO ARGO (Global Ocean Observing in Infrastructure). The EURO-ARGO array is the European component of a world wide in situ global ocean observing system, based on autonomous profiling floats. The ARGO objective is to develop a global array of floats (spaced 300 km apart, on average) throughout the ice-free areas of the deep ocean. It is estimated that some 3,000 floats are required to reach this objective. The data are transmitted in real time by satellite to data centres for processing, management, and distribution. The EURO-ARGO objective is to provide a sustained European contribution to the international ARGO programme.

The ARGO array was initiated in 2000 (first deployments) and is expected to reach its world target of 3000 floats in operation during 2007. The individual lifetime of a profiling float being around 4 years, the maintenance of the infrastructure would consist in 800 floats deployed per year over the period 2007–2010, with full implementation over the extended period of 2011–2020. The European contribution will

consist in the deployment of ~250 floats per year as well as the operation of the CORIOLIS Data Centre (one of the two Global Data Assembly Centres) to collect, validate and deliver the data to users. Because of the multi-year research objectives linked with the EURO-ARGO infrastructure, a twelve-year period has been considered as a typical lifetime, including the build-up period of four years. The budget requested for this period would be ~€ 76 million.

www.coriolis.eu.org

IAGOS-ERI (In-service Aircraft for a Global Observing System – European Research Infrastructure) uses, as platforms, commercial passenger aircrafts and proposes an integration of routine aircraft measurements into a Global Observing System – a European Research Infrastructure, to establish and operate a sustainable distributed infrastructure for regular observations of atmospheric composition from a fleet of initially 10–20 in-service aircrafts. This will be achieved by installing autonomous instrument packages, certified for commercial aircraft (Airbus).

Preparatory cost € 5–7 million (mostly covered by the IAGOS-DS). Construction cost € 14 million total for instrumentation of 20 aircraft during the first 9 years. Operation cost (total) € 6 million/year at full operationality, € 50 million over 10 years.

www.fz-juelich.de/icg/icg-ii/iagos

ICOS (Integrated Carbon Observation System) is an infrastructure for coordinated, integrated, long-term high-quality observational data of the greenhouse balance of Europe and of adjacent key regions of Siberia and Africa. Consisting of a centre for co-ordination, calibration and data handling in conjunction with networks of atmospheric and ecosystem observations, ICOS is designed to create the scientific backbone for a better understanding and quantification of greenhouse gas sources and sinks and their feedback with climate change.

ICOS must be operating during the Kyoto commitment period 2008–2012 and beyond. Possible timetable for implementation: most elements are already existing in a research mode, and can be easily transferred into ICOS. Major milestones are decisions about location of the ICOS-Centre facilities, and then their installation and equipment. Once the decision about funding and the location of the ICOS-Centre is made, the preparatory phase will take about 3 years. ICOS would be operational after 5 years, with a 20 years perspective. Preparatory costs € 5 million, total costs for implementation and operation over 20 year: ~€ 250 million.

<http://icos-infrastructure.ipsl.jussieu.fr/>

LIFE WATCH (Research Infrastructures Network for Research in Biodiversity) will construct and bring into operation the facilities, hardware, software and governance structures for research on the protection, management and sustainable use of biodiversity. It will consist of facilities for data generation and processing, a network of observatories, facilities for data integration and interoperability, virtual laboratories offering a range of analytical and modelling tools; and a Service Centre providing special services for scientific and policy users, including training and research opportunities for young scientists. The infrastructure has the support of all major European biodiversity research networks. Preparation phase 2005–2008, Construction 2008–2014, Test and operation 2014–2032. Construction costs: ~€ 370 million.

www.lifewatch.eu

Energy

HiPER (High Power Experimental Research Facility) will be a large scale laser system designed to demonstrate significant energy production from inertial fusion, whilst supporting a broad base of high power laser interaction science. This is made feasible by the advent of a revolutionary approach to laser-driven fusion known as “Fast Ignition”. HiPER will make use of existing laser technology in a unique configuration, with a 200 kJ long pulse laser combined with a 70 kJ short pulse laser.

Based on the ongoing conceptual design work and experience with LIL-PETAL, the construction cost of the facility is estimated at ~€ 800 million, with a preparatory cost of ~€ 55 million (including completion of PETAL), and an annual operating cost of ~€ 80 million. The present scientific and technological basis of the facility allows a 3-year detailed design phase to start immediately, with construction envisaged for the turn of the decade for delivery to users by 2015–2017.

www.hiper-laser.org

IFMIF (International Fusion Materials Irradiation facility) is an accelerator-based very high flux neutron source utilising the deuteron lithium-stripping reaction with the aim to provide timely a suitable data base on irradiation effects on material needed for the construction of a fusion reactor. Although IFMIF does not rely on aggressive innovative technologies, its beam power of 2 x 5 MW is by far the most intensive that has ever been built.

For construction: ~2012 to 2017 (first phase) first operation: ~2017 with one beam; 2017–2020 (second phase), lifetime 20–30 years. Preparation costs ~€ 88 million, starting around 2007 and lasting about 5–6 years to validate long term reliability of some large scale components, conceptual design and costs. Construction ~€ 770 million, operation costs ~141 (over first 3 years), € 78.5 million/yr from the 4th year.
<http://www.frascati.enea.it/ifmif/>

JULES HOROWITZ REACTOR

This new research reactor will allow high flux irradiation experiments dedicated to the study of the materials and fuel behaviour under irradiation with sizes and environment conditions relevant for nuclear power plants in order to optimise and demonstrate safe operations of existing power reactors as well as to support future reactors design.

JHR is now a mature project; detailed design, public consultation and safety files have been completed and construction phase has been launched early in 2006 for a start of operation scheduled in 2014. JHR will be built and operated by a consortium of government agencies and industrial partners from several European states. Construction costs ~€ 500 million, yearly costs € 24–33 million, decommissioning preparation costs are estimated at ~€ 80 million.
<http://www.cad.cea.fr/rjh/index.html>

Biomedical and Life Sciences

EATRIS (European Advanced Translational Research Infrastructure for medicine) will first establish a small number of research facilities distributed in Europe, with the task of translating basic discoveries into clinical practice. Each node of the network will include cutting-edge technologies for translational research and will cover one of the major disease fields: cardiovascular diseases, cancer, metabolic syndrome, brain disorders and infectious disorders. In later steps, additional dedicated centres are expected to join the EATRIS partnership.

Preparatory phase: 2007 (€ 5 million). Construction phase: 2008–2010 (€ 255 million). Operation: 2010–2012 onwards (€ 50 million per year).
<http://www.eatris.eu/>

EUROPEAN BIOBANKING AND BIOMOLECULAR RESOURCES is a pan-European and broadly accessible network of existing and de novo biobanks and biomolecular resources. The infrastructure will include samples from patients and healthy persons, molecular genomic resources and bioinformatics tools to optimally exploit this resource for global biomedical research.

Preparatory phase: Years 1–3 (€ 70 million in total). Construction phase: Years 2–7 (€ 100 million in total). Operation: total over years 3–10 (€ 15 million per year).
www.biobanks.eu

INFRAFRONTIER (Infrastructure for Phenomefrontier and Archivefrontier) will organise two complementary and interlinked distributed infrastructures. (1) “Phenomefrontier” will provide a European platform equipped with the latest technologies, in particular in vivo imaging and data management tools, for the phenotyping of medically relevant mouse models; (2) “Archivefrontier” will provide a European resource for state-of-the-art archiving and dissemination of those mouse models and will consist in a major upgrade of the European Mouse Mutant Archive (EMMA).

Preparatory phase: 2006–2007 (€ 50 million). Construction phase: 2007–2017 (€ 270 million). Operation: 2007 onwards (€ 36 million/year).
www.emma.rm.cnr.it

INFRASTRUCTURES FOR CLINICAL TRIALS AND BIOTHERAPY will (1) interconnect existing national networks of clinical research centres and clinical trial units; (2) upgrade or create new facilities for the evaluation of innovative biotherapy agents; (3) make available professional data centres allowing high quality data management across the European Union; (4) establish connections with disease-oriented patient associations and registries, and disease-oriented investigators networks in order to foster patients' enrolment.

Preparatory phase: 2006–2007 (€1 million). Construction phase: 2007–2008 (€35 million). Operation: total over years 1–6 (€5 million per year).

www.ecriin.org

INTEGRATED STRUCTURAL BIOLOGY INFRASTRUCTURE will consist of distributed Centres for Integrated Structural Biology. All Centres will maintain a set of core technologies such as protein production, NMR, crystallography, and different forms of microscopy. However, each Centre will have a specific biological focus that will drive the development of technological and methodological expertise, notably for production and analysis of functional complexes. The network of Centres will be organised in order to obtain multi-scale structural data and translate these data into functional knowledge.

Preparatory phase: 2007–2009 (€50 million). Construction phase: 2010–2013 (€250 million). Operation: 2008–2013 (€25 million per year).

www.strubi.ox.ac.uk

UPGRADE OF EUROPEAN BIOINFORMATICS INFRASTRUCTURE The infrastructure will be a secure but rapidly evolving platform for data collection, storage, annotation, validation, dissemination and utilisation, consistent with the unique requirements of shared resources in the life sciences. The new infrastructure will be based around a substantial upgrade to the existing European Bioinformatics Institute (EBI) handling primary data resources. It will also integrate secondary data resources that are distributed across Europe and make the most of the diverse expertise of its scientists.

Preparatory phase: Years 1–7 (€80 million). Construction phase: Years 1–7 (€470 million). Operation: total over years 1–7 (€7 million per year).

www.ebi.ac.uk

Material Sciences

ELI (Extreme Light Infrastructure) will be a research infrastructure open to European scientists dedicated to the investigation and applications of laser matter interaction at the highest intensity level, i.e. more than 36 orders of magnitude higher than today's state of the art. ELI will comprise three branches: Ultra High Field Science that will explore laser matter interaction up to the nonlinear QED limit, Attosecond Laser Science will make possible temporal investigation at the attosecond scale of the electron dynamics in atoms, molecules, plasmas and solids and the High Energy Beam Facility devoted to the development of dedicated beam lines of ultra short pulses of high energy particles up to 100 GeV and radiation for European users. ELI will have a large societal benefit in medicine, material sciences and environment. ELI conceptual design calls for three stages. They will be made available as they are completed, with a preparatory cost of €14 million. The Front End at the PW level, the second one at the 50 PW and the final stage, above the 100 PW. It is foreseen a two-year design study followed by five years for the construction. The project cost is estimated at €138 million, with operation and maintenance at €6 million/year.

www.extreme-light-infrastructure.eu

ESRF UPGRADE (European Synchrotron Radiation Facility). ESRF located in Grenoble, France, is a joint facility supported and shared by 17 European countries and Israel. It operates the most powerful high energy synchrotron light source in Europe and brings together a wide range of disciplines including physics, chemistry and materials science as well as biology, medicine, geophysics and archaeology. There are many industrial applications, including pharmaceuticals, cosmetics, petrochemicals and microelectronics.

The upgrade programme is estimated to cost €232 million and to take approximately 7 years to implement. It is planned to carry out the programme with minimal disruption to existing research, and the running costs will be only slightly increased.

www.esrf.eu

EUROPEAN SPALLATION SOURCE FOR PRODUCING NEUTRONS (ESS) will be the world's most powerful source of neutrons. Its built-in upgradeability (more than the initial 20 instruments, more power, more target stations) makes it the most cost-effective top tier source for 40 years or more. A genuine

pan-European facility, it will serve 4,000 users annually across many areas of science and technology. Start of construction 2009; First neutrons 2016; First user operations 2017–2018. Preparatory costs € 30 million. Total expected construction costs ~€ 1,000 million, operation cost ~€ 80 million/year. <http://neutron.eu.net/neutron-eu.net/neutron-eu.net>

EUROPEAN XFEL (The European X-ray Free Electron Laser) to be built in Hamburg, Germany, will be a world leading facility for the production of intense, short pulses of X rays for scientific research in a wide range of disciplines.

The construction costs are estimated in ~€ 986 million with additional costs of € 50 million for R&D, instrumentation and detectors. Construction is expected to begin in 2007 and be completed in 2013, on the basis of an ongoing preparatory phase costing ~€ 30 million. The yearly operation costs are estimated at ~€ 84 million and decommissioning costs at ~€ 100 million. <http://xfel.desy.de>

ILL 20/20 UPGRADE (Institute Laue Langevin). The reactor-based laboratory at the ILL is recognised as the world's most productive and reliable source of slow neutrons for the study of condensed matter, and its overall upgrade is the most cost-effective response in the short to medium term to users' requirements.

This project will be implemented in two consecutive 5-year phases from 2007 to 2011 and from 2012 to 2016. The ILL 20/20 proposal is estimated to cost ~€ 160 million. Discussions are underway with regional and local governments to obtain support for additional infrastructural aspects proposed for the joint site together with ESRF. www.ill.fr/Perspectives

IRUVX-FEL (from Infrared to Ultraviolet and soft X- rays Free Electron Lasers). Intense light beams from the Infrared to the Soft X-rays are the major probe to study the electronic properties of Matter and will involve a very large user community. The development of Free Electron Lasers allows a new, virtually unexplored, regime of coherent light flashing with femto-second pulses. The IRUVX Consortium will join the resources now in construction and planned in Europe into a unique Research Infrastructure, allowing to offer novel and powerful complementary instruments for the microscopic and the dynamical study, as well as an optimal service to users, prioritising the development and location of the specific beam lines. Five facilities, in different and scaled phases of development are involved in the proposal. One in operation (FLASH at DESY, Hamburg), one in construction (FERMI at Elettra, Trieste), two in advanced technical demonstration and technological development phase (4GLS in Daresbury and BESSY in Berlin) and one in conceptual phase (MaxLab in Lund). Other projects may enter the consortium from The Netherlands, France and Switzerland. FLASH and Elettra are approved for a total cost of € 237 million, as well as the development costs of 4GLS and BESSY for a total of € 71 million. Total implementation has an estimated cost of ~€ 660 million, a preparatory cost of ~15% of the construction, and an estimated operation Material Sciences cost of € 65–70 M. www.iruvx.eu

PRINS (PanEuropean Research Infrastructures for Nano-Structures) is the Research Infrastructure arm of a broader initiative, the ENIAC European Technology Platform. PRINS will bridge the area between research and market-driven applications and provide Europe with the ability to master the revolutionary transition from Microelectronics to Nano-electronics, i.e. down to the level of individual atoms.

The PRINS infrastructure at the three integration centres will be built in a modular way in the period 2007–2013 for a total cost of ~€ 1,110 million. The yearly operational costs for the 3 centres combined will be approximately € 220 million. www.eniac.eu/web/about/PRINS.php

Astronomy, Astrophysics, Nuclear and Particle Physics

ELT (European Extremely Large Telescopes) are seen world-wide as one of the highest priorities in ground-based astronomy. They will vastly advance astrophysical knowledge allowing detailed studies of inter alia planets around other stars, the first objects in the Universe, super-massive Black Holes, and the nature and distribution of the Dark Matter and Dark Energy which dominate the Universe. The European Extremely Large Telescope project will maintain and reinforce Europe's position at the forefront of astrophysical research.

The preparatory and design phase of the ELT will last until 2009, with construction expected in the period 2010–2017. Construction cost for such a large facility will likely be in the € 800 million range, with a preparatory cost of about € 100 M already partly covered by the EU. An annual operation cost of ~€ 40 million is foreseen.
www.eso.org/projects/e-elt

FAIR (Facility for Antiproton and Ion Research) will provide high energy primary and secondary beams of ions of highest intensity and quality, including an “antimatter beam” of antiprotons allowing forefront research in five different disciplines of physics. The accelerator facility foresees the broad implementation of ion storage/cooler rings and of inring experimentation with internal targets. Two superconducting synchrotrons will deliver high intensity ion beams up to 35 GeV per nucleon for experiments with primary beams of ion masses up to Uranium and the production of a broad range of radioactive ion beams.

The FAIR construction cost (total investment) is € 1,002 million. In addition manpower equivalent to 2,400 person/years is required. The start of the construction is projected for 2007. FAIR shall be constructed in three phases until 2014. The full performance with the parallel operation of all experimental programmes will be reached in 2015. The operation cost is estimated to be € 118 million per year (price index 2005).

www.gsi.de/fair/index_e.html

KM3NET (Cubic Kilometre Neutrino Telescope) is a deep-sea research infrastructure in the Mediterranean Sea will be hosting a cubic-kilometre sized deep-sea neutrino telescope for astronomy based on the detection of high-energy cosmic neutrinos and giving access to long-term deep-sea measurements. By 2009, the Design Study will culminate in a Technical Design Report laying the technical foundations for the construction of the KM3NeT infrastructure. Thereafter, 4 to 5 years time will be required to establish funding, for industrialisation and deployment. KM3NeT data is thus expected to become available concurrently with the data taking of the full IceCube detector. A solid estimate of the construction cost will result from the Design Study; the objective is to achieve a price tag below € 200 million for a cubic-kilometre installation (salaries not included). Preparatory cost of about € 20 million.

www.km3net.org

SKA (The Square Kilometre Array) will be the next generation radio telescope. With an operating frequency range of 0.1 – 25 GHz and a collecting area of about 1,000,000 m², it will be 50 times more sensitive than current facilities. With its huge field-of-view it will be able to survey the sky more than 10,000 times faster than any existing radio telescope. The SKA will be a machine that transforms our view of the Universe.

Preliminary design and technology development: 2000–2007; costed system design from 2008–2010; with an overall preparatory cost of ~€ 160 million. Phase 1 construction and first data: 2011–2014, completion of the full SKA: 2014–2020. Costs are presently estimated at ~€ 1,150 million (capping at € 1,000 million), with an annual operations cost estimated at ~€ 100 million.

www.skatelescope.org

SPIRAL2 (Système de Production d'Ions RAdioactifs en Ligne) is a new European facility to be built at the GANIL laboratory in Caen, France. The project aims at delivering rare (radioactive) isotope beams with intensities not yet available with present machines. SPIRAL2 will reinforce the European leadership in the field of nuclear physics based on exotic nuclei.

The construction costs are estimated to be € 130 million. The construction will last about five years (2006–2010) and operation of the facility will cost about € 6.6 million, with preparatory and decommissioning costs of € 6.6 million and € 10 million respectively.

www.ganil.fr/research/developments/spiral2

Computer and Data Treatment

European High-Performance Computing Service gives a European strategic approach to high-performance computing, concentrating the resources in a limited number of world top-tier centres in an overall infrastructure connected with associated national, regional and local centres, forming a scientific computing network to utilise the top-level machines. This overall architecture will respond both to Capability (high-performance) and Capacity Computing (high-throughput) needs. Different machine architectures will fulfil the requirements of different scientific domains and applications. This can be represented as a pyramid, where local centres would constitute the base of the pyramid, national and regional centres would constitute the middle layer and the high-end HPC centres would constitute the top.

www.hpcineuropetaskforce.eu

Appendix C

INFRASTRUCTURE PROJECTS THAT RECEIVED NORDFORSK FUNDING IN 2007

Efficient and accurate characterization techniques for small antennas

Pertti Vainikainen
Helsinki University of Technology
FINLAND

Sensor networks of Nordic Lakes, Sensor-Lakes

Thorsten Bleckner
Uppsala University
SWEDEN

Advanced spectroscopy using MAX-laboratory in Lund

Svante Svensson
Uppsala University
SWEDEN

Enhancing Nordic access to the JYFL Accelerators Laboratory and FAIR

Rauno Julin
University of Jyväskylä
FINLAND

Nordic Infrastructure for Mouse Models

Taina Pihlajaniemi
University of Oulu
FINLAND

LHC and beyond

Paula Eerola
Lund University
SWEDEN

Promoting New Generation Sequencing Technology in Nordic Countries

Leena Peltonen
Helsinki University
FINLAND

A Nordic Functional Genomics Initiative: New tools for discovery biology

Outi Monni
University of Helsinki
FINLAND

Spatial categorization and language across populations

Mila Vulchanova
NTNU
NORWAY

Scandinavian Dialect Infrastructure: Corpus, Database and Dialect Maps

Janne Bondi Johannessen
University of Oslo
NORWAY

Nordic Signals: an omics network for cell signaling in health and disease

Garry Corthals
Turku Centre for Biotechnology
FINLAND

Research and Training for Nordic Astronomy. Part 1: Submm

Hans Olofsson
Onsala Space Observatory
SWEDEN

Research and Training for Nordic Astronomy. Part 2: Optical

Johannes Andersen
Nordic Optical Telescope Scientific Association
DENMARK

Infrastructure for organism names to facilitate data sharing

Hannu Saarenmaa
Finnish Museum of Natural History
FINLAND

The Nordic Canine Bio-bank

Göran Andersson
SLU
SWEDEN

Joint use of high-throughput SNP assay infrastructure in Atlantic salmon

Craig Primmer
University of Turku
FINLAND

Joint Nordic use of WAB Bergen and VWA Helsinki (JNU VWAB)

Alois Pichler
University of Bergen
NORWAY

Construction of the Nordic Prenatal Stress Cohort

Jørn Olsen
University of Aarhus
DENMARK

Nordic link to the Pan-European Research Infrastructure for Nanostructures

Andrej Kuznetsov
University of Oslo
NORWAY

ENDNOTES

- 1 Danish Council for Strategic Research (2005) "Future research infrastructures" – needs survey and strategy proposal.
- 2 The Danish Government (April 2006), "Progress, Innovation and Cohesion Strategy for Denmark in the Global Economy – Summary".
- 3 <http://fi.dk/site/english/apply-for-funding/calls/calls-2008/the-national-programme-for-research-infrastructure>
- 4 See Section 1.5 for an overview of the expression of interest from Nordic countries.
- 5 Academy of Finland (2007), Academy of Finland International Strategy 2007. Page 68.
- 6 Large Scale Facilities. En överblick av organisation och aktuella frågor i Danmark, Finland, Frankrike, Italien, Norge, Spanien, Storbritannien och Tyskland. 2004–2005.
- 7 Ministry of Education (2007), Memorandum of the Research Infrastructure Committee. Further information is also available on the roadmap's webpage at www.tsv.fi/tik
- 8 The Icelandic Science and Technology Policy Council (SPTC) formulate public policy on scientific research and technological development, and is headed by the Prime Minister of Iceland. The role of the SPTC is to promote scientific research and training and encourage technological progress in Iceland, for the purpose of strengthening the foundations of the country's culture and boosting the competitive capacity of its economy. Ministers, scientists, academics and business representatives sit on the council. The non-ministerial members of the council form a Science Committee and a Technology Committee, which meet regularly throughout the year to discuss science, technology and innovation.
- 9 Ministry for Education and Research (2008), "Strategi for Norges samarbeid med EU om forskning og utvikling".
- 10 Research Council of Norway (2008), "Tools for Research – National strategy for research infrastructure".
- 11 The bill was not yet published when this report was concluded.
- 12 They are: ELIXIR (European Life Sciences Infrastructure for Biological Information), ESS (European Spallation Source), PRACE (Partnership for Advanced Computing in Europe), FAIR (Facility for European strategy Forum on Research Infrastructures The Swedish Research Council's Guide to Infrastructure Antiproton and Ion Research), Infrafrontier (Infrastructure for phenotyping and archiving of model mammalian genomes), LifeWatch (eScience and technology infrastructure for biodiversity data and observations), and XFEL (X-ray Free Electron Laser).
- 13 Swedish Research Council (2008), The Swedish Research Council's Guide to Infrastructure. English Summary.
- 14 University of Lund, "Research and Education Strategy 2009–2012".
- 15 Swedish Research Council (2008), The Swedish Research Council's Guide to Infrastructure. English Summary. Page 21.
- 16 Source: Nordforsk presentation of Nordic Centres of Excellence in research. www.nordforsk.org
- 17 Source: Nordforsk presentation of Networks of National CoE. www.nordforsk.org
- 18 The idea for this policy measure originated from the Strasbourg Conference on Research Infrastructures in 2000 organised by the European Commission, the French presidency and European Science Foundation.
- 19 European Roadmap for Research Infrastructures. Report 2006. European Strategy Forum on Research Infrastructures, European Communities, 2006, Luxembourg.
- 20 ESFRI Report 2006, pp 29.
- 21 ESFRI Report 2006, pp 67.
- 22 Developing World-class Research Infrastructures for the European Research Area (ERA). Report of the ERA Expert Group. Directorate-General for Research, EUR 23320 EN 2008.
- 23 The coordination and collaboration organisation of the Council of the European Intergovernmental Research Organisations.
- 24 See Appendix B for a short description of ESFRI facilities.
- 25 Source: National reports of the ERAWATCH specialisation study. Available at <http://cordis.europa.eu/erawatch/index.cfm?fuseaction=intService.rdSpecialisation>
- 26 The ERAWATCH study is but one in the field and has some methodological limitations. Other studies with other methodologies will probably reveal other arenas open for cooperation.

- 27 The Norwegian strategy for RI (“Verktøy for forskning”) defines for example national level “smaller research infrastructures” in the range NOK 2–30 million, while “large-scale infrastructures” are defined in the range NOK 30–200 million. Since there are defined needs for several new or improved RIs, total investments required in the coming years are still considerable in the Nordic countries too. The Swedish recommendations for RI (Vetenskapsrådets Guide till Infrastrukturen 2007) thus estimate for example a need for investments, in addition to the current ones, totalling SEK 2,800 million until 2012.
- 28 See Appendix A for the experts interviewed. This section builds on the viewpoints expressed by the experts. Their viewpoints are interpreted and analysed by the authors, and the emerging statements and conclusions are thus the sole responsibility of the authors.
- 29 Work on developing a Nordic Research Excellence initiative (“nordisk toppforskning”) in the fields of climate and energy started in 2007 at the request of the Nordic prime ministers. The initiative is the single biggest Nordic research cooperation project to date.
- 30 The Nordic Research Council Directors (NordHorcs) has already proposed to establish a common Nordic platform to discuss national infrastructure priorities. This platform can fulfill the intentions of the High Level Group.
- 31 Source document: European Roadmap for Research Infrastructures – Report 2006 Luxembourg: Office for Official Publications of the European Communities. ISBN 92-79-02694-1 (pp 31-65). <http://cordis.europa.eu/esfri/large-scale.htm>

Research infrastructures are an essential precondition for gaining new scientific insights and the development of new infrastructures is an important element in science policy.

Larger infrastructures are technologically and economically demanding to construct, and their realisation is often dependent upon extensive international cooperation. To facilitate further development of research infrastructures, extensive policy processes have been initiated at European, Nordic and national levels. The Nordic countries are - like most other European countries - in the process of assessing their need for new and improved research infrastructures. The long tradition of research cooperation in the Nordic region constitutes an excellent base for increased Nordic coordination and cooperation in the field of research infrastructure and for gaining a stronger position in the European research arena.

This study gives an overview of current policies for research infrastructures in the Nordic countries and Europe and points to some alternative paths for increased Nordic cooperation and coordination.

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