SMARCTIC

A roadmap to a smart Arctic specialisation

Tekes - Strategic research opening:
Creation of new knowledge and competences in areas of expertise that are expected to be important for businesses in the future

THULE INSTITUTE

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TIIVISTELMÄ

Tässä hankkeessa on esitetty visio ja tiekartta Suomen arktisen osaamisen kehittämiselle ja hyödyntämiselle. Arktisilla alueilla on noin 4 miljoonaa asukasta ja alueen kansainvälinen vetovoima on lisääntynyt merkittävästi viime vuosina. Taustalla ovat globaalimuutoksen ajurit kuten, ilmastonmuutos, energian kysyntä, öljyn/raaka-aineiden hinnat, matkailu, maailmanlaajuinen kuljetus, kaupungistuminen, maailman väestönkasvu ja teknologioiden kehittyminen. Arktisille alueille ominaisia piirteitä ovat pitkät etäisyydet, syrjäinen sijainti, eristyneisyys, harva asutus ja vaikeat ilmasto-olosuhteet sekä kulttuurierot ja perinteiset elämäntavat. Jotta palvelut alueella voidaan säilyttää ja ihmisten elinolot sekä ympäristön monimuotoisuus turvata, pitää kilpailukyvyn kehittyä menestyksellisesti ja tuottavuuden oltava maailman kärkeä arktisilla alueilla.

Visiomme on kestävä ja älykäs taloudellinen toiminta, joka turvaa yhdyskuntien ja ympäristön hyvinvoinnin arktisella alueella pitkällä aikavälillä.

Projektissa laaditussa tiekartassa on neljä tasoa, jotka kuvaavat globaaleja muutosajureita, arktisen alueen toimintaympäristöä, strategisia haasteita ja polkuja arktisenosaamisstrategian toteuttamiseen. Ehdotetut strategiset polut ovat seuraavat:

- Keihäänkärkistrategia: Keskittyminen arktiseen meriteknologiaan ja meriliikenteeseen liittyvään osaamiseen (Polku 1),
- Kurkiaura-lähestymistapa: Laajempi osaamisstrategia, jossa kärkialan rinnalle nostetaan valitut vahvan arktisen osaamisen alat (polku 2),
- Arktinen kokeilukulttuuri: Strategia, joka painottaa kokeilukulttuuria innovaatiopolitiikassa ja arktisen teknologian kehityksessä (Polku 3), sekä
- Lumikinos-strategia: Arktiset liiketoimintamahdollisuudet jäävät realisoitumatta: Arktinen fokus ei muodosta uskottavaa pohjaa toiminnalle ja arktista osaamista kehitetään osana muuta osaamista (Polku 4).

Arktisia liiketoimintamahdollisuuksia voidaan tunnistaa liittyen ihmisiin, jotka asuvat, työskentelevät ja vierailevat arktisilla alueilla. Sellaiset sovellukset kuin ”Winternet of Things”, omavalvonta mittalaitteita, NordLab ja eTerveys toisivat uusia ihmisiä kokeilemaan yritysten kehittämiä ratkaisuja. Tulevaisuuden energialiiketoiminnasta merkittävän osan muodostavat todennäköisesti ICT-pohjaiseen älykkääseen sähköverkkoon sidotut palvelut. Metallurgiateollisuuden integrointi biotalouteen voisi tuoda mielenkiintoisia mahdollisuuksia lisätä materiaali- ja energiatehokkuutta. ■

ABSTRACT

In this project, we have introduced a vision of the future and created a roadmap for maintaining and further developing Finnish arctic expertise. Around 4 million people live in the Arctic regions and the attractiveness of the region internationally has increased significantly in recent years. Behind this interest are drivers of global change such as climate change, energy demand, oil/raw material prices, tourism, new bio-economic structures, global transport, urbanisation, world population growth and development of technologies. Arctic regions are characterised by long distances, remoteness, isolation, sparse population and difficult climate conditions, as well as cultural diversity and traditional lifestyles. However, the Arctic region has to be a world leader in productivity in order to develop competitiveness successfully. This is also a prerequisite for securing human services in the area. Product development requires the utilisation of the latest technology and novel innovations.

Our vision is sustainable and smart economic activity, which safeguards the long-term welfare of societies and ecosystems in the Arctic region.

The roadmap developed in this project has four layers, which describe the landscape drivers, operational environment, strategic challenges and paths for the implementation of the Finnish strategy for Arctic region. The four proposed strategy paths are:

- Spearhead strategy: Arctic marine technology and maritime transport – a focused strategy that emphasises traditional Finnish competences in ship building and maritime industry set in the Arctic context;
- Flying geese approach: emerging Arctic path ways – a widened strategy emphasising selected number of strong competence fields relating to the Arctic context;
- Culture of Arctic experimentation – a strategy emphasising principles of experimentation in innovation policy and in the field of Arctic competences; and
- Snowdrift strategy: fading Arctic business – the Arctic does not form a credible focus of activities and is forgotten or set as a subordinate perspective inside some other topic.

Arctic business opportunities and potential can be identified in relation to the people who are living and working in, as well as visiting the Arctic regions. Such applications as “Winternet of Things”, self-monitoring devices, NordLab and e-Hedalth would bring new users for solutions developed by companies. The future energy business will in great part be based on smart grid dedicated, ICT-based services. The integration of bioeconomy and metallurgical industries might bring interesting opportunities to increase material and energy efficiency.

1 INTRODUCTION

Northern peripheral areas experience differing levels of accessibility issues, for example, continental (distance to main markets in the south) and regional (lack of sufficient population). The Arctic's accessibility is characterised by long distances, sparsely populated areas and the problems caused by geographic and seasonal variations. Access to the four possible means of transportation – air, sea, road and railway – is very limited in the Arctic. The most remote communities often have no land connections of any kind. For this reason, many communities in the Arctic are highly dependent on costly travel options, particularly air transportation. Internal connections in the Arctic are scarce, and usually connections run only in a North-South direction, taking resources out of the Arctic and bringing consumer goods into the region.

There have been several attempts to open up inter-Arctic connections, but many of them have only lasted for short periods of time because of limited usage and the high cost of maintaining them. There have been extensive efforts to compensate for these issues, but the costs are constantly rising. As ordinary solutions are often insufficient and unsuitable for the Arctic environment, unconventional measures have become more common. At the same time, the importance of information and communication technologies has become even more essential for remote communities with poor accessibility. In addition to connecting people with the rest of the world, communication technologies make it possible to offer previously unavailable multiple services unreachable, such as education, health care and different commodities. With proper connections, isolated communities can be offered a sufficient level of services and be brought closer to other areas.

Finland's Strategy for the Arctic Region (Prime Minister's Office, 2013) defines a vision for Finland as follows: Finland is an active Arctic actor with the ability to reconcile the limitations imposed and business opportunities provided by the Arctic environment in a sustainable manner while drawing upon international cooperation.

This vision embodies the idea of Finland as an Arctic country that has shaped an Arctic identity based on its nature, geography, history and experience. The strategy document also states that Finland possesses the top-level expertise and know-how needed for understanding, adapting to and utilising the change that is taking place in the Arctic. The strategy document also defines a policy that maintaining and developing a high standard of expertise and research are of primary importance, and Finland wants to set an example as an Arctic expert both in research and in the responsible commercial exploitation of such expertise. An important aspect in the latter goal is to comply with the principles of sustainable development in Arctic operations. Another key objective, according to the strategy document, is to promote international cooperation and maintain stability in the Arctic region.

Although the definition of the Arctic region may differ among experts and scholars of different fields and disciplines, we operate under the paradigm that Finland, in its entirety, is an Arctic Country. More specifically, Finland's identity as a member of the Arctic community has been defined by its environmental, climatic and socio-cultural background.

Finland is an Arctic expert, able to provide top level knowledge and know-how to monitor and manage the major transitions currently taking place in the Arctic region. Furthermore, the aim is for responsible commercial exploitation of this expertise to support the sustainable use of natural resources in recognition of the particular conditions imposed by the Arctic climate and environment. In this framework, Finland's aim is to set an example as an expert in research and technology, reinforcing its position in the Arctic community and to promote stability an internal cooperation in a time and age characterised by rapidly growing political and commercial interest toward the Arctic.

The objective of the project was to formulate a vision and roadmap for maintaining and further developing the Finnish Arctic expertise. Figure 1 shows the structure of the project.

personalised and interactive services supporting human well-being and sustainable development will be analysed. The vision is to support the development of wireless communication technologies and smart metering methods to maintain Arctic capabilities.

Smart logistics, infrastructure and living environment. The aim is to look at the impact of new traffic openings and intensified use of natural resources on traffic flows, urban structures and infrastructure, as well as to identify and list those issues related to new business opportunities and the development of services. Key priorities are accessibility, sustainability and growth. The vision is to support the development of a vibrant community in the North, with sufficient logistics secured for people and companies, accessible services, as well as an ecologically, socially and economically sustainable environment.

Natural resources management and economics. The aim is to identify and list synergistic solutions to the

Figure 1. Schematic representation of the SMARTIC project WPs and their respective role within the roadmap building strategy.

The Arctic context. The aim is to identify the level of knowledge of the Arctic, the level of Finnish organisations' Arctic expertise and the potential added value of Finland's key technology areas of competence.

Environmental informatics and mobile technology. The aim is to identify the future development of the wireless communication environment, human measurement and data transmission. Based on this analysis,

sustainable use of Arctic resources to support and identify related innovations and business opportunities. The vision is to support the development of an Arctic IT-enhanced eco-industrial system.

People in the North. The aim is to characterise and list the measurement and information systems related to the monitoring of the well-being of Arctic residents and those moving to the Arctic in search of work; furthermore, to identify related services and new business development opportunities. The vision is to identify the factors affecting the welfare and safety of individuals and the community – health indicators monitored in real-time. Data on welfare are to be collected in databases that allow comprehensive assessment and enable influencing interfering factors at an early stage.

Roadmap to Arctic expertise. The aim is to develop roadmaps for selected Arctic regions and, based on them, produce a vision for formulating strategic openings.

Strategic opening and business potential. This work package evaluates suitable business models and innovation ecosystems for the Arctic and analyses them through a scenario process to link with the roadmaps. The future-oriented assessment of business opportunities is to be linked to enablers and substance work packages in order to result in integrated scenarios. ■

2 TRENDS RELEVANT FOR THE ARCTIC

2.1 The framework of participation in the foresight process

In the SMARCTIC project, a strong prospective trend approach was applied (SPT/SP trend) in the future analyses of business potential and possibilities of the Arctic environment. A strong prospective trend is synonymous with the mega trend, but it has a more specific scientific definition (see e.g. Toivonen 2004 Myllylä 2008, six in 2008). Mega trends today are characterised by the developments of large development waves. If a phenomenon has a clear pattern and includes regular aspects of development and experts estimate that this phenomena will continue until the date specified for the future, the trend can be seen as a strong prospective trend.

A strong prospective trend affects decision making, business strategies and also the political agenda. For example, if mineral prices have been rising and stock market prices are expected to continue to rise, this trend creates the pre-conditions for pro-active mining operations, a successful mining cluster, mining companies and other business models, such as educational services, formed in the business network. The trend can be cyclic, for example a variable, such as prices of raw materials typically are. An essential aspect of a strong prospective trend is regularity and the fact that experts estimate it will continue in the future.

Strong prospective trends can be divided into so-called PESTE categories of trends (Political, Economic, Social, Technological and Environmental). For example, in the SMARCTIC-project research team and other experts performed a trend analysis of 24 trends. The background report identifies and describes relevant PESTE trends in the Arctic region, which can be seen as strong prospective trends (Kaartemo, & Kaivo-oja 2010, Kaivo-oja & Myllylä 2013). This deskwork study was linked methodologically to the future workshop concept, which is the typical participatory foresight method with Delphi methodology.

According to the original SMARCTIC Work package plan, the work on the future was performed in four thematic expert groups, who elaborated and discussed the importance of strong prospective trends for Arctic business potential and new business opportunities. In addition, there was also a special workshop group for weak signal analyses and wild card scenarios. There were about 50 experts participating in the SMARCTIC workshops at the University campus of Oulu. The total number of experts, who delivered the formal interview format, was 31. This interview material was analysed carefully and later published as a SMARCTIC workshop document (Myllylä & Kaivo-oja 2013). The following table (Table 1) reports the expertise background and workshop groups in the SMARCTIC foresight workshop.

The key results of the SMARCTIC foresight workshop are reported in a nutshell in Table 2. Table 2 is a summary of selected identified influential business opportunities which were linked to strong prospective trends.

Table 1. Summary of the foresight workshop data information: Number of persons who responded to the SMARCTIC interview format, number of completed forms and interest groups (percentages of different perspectives of expertise).

	WG1	WG2	WG3	WG4	WGR5	Total
Total number of experts who delivered full SMARCTIC interview format	6	11	10	2	2	31
Total sum of formats	11	17	13	3	2	46
Entrepreneurial perspective with business perspective, %*	33	50	36	50	50	43
R&D perspective,%*	67	50	46	50	50	50
Other expert perspectives, %*			18			7
Note: WG 1 (Foresight group 1) = Environmental informatics and mobile technology solutions, WG 2 (Foresight group 2) = Smart logistics, infrastructure and living conditions, WG 3 = Management of natural resources and economy, WG 4 (Foresight group 4 = Human beings in the Northern conditions, WG 5 = Wild Card foresight group. // * mark = Percentage of specific interest perspective of all experts, who participated to the SMARCTIC foresight workshop.						

2.2 Critical Strong Prospective Trends

Based on the SMARCTIC workshop analyses, the main SP PESTE-trends relevant for business potential in the Arctic region are (based on "expert votes"):

(1) SP trends related to technological change (35),
(2) SP economic trends (28),
(3) SP environment and sustainable development trends (27),
(4) SP social Trends (19),
(5) SP political trends (19).

The big picture on the basis of the participatory workshops is that technological, economic trends and environmental are seen as the most powerful ones. The other SP trends (social and political SP trends) are a little bit less influential for business potential in the Arctic region. It is good to remind readers of this report that the decision making environment has changed to some extent after the running of SMARCTIC workshop (5.4.2013) as a result of the emerging crisis and conflict situation in Ukraine. The new changes in the decision making environment might affect the expert assessment, especially the assessment of economic and political trends because of the crisis in the Ukraine.

The most impactful sub-systemic trends are reported in Figure 2. One very interesting result is that the most mentions/"votes" were given to the rising prices of natural resources (Rank 1, 18 votes). The sub-group of PESTE SP trends were evaluated to be important and influential:

- Climate change and its impacts (pressures) on energy economy, economic structures and consumption patterns (Rank 2, 10 votes)
- Resource wise and eco-efficient technologies and growing importance of these systems and their increasing use (Rank 3, 9 votes)
- The rise of importance of bio-economy and biotechnologies (Rank 3, 9 votes)
- New transport corridors to the North and strengthening logistic flows in the North (Rank 3, 9 votes)
- Suitable technological solutions suitable for the Arctic environment and growing need for them (Rank 4, 8 votes)
- Globalisation and corresponding major decentralisation of power, developments towards a multipolar global economy (Rank 4, 8 votes)
- Digital evolution and ubiquitous technology revolution (Rank 5, 7 votes)
- World population growth from the current 7 billion to about 9 billion by the year 2050 (Rank 6, 6 votes)
- Increased environmental consciousness in the world (Rank 6, 6 votes)
- The growing importance of the Northern Dimension and the Arctic regions for the European Union and international development (Rank 6, 6 votes)
- World population growth from the current 7 billion to about 9 billion by the year 2050 (Rank 6, 6 votes)

Table 2. Summary of strong prospective trends relevant to the Arctic region.

Summary of strong prospective trends relevant to the Arctic region						
In the SMARCTIC participatory foresight workshop all the participants were asked to select the six most promising and impactful business opportunities linked to SP trends of the considered phenomenon from the perspective of the specific field. The fields were: WG 1 = Environmental informatics and mobile technology solutions WG 2 = Smart logistics, infrastructure and living conditions WG 3 = Management of natural resources and economy WG 4 = Human beings in Northern conditions		The number of references				
		Total	WG1	WG2	WG3	WG4
Technological trends		35	9	13	12	1
TeT1	Resource wise and eco-efficient technologies and growing importance of these systems and their increasing use	9	1	4	4	-
TeT3	The rise of importance of bio-economy and biotechnologies	9	3	1	5	-
TeT2	Suitable technological solutions suitable for the Arctic environment and growing need for them	8	1	5	2	-
TeT4	Digital evolution and ubiquitous technology revolution	7	4	2	1	1
TeT5	The convergence of technologies: nanotechnology and increasing smartness of products	1	-	1	-	-
Economic trends		29	3	11	12	3
TT2	Growing prices of natural resources	18	3	6	8	2
TT1	Population growth in the world	3	-	2	1	-
TT3	Internationalisation and the development of network economy	3	-	2	-	1
TT4	The growing economic importance of BRICSA countries and the N11 countries in the global economy	3	-	-	3	-
TT5	Mobility developments in relation to tourism and labour markets	1	-	1	-	-
Environmental trends		27	6	10	8	3
YT2	Climate change and its impacts (pressures) on energy economy, economic structures and consumption patterns	10	2	3	4	1
YT1	New transport corridors to the North and strengthening logistic flows in the North	9	2	5	1	1
YT3	Increased environmental consciousness in the world	6	1	1	3	1
YT4	Increasing public awareness of the rights of indigenous peoples	2	1	1	-	-
Social trends		19	2	10	6	1
ST1	World population growth from the current 7 billion to about 9 billion by the year 2050	6	-	2	4	-
ST2	The demographic shift towards an ageing society, e.g. in. Finland	4	1	4	-	-
ST3	*The development of service society and increasing demand for welfare*	3	1	2	-	-
ST4	The spread of social instability in various forms	2	-	1	1	-
ST5	Growth and development of multicultural societies	2	-	-	1	1
ST6	The growing importance of social media, web-based e-democracy and crowd-sourcing	1	-	1	-	-
Political trends		19	4	11	2	2
PT3	Globalisation and corresponding major decentralisation of power, developments towards a multipolar global economy	8	3	3	1	1
PT2	The growing importance of the Northern Dimension and the Arctic regions for the European Union and international development	6	1	4	1	1
PT1	Russia's interests shift to the North after the end of the Cold War Era	2	-	2	-	-
PT4	Development of global governance institutions and growing importance of these institutions	-	-	-	-	-
”Votes” for SP trends, total		129	24	55	40	10

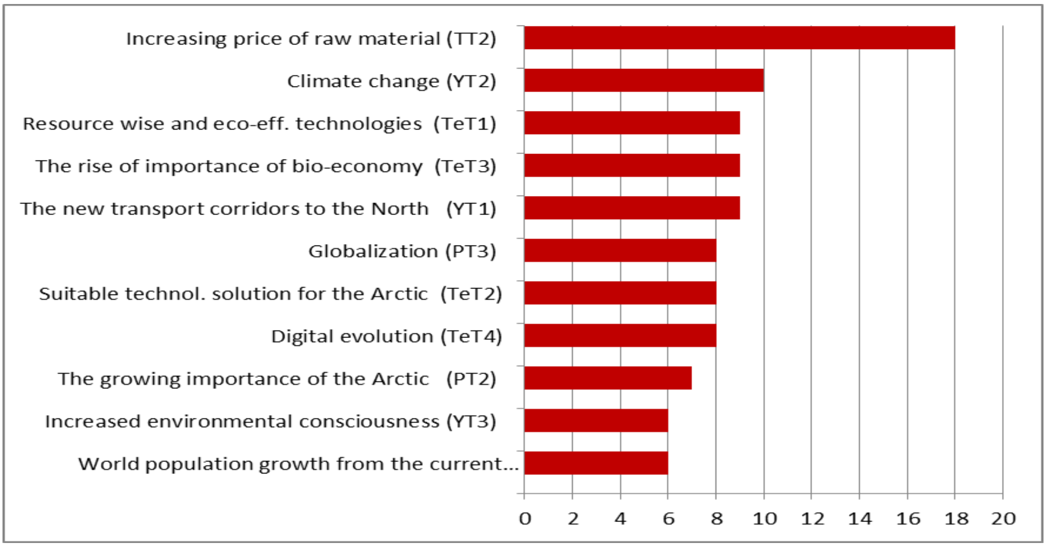

Figure 2. The analysis of SP trends: 11 of the most important SP trends in relation to Arctic business potential and emerging business opportunities according to the SMARCTIC participatory foresight workshop (number of mentions) (Source: Kaivo-oja & Myllylä 2013, Myllylä & Kaivo-oja 2013, SMARCTIC project document 5.9.2013).

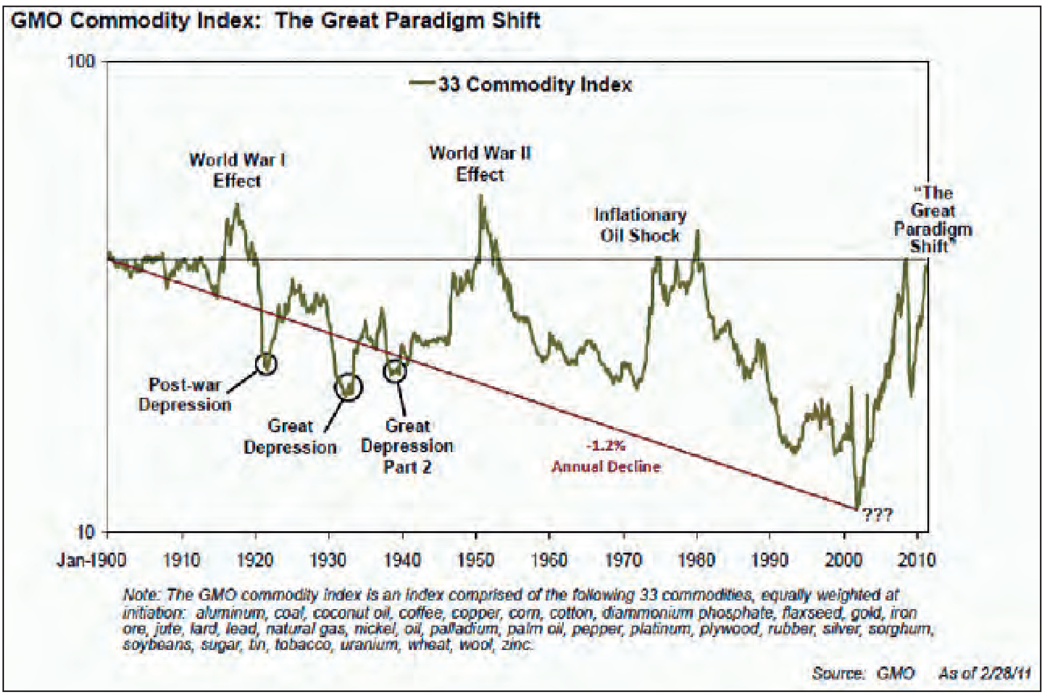

Figure 3. Rising cyclical price development of 33 raw materials from early 1900s until 2010.Source: Jeremy Granthalm (2011) < http://www.timera-energy.com/commodity-prices/global-commodity-markets-part-i-a-paradigm-shift/>.

There were some variations in different foresight working groups, because of the different size of the groups. For example, in three foresight working groups (WG 2 = Smart logistics, infrastructure and living conditions and WG 3 = Management of natural resources and economy, (WG 4 = Human beings in Northern conditions), the SP trend “Growing prices of natural resources” was evaluated to be the most important trend affecting. However in WG 1 (WG 1 = Environmental informatics and mobile technology solutions), SP trends “Digital evolution and ubiquitous technology revolution” and “Suitable technological solutions suitable for the Arctic environment and growing need for them” received more votes. The result of the SMARCTIC foresight workshop can be linked to other findings in Arctic and global research activities (Wilenius, 2013, Myllylä 2012, Granthalm 2011, Smith 2011). The following Figure 3 shows the analysis of Jeremy Granthalm, who compiled a price index for 33 raw materials over the past 110 years. In Figure 4, new opening logistical paths and critical exploitation zones for marine natural resources are re-visualised.

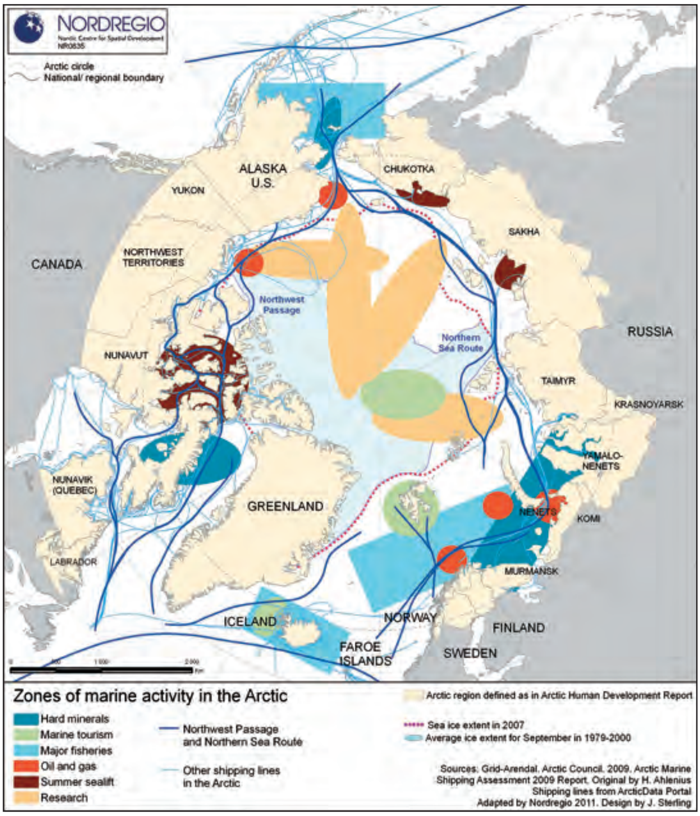

Figure 4. New opening logistical paths and critical exploitation zones for marine natural resources.

Note: We note that in the Nordregio map, ongoing LNG facility investments are not properly marked, On the other hand, the “frozen” Stockman gas field is given too much emphasis in this map visualisation. Sources: Nordregio/ Energy Enviro, Myllylä, McEwan and Kaivo-oja 2013 http://www.energy-enviro.com/index.php?PAGE=7&LANG=1&ID=4790&LETTER_ID=237

2.3 Critical strong prospective trends and business potential analysis: some key results

Among SP trends, rising raw material prices are by far the most emphasised as a critical trend having impacts on business opportunities evaluation (see Table 2, Figure 1). In economic terms, the future of non-renewable resources and minerals are of great strategic importance. As one key result we conclude that the transition period to a low-carbon economy will be critical for the realisation of Arctic business potential. When raw material costs increase, not only does it create pressure on the exploitation of natural resources, it also provides business opportunities for resource and eco-efficient solutions and systems to introduce. For example, we have already seen concrete examples that some ore beneficiation vessel ships of Norlisk Nickel have sailed without the assistance of an icebreaker in the Northeast Passage. Another very good example would be a satellite navigation and GPS system, as well as a conveyor belt transport technology solution, which eliminates costly truck traffic from mining operations. These kinds of novel technological solutions will be needed for the realisation of business potential in the Arctic region.

In this study, we have focused on the direct impacts of SP trends on business potential. We know that many trend variables have an impact on each other. We have

Table 3. Evaluation of direct and indirect business and public sector decision-making impacts of SP trends in the Arctic region.

SP trend	**Direct impacts on decision making in the Arctic**	**Potential non-direct impacts in the Arctic**
Rising prices of natural resources (Rank 1, 18 votes).	The availability of strategic natural resources and minerals needs special political and economic attention	The role of potential substitutes for strategic resources and minerals requires more attention
Climate change and its impacts (pressures) on energy economy, economic structures and consumption patterns (Rank 2, 10 votes)	Need to develop novel eco-innovations and low-carbon solutions	The Northeast Passage will be opened and it requires transition management strategies
Resource-wise and eco-efficient technologies and growing importance of these systems and their increasing use (Rank 3, 9 votes)	Need to develop resource wise and eco-efficient technologies	Need to raise awareness of future roadmaps of resource wise and eco-efficient technologies
The rise of importance of bio-economy and biotechnologies (Rank 3, 9 votes)	Concrete bio-economy investment plans are needed	Education programs and dynamic capabilities of bio-economy and biotechnology know-how are needed
The new transport corridors to the North and strengthening logistic flows in the North (Rank 3, 9 votes)	Monitoring of new developments of transport corridors to the North are needed	The strategic analysis of spill-over effects of new transportation corridors will be needed
Suitable technological solution suitable for the Arctic environment and growing need for them (Rank 4, 8 votes)	Need to develop novel eco-innovations and low-carbon solutions	Need to raise awareness of future roadmaps of resource-wise and eco-efficient technologies
Globalisation and corresponding large power decentralisation, developments towards a multipolar global economy (Rank 4, 8 votes)	Updated follow-up of Russian, Chinese, United Nations, WTO and NATO policy decisions and international agreements will be needed	New role of BRICSA and N11 countries need more attention
Digital evolution and ubiquitous technology revolution (Rank 5, 7 votes)	Need invent business potential of ubiquitous technologies in the Arctic region New focused “Arctic UBI” technology programs are needed	Education programs and development of dynamic capabilities of frontline solutions of digital evolution and ubiquitous technology tailored to the Arctic conditions
World population growth from the current 7 billion to about 9 billion by the year 2050 (Rank 6, 6 votes)	Strategic evaluation of immigration and migration flows in the Arctic region	Pressures to develop arctic cities and urban infrastructures for growing population concentrations
Increased environmental consciousness in the world (Rank 6, 6 votes)	Need to develop green consumer-driven innovation policy in the Arctic region	Branding “Green Arctic” consumer market and develop associated new green production and service innovations
The growing importance of the Northern Dimension and the Arctic regions for the European Union and international development (Rank 6, 6 votes)	Need to have new definition of European Union’s policy focus in the Arctic region	Need to develop long-run security and sustainability solutions in the Arctic region

not analysed cross-impacts of trend variables, however; already the analysis of direct impacts informs decision-makers in many ways. Concerning identified SP trends we can present some strategic insights, which should be taken into consideration in future decision making.

These SP trends were used as framing tools also in other work packages of the SMARCTIC project.

Participatory foresight workshop, in the first stage, presented SP trends and experts evaluated the most important SP trends affecting the key theme of each SMARCTIC work package. In the second phase of the workshop process, the impacts of SP trends on the development of thematic clusters and development were elaborated. The third stage was a discussion about enterprise projects, network projects and potential broader future projects. *The enterprise project* is one where a company is leading the project with some strategic partners. *The network project* is a larger company network and joint effort aimed at the wider business area or mini-cluster of significant development potential. *The future project* is a completely new case or package to launch a project which usually has wider network of actors involved.

The project may include capacity building aimed partitions, or technological innovation, business innovation, social innovation, or the beginning of the grand implementation of activities.

As a general observation based on expert evaluations in the SMARCTIC workshop, we note that issues such as *arctic mobility, distributed systems, modularity of innovations/solutions, ubiquitous sensors and blue water cluster* are going to be very important business potential issues for more detailed business model planning.

2.4 Links to other chapters and results such as technological road maps

The main task of the FFRC activity was analyse strong prospective trends and their links to business potential in the Arctic region. The identification and analyses of SP trends and associated project ideas (in three categories) helped other work packages to make deeper thematically motivated further analyses. The working groups from spring 2013 to autumn 2014 made more analyses and business planning work. The main results (Kaivo-oja & Myllylä 2013, Myllylä & Kaivo-oja 2013) were delivered to other SMARCTIC work groups and work packages. In addition, the production of intelligent logistics, infrastructure and habitat of the working group on in-depth analysis on the basis of a workshop paper

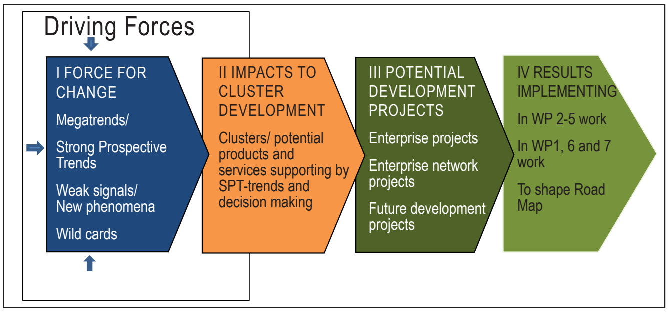

Figure 5. Prospective trend analysis framework and relation to each work stages of SMARCTIC-process. (Myllylä & Kaivo-oja 2013)

(Myllylä 2013a). In addition, deeper analyses were delivered to the groups of the WG 2 group "Smart logistics, infrastructure and living conditions" (Myllylä 2013a).

The working groups of the SMARCTIC project have continued to work after the workshop phase and presented the results in this integrated summary report. A VTT-MDI coalition has been working on the technological roadmaps based on the previous work phase. Thus, SP trend analyses have motivated strategic background assumptions of technological roadmaps and thematic choices for Arctic technology road mapping.

We would like to emphasise that when business potentials of the Arctic region are evaluated, we must understand not only the basic nature of SP trends, but also comparative business advantages of the Arctic environment as such. This means that, in order to create new business opportunities in the Arctic region, we should also link the concrete challenges of the Arctic environment, including long distances, cold, snow, rapid fluctuations in weather conditions, darkness, light etc. to new business ideas and business model potentials (Myllylä 2013a,b). ■

Participants

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3 ARCTIC COMPETENCE AND STRATEGIES – SMARCTIC ROADMAP

3.1 Roadmapping method

Finland's location in the Nordic region has led to the creation of expertise in arctic operations and technologies. However, this arctic competence is scattered over different technological and industrial areas. The utilisation of arctic potential requires the persistent development of competences and support of high level arctic research. The objective of the project was to identify the meaning of arctic competence in different technological areas and to create a roadmap, which supports the formulation of Finnish industry and innovation policies in relation to arctic competences. The roadmaps can be used in formulation of strategy recommendations and strategy related decision-making on a national, regional or firm level.

Background for the roadmap work in the SMARCTIC project is Finland's Strategy for the Arctic Region, which was published in August 2013 (Prime Minister's Office, 2013). Roadmaps support strategic alignment through the creation and use of structured visual representations. As a methodological framework, we used innovation policy roadmapping (IPRM) (Ahlqvist et al. 2012), which links R&D results to systemic policy contexts and to forward-looking policy design. IPRM integrates the approach of technology roadmapping – including such contents as enabling technologies, applications, products, markets and drivers – with the perspectives of systemic policies and policy instruments. IPRM is also targeted at the systemic level of multiple actors and organisations. Thus, this visionary process includes many participants and different interests. In this project, the policy analysis was carried out by a consultant company MDI Public as a separate analysis on the preparation and contents of Finland's Strategy for the Arctic Region. In this analysis, several challenges for strategy implementation and four different paths for the implementation of the Arctic strategy were outlined. These paths constitute the basis for the systemic level of the IPRM process, and the technology roadmaps were created to reflect these developments. In the following, the IPRM process and its outcomes are presented briefly.

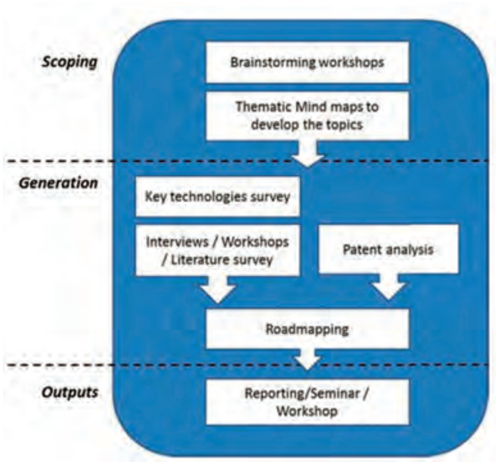

Figure 6. The roadmap process in the SMARCTIC project.

Figure 6 shows the foresight process implemented in the SMARCTIC project. The main stages of the process are scoping, generation and outputs. In various stages, a variety of foresight methodologies were applied to formulate the outcome. In the scoping phase, the topic – arctic competence or arctic technology – was defined. These results were combined with the outcomes of the innovation policy analysis by MDI Public to formulate the topics for the technology roadmaps. The generation stage involved the steps needed for knowledge generation and vision building to create the technology roadmaps. Finally, the outputs refer to reporting and communication activities at the end of the process.

3.2 Scoping: Strategy paths and arctic competences

The innovation policy analysis carried out by MDI Public as a part of the project generated four different strategy paths to concretise the vision presented in Finland's Strategy for the Arctic Region. These paths are the following (Antikainen et al. 2014):

- **Path 1** – Spearhead strategy: Arctic marine technology and maritime transport
  - A focused and narrow strategy emphasising Finnish traditional competences in ship building and maritime industry, but now set explicitly in the Arctic context.
- **Path 2** – Flying geese approach: emerging Arctic pathways
  - A widened strategy emphasising a selected number of strong competence fields relating to the Arctic context.
- **Path 3** – Culture of Arctic experimentation
  - An alternative strategy emphasising principles of experimentation in innovation policy and in the field of Arctic competences.
- **Path 4** – Snowdrift strategy: fading Arctic business
  - The Arctic context as a focus area is forgotten due to unrealised business potential.

The task for the roadmap process was to ascertain what these strategy paths would mean from the perspective of Arctic competences and outline technology roadmaps for these paths.

Another task of the scoping phase was to generate a coherent understanding of the Arctic competence base, especially in relation to on-going technological developments.

Arctic competence and research are often defined in relation to geographical region, which can be determined by political treaties (area above Arctic Circle) or biological zones (e.g. tree line, south line of tundra or permafrost). This is not necessarily a fruitful approach as regards competences. Firstly, competence is bound to people rather than geographical regions. In other words, competences are not necessarily found in the target region, but in locations where experts, research institutes and companies are. Secondly, competence is not bound to a single application area, or in this case to geographical area, but the generic elements of competences can be applied also in other contexts. As there was no clear or generally accepted definition of Arctic competences or Arctic technologies, we organised two workshops gathering 42 researchers from various research institutes to formulate a shared view. The workshops produced raw material for further analysis in the project group. Based on this analysis, we developed a layered structure of Arctic competences (see Figure 7) where competences are divided into three classes:

1) Competences relating to Arctic conditions,
2) Applied technology competences and
3) Cross-sectional technology competences.

These competences have different weight in the above-mentioned strategy paths. The paths 1 (Spearhead strategy) and 2 (Flying geese approach) emphasise applied technology competencies, the first one being narrower and more focused than the second one. The third path (Culture of Arctic experimentation) is an alternative way of organising innovation policy to thematic focus. Therefore, it is not selective on the competences, but requires a wide range of competences. Especially, this path highlights the importance of combining different competences to find new solutions. In the fourth path (Snowdrift strategy), competences are not developed under the Arctic strategy umbrella, but the development is seen to take place in relation to other technology fields, based on existing activities and regional needs and possibilities.

3.3 SMARCTIC roadmap

Figure 8 shows the roadmap that was created in the SMARCTIC project. This roadmap is a general strategic roadmap which is based on literature and the policy survey carried out in the SMARCTIC project. A starting point for roadmap development was Finland's Strategy for the Arctic Region, and therefore the vision for the roadmap was adopted from the strategy.

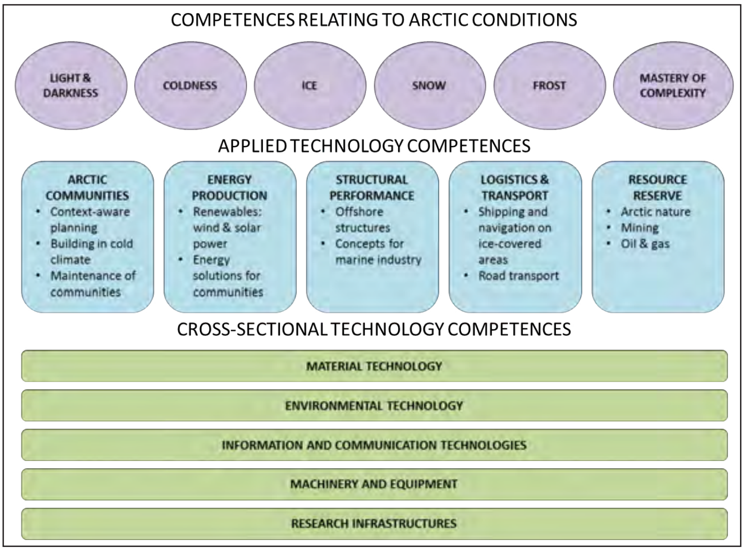

Figure 7. Arctic technology competences based on the SMARCTIC workshops.

The purpose of this roadmap is to outline the developments taking place in the Arctic operational environment. There are four layers in the roadmap. The top layer (Landscape drivers) describes global changes and developments affecting the Arctic area. The next layer down (Operational environment) describes the economic activities in the Arctic area.

This layer is needed to anticipate the potential markets and application areas for Arctic technologies. The two layers on the bottom view the Arctic development from a national perspective. Strategic challenges layer describe the challenges that were identified in relation to the implementation of Finland's strategy for the Arctic region, and the bottom layer (Paths for Arctic strategy implementation), identifies the possible strategy paths in relation to Finnish Arctic competences. We developed more detailed technology roadmaps

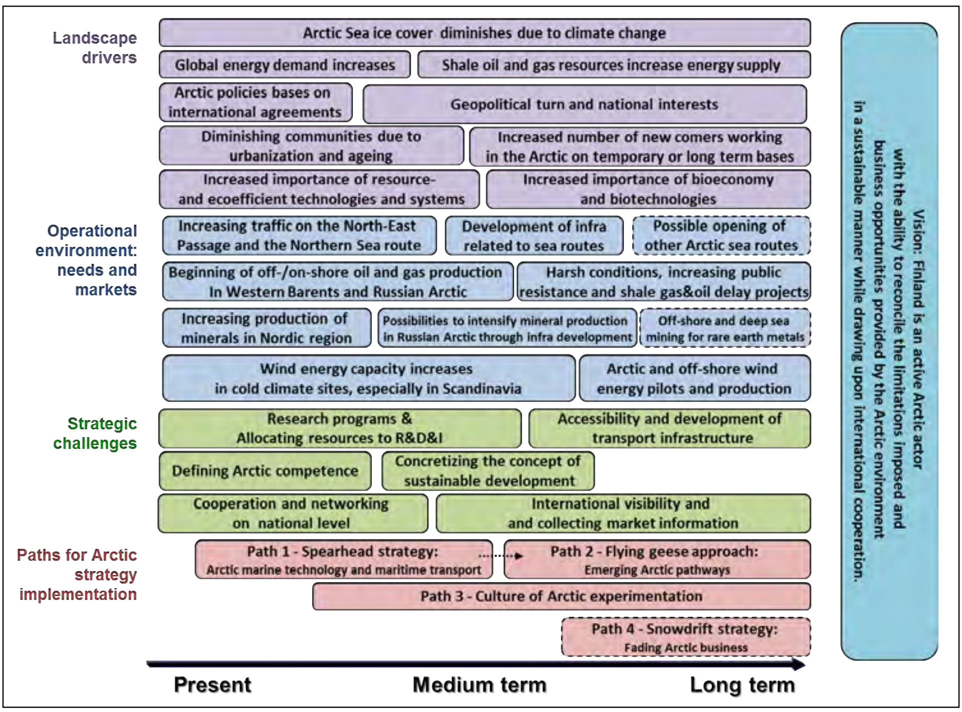

Figure 8. A strategic roadmap for Finland to utilise and develop Arctic competences.

for these paths in SMARCTIC project, but they are reported in a separate report. The suggested timescale of the roadmap is fifteen years, but the time axes are intentionally left open, because the roadmap is not intended to describe future development as a definite series of events tied to fixed points in time. Rather, it is a collection of possible developments that are intended to take place. The roadmap outlines the complexity of the Arctic context and marks out the path for Finland's Arctic vision. In the following, the various parts of the roadmap are discussed in more detail.

Landscape drivers

Landscape drivers are trends or developments that exist in the world and have an impact on the possibilities of the vision becoming reality. Fundamentally, drivers are factors that support or promote the development of the vision, for example by creating demand for certain solutions. However, the positive effect of a driver may end at some point in time, or the trend may turn into more of a hindering factor. The previous chapter presented the results of trend analysis carried out in the SMARCTIC project. Based on this analysis and literature survey, we have selected some key drivers into the roadmap (Figure 8), and they are discussed briefly below.

Climate change: Over the last decades, the average temperature in the Arctic region has risen almost twice as fast as the world's temperature on average. Climate change is expected to have significant changes in the Arctic region in future and some of these processes are already ongoing. Often, even the same change can be considered either negative or positive, depending on one's point of view or interests. Melting sea ice is a good example. At the same time as it enables planning new logistical routes for transporting goods and acquiring resources, it can have drastic, negative effects on local ecosystems and accelerate changes in global climate. Negative effects of climate change are seen also in the Arctic territories, where the melting of permafrost creates big challenges for human built infrastructures.

Energy demand, oil/ raw material prices: Arctic oil, gas and mineral resources are becoming more interesting due to increased demand and decreasing resources elsewhere. Harsh Arctic conditions make it more challenging to utilise these natural resources. Therefore, changes in oil and raw material prices are crucial. Other possible, but less known resource reserves, e.g. in Africa or shale gas reserves in Northern America, are therefore competing areas of interest in the Arctic region, and any changes in these areas can have significant effects on the feasibility of Arctic projects. Also, public resistance towards the exploitation of Arctic natural resources may increase over time, especially if there is any damage to the environment that pricks the public's conscience.

Cooperation policy & geopolitical turn: Over the past few years, the predominant discourse concerning transformation in the Arctic has been based on the paradigm of "Arctic cooperation". The Arctic states have recognised the importance of cooperation and international law has been accepted to guide agreement (e.g. the United Nations Convention on the Law of the Sea). Therefore, the risk of conflict inside the Arctic area has been considered to be small. However, the Arctic area is not shielded from global dynamics and political crises. The political scene has changed significantly since the start of SMARCTIC project due to the ongoing crisis in Ukraine. The relations between Russia and the West have turned colder, and this may have profound direct and indirect effects on the cooperation in the Arctic context in the long run. Even if the need for western technology know-how in the offshore megaprojects in Russian Arctic Ocean still existed, the crisis may increase the overall risk levels of international investors, and these indirect effects will affect the capital intensive and long-lasting projects.

Demographic changes: The demographic development of the Arctic area is characterised by two trends: urbanisation and ageing population. Since the 1960s, most of the population growth in the Arctic has occurred in urban centres tied to industrial activities, social services and public administration. Urban areas attract people by providing better opportunities for work, education and better standard of living. At the same time cities are often characterised by social stratification. While they can be viewed as hubs in the economic development of their regions they also potentially foster social inequality. Ageing is a consequence of several demographic trends, including longer life expectancy, decreasing birth rates in the Arctic communities and decline in the younger age groups due to migration out of the area. The share of the population aged over 65 years is especially high in the northern parts of Nordic countries. The general trend of ageing will become a potentially significant economic challenge in the whole Arctic area in the years to come due to the increases in dependency rations. However, the demographic development is difficult to anticipate, as the labour markets have integrated increasingly with labour markets outside the Arctic. In the European Arctic male workers arrive from East European countries and Poland in particular. In Russia, Canada and Alaska the new males come from the "south". In terms of female workers the majority of immigrants come from Thailand and Indonesia. This creates a much higher level of diversity in community structures. There is also a need for management approaches able to cope with more diverse social situations including questions of indigenous/non-indigenous and permanent/temporary inhabitants (Megatrends 2011).

Technological trends: Increased industrialisation and population growth have created concerns about the carrying capacity of earth. Therefore, concepts like resource and eco-efficiency has been introduced into public discussion and as guidelines for economic or business activities. Eco-efficiency refers to a principle of creating more goods and services while using fewer resources and creating less waste and pollution. Similarly, resource efficiency is a way to deliver more with less (natural resources). It increases aggregate economic value through more productive use of resources, taking their whole life cycle into account (ECN 2013). These principles of eco-efficiency should be implemented also in technology development so that new technologies and solutions are designed to meet the resource and eco-efficiency requirements.

While eco-efficiency has appeared on political agenda since 1990s, bioeconomy (or circular economy) is a more recent concept. Bioeconomy refers to new way of seeing the industrial activities as part of the natural system and biosphere, and it entails the following principles (Kuisma 2011): (1) Renewal natural resources substitute for non-renewable ones, (2) sustainable use of natural resources, and (3) closed loops in material and energy circulation. Finland has great potential in bioeconomy due good biocapaciy, i.e. profusion of natural resources, such as forests, high level of competences and technological know-how, as well as industrial activities in the field (Biotalousstrategia 2014).

Operational environment

Global warming and the enormous deposits of natural resources increase the future importance of the Arctic area. Its central location in geographical terms and the short direct sea routes to the main population centres of the globe, still predominantly located in the northern hemisphere, are significant assets (Megatrends 2011). There are four sea routes that appear in the discussions on Arctic maritime transport. *The North-East Passage* (NEP), along with *the Northern Sea Route* (NSR), is considered to be the most potential global logistical routes in the Arctic. Several factors favour these routes over the two other Arctic sea routes, *The Northwest Passage* (NWP) and the *Trans Polar Passage* (TTP) through the North Pole. The North-East Passage and the Northern Sea Route go along the parts of the Arctic that are abundant with natural resources, and the extraction of these resources creates cargo traffic. There is already existing infrastructure along the NEP, and there are plans to develop it further. Also, tourism and the fishing industry are likely to increase the economic activity and importance of this region. Although NEP and NSR are better developed in comparison to the other Arctic sea routes, there are still severe gaps in the infrastructure necessary for safe passage; including a lack of search and rescue capabilities, ice-management capabilities, salvage points, sea ports, and communication infrastructure. (Brigham 2011).

Transit traffic on the Northern Sea Route is still small, and the Russian regulations and legislation needed for the use of the sea route are being developed (Rautio & Hahl 2013). In 2012, the number of vessels passing the Northern Sea route was 46 (RosAtomflot /Arctis 2013). Some estimates suggest that shipping along the Northern Sea Route will grow more than 30-fold over the next eight years, which could account for a quarter of the cargo traffic volume between Europe and Asia by 2030 (Koranoy 2013). On the other hand, others predict that Arctic shipping along the NSR is likely to continue at the same level in the near future (Jørgensen-Dahl 2010). Even though ice coverage continues to decrease, the Arctic sea routes are not likely to be available for year-round transport this century, at least not without ice-strengthened Polar class ships and/or with ice-breaker assistance, which increases the costs of the year-round arctic shipping making it economically infeasible. (Mikkola & Käpylä 2013).

Climate change has a twofold effect on arranging logistics in the Arctic area. Besides enabling the opening new logistical maritime routes, melting (perma) frost already disturbs land transportation and pipes.

Oil and natural gas drilling, as well as the forest industry, are facing challenges due to a shortened transportation season on frozen tundra and ice roads. Difficulties in transportation also affect communities through the changes in accessibility of commodities (Acia 2004). Infrastructure in the Arctic is underdeveloped, excluding the Nordic states. Road systems are sparse, unpaved, and not maintained. Rail systems are limited. Airports are regional, with the commercial hub to the south. Seaports and inland waterways are developed in accordance with the states' reliance on resource exports. (Knell 2008) Consequently, large-scale development of road, rail, air transport and port infrastructure (aerodromes, airports, ports, wave breakers) is needed. No less significant a question is the subsequent usage and maintenance of infrastructure. (Finpro 2012)

The recent oil and gas field projects in the Russian Arctic focus on onshore projects, like the Yamal development, and offshore projects in the Barents, Pechora and Kara seas. The offshore projects are riskier and have often taken the form of joint-ventures between Russian and international energy corporations (Mikkola & Käpylä 2013). Shtokman (also Stockman field; Russian: Штокмановское месторождение), gas and condensate field development project, which is one of the largest development projects in the Barents area, is a good example of a risky offshore project. The field is located on the Barents Sea shelf 600 kilometres northeast of Murmansk (Gazprom 2014a). The project that was initiated together with Gazprom, Statoil and Total has faced severe uncertainty, due to the North American shale gas boom and rising costs. Statoil withdrew from the project in 2012, which led Gazprom and Total to postpone the project (Barents Observer 2013). Since then the project has been continued (Ernst & Young 2013). Other key offshore projects, like Prirazlomnoye oil field, have also faced difficulties (Mikkola & Käpylä 2013). In April 2014, Gazprom announced the loading of the first cargo of oil produced from the Prirazlomnoye field, which is still the only Russian project for hydrocarbon development in the Arctic shelf (Gazprom 2014b). The development of large onshore petroleum fields is in progress on the Yamal Peninsula in the Kara Sea.

So far, there are no ongoing offshore drilling projects in Alaska, Canada or Greenland (Ernst & Young 2013). Statoil has estimated that Arctic offshore drilling in harsher areas will start at the earliest in 2030 but most likely closer to 2040 or 2050. (Kauppalehti 2013). The situation in Northern Norway has been described as resembling the Russian Shtokman project and the planned projects, like Johan Castberg oilfield (12 000m€) is still waiting for better times. If the Norwegian offshore projects are postponed, development in the region will slow down (Rautajoki 2014).

Even though the Norwegian Snow White gas field is producing gas to Menköya LNG-plant (liquefied natural gas plant) with production likely to increase (Rautajoki 2014), and Prirazlomnoye oil field managing to start oil production, many other Arctic oil and gas drilling projects have been cancelled or postponed. Many energy economists and experts evaluate that LNG will be an energy source for the transition period, when the transformation from carbon dominated economies to low-carbon economies is made. In the energy sector, LNG investments require special strategic attention during the on-going transition phase to sustainable, green growth economies. The reasons mentioned include harsh arctic climate conditions, high costs and heavy regulation (Kauppalehti 2013). The success of shale gas and oil in the USA has also decreased the profitability of oil wells and gas in the Barents Sea (Rautajoki 2014). Besides financial reasons, the environmental concerns of the general public, environmental organisations, and governments is expected to slow down hydrocarbon development projects in the high Arctic region.

An increased global demand for mineral commodities has increased the deployment of existing mineral resources during the past few years. In the Nordic region, a considerable increase in production volumes is seen to take place in both shorter and longer time perspectives. The production volumes in the region are estimated to increase from today's 75 Mt/year to 106 Mt/year in 5 years' time reaching 118 Mt/year in 10 years. In Finnish Lapland, the mining industry has been the fastest growing sector. Growth is estimated to continue after the financial crisis, and the investment potential (6 980 m€) is high for the mining projects on hold. Mining industry growth will affect the development of transport infrastructure, including the realisation of the Arctic railway project. In the Russian Arctic, the main mining centres are located in the Barents region on the Kola Peninsula, around the city of Murmansk, as well as in the Krasnoyarsk region, around the city of Norilsk. There are about 25 mines operating in the Russian Arctic (Arctic info 2013). Finnish companies, such as Metso, Pöyry, Ahma Insinöörit Oy, Firote Oy and Paakkola Conveyors

Oy, are already involved in mining project in the Murmansk region. The investment potential in the Kola Peninsula mining project is estimated to be 4 090 m€, and the mining project is expected to be implemented within this decade. (Rautajoki 2014)

Arctic offshore mining is still in an early development phase. The increasing demand for valuable minerals may trigger the development of deep sea mining technologies. Despite the availability of the technology and the profitability of deep sea mining, environmental concerns and legislation have prohibited the excavation of deep sea minerals. In spring 2014, a Canadian mining company finalised an agreement to start excavating an area of seabed in Papua, New Guinea. This will be the first attempt to extract ore from the ocean floor (Shukman 2014).

The deployment of wind energy in cold climate areas is growing rapidly. Cold climate sites often have favourable wind conditions, and they are usually sparsely populated locations. Technological innovations improve the technical performance of wind turbines in cold and freezing conditions. The trend towards renewable and clean energy is getting stronger, which increases the general interest in wind energy. However, current technological performance does not guarantee that all cold climate wind turbines could operate in harsher, freezing conditions. It has been estimated that approximately 60% of the new capacity added to cold climate areas would operate in freezing conditions. It is estimated that 45-50 GW of new wind energy capacity will be added to cold climate sites by 2017, leading to 75 bn € investments. (Navigant research 2013).

Investments in wind energy have increased in Northern Europe, and several wind parks are being planned to be built in Northern Sweden (12 000 m€ investment) and Norway (15 921 m€ investment). Wind energy has not yet gained a significant role in the Russian Arctic, because hydrocarbon and biobased energy is more established in the region. There are plans for smaller investments, e.g. 320 m€ investment in the Murmansk region, but it is not likely to occur soon (Rautjoki 2014). The global economic recession creates pressure on wind energy investments, especially in Europe, where governments subsidise wind energy production. This may lead to the postponing of large onshore wind park projects in Europe (Valor 2013)

Offshore wind energy is still at early development stage and the first floating wind turbine was developed and piloted in 2010 by Statoil. Arctic climate conditions create additional challenges to onshore and offshore wind energy production in comparison with cold climate wind energy production. Despite recent developments, offshore wind energy is seen as a developing market with growth potential in the medium to long term (Valor 2013).

Strategic challenges

The innovation policy analysis carried out in this project (Antikainen et. al. 2014) disclosed six main challenges that the interviewed experts and surveyed regional actors and entrepreneurs wished to be managed. The challenges are linked to the implementation of Arctic strategy.

In the short term, adequate *research funding* and *allocation of resources to R&D&I* are central challenges. Concrete development projects are needed for allocating the funding for business oriented R&D&I action, in which SMEs may also participate. Overall, the funding should be directed to R&D near the customer and in the implementation end of the innovation cycle. In research, the Arctic research programme of the Academy of Finland and the EU funding schemes are important instruments for increasing understanding of Arctic issues. Developing and maintaining research infrastructure (laboratories, measuring technology, simulators etc.) should also be ensured. Among Arctic technologies, new business models, standards, networks, markets etc. should be studied and developed. Arctic issues should be recognised in university and school curriculums. Arctic employment is often seasonal and varying, thus it needs flexible and experimentational development.

In the longer run, *accessibility and development of infrastructure* become increasingly important issues. Solutions for transport and logistics are crucial for Arctic business. Government guidelines are awaited regarding transport policies. We need a clear vision about what kind of logistics is wanted in the Arctic region; this includes the necessary digital services and ICT solutions. New logistics routes are opening and this requires dialogue especially with Norway. Finland's role as an Arctic region window to the EU needs strengthening and discussion. Different strategy processes and projects related to transport and logistics are in progress (e.g. Development overview of the regional structure and traffic system ALLI (Ministry of Environment), Joint Barents

Transportation Plan, strategies by the Regional Council of Lapland etc.).

To increase the societal impacts and visibility of Arctic research, a clear *definition of Arctic competence and concretising of sustainable development* in the Arctic context is needed. The interviews and surveys done by MDI show that Arctic competence is not a well-established concept, and the experts, technologies and markets of the area are not fully recognised. The obscurity of the concept complicates coordination, cooperation and implementation of strategies. A comprehensive definition would clarify Finnish Arctic competence resources and reposition them in the international landscape. A clear definition and commitment also supports the possibilities to develop Arctic competence with a Finnish spearhead.

Arctic competence links together Arctic land and sea areas, maritime industry and services, environmental technologies, ICT and even space technology. Sustainable development is one of the key requirements of Arctic cooperation and business. It includes both the inclusion of local people and sustainable use of raw materials. Finland can act as an international forerunner in, for example, combining new business solutions and improving the livelihood of indigenous people. Sustainable mining (Tekes green mining, Nordic NordMin etc.) is one of the openings that awaits national insights. This also requires transparent public dialogue about environmental issues in the Arctic.

Cooperation and networking is essential for strengthening Arctic competence and for utilising business opportunities. The Strategy for the Arctic Region emphasises that the whole Finland belongs to the Arctic region. Arctic organisation is new and the actors do not know each other or recognise themselves as Arctic actors. Overall, the on-going development related to Arctic competence is scattered and not recognised, and Arctic actors need to be mapped on different levels both horizontally and vertically. Cross-regional networking is important and requires active enterprise federations. Big and small companies should work together in order to create globally attractive business (e.g. infrastructure solutions). Similarly, cooperation between research organisations and business needs to be enhanced. Different projects concerning Arctic themes need mutual dialogue and they could be linked to larger issues such as INKA, the Innovative Cities Programme. Cooperation between Tekes, the Academy of Finland and the Ministry of Employment and the Economy improves the needed coordination, with the Team Finland process helping to clarify the roles of different actors and processes.

International visibility and collecting market information are longer term challenges. Finland aims to be an active Arctic actor in the global arena and connect to international customers. International cooperation and increasing Arctic business requires long-term orientation and continuity; the cooperation should be based more on wide networks than on direct technology-oriented business. Here the Team Finland process seems to be crucial. At the moment, the most important partners are Norway and Russia, with whom continuous discussion, market knowledge collection and sharing, and utilising opening investment opportunities is required. In addition, Sweden and maritime related to the Baltic Sea is interesting. Overall, the Arctic region and environment should be considered widely. Similarly, the business opportunities should not be limited to large-scale operations such as gas or oil markets but include small local imports and SMEs. At the moment, many Arctic SMEs feel that they do not get enough information about market possibilities. Regional knowledge sharing should be strengthened; local Chambers of Commerce and the Centres for Economic Development, Transport and the Environment are key actors in this.

Paths for Arctic strategy implementation

The bottom layer of the roadmap covers four possible paths for the implementation of Finland's Strategy for the Arctic Region. They combine the Arctic operational environment, competences and innovation policies. They are not alternatives in the sense that one would exclude other, but differ in the wideness of their scope (paths 1 and 2) and in the means of applied innovation policy (path 3).

Path 1 *– Spearhead strategy: Arctic marine technology and maritime transport*

This path is based on a hypothetical strategy that Finnish actors would focus their perspective on Arctic futures entirely through the lens of marine technology and maritime transport. In short, it would be a focused and narrow strategy emphasising Finnish traditional competences in ship building and maritime industry, but now set explicitly in the Arctic context. On the other hand, this path can be seen as the one that has already started, for example in the form of the Tekes Arctic Sea programme.

***Path 2** – Flying geese approach: emerging Arctic pathways*

The second path widens the scope of arctic research and business opportunities from the Arctic area and Arctic sea to near-by markets. Living and everyday life in the North is an important starting point for technology development in this path. Therefore, also emerging technology areas are sought for, in addition to marine technology and maritime transport. The emerging themes included in this path are largely those that were covered in the subject working packages of the SMARCTIC project. The later parts of this report cover the outcomes of this work, and therefore also elaborate the contents of Path 2.

***Path 3** – Culture of Arctic experimentation*

The third path does not focus on any specific Arctic technology but on creating infrastructure, tools and innovation policy that support experimentation leading to faster commercialisation of new technologies and services of Arctic applications in traditional and emerging sectors. The third path leads to Arctic futures via agile experimentation, such as living labs, pilot environments, fast prototyping, cross-breeding of sectors and ideas, as well as test beds. Living labs are considered to be user-centred open innovation environments, while test beds are seen as platforms for experimentation of large development projects.

***Path 4** – Snowdrift strategy: fading Arctic business*

The fourth path is based on a supposition that Arctic business potential remains unrealised. In these circumstances, it is reasonable to forget the Arctic context as a focus area. In this path, arctic conditions are not the starting point of competence development, but rather an additional element or approach of the competence development in other fields. The needs for competence development may rise from local or regional needs. In the end, Finland is still situated in the Northern hemisphere, and there is a need for solutions for cold climates in construction, energy efficiency and human well-being. On the other hand, our location provides possibilities for local businesses, e.g. in relation to tourism. Another alternative in this path is to widen the concept of an Arctic competence base to cover also other areas with some element of "extreme conditions".

In this case, Finnish actors in R&D or companies could provide solutions for extreme conditions to global markets e.g. in the tropics, in mountain areas or in sparsely populated areas.

3.4 Conclusions of the roadmapping section

The process for constructing roadmaps was based on the innovation policy roadmapping (IPRM) approach, developed at VTT (see Ahlqvist et al 2012). In this approach, the idea is to produce roadmaps in at least two levels (technology level and strategic level) in order to find out the relevant future perspectives both at the level of singular technologies and at the level of strategy and innovation policies. In this roadmapping section, we reported only the strategic roadmap. The roadmapping process consisted of three phases: (1) scoping (brainstorming workshops, construction of thematic mindmaps), (2) generation (technology surveys, interviews, patent analysis, roadmapping workshops), and (3) outputs (reporting and seminar). This report presents only the tip of the iceberg of the produced material – as is the most suitable wording in this context. The process produced plenty of minute data, for example, visionary application examples and demonstration projects that bring useful practical elements to endorse the four strategy paths. A more detailed and consistent roadmapping report is published as a separate report in the VTT publication series.

The first key result of the roadmapping process was the characterisation of a novel way to scope the "Arcticness" in the context of emerging technologies. The competence and technology scoping was formed to identify the specific Arctic competences and related technological competences, and to set these in an explicit Arctic context. The rationale was to find out what is the specific "Arctic element" in different emerging technology pathways. Further, the key results of the roadmapping process are crystallised in four strategy paths for the Arctic regions. These are: (1) Spearhead strategy: Arctic marine technology and maritime transport – a focused strategy that emphasises traditional Finnish competences in ship building and maritime industry set in the Arctic context; (2) Flying geese approach: emerging Arctic pathways – a wider strategy that emphasises a selection of strong Arctic competences; (3) Culture of Arctic experimentation – a strategy based on experimental policies and technology approaches; and (4) Snowdrift strategy: fading Arctic business – the Arctic does not form a credible focus of activities and is forgotten or set as a subordinate perspective inside some other topic. These paths should be seen as potential or possible ways to develop Arctic competences in the future. They can be seen as alternatives to each other, but especially the three first paths are more complementary than exclusive. The fourth path is more clearly an alternative way to proceed, because it is based on the presupposition that Arctic business potential is not realised.

The generic outcomes of the entire roadmapping process can be wrapped up in three groups. The first group is called the outcomes channelled by Arctic conditions. This group consists of results that are explicit consequences of Arctic conditions, such as harsh climate conditions, sparse population and long distances. The key outcomes in this group are related to emerging Arctic logistics (like maritime transportation, pipelines, transport infrastructure), natural resources (like onshore oil and gas, emerging offshore projects, minerals), and use of alternatives (such as wind energy and biobased energy). The second group is called the questions of policy, regulation and infrastructure. These include the possibilities and challenges of R&D funding and resource allocation, development of infrastructure, co-operation in Arctic policy issues, and, in the end, realising this all systematically by taking into account the demands of sustainability in the widest possible sense. The third group is called novel technological possibilities. Our new way to scope Arctic competencies, and identify related technologies, has shown that there are plenty of novel possibilities for technology development, and even rethinking technological development, when set in the Arctic context. The key possibilities emerge from specific Arctic competences, such as Arctic communities, energy production, and structural performance. These specific Arctic competences are endorsed by more generic cross-sectional technology competences, based on e.g. material technology, environmental technology, ICT, machinery and equipment, and related research infrastructures. ■

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4 DISCUSSION OF THE SELECTED THEMATIC AREAS

This chapter includes description of what would be the potential applications and foreseen challenges on the path for the development of business in Arctic area. The reports and publications (list) can be found in the appendices.

4.1 Environmental informatics and mobile technology

The aim of these services will be two-fold: on the one hand the monitoring of well-being of people working and living in the Arctic as measured by physiological and environmental parameters and, on the other hand, the application of sensor technology to create new business opportunities. This summary includes a short discussion of various applications of sensor networking and related communication and data fusion topics as well as a brief overview of long-range communication and related wireless/wired communication infrastructure in the arctic regions.

It should be pointed out that many of the technology development issues related to specific applications are not necessary, especially for the Arctic environment.

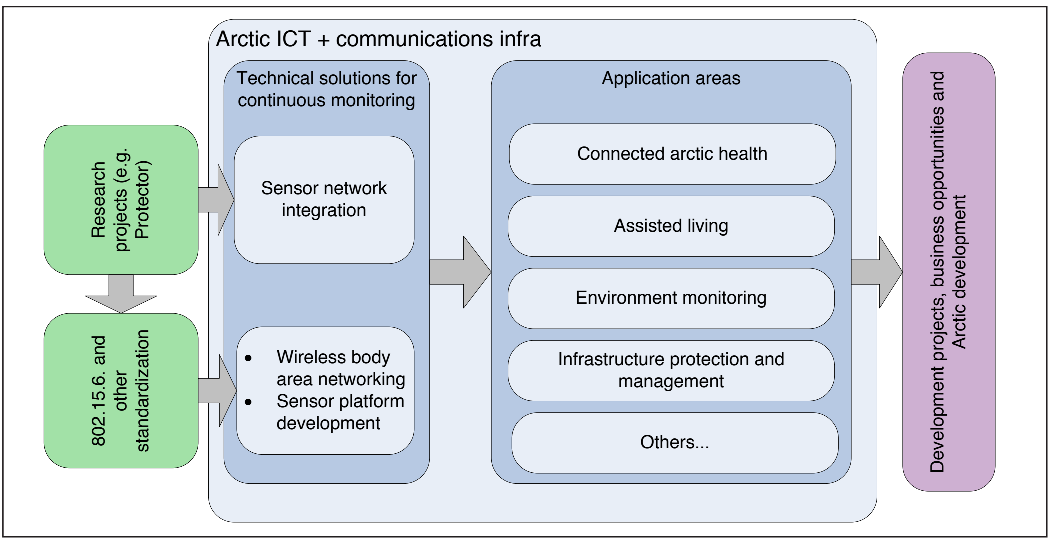

Figure 9. A summary of ICT development for the Arctic.

Table 4. A summary of the identified ICT application and development areas.

	Connected arctic health and assisted living	**Environment monitoring**	**Infrastructure protection and management**
Motivations and needed applications (examples)	• To enable safe living in remote locations by providing medical expertise based on real-time physiological data measured on-site. • Additional safety to potentially hazardous working environments such as mines.	• Monitoring of environment parameters to alert for emerging crisis situations. • Long term and wide-area surveillance of natural habitats for particular substances, such as toxic contaminants or CBRN[1]-materials.	• Real-time management and analysis of structural and functional integrity of infrastructure components (e.g. power grid). • Surveillance and protection in any environments and scales • Border control • Smart cities
Key technology components	• Reliable and easy to use medical sensor devices. • Wearable technology for monitoring of physiological parameters. • In-body sensors. • Trustworthy sensor fusion site (cloud) and technology for handling the private information that is collected.	• Battery efficiency for long term self-sufficient monitoring applications. • Energy harvesting. • Sensor fusion at or near the sensors.	• Ubiquitous sensors and Internet of Things (IoT). • Battery efficiency and energy harvesting (e.g. in border control).
Wireless issues	• Reliable (DWN) and always available short range wireless technology to move sensor measurements to central processing in real-time. • Reliable long-reach connection between patient and medical expert.	• Long-reach wireless communication from sensor nodes.	• High number of sensor nodes in wide area. • Sensor mesh –networking.
Arctic dimension	• Long distances and low population density.	• Harsh conditions for electronics. • Long distance communications are needed.	• Harsh conditions for electronics. • Specific conditions and applications require tailored design. • Long distance communication is needed.
WP2 contribution	This topic was advanced to an Academy application together with WP5 and other instances.	–	Smart (electric) grid was addressed in the arctic context (in cooperation with WP4). Especially the low density smart grid operation was identified as a key problem in the arctic.
References	[O'Connell, 2013], [RSC10], [IEEE15.6], [Nordicity2014]	[Dunbabin and Marques 2012], [Ho et al. 2005]	[Hackmann et al. 2012], [Roscia et al. 2013], [Naphade et al.2011], [Savazzi et al. 2013]

Therefore, it is best to regard it as a general list of what is possible using today's state of the art technology related to sensors and their networks. Figure 9 and Table 4 summarises our views of ICT and communication related technology development for use in the Arctic environment. Key issues are the development of new technical solutions for dependable wireless communications, especially for short range use, and the development of sensor technology and their platforms. In the latter, size and energy consumption are no doubt the most important factors that still need development.

A brief analysis of the network infrastructure in the Arctic

The main wireless communication infrastructure consists of cell towers and related technology owned and operated by cellular operators. Due to the long distances and limited range and terrain-attenuation of the communication frequencies of the current cellular technology, the whole of Finnish Lapland is not perfectly covered even by the old 2G (GSM) network. An example (and a current status) of cellular coverage of one major operator in the Lapland area is given in /SONERA 2014).

The Finnish Government's stated policy is to provide broadband connections to 99% of the population by 2015. To realise this goal, public funding in some of the most sparsely populated areas, e.g. in Lapland, is required (LVM 2014).

There are several special requirements for communications infrastructure in arctic conditions. The weather conditions are more extreme, which may cause additional requirements for communication technology/hardware, e.g., for cell towers. Longer battery operation in case of electric outages may be required due to longer service distances. At the same time, battery operation in cold conditions is more challenging than in a milder climate. These factors suggest that completely autonomous infrastructure would be a good solution and, e.g., wind or solar cell powered base stations could provide the required dependability.

The longer service distances also suggest that the actual operation of the cell infrastructure should be designed to be autonomous, i.e. the cell network should autonomously recover from temporary outages. A more extreme design of the new cell infrastructures would include, e.g., mobile end devices that could, at least temporarily, operate as access points to other devices. In extreme conditions, cell phones could form an ad hoc network that provides local communication although the connection to the outside is broken. This would be a useful feature during natural disasters and other events requiring reliable communication between rescue personnel and the public. However, this feature is not supported yet by commercial mobile terminals.

The operation of wireless networks can also benefit from longer distances to other infrastructure (mainly other similar wireless networks.) Namely, there are less interfering networks and also there may be more operation frequencies available, provided that the infrastructure is able to utilise these possibilities. A novel concept of ASA (Authorised Shared Access) (Matinmikko et al. 2013) aims to enable more flexible utilisation of free frequency bands, e.g., in commercial cell phone operation.

In addition to traditional commercial communication infrastructure, communication needs in the Arctic can be arranged with more specialised methods and architectures. One obvious possibility is to use satellites. However, equatorial satellites, for example, are not usable in the very high latitudes due to poor coverage. Commercial satellite phones, e.g. Iridium provide only limited bandwidth (few kbps) and are typically quite expensive to use. Moreover, a communication terminal with an HEO (High Earth Orbit) satellite requires a tracking antenna. Therefore, the conclusion is that in the Arctic regions, satellite-based communication technology can be utilised only in special circumstances, e.g. in rescue missions or during long reach expeditions, not to support everyday life and applications on a regular basis, especially when high bandwidth services are needed.

One possible way of arranging long range wireless communications is to use HF-frequencies (3 – 30 MHz) that are able to propagate over very long distances, at least 100 km, but sometimes in the order of several thousands of kilometres. The downside is that the bandwidth for data traffic remains low (few kbps) and the communication links may be unstable or at least unpredictable. This is due to the effect of the higher atmosphere/ionosphere on the propagation characteristics of HF waves. Despite the fact that HF-technology is already well known and "legacy technology", it is still being studied to some extent. New advances in other wireless communication fields are considered and applied at this frequency band, for example cooperative communications.

A realistic approach to cover at least some vital areas is to rely on conventional mesh or Wide Area Networking (WAN) technology such as WiMAX. Even using this kind of technology, the cost of infrastructure may become too high. To be more cost effective, mesh networking could be used only in critical areas to extend the existing cellular or fibre coverage. A WiMAX based wireless backbone network has been proposed for temporally deployed emergency management networks and for rural areas.

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4.2 Smart logistics, infrastructure and living environment

The geographical part focuses on Arctic geographical accessibility. In two reports the state of accessibility and health care services in the Arctic are reviewed. For the purposes of researching arctic themes, a geographic information system (GIS) network database has been collected.

The database includes air and road travel networks with travelling times from the area containing Finland and adjacent areas. The database has ability for multimodal analyses for reviewing accessibility of the Arctic on different scales: local, regional, national and supranational.

The second part is a history review of the *development of the built environment and construction in the Arctic*. With cases from indigenous peoples until the present day, what kind of construction and visions there have been in the Arctic have been identified, along with what direction development is going in. By analysing the examples, the key elements of future Arctic construction have been outlined and the possible business potential ascertained. The results of the report can be utilised when planning new human activities generated by the construction in the Arctic.

Smart Arctic Logistics gives three cases to illustrate the development and business opportunities related to arctic transport and logistics. The first case handles Arctic road and railroad infrastructure maintenance coping with arctic conditions. In the second case, the Smartport concept is used to describe the opportunities of port organisations to serve as intelligent nodes in transport corridors especially in the Arctic region. The third case is about logistics being a crucial part in producing health care related services in peripheral areas with arctic conditions.

The intersection points of the different viewpoints are being gathered into an interdisciplinary conclusion. The same features both separate the Arctic from other areas and join it as one: long distances, remoteness, isolation, sparse population and difficult climate conditions, as well as cultural differences and traditional lifestyle. These features have a major impact on the accessibility, mobility and functioning of people living there and supplying of services.

For the purposes of researching Arctic themes, a *geographic information system (GIS) network database* has been compiled. The database includes air and road travel networks with travelling times from the area containing Finland, Sweden, Norway, Western Russia (Arkhangelsk, Karelia, Murmansk, St. Petersburg and Leningrad), Estonia, Latvia and Lithuania. The database can be used for multimodal analyses for reviewing accessibility of the Arctic on different scales; local, regional, national and supranational. It has been designed mainly for Finland's research purposes to examine how Finland's Arctic areas are connected to other adjacent areas. The database is collected solely from various open sources, which can be freely accessed by anyone. Open sources were used to apply comparable data from different countries for cross-border research purposes. The observations made in reports of accessibility and health care structure in the Arctic support the use of specific data for research made in the area. As said, to make successful decisions and increase the well-being of Arctic communities, consideration of its distinctive features is required. To demonstrate the possibilities of the GIS network, the database has been made an example of potential accessibility in Northern Europe (Figure 10.)

In figure 10 it can be observed how in addition to Stockholm-Helsinki-Tallinn region's strong accessibility, there is a strong significance of northern airports in connecting regions. With the network database it is possible to create different scenarios using many accessibility possibilities.

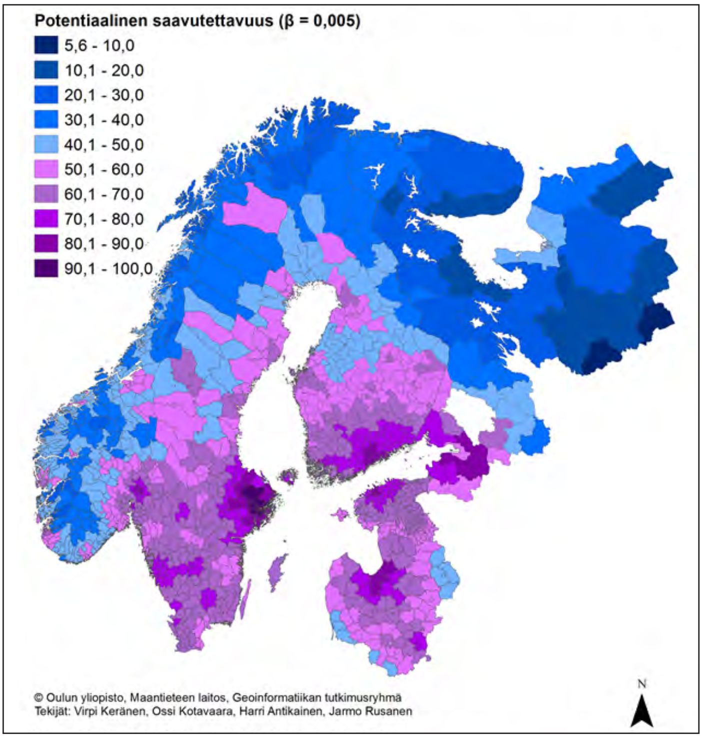

Figure 10. Potential accessibility in Northern Europe (road and air transport).

Arctic Urban Development and Construction

Arctic regions are assumed to meet major changes in the next few years. The increased need for new urban development is based on the assumption of future changes in the world: climate change, population growth, globalisation of the economy and demand for resources. The Arctic is mostly very sparsely populated. For example, Lapland has a population density of 2 inhabitants /km^2 and the northern parts of Canada only 0.03 inhabitants/km^2. So the scale of urbanisation in these areas is likely to be different from anything that has been seen elsewhere. The trend is, however, away from the traditional villages towards denser, internationally connected cities that meet the requirements of modern communities.

When talking about the future exploitation of natural resources or inhabiting the North, the core questions will be how to handle the long distances and maintain the existing communities and infrastructure. The infrastructure is already partly outdated or in a very poor condition. The thawing permafrost caused by global warming will give an extra challenge for the whole design process. It will cause more and more problems for the maintenance of existing roads and building stock.

The question will be how to maintain the old infrastructures in an economic way and on the other hand, how to build new ones. Designers and regional planners find themselves in a situation where they need to find new innovative solutions to ensure the accessibility and survival of the old villages.

The arctic urban utopias from the past and recent infrastructural megaprojects act as warning examples of what kind of consequences an economy-based industry-driven large-scale urban development could cause in the fragile Arctic. The lately drawn visions of urbanism (for example, eco-city and ubiquitous city concepts) try to take a more sustainable direction instead. The plans try to ensure the survival of the existing communities by utilising the wealth brought by new businesses. This is done by maximising the utilisation of existing urban structures, finding co-operation between different actors, safeguarding traditional livelihoods, preventing the damage caused by global warming, reducing economical dependency on just one source of livelihood by diversifying the economics of the villages and designing larger regional concepts.

By combining traditional arctic building techniques and materials with the latest technology, the new solutions for arctic urban and building design can be found. For example, Halley VI in the Antarctic is a modular, portable, self-contained, zero-waste research station that adapts in every way to the harsh cold climate. It can be moved from one place to another without leaving traces of where it stood. The design is based on solutions using the latest technology. Another recent project also in the Antarctic, Iceberg Living Station, is based on the old Inuit way of constructing. It is a temporary living station dug in an iceberg. Nevertheless, the construction is done with modern excavators and the maintenance of its facilities utilises the latest technology. As the summer comes, the iceberg will melt away leaving no sign of a human settlement behind.

When designing new constructions in the Arctic, the keywords that should be lifted up are temporality and continuity. New constructions should not anymore be seen as permanent but as temporal activities, which are dependent on the duration of profitability. Here, continuity means the survival of nature and the settlements within the new changes. The new businesses with their constructions should be able to support this without leaving abandoned building stock or infrastructures behind them.

Arctic Logistics

Three cases are presented in this section to illustrate the development and business opportunities related to arctic transport and logistics. The first case examines Arctic road and railroad infrastructure maintenance coping with the arctic conditions. For many regions in Northern Finland, arctic conditions, decreasing population and transport volumes will entail severe challenges related to accessibility and service level in logistics. Also, in many cases, problems with repair or maintenance can be critical because alternative routes and connections in sparsely populated regions are lacking. The second case is about smart logistics in Arctic port areas. In this case, we use the Smartport concept in a general sense to describe the opportunities of port organisations to serve as intelligent nodes in transport corridors, particularly in the Arctic region. The third case gives a view at producing health care related services in arctic conditions.

Arctic conditions such as long distances, low density and demanding climate are in many ways intensifying the challenges. One initiative to face these challenges is centralisation that requires more attention into logistical systems, but can bring benefits in saving costs and enhancing the level of service.

There are particular conditions related to the *management and maintenance of arctic transport and infrastructure* including cold weather, darkness, snow and ice, as well as long distances and sparse population. However, it seems that the people and organisations working in northern regions are fairly accustomed to these conditions and stable winter conditions are not considered to be too problematic. Exceptional conditions create more challenges and it is possible that they occur more frequently as climate change progresses. From an arctic transport and logistics point of view, it is hardly feasible to build heavy information superstructure for monitoring and controlling traffic conditions outside the core corridors with high traffic density. However, innovative and affordable solutions should be encouraged for detecting and disseminating information on exceptional conditions and traffic incidents. Mobile applications of digital evolution and common information platforms can offer a good foundation for developing solutions in remote regions. Also, ubiquitous vehicle-to-vehicle communication using ad hoc networks can offer new opportunities for improving situational awareness without heavy telematics investments.

The *Smartport concept* has been used in various contexts. In this study, we use the Smartport concept in a general sense to describe the opportunities of port organisations to serve as intelligent nodes in transport corridors, particularly in the Arctic region. Arctic ports already have smart solutions but more could be used and developed. Common data systems would benefit all parties and needed information could be found easily from the same place. Accessible information and sharing involves also icebreaking, which is needed in Arctic areas - lack of coordination leads to delays in transportation and changing variables are harder to take into account. The resources in use should be optimised and the total system should be managed in a coordinated manner.

Arctic conditions set challenges in providing public services as *health care*. Centralising parts of service processes is seen as one option in delivering better service for lower cost in areas with long distances and low density. In northern Finland, one example is laboratory services. These have been recently centralised into one organisation called NordLab. Operational advantage is reached by optimising the competencies of various laboratories. Same kinds of samples from a wider area are centralised into more specialised laboratories. From a service point of view, the goal is that the end user (patient) can leave their sample in a nearby health centre without having to travel into hospital. From a business opportunity point of view, NordLab offers quality and partly differentiated services that could be scaled more widely. Potential for growing internationally mostly in Barents region is seen, but the current type of business entity does not allow that. NordLab is focused in laboratory samples, but the same kind of logistical system could be applied also in other material flows in health care.

Table 5. Current state, competence needs and opportunities of the three cases.

Development area	Current state and competence needs	Opportunities
Management of Arctic transport & infrastructure		
Infrastructure construction	Development of international project competence	Infra projects in Northern Sweden and Northern Norway; North-Western Russia is a question mark.
Infrastructure maintenance	Lean and agile operating models in infra maintenance	Intelligent solutions for infra maintenance (utilization of ICT in all operations)
ICT and traffic situation awareness	Situational awareness data is available but user-friendly applications are needed	Utilization of open data sources, GIS, mobile applications
Smartports in the Arctic transport networks		
Navigations in Arctic conditions	Finland has expertise regarding navigation in ice conditions	Utilization of the expertise in international maritime transport and developing intelligent solutions
Design/construction of Arctic vessels	Finland has expertise in design and construction of vessels for Arctic conditions	Growing demand in Arctic maritime transport supported by intelligent solutions
Healthcare logistics – Case laboratory services		
Domestic health care services	Current service covers health care districts in Northern Finland	Extension of service to domestically (Northern Finland, rest of Finland)
International service markets	Current law prevents growth to international markets	Extension of laboratory services to the Barents Region (for special services also on wider international markets)
Supporting logistics system	An all year pilot service for laboratory logistics soon available	Development of intelligent logistics system and its extension to related support services in health care

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4.3 Natural resources management and economics

In terms of natural resources management and economics, the vision we put forward for the future is that of a synergetic use of resources (Figure 11), based on the optimisation of material, energy and information flows and cross-sectorial exchanges. The basic idea is similar to that of an eco-industrial park; the difference is in the potentially large distances between the different actors.

This would require that materials are processed where they originate from and are transferred to the recipient in a pre-processed form.

Natural resources management and economics was explored 3 case studies and put forward goals for future development (Figure 12). The three case studies are:

(1) Zero-waste integrates of metallurgical industry and bioeconomy;
(2) Bioeconomy and closed nutrient cycles; and
(3) Smart energy networks.

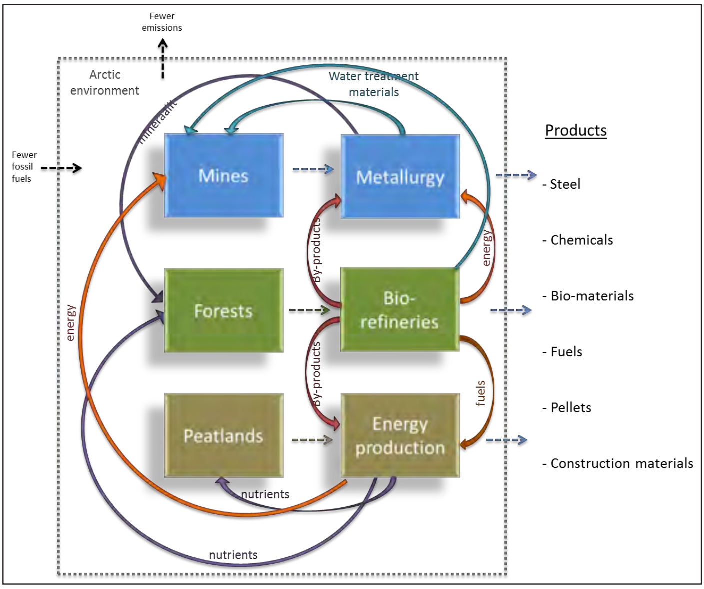

Figure 11. Vision of an Arctic with synergistic material and energy flows.

Case 1: Zero-waste integrates of metallurgical industry and bioeconomy

The bioeconomy offers the chemical industry and traditional forest based industries significant new business opportunities. The national goal, and the aim of industry in these sectors, is to generate the greatest added value possible from sustainable and renewable resources. This is already under much research and development. However, new production technologies can be created at the intersections of current scientific disciplines and industrial sectors, by combining, for example, process chemistry and bio and nanotechnology to the supply chain and bulk refining capabilities of wood and other renewables. Petroleum-based source materials could often be replaced with new biomass-based chemicals and materials.

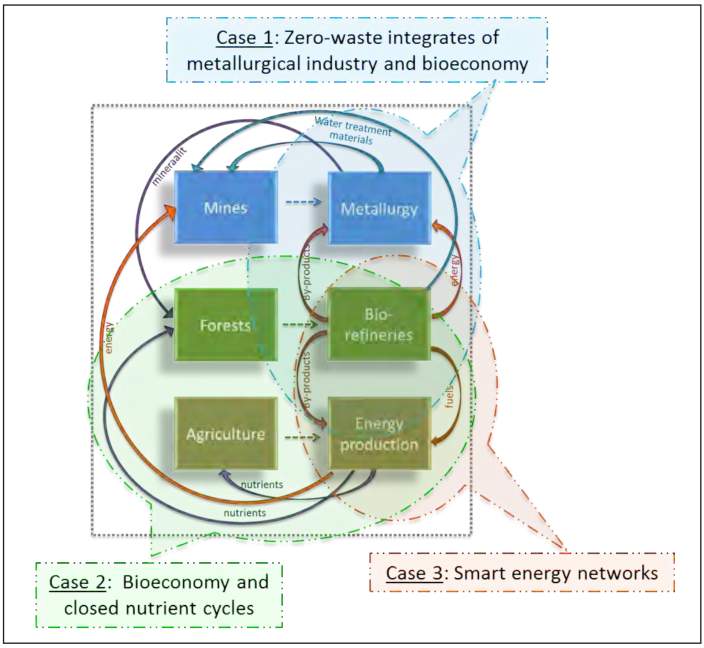

Figure 12. Case studies explored.

Novel, high-value applications can be found in medicine, cosmetics, coatings and adhesives, while the bulk products include biofuels, bioenergy and novel packaging and construction materials.

The report concluded that joint interests for today's development between these industries can be found in the platforms of energy production. To meet its international obligations, Finland must gradually replace fossil fuel consumption with renewables and preferably introduce carbon-free production. The most likely scenario seems to be one where there is considerable co-evolution between energy and other end uses of available biomass and the final form of the prevailing value chain remains to be seen. Finland's energy solution will probably be increasingly based on small-scale distributed energy production. The input that bioeconomy can provide to this development is two-fold: on one hand the biotech way to promote emergence of new plants for energy use, on the other , optimisation of the current resource pool, processes, value chain operations, residues and wastes – a task where also the integration of technologies comes into play.

Biomaterials and chemicals can in many cases utilise industrial process residue almost as easily as the energy sector, but the yield could add more value to the raw material than that provided by heat and power. Inorganics such as ash and sludge can be housed in materials such as concrete, cement or geopolymers. Waste heat has many potential uses, from algae growth to biomass drying. Finding synergies and win-win scenarios takes time, effort and the ability to think outside the box. It is not in the interest of any particular player to change the conventions of doing business - it takes team effort and a lot of communication to realise and jointly capitalise industrial and municipal resource streams.

The researchers identified ten innovative alternatives to develop new products and increase the efficiency of current production platforms. Each of the alternatives has differing technological gaps and economic potential, which are clarified in the report. These alternatives are:

(1) Utilisation of available heat sources in metal and pulp production
(2) More efficient utilisation of by-products from the steel industry
(3) Short-term possibilities to integrate biomass upgrading with steel plants
(4) Short-term possibilities to develop new products from biomass
(5) Upgrading the biomass into bioreducers
(6) Integration of bioreducer production within steel plants
(7) Utilisation of metal production gases to produce chemicals and fuels
(8) CHP, bio-oil and charcoal production
(9) Pulp and paper industry residue utilisation
(10) Integration of biomass upgrading technologies in sawmills.

These ten alternatives where further assessed by researchers of the WP4 team in terms of their economic and technological potentials. The economic potential was evaluated as low, medium and high, in terms of market size. The technology potential in turn was evaluated as short and medium to long term, based on the "readiness" of the technology to go to market. The results are shown in Figure 13. This type of matrix assessment also allows for the formulation of strategic goals in terms of go/no go investment decisions.

To implement these solutions will require bold investments, the adoption of new technologies and the upgrading of existing business models. Probably, new business model innovations are also needed. It is likely that present business units are unable, and to some extent unwilling, to pursue marginal business opportunities offered by these residual material and heat sources, some of which are currently wasted. New SMEs, either jointly owned or fully independent, should be encouraged by tangible incentives to make use of these cheap production factors.

It was concluded that the integration of bioeconomy and metallurgical industries might bring interesting opportunities to increase material and energy efficiency. Some of the ideas presented have already been re-

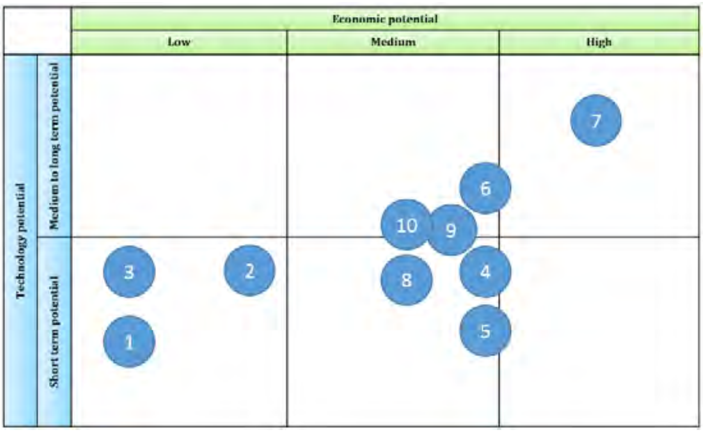

Figure 13. The ten most promising options of bioeconomy and metallurgical industry integration in terms of their economic and technological potentials.

alised in one way or another, and there is also on-going research in this area:

- Biomass use as a reductant in blast furnaces in Finnish conditions has been investigated in the PhD thesis of Suopajärvi currently in pre-examination (Bioreducer use in blast furnace ironmaking in Finland – Techno-economic assessment and CO_2 emission reduction potential).
- To further study the opportunities to produce valuable fuels from off-gases from of plant offer via gas upgrading, conditioning and cleaning, along with integrating bioreducer production to steel plant processes, was suggested to the Finnish Academy New Energy Research Programme as a letter of intent. The objective of the proposal was to study steel plant off-gas mixing, gas cleaning and catalytic conversion of off-gas derived syngas to hydrocarbons, olefins, or methanol. At the same time, the impact of introducing bioreducer to the blast furnace is to be studied with iron burden reduction studies and biocoke research. The proposal included also pyrolysis process and steel plant mass and energy balance modelling tasks to evaluate the feasibility of the proposed system.

On-going research and interest in continuing research in this scope ensures continuity and indicates the scientific relevance of this development path.

Case 2: Bioeconomy and closed nutrient cycles

Finland's bioeconomy strategy specifies that natural resources are to be utilised efficiently. Also, the national climate change strategy mentions the use of biomass for energy and emphasises the need to develop closed nutrient and material cycles in the agriculture-based energy production. For this report, a survey was made on the bioeconomy potential of northern regions and a survey of research and project activities in the region. The survey was based on ongoing and planned projects to be implemented in the near future and suggested business opportunities, which could be further explored. The following subjects were suggested for further economic analysis:

(1) The economic viability of biogas production in farms, taking into account the use of biogas for heating, electricity generation, vehicle fuel, as well as the use of digestion residues as fertilizer.

(2) The economic benefits of fertilizer value of biogas production by-product, costs savings when the digestate is used as fertilizer on one's own field.

(3) Regional benefits of renewable energy, taking into account both the economic potential of raw materials, as well as the impact on employment.

(4) Logistics problems of biogas co-generation.

(5) Determination of the total potential of various types of biomass (forest, field, manure, industrial waste streams, household waste) in the bioeconomy by production region and assessment of their economic value.

(6) Bio-ash utilisation potential in the Northern regions and its utilisation for the production of fertilizers, as well as its economic viability.

Case 3: Smart energy networks

The International Energy Agency's roadmap for smart grids established that the development of smart grids is essential if the global community is to achieve its shared goals for energy security, economic development and climate change mitigation. Smart grids enable increased demand response and energy efficiency, integration of variable renewable energy resources and electric vehicle recharging services, while reducing peak demand and stabilising the electricity system. The "smartening" of grids is already happening; it is not a one-time event (Figure 14). However, large-scale, system-wide demonstrations are needed to determine solutions that can be deployed at full scale, integrating the full set of smart grid technologies with existing electricity infrastructure.

A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users. Smart grids include electricity networks (transmission and distribution systems) and interfaces with generation, storage and end-users (Figure 15). Smart grids co-ordinate the needs and capabilities of all these stakeholders on the electricity market to operate all parts of the system as efficiently as possible, minimising costs and environmental impacts while maximising system reliability, resilience and stability.

While many regions have already begun to "smarten" their electricity systems, all regions will require significant additional investment and planning to achieve

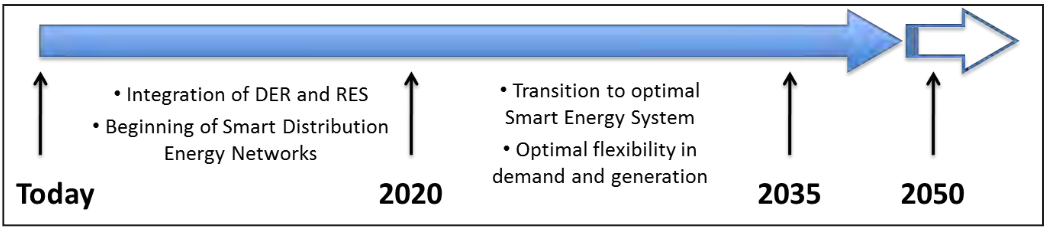

Figure 14. The process of "smartening" the electricity system (SmartGrids 2012).

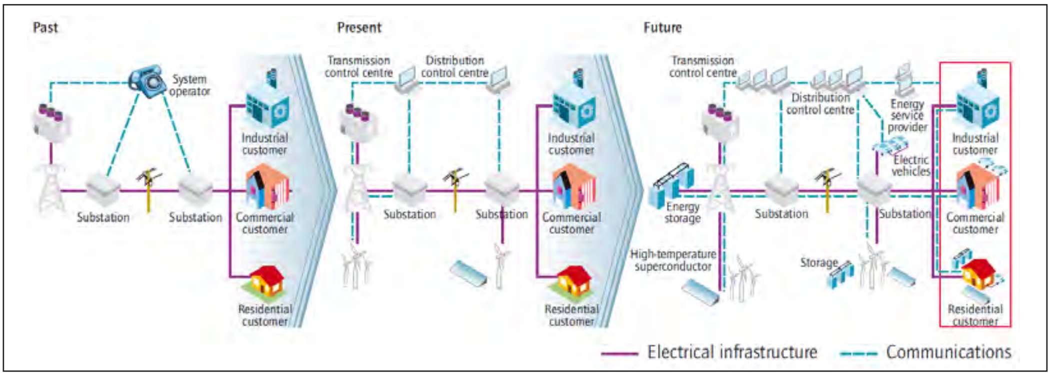

Figure 15. Smarter electricity systems (SmartGrids 2012).

a smarter grid. The scale of the investment needed is tremendous, the European technology Platform's Smart Grid SRA estimates investment needs of 50 000 M€/ on average up until 2050, adding up to 1.5-2.2 trillion (1012) euros in total. The physical and institutional complexity of electricity systems makes it unlikely that the market alone will implement smart grids on the scale that is needed. Governments, the private sector, and consumer and environmental advocacy groups must work together to define electricity system needs and determine smart grid solutions.

Smart grids are still in development and the economic potential is vast. In the case report, a list of strategic sectors were suggested where Finland could play an important role, in terms of both strategic R&D and business potential. The 9 strategic technology sectors identified in the report are:

(1) Deployment of smart metering infrastructure
(2) Electric vehicle fleet (including EV, HEV, PHEV) -related technologies
(3) Exploring wind power potential
(4) Solar power potential
(5) Heavy transport sector
(6) ICT based SG services to consumers
(7) Local and regional energy market tools and systems
(8) Smart technologies for domestic solutions
(9) Small-scale biomass boilers
  a. for home use
  b. for the power grid

The business potential of these strategic technology sectors is illustrated in Figure 16 (page 40).

Also in this case, the above ten most strategic technology sectors were further evaluated by researchers of the WP4 team in terms of their economic potential and the time span for these markets to be realised. The economic potential reflects the size of the market, and the time span illustrates how long until market saturation is reached. As can be seen in Figure 16, many of the smart grid business opportunities have very high market potential and will be there for a long time more, such as wind energy, smart heavy transport, biomass boilers, as well as ICT-based tools and market instruments. At this point it also needs to be mentioned that the University of Oulu has considerable expertise in modern energy markets, in term of real-time pricing, renewable resources and efficient distribution (Kopsakangas-Savolainen and Svento 2012).

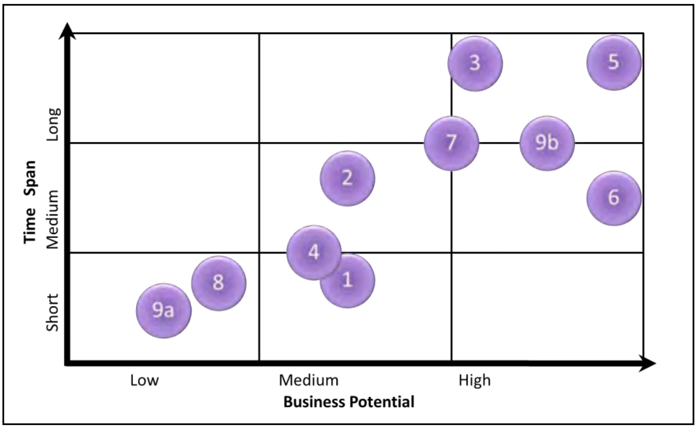

Figure 16. Strategic business opportunities in smart grids.

In terms of times scales, the EU 2020 goals provide the first milestone to be reached, however, it is estimated that smart grid development and investments will accelerate around 2020 up until 2050. This is partially due to legislative pressures (2050 goals), but also to the fact that across Europe the electricity utilities network will have to be renovated within the post-2020 decade, and the expectation is that the new infrastructure is going to incorporate smart elements. It is worth mentioning as well that, in the case of smart grids, the research potential is also substantial, and smart grid research will be of high importance in the coming 20 years.

Recommendations

All three cases represented technologies that have gained substantial interest in recent years. Research has accelerated and industry interests are driven by both legislative pressures and market incentives. On the basis of the three case study reports and applying the action-priority matrix (Figure 17), it is recommended that attention is given to "quick wins" and "major project" proposals in parallel. Quick wins are strategic decisions that can be quickly implemented bringing immediate benefits and where the technology is ready to be deployed. In turn, major projects are large and long term investments that will be necessary to implement, and which now require research effort. "Fill-ins" can then be incorporated after quick wins have been made and major projects are on the way.

All three cases represented technologies that have gained substantial interest in recent years. Research has accelerated and industry interests are driven by both legislative pressures and market incentives. In order to set priorities in terms of which proposals to pursue, the Action Priority Matrix (Figure 17) is recommended. The Action Priority Matrix is a simple diagramming technique that helps illustrating which projects give the greatest returns in ratio to the effort made (Mind Tools 2009). It is also recommended that attention is given to low effort-high gain "quick wins" and high effort-high gain "major project" proposals in parallel. Quick wins are strategic decisions that can be quickly implemented and bring immediate benefits and where technology is ready to be deployed. In turn, major projects are large and long term investments that will be necessary to implement, and which now require research effort. Low effort-low gain "fill-ins" can then be incorporated after quick wins have been made and major projects are on the way. Although "hard slogs" are characterised as high effort-low gain, they can also be viewed as "wildcards" that may turn into lucrative investments in time. The action-priority matrix is a dynamic exercise and one may need to return to re-evaluate the priorities.

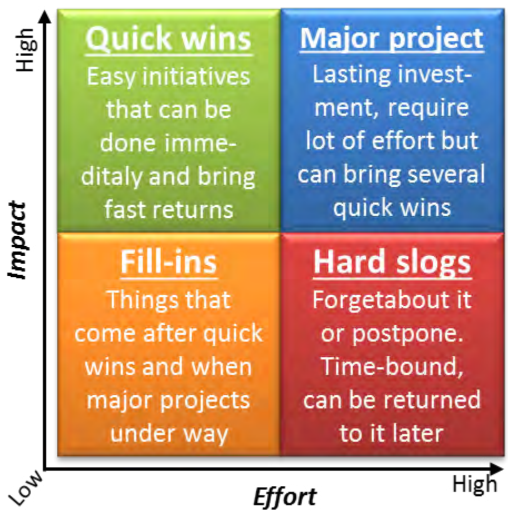

Figure 17. The action-priority matrix.

"Quick wins" = market ready solutions that need to be promoted:

- Domestic deployment of smart meters and international market of smart meter technologies
- Small-scale solar technology deployment and support
- Utilisation of waste heat sources in heavy industries (p&p & metallurgy)
- Farm-scale biogas for own energy needs and use of digestate as fertilizer on one's own field
- Bio-ash utilisation as fertilizer

"Major projects" = substantial research needs:

- Integration of bioreducer production into steel plants
- Utilisation of metal production off-gases for the synthesis of advanced chemicals and fuels
- Development of smart grid services to customers (e.g. energy billing, power quality support, real-time pricing, information extraction, data acquisition and management
- Development of energy market tools (advanced forecast methods; establishment, maintenance and support of real-time market solutions)
- Large scale energy storage technologies
- The food-land-energy-water nexus: Research integrated approaches to food security, low-carbon energy, sustainable water management and climate change mitigation - To find the best solutions for biomass utilisation, considering ecological/carbon/water footprints, nutrient cycles, competing demands and costs
- Smart heavy transport infra – EV transport fleet, smart logistics and infra, support and optimisation

"Fill ins" = market on the rise, technology mainly ready, but there are some research needs:

- Deployment of small-scale energy technologies, such as small boilers and small-scale storage in order to encourage the rise of "prosumers" (energy consumers who also produce energy)
- Small-scale electricity storage technology development and marketing
- Biogas co-generation
- Research into the regional benefits of renewable energy, taking into account both the economic potential of raw materials as well as the employment impacts.

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4.4 People in the North

Human health and well-being are the result of complex interactions among genetic, socio-cultural and environmental factors, and this is especially in the Arctic regions, where climate and global change is happening more rapidly than in other places on the globe. What are the elements of a good and safe working life and every-day life? In the Arctic regions there are about 4 million people living permanently, 10% of these are indigenous, but due to the warming climate and new economic expectations in the next 10 to 20 years, there could be many more. New mines have already changed the landscape and life conditions in many rural areas, and the balance between the local residents and newcomers is changing. From the point of view of human well-being, this means that the newcomers and indigenous populations will work in circumstances they are not used to. For example, a) communities will be exposed to new languages and cultures, b) they have to adapt to new means of livelihood and c) they will meet the changing environment where they will live also after industrial activities have ended. What are the most relevant possible challenges for well-being, and what we should know when making future estimates on the success factors of Northern regions when focusing on the community and individual well-being of people in the Finnish North?

The interesting perspectives on the Humans in the north are:

1) Arctic working conditions,
2) self-evaluated and measured well-being, and
3) the adaptation of human communities for the changing environment, Figure 18 (page 42).

The People in the North created the following three viewpoints to study human/environment interactions.

HUMAN WELL-BEING IN THE NORTH

ARCTIC WORKING CONDITIONS
– Permanent new workforce
– Seasonal workforce
– Indigenous population:
  • New professions
  • Traditional pforessions
– Marginalisation prevention

MEASURED AND SELF-EXPERIENCED WELL-BEING
– Development of measuring technology
– Development of measuring self-experienced well-being
– Building of co-operation in measuring research

LONG TERM ADAPTATION
– Environmental changes
– Cultural and lingual change
– Risk recognition
– Risk prevention
– Assessing adaptation over short term economic cycles

Figure 18. The main focuses of research in the Humans in the North.

I. Evaluation and development of intelligent sensor networks for self-monitoring of human well-being in cold climates

Self-monitoring of physiological variables in work and living in the Arctic is considered both from the point of view of an individual's own well-being, as well as a part of occupational healthcare services and safety systems in remote medical solutions. The plan compiles the existing information and produces new knowledge about the validity, functions, experienced benefits and possible drawbacks of self-monitoring in demanding environments. It has a multi- and trans-disciplinary approach, combining the understanding of human physiological responses, the functioning of the portable devices

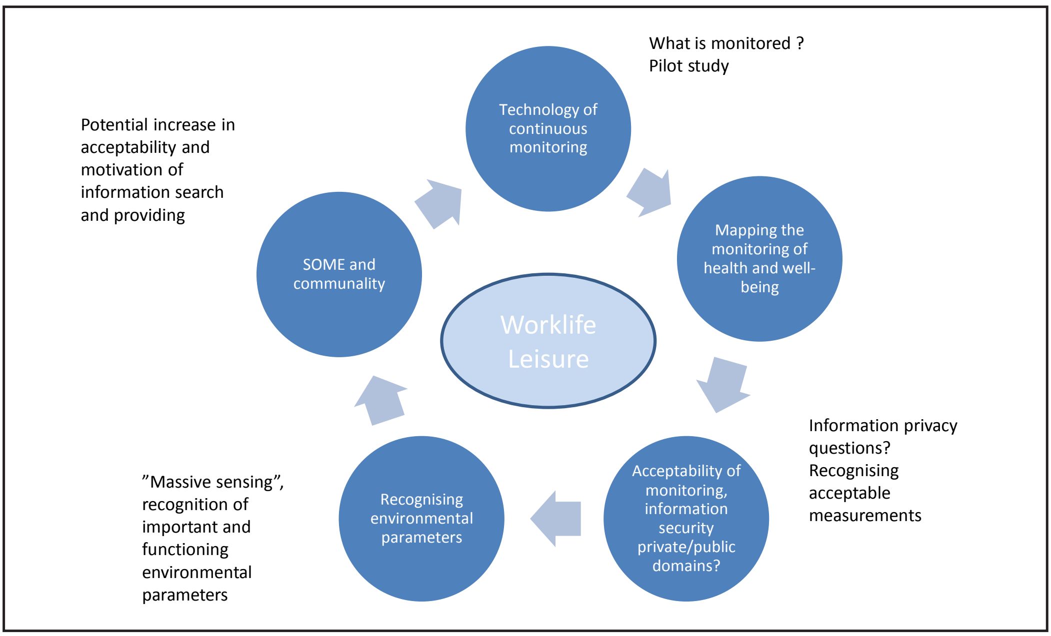

Figure 19. The intelligent sensor networks for self-monitoring of human well-being.

measuring these responses, the usability of the devices and the acceptability of the measuring systems and wireless communication of the instruments, Figure 19.

II. Arctic Salutogenic Built Environment – Integrative Planning Concept

The research focuses on topical questions concerning the planning of the built environment and promotion of health, well-being and human adaptation to changing living environments in the Arctic region. The objective is to gain new knowledge of the salutogenic mechanisms between the built environment, physical outdoor activity and well-being particularly in cold climates. The research integrates the fields of sciences of urban planning, ICT and health sciences.

III. Smart Arctic Communities: Integrating smart systems, structures and change

The Smart Arctic Communities do not merely adapt to changes, but integrate changes through smart systems and structures, to provide well-being to people within sustainable limits. Smart communities are high-tech, economically thriving, socially inclusive and live in harmony with nature. ■

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5 STRATEGIC OPENING AND BUSINESS POTENTIAL

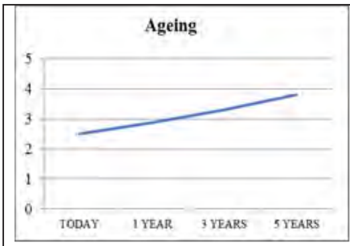
WP 7, strategic opening and business potential focused on the specific business features and trends of the arctic context, building on the WP 1-5 findings and outcomes. The objective of the WP 7 was to identify key trends and create alternative, integrated business scenarios for the other work package themes, and to identify business opportunities and business models for the selected businesses of the work package themes. The time horizon selected for analysis was moderately short, the next five years, as longer-term business discussion would make sense only for large-scale projects for which specific data would be available.

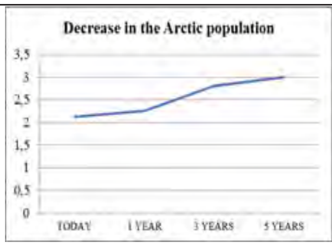
Key trends relevant for business and Arctic economy

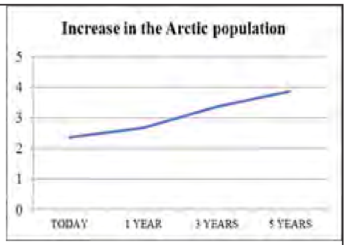
As the starting point of the arctic business-related discussion, originating from the work-package-teams, 24 business trends were identified and assessed by the work package teams. The assessment of the trends was based on the Likert scale, from 1 (weak) to 5 (strong), with a time scale varying from the present to one, three, and five years from the present. We identified increasing competition as a key trend influencing the Arctic; among all analysed items it was seen as the most rapidly increasing one. Similarly, we anticipate the role of the long distances to decrease, despite increasing energy prices. In addition, climate change is seen to influence business potential in the longer run. Slow economic growth, combined with decreasing public funding, is anticipated to influence business only up to next three-years, after which the influence of these two items is seen to diminish.

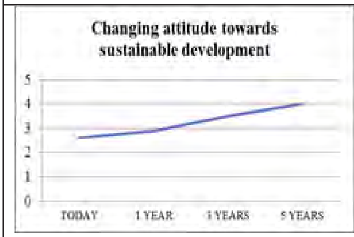
Ageing of the local population was seen to influence businesses negatively, but the role of people living only temporarily in the region was seen to increase and also override the influence of permanent Arctic dwellers regarding business potential. Looking at the values of the people in the Arctic region, we anticipate that sustainable development will be more influential to Arctic development than technological innovations, especially ICT solutions. Waste-based materials, new materials, especially nanotechnology based ones, were seen by the work package representatives as increasingly important.

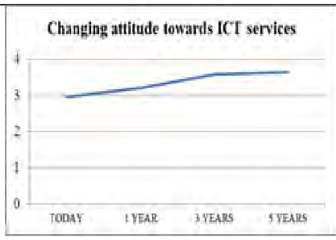
However, smart technologies, sensors and sensor networks, building-in-the-cold technologies, as well as cloud technologies were, however, seen as influential for business potential. Finally, we anticipate that national and regional policies may have much stronger role in the development of the Arctic businesses that the EU level policies. Figure 20 on next page depicts the trends relevant for business, discussed in this section.

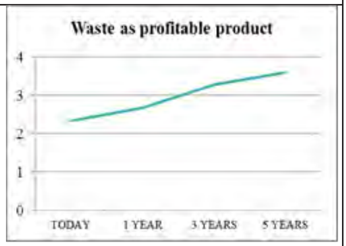

Ageing
5
4
3
2
1
0
TODAY
1 YEAR
3 YEARS
5 YEARS

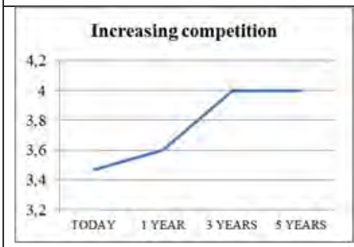

Decrease in the Arctic population
3,5
3
2,5
2
1,5
1
0,5
0
TODAY
1 YEAR
3 YEARS
5 YEARS

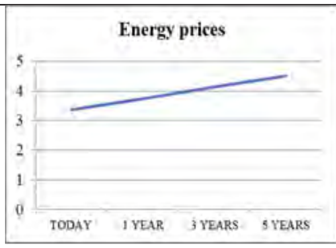

Increase in the Arctic population
5
4
3
2
1
0
TODAY
1 YEAR
3 YEARS
5 YEARS

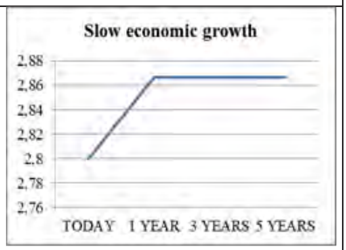

Changing attitude towards sustainable development
5
4
3
2
1
0
TODAY
1 YEAR
3 YEARS
5 YEARS

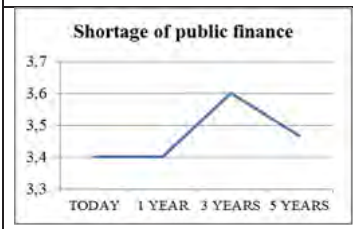

Changing attitude towards ICT services
4
3
2
1
0
TODAY
1 YEAR
3 YEARS
5 YEARS

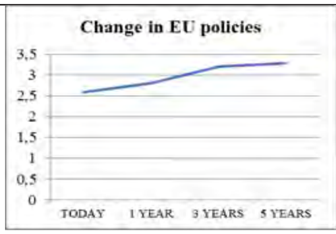

Waste as profitable product
4
3
2
1
0
TODAY
1 YEAR
3 YEARS
5 YEARS

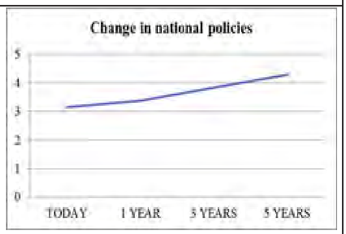

Increasing competition
4,2
4
3,8
3,6
3,4
3,2
TODAY
1 YEAR
3 YEARS
5 YEARS

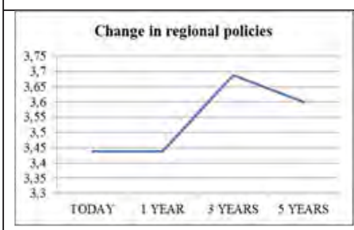

Energy prices
5
4
3
2
1
0
TODAY
1 YEAR
3 YEARS
5 YEARS

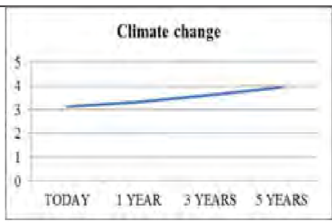

Slow economic growth
2,88
2,86
2,84
2,82
2,8
2,78
2,76
TODAY
1 YEAR
3 YEARS
5 YEARS

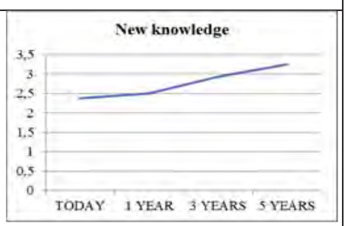

Shortage of public finance
3,7
3,6
3,5
3,4
3,3
TODAY
1 YEAR
3 YEARS
5 YEARS

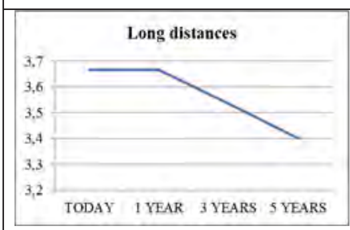

Change in EU policies
3,5
3
2,5
2
1,5
1
0,5
0
TODAY
1 YEAR
3 YEARS
5 YEARS

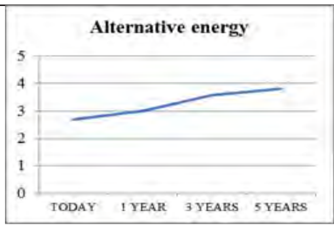

Change in national policies
5
4
3
2
1
0
TODAY
1 YEAR
3 YEARS
5 YEARS

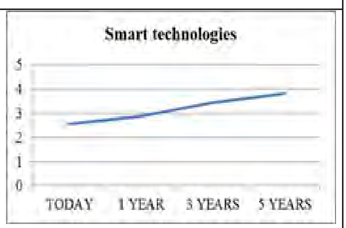

Change in regional policies
3,75
3,7
3,65
3,6
3,55
3,5
3,45
3,4
3,35
3,3
TODAY
1 YEAR
3 YEARS
5 YEARS


Climate change
5
4
3
2
1
0
TODAY
1 YEAR
3 YEARS
5 YEARS


New knowledge
3,5
3
2,5
2
1,5
1
0,5
0
TODAY
1 YEAR
3 YEARS
5 YEARS


Long distances
3,7
3,6
3,5
3,4
3,3
3,2
TODAY
1 YEAR
3 YEARS
5 YEARS


Alternative energy
5
4
3
2
1
0
TODAY
1 YEAR
3 YEARS
5 YEARS


Smart technologies
5
4
3
2
1
0
TODAY
1 YEAR
3 YEARS
5 YEARS

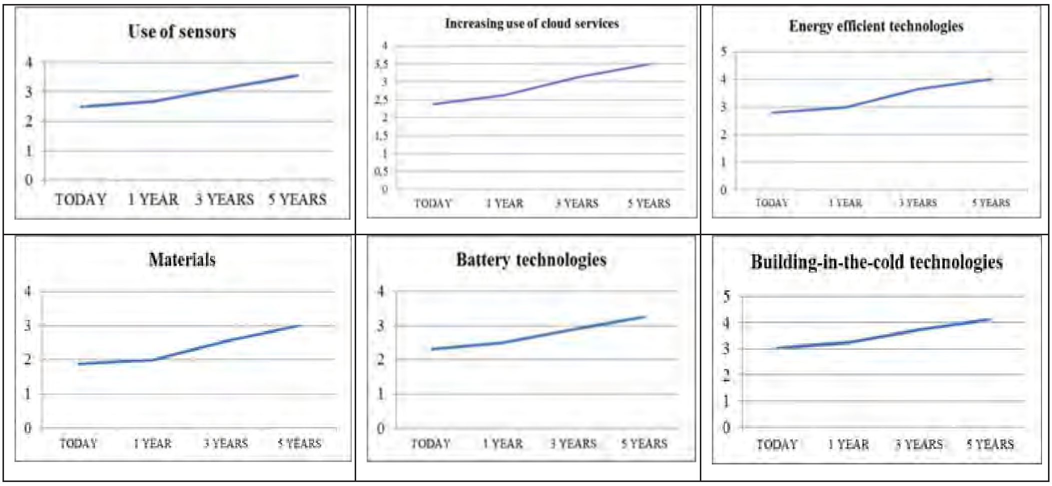


Figure 20. 24 trends influencing Arctic economy and businesses.

1. Ageing, 2. Decrease in the number of people living permanently in the Arctic, 3. Increase in the number of people living temporarily in the Arctic, 4. Change in people's attitudes towards sustainable development, 5. Change in people's attitude towards ICT services (privacy, security), 6. Turning waste into profitable products, 7. Increasing competition in attracting tourists to the Arctic, 8. Increasing energy prices, 9. Slow economic growth, 10. Shortage of public finance, 11. Change in EU policies, 12. Change in national policies, 13. Change in regional policies, 14. Climate change, 15. New knowledge about living in the Arctic, 16. Long distances, 17. Use of alternative sources of energy, 18. Smart technologies, 19. Increasing use of sensors, 20. Increasing use of cloud services, 21. Energy-efficient technologies, 22. Nanomaterials; biomass-based materials, 23. Battery technologies, 24. Building-in-the-cold technologies)

Business Scenarios

Based on these trends, several integral business scenarios were created for the Arctic by the working groups. For more detailed discussion, we take two scenarios indicative of wider influences on the Arctic businesses in general or exemplifying the opportunity/challenge field of the Arctic in particular. The first one focuses on Arctic Solutions, and the second one focuses on the Sustainable Arctic.

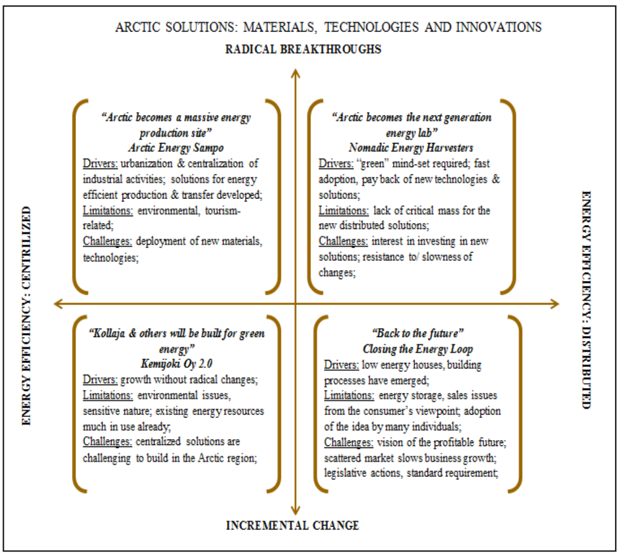


Figure 21. The scenarios of Arctic Solutions. Energy efficiency and the nature of change.

Built on the assessment of the trends influencing the use of materials, technologies, and innovations, the four scenarios depicted in Figure 21, Arctic solutions, is based on the idea of confronting radical versus incremental innovation against energy efficiency achieved either through centralisation or through distributed production. In the incremental innovation perspective in the scenario *Kollaja and others will be built for green energy*, it is anticipated that Kollaja and other possible water energy sources will be built in order to generate green energy. The scenario limitations include mainly environmental concerns. The *Back to the future* scenario counts on energy savings. However, energy storage, potentially increasing energy prices, and required investments indicate of slow growth for businesses. Also, this scenario rests on the idea that legislative action and standards are required for this kind of development to take place.

Assuming that radical innovation takes place, the scenario Arctic becomes the next generation energy lab anticipates that green thinking and R&D will result in innovative and "nomadic" energy harvesting solutions, limited by the restricted demand of the Arctic and resistance to change. However, if such innovations can be leveraged for wider use also in other areas with low enough costs for users, there is business potential. The other radial innovation scenario Arctic becomes a massive energy production site indicates urbanisation and centralisation of human activities as key drivers in the North, leaving the scarcely populated Arctic to be an energy source. This scenario may have negative side effects to tourism, but it rests on the radical innovation model regarding materials and technologies needed in energy production and transportation.

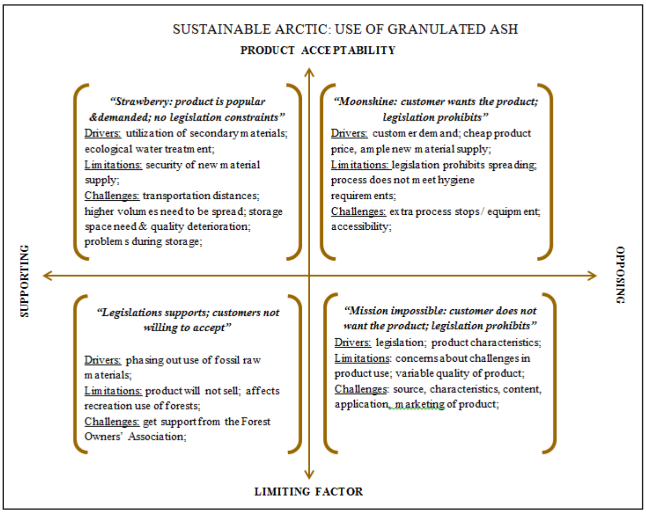


Figure 22. The scenarios of sustainable development in the Arctic region. Legislation and customer behaviour.

The four scenarios are depicted in Figure 22, Sustainable Arctic, exemplify with one material, granulated ash, the future of sustainability in the Arctic. The material could be seen either as a limiting factor or as having differing acceptability, or be supported or opposed by legislation or the people. The scenario *Mission impossible* projects the use of granulated ash both legally and by customers as something unwanted, even though it might bring about several advantages and have considerable potential. As a pessimistic scenario, the presented projection relates to several other discussions concerning the future business opportunities of the north, such as to the energy production discussion presented in Figure 21. Even though legislation turned positive on the use of granulated ash, as in scenario *Legislation supports*, there may still be green or pro-tourism values based opposition for the material. Contrary to the preceding scenario, the scenario *Moonshine* presents the material as wanted by the customers but not allowed by legislation, e.g., due to tight restrictions or requirements for the product. If the restrictions and requirements can be met, as in scenario *Strawberry*, due to innovations related to use or complementarities of the material, a positive influence on the business activities can be anticipated.

The two discussed sets of scenarios, the Arctic solutions and Sustainable Arctic, indicate of several business related challenges. Firstly, there is no generally accepted vision of the future of the Arctic that neither the people nor the researchers of the Arctic could be related to it. In the absence of such a vision, it is difficult to build novel innovations in relation to development plans or projections for Arctic businesses. Another, alternative interpretation could be that the trust regarding the future of the Arctic is lacking where or amongst whom major investment decisions are made regarding the Arctic project portfolio. Also, the scenarios might be seen to indicate that so far rather sporadic and to some degree contradictory development activities should somehow be aligned and connected to a realistic future vision of the Arctic.

Toward a business model of the Arctic?

Business models are centred on business opportunities to exploit them. A business model can be defined as a tool which explains *what* a business is about regarding customers, offering, value proposition and differentiation, and *how* the business is conducted regarding key activities, resources, and competences, especially related to customer-oriented activities, where the activities are realised (by the organisation or partners), and why it is profitable regarding to costs and revenue generation.

When searching for a business model for the Arctic, the research group created a concept called *Winternet-of-things* (Figure 23), a collaborative real-time online service that could combine the private, public and business data available from and for the Arctic, and refine and share it to the various consumer, business, and public customers in or planning to visit the Arctic. The offering and value proposition could cover environmental, weather, northern lights, location, logistics, social and event information in real-time in open access sharing mode that could foster personal influence and experience. The key activities could include data collection, refining, and sharing through various media. The revenue model and pricing of the service could be based on the type and quality of information made available in the service.

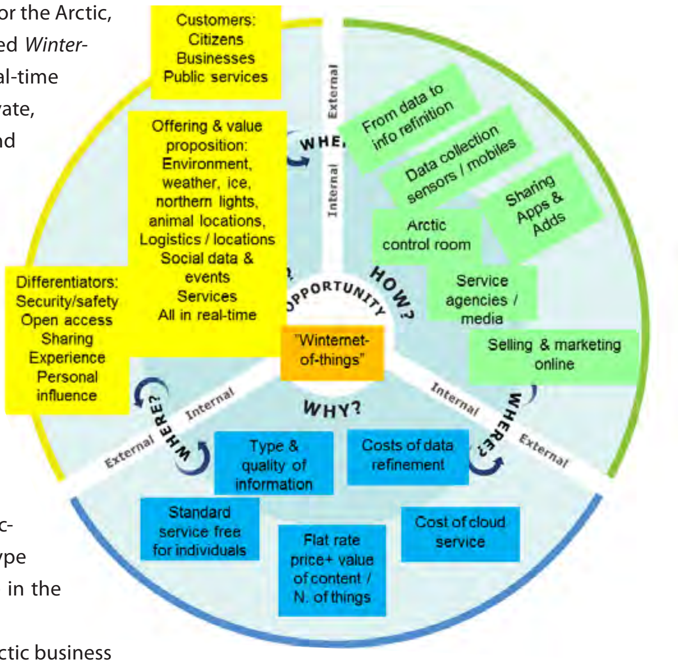


Figure 23. Winternet-of-things. A broad generic business model for the Arctic.

As a recommendation based on the Arctic business opportunities and potential, the following items could be highlighted in the future:

- The work packages of the research pinpoint to business potential that would require investments and central players with the involvement of other stakeholders.
- In order to tackle the potential, the creation of a set of thematic business development actions is needed. Special attention should be paid to the intersections of the planned actions.
- Business development actions will create and modify ecosystems as well as networks of collaborating actors and actions that would need to be addressed in addition to individual businesses. Non-commercial actors play a role in business ecosystems, too.
- The people living, working and visiting in the Arctic regions cannot be forgotten in business development and business ecosystem evolution. However, "Winternet of Things" as a part of smart Arctic may make many new people exposed to arctic businesses and development. ■

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Oulu University of Applied Sciences:
Sami Niemelä, Jouko Isokangas

6 CONCLUSIONS

The same features both separate the Arctic from other areas and join it as one: long distances, remoteness, isolation, sparse population and difficult climate conditions, as well as cultural differences and traditional lifestyle. These features have a major impact on the accessibility of the area, and thus in the moving and functioning of people living there. Additionally, they affect greatly the supply of services, especially health care. People living and working in the Arctic are used to the harsh conditions and the everyday working practices and methods are not seen as arctic innovations. These practices should be identified. By combining traditional and new methods new innovations could be found.

Our vision is to have sustainable development and smart economic activities, which safeguard the welfare of societies and ecosystems in the arctic region in the long run.

The outcome of the roadmapping process carried out in this project is crystallised in four strategy paths for the Arctic regions. They are: (1) Spearhead strategy: Arctic marine technology and maritime transport – a focused strategy that emphasises traditional Finnish competences in ship building and maritime industry set in the Arctic context; (2) Flying geese approach: emerging Arctic pathways – a wider strategy that emphasises a selection of strong Arctic competences; (3) Culture of Arctic experimentation – a strategy based on experimental policies and technology approaches; and (4) Snowdrift strategy: fading Arctic business – the Arctic does not form a credible focus of activities and is forgotten or set as a subordinate perspective inside some other topic. The four paths describe potential or possible ways to develop Arctic competences in the future. They are intended to open the scene and shed light to possibilities, and therefore they should not be interpreted as explicit directions or realisations of future development.

The thematic approaches to Arctic possibilities that were included in this project were:

- Environmental informatics and mobile technology,
- Smart logistics, infra and living environment,
- Natural resources management and economics, and
- People in the North

The multidisciplinary approach combining dimensions of individual and social well-being, environment, livelihood and welfare technology proved to be fruitful. There is a need to gather and produce scientific information on the possibilities and limitations to measure and analyse well-being, performance and health related parameters in demanding environments. The trend in healthcare sector is to go more towards personalised healthcare, which means that person him/herself is taking care of own health. Due to that, modern measurement and communication technologies will be utilised. In the Arctic, or rural areas in general, medical services and their availability can be guaranteed only with utilisation and adaptation of those medical devices. In the Arctic, alternative health care services, such as NordLab and eHealth services, have already been developed to make use of smart solutions. This makes it possible to keep health care services in the communities and reduces patients need to travel. Another example is the concept of combining health care with air traffic. This way the patients have better access for health care and the general accessibility is also being improved. We also need better understanding of the validity, usability and acceptability of self-monitoring devices, Nordlab and E-health.

Current developments in microelectronics and MEMS technologies have led to an explosion in possible sensors that can be used to monitor physical phenomena and chemical substances in multitude applications in the North. An interesting current development in sensor ICT field is the integration of several sensors systems into more advanced environment monitoring and infrastructure management.

ICT-based smart grid dedicated services are likely to represent a significant share of the future energy business as well as one of its strategically important elements. Energy billing, power quality support services, real time energy prices, energy data acquisition and management, information extraction, etc. These services have a pivotal role in the functioning of smart grid based systems, and they provide a business potential whose scale is by no means limited to or by local physical infrastructure. Based on the significant scale of importance and experience Finland has in the ICT sector, time wise, the economic benefits of this strategic sector are likely to emerge within a shorter time span. Integration of bioeconomy and metallurgical industries might bring interesting opportunities to increase material and energy efficiency.

To secure sustainable growth in the Arctic, it is essential that the Arctic's resources are exploited in a controlled manner, taking into account economic, social, cultural and environmental impacts. It is highly important that business activities maintain the balance between environmental protection and sustainable use of natural resource. In order to create new business opportunities in the Arctic region, we need to link the concrete challenges of the Arctic environment – including long distances, coldness, snow, rapid fluctuations in weather conditions, darkness and lightness– to new business ideas and business models. The harsh conditions mean that Arctic regions have to be world leaders in productivity in order to develop competitiveness successfully and secure human services. Product development to these conditions requires the utilisation of the latest technology and novel innovations. ■

BIBLIOGRAPHY

Acia (2004). "Arktisen alueen lämpenemisen vaikutukset". Ympäristöministeriö, Ulkoasiainministeriö, Helsinki. Available at: http://www.ym.fi/download/noname/%7B687A54EC-BCC0-4AA5-AC21-424A3B3AC5F7%7D/32837 [ref. 18 Sept 2014]

Ahlqvist, T., Valovirta, V., Lokkanen, T. (2012). "Innovation policy roadmapping as a systemic instrument for forward-looking policy design", Science and Public Policy. Vol. 39, 178-190.

Antikainen, J., Tolonen, S., Yli-Koski, M. (2014). "Arktinen osaaminen ja politiikka. Suomen arktisen osaamisen strategiset avaukset". MDI, Helsinki. SMARCTIC-hankkeen raportti.

Arctic info (2013). "Arctic Mining, Resources and Activity". Available at: http://www.arctis-search.com/Arctic+Mining,+Resources+and+Activity [ref. 6 May 2014]

Arctis (2013). "NSR Transits 2012". Available at: http://www.arctis-search.com/NSR+Transits+ 2012&structure=Arctic+Sea+Routes [ref. 2 May 2014]

Barents Observer (2013). "Roadmap for Shtokman development". 3.4.13 Available at: http:// barentsobserver.com/en/energy/2013/04/roadmap-shtokman-development-03-04

Biosensors in briefs, RSC Publishing, Vol. 2010, No. 5. Royal Society of Chemistry. [IEEE15.6] IEEE Standard for Local and metropolitan area networks, Part 15.6: Wireless Body Area Networks

Biotalousstrategia (2014). "Kestävää kasvua biotaloudesta Suomen biotaloustrategia", toukokuu 2014, available at: https://www.tem.fi/files/39784/Suomen_biotalousstrategia.pdf [ref. 17 Sept 2014]

Brigham, Lawson W. (2011). "The Challenges and Security Issues of Arctic Marine Transport", in Kraska, James (ed.) Arctic Security in an Age of Climate Change. Cambridge: Cambridge University Press, p. 27.

Dalmasso et al. (2012). "WiMAX network for emergency management based on UAVs", IEEE ESTEL 2012.

Dunbabin M. and L. Marques (2012). "Robotics for Environmental Monitoring", IEEE Robotics and Automation Magazine, March 2012.

ECN (2013). "Resource Efficiency: What does it mean and why is it relevant?" Policy brief ECN-O—13-004, available at: http://www.ecn.nl/docs/library/report/2013/o13004.pdf [ref. 17 Sept 2014]

Ernst & Young (2013). "Arctic Oil and Gas. Available at: "http://www.ey.com/Publication/ vwLUAssets/Arctic_oil_and_gas/$FILE/Arctic_oil_and_gas.pdf.

Finpro (2012). Arctic Sea Exploration, Finnode phenomena study. Finpro St. Petersburg-team, 11/30/2012

Gazprom (2014a). "Yamal megaproject". Available at: http://www.gazprom.com/about/production /projects/mega-yamal/ [ref. 12 Sept 2014]

Gazprom (2014b). "Shtokman". Available at: http://www.gazprom.com/about/production/ projects/deposits/shp/ [ref. 5 May 2014]

Granthalm, Jeremy (2011). "In article: Global commodity markets (Part I): a paradigm shift? Timera Energy". http://www.timera-energy.com/commodity-prices/global-commodity-markets-part-i-a-paradigm-shift/

Hackmann G, Sun F., Castaneda N., Lu C., and Dyke S. (2012). "A holistic approach to decentralized structural damage localization using wireless sensor networks", Computer Communications, Volume 36, Issue 1, 1 29–41.

Ho C. K., Robinson A., Miller D.R. and Davis M.J. (2005). "Overview of sensors and needs for environmental monitoring", Sensors 2005, 5, 4-37. http://mdpi.org/sensors/papers/s5010004.pdf

International energy Agency (2011) Technology Roadmap. Smart Grids. Available athttp://www.iea.org/publications/freepublications/publication/smartgrids_roadmap.pdf

Jørgensen-Dahl, A. (2010). "Future of Resources and Shipping in the Arctic", The ARCTIS database. Centre for High North Logistics (CHNL). Available at http://www.arctis-search.com/Future+of+Resources+and+Shipping+in+the+Arctic&structure=Marine+Transport+and+Logistic [ref. 2 May 2014]

Kaartemo, Valtteri & Kaivo-oja, Jari (2010) Finland 2050 in the Perspective of Global Change. In Jakubowska, Patrycja, Kukliňski, Antoni & Zuber, Piotr (Eds.) The Future of Regions in the Perspective of Global Change. Case studies. Part Two. Volume 4. Second Edition. Sponsored by Lower Silesian Foundation for Regional Development, Warsaw and Wrocław, Poland, 113-122.

Kaivo-oja Jari & Myllylä, Yrjö (2013). Arktisen toimintaympäristön kannalta relevantit PESTE-trendit. 38 s. Taustaraportti Arktisen toimintaympäristön tulevaisuusverstaaseen 5.4.2013. Oulun yliopisto, Thule-instituutti, VTT, Oulun ammattikorkeakoulu, Tekes. <http://rdaluekehitys.net/2013/11/20/tutu-seuran-alustus-25-11-2013-ytt-yrjo-myllyla-arktisen-toimintaympariston-vahvat-ennakoivat-trendit-ja-suomalaisen-elinkeinoelaman-mahdollisuudet/>

Kauppalehti (2013). "Statoil: Arktiset öljyvarat vuosikymmenten päässä". 1.12.2013. Available at: http://www.kauppalehti.fi/etusivu/statoil+arktiset+oljyvarat+vuosikymmenten+paassa/201312577615 [ref. 4 May 2014]

Knell, N. (2008). "The Re-emergence of the Arctic as a Strategic Location."

Kopsakangas-Savolainen M and Dvento R (2012) "Modern Energy Markets. Real-Time Pricing, Renewable Sources and Efficient Distribution. Springer."

Koranoy, B. (2013). "Ice levels, rule changes to boost Arctic northern sea route" Reuters. 29.5.2013. Available at: http://www.reuters.com/article/2013/05/29/us-shipping-arctic-idUSBRE94S0DG20130529 [ref.5 May 2014]

Kuisma, Juha (2011). Kohti biotaloutta. Biotalous konseptina ja Suomen mahdollisuutena, Työ- ja elinkeinoministeriö julkaisuja, Kilpailykyky 6/2011, available at: https://www.tem.fi/files/-29342/TEM_6_2011_netti.pdf [ref. 17 Sept 2014]

Kuusi, Osmo (2008). "Miten tulevaisuutta voi tutkia tieteellisesti?" Tieteessä tapahtuu 5/2008. pp 40-42. < http://ojs.tsv.fi/index.php/tt/article/viewFile/541/458>

Lapin Kansa (2014) "Jäämeren radan kannatus kasvaa", 26.2.2014.

Libelium, http://www.libelium.com/products/waspmote/sensors/ (Site accessed 07.07.2014).

LVM 2014, http://www.lvm.fi/en/broadband (Site accessed 22.4.2014)

Matinmikko et al. (2013). "Cognitive Radio Trial Environment: First Live Authorized Shared Access-Based Spectrum-Sharing Demonstration", IEEE Vehicular Technology Magazine, Vol. 8, No. 3, 2013.

Megatrends (2011). TemaNord 2011:527, Nordic Council of Ministers, Copenhagen, available at: http://www.nordregio.se/en/Publications/Publications-2011/Megatrends/ [ref. 18 Sept 2014]

Mikkola, H. & Käpylä J. (2013) "Arctic economic potential. The need for a comprehensive and risk-aware understanding of Arctic dynamics", FIIA Briefing paper 127.

Mind Tools (2009) Time Management Toolkit. Available at: http://inspiredindividuals.org/wp-content/uploads/2012/06/Time-Management-Toolkit2.pdf

Myllylä, Yrjö (2008). "Industrial, Logistic and Social Future of the Murmansk Region – Summary of the Doctoral Dissertation by Yrjö Myllylä". 64 p. Publications of the Ministry for Foreign Affairs of Finland 3/2008. <http://aluekehitys.internetix.fi/fi/sisalto/uutiset/uutiset/ ummurmanskkirja>

Myllylä, Yrjö (2012). "Pohjoisen tutkimuksen erityiskysymykset – NorNet verkoston / Luonnonvara- ja ympäristöalan ennakointi vuoteen 2025". Northern Research and Innovation Platform, NorNet-verkosto, Thule-instituutti, Oulun yliopisto. Loppuraporttiluonnos 7.3.2012. NorNet-verkoston kumppanit Oulun yliopisto, Ilmatieteen laitos, Metsäntutkimuslaitos, Riista- ja kalatalouden tutkimuslaitos, Suomen ympäristökeskus, Elintarviketurvallisuusvirasto Evira, Maa- ja elintarviketalouden tutkimuskeskus MTT, Mittatekniikan keskus, <http://www.oulu.fi/nornet/>

Myllylä, Yrjö (2013a). "Arktinen toimintaympäristö: Vahvojen ennakoivien trendien vaikutus logistiikkaan, infrastruktuuriin ja elinympäristöön – sekä niihin liittyvät uudet liiketoimintamahdollisuudet Suomessa". Asiantuntija-artikkeli SMARCTIC-hankkeen työpaketti 3:een liittyen 27.5.2013. Oulun yliopisto, Thule-instituutti, VTT, Oulun ammattikorkeakoulu, Tekes. <http://www.oulu.fi/thule/node/14154> <http://www.cemis.fi/in-english/projects/active-projects/smarctic-2>

Myllylä, Yrjö (2013b). "Arktisen meriteknologian ennakointi – Uudenmaan pk-yritysten näkökulmasta". (Arctic Maritime Technology Foresight) 141 p. Uudenmaan ELY-keskuksen julkaisuja 13/2013. <http://amtuusimaa.net/2013/06/01/arktisen-meriteknologian-ennakointi-loppuraportti/ >

Myllylä, Yrjö & Kaivo-oja, Jari (2013). "Arktisen toimintaympäristön tulevaisuusverstas" 5.4.2013 – yhteenvetoraportti. 60 p. SMARCTIC-hanke, Oulun yliopisto, Thule-instituutti, VTT, Oulun ammattikorkeakoulu, Tekes. <http://rdaluekehitys.net/2013/11/20/tutu-seuran-alustus-25-11-2013-ytt-yrjo-myllyla-arktisen-toimintaympariston-vahvat-ennakoivat-trendit-ja-suomalaisen-elinkeinoelaman-mahdollisuudet/>

Myllylä, Yrjö & McEwan, Jon (2013). "Finland's world class Arctic marine technology know-how". Baltic Rim Economies Expert Article 1245. Baltic Rim Economies 28.3.2013. Quarterly Review 2/2013. Page 15. Pan Europe Institute <Baltic Rim Economies 2/2013 Special Issue on the Future of the Arctic >

Myllylä, Yrjö, McEwan, Jon & Kaivo-oja, Jari (2013). "Finland Plays a Key Role in Developing Arctic Marine Technology". Energy, Enviro World. News and Information on Sustainable Solutions. Webpages: http://www.energy-enviro.com/index.php?PAGE=7&LANG=1&ID=4790&LETTER_ID=237

Naphade M., Banavar G., Harrison C., Paraszczak J. and Morris R. (2011). "Smarter cities and their innovation challenges", IEEE Computer, June 2011.

Navigant Research (2013). BTM World Market Update 2012.

Nordicity (2014). "Northern Connectivity Ensuring Quality Communications", NCIS-WG report,

O'Connell, K. P. (2013). "Wearable Physiological Sensors", IQT Quarterly, vol. 4, no. 4, 2013.

Prime Minister's Office (2013). "Finland's Strategy for the Arctic Region 2013", Prime Minister's Office Publications 16/2013. Available at: http://vnk.fi/julkaisukansio/2013/j-14-arktinen-15-arktiska-16-arctic-17-saame/PDF/en.pdf [ref. 18 Sept 2014]

Rautajoki, T. (2014). "Arctic Business forum yearbook 2014. Lapland Chamber of Commerce", 2014. p. 166.

Rautio & Hahl (2013). "Economic cooperation in the Barents Region" – Draft 010613 Akvaplan-niva AS Report 6265 –p. 88Shukman (2014)

Roscia M., Longo M. and Lazaroiu G.C. (2013). "Smart city by multi-agent systems, International Conference on Renewable Energy Research and Applications", Madrid, Spain, October 2013

Savazzi et al. (2013). "Ultra-Wide Band Sensor Networks in oil and Gas Explorations", IEEE Communications Magazine, April 2013

SmartGrids- European technology platform (2012). "SmartGrinds SRA 2035- Strategic research agenda update of the SmartGrids SRA 2007 for the needs by year 2035" (http://www.smartgrids.eu/documents/sra2045.pdf)

Smith, Laurence C. (2011). "Uusi Pohjoinen – Maailma vuonna 2050". Suomentanut Tuukka Perhoniemi. (The World in 2050: Four Forces Shaping Civilization's Northern Future). 378 p. Tähtitieteellinen yhdistys Ursa. Helsinki.

SONERA (2014). www.sonera.fi, site accessed 10 February2014

Sponsored by Cargotec, Aker Arctic Technology, Finstaship, Lapland Chamber of Commerce, Municipality of Salla, Barents Group Ltd and Management & Transportation Experts Matrex Oy

Toivonen, Marja (2004). Expertise as Business. Long-Term Development and Future Prospects of Knowledge-Intensive Business Services (KIBS). Helsinki University of Technology. Laboratory of Industrial Management. Doctoral Dissertation Series 2/2004. Helsinki.

Wilenius, Markku & Kurki, Sofi (2013). "Surfing the sixth wave. Exploring the next 40 years of global change". 126 p. Finland Futures Research Centre FFRC eBOOK 10/2012.University of Turku. <https://www.utu.fi/fi/yksikot/ffrc/julkaisut/e-tutu/Documents/eBook_2012-10.pdf>

Valor (2013). The Finnish offshore industry 2013.

APPENDICES

Deliverables:

Smarctic WP3 Summary (http://www.taloustieteet.oulu.fi/file.php?fid=1004)

Smart Arctic Logistics (http://www.taloustieteet.oulu.fi/file.php?fid=994)

Arktinen maantieteellinen saavutettavuus (http://www.oulu.fi/sites/default/files/content/Arktinen%20maantieteellinen%20saavutettavuus.pdf)

Kaivokset Lapin matkailun voimavarana: kestäviä ratkaisuja muuttuvan arktisen rakennetun ympäristön suunnitteluun (http://jultika.oulu.fi/Record/nbnfioulu-201405271507)

Yrjö Myllylä and Jari Kaivo-oja (2013), Arktisen Toimintaympäristön tulevaisuusverstas raportissa

Eva Pongrácz (2014) WP4 final report

Hannu Suopajärvi and Antti Haapala (2014) Case 1: Zero-waste integrates of metallurgical industry and bioeconomy. WP4 report. 62 p.

Heikki Keränen (2014) Case 2: Biotalous ja suljetut ravinnekierrot. WP4 report. 18 p.

Antonio Caló and Eva Pongrácz (2014) Case 3: Smart Energy Grids. WP4 report. 59 p.

Tim Luoto, Hannu I Heikkinen and Arja Rautio: Globalising challenges of well-being in Finnish north, manuscript submitted to journal 8/2014.

Dissemination:

Smart Grids in the North: Distributed energy systems and the future of energy services. Smarctic workshop at Älyäkkönää energiaa seminar, led by Antonio Caló and Eva Pongrácz, 11.11.2013. http://nortech.oulu.fi/eng/SGworkshop.html

Improving Nordic Logistic and Connections: How do we do? – Smarctic-related workshop at the Jokkmokk Winter Conference lead by Antonio Caló, 4.2.2014

Participation at the Arctic Frontiers conference. Poster titled: 'Laboratory study of oil slick behaviour in sea water in cold weather conditions: Improving the oil spill response system for the Barents Sea'

Participation at the Second Urban Mining Conference (SUM 2014), 19.-21.5.2014, Bergamo, Italy. Presentation titled: 'Critical minerals: recycling vs. dissipative losses – The case of Indium'

Participation at the 10th Int'l Conference on Autonomic and Autonomous Systems (ICAS 2014), 20.-24.4.2014, Chamonix, France. Presentation titled 'Concerning the Sustainability of Smart Grids: A critical analysis of the sustainability of current Smart Grid models and on indicators of Smart Grid sustainability assessment'

Current research (publications):

Smarctic – tiekartta älykkääseen arktiseen erikoistumiseen, Liikenteen suunta 2/2013 (http://www.liikenteensuunta.fi/fi/artikkelit/tk/smarctic-tiekartta-alykkaaseen/)

Caló A, Louis JN, Pongrácz E (2014) Concerning the Sustainability of Smart Grids: A critical analysis of the sustainability of current Smart Grid models and on indicators of Smart Grid sustainability assessment. Proc. 10th Int'l Conference on Autonomic and Autonomous Systems (ICAS 2014), 20.-24.4. 2014 - Chamonix, France, (Publisher: International Academy, Research and Industry Association)

Pongrácz E (2014) Critical minerals: recycling vs. dissipative losses – The case of Indium. SUM 2014, Second Symposium on Urban Mining, May 19-21, Bergamo, Italy. http://urbanmining.it/search-app/pdf/123.pdf.

Dedkov N, Ripachova R, Gorshenina E, Mikhailova O, Pongrácz E. (2014) Laboratory study of oil slick behaviour in sea water in cold weather conditions: Improving the oil spill response system for the Barents Sea. Arctic Frontiers, Part III: Shipping and Offshore in the Arctic. Abstract ID: 0205. http://arcticfrontiers.conference-services.net/programme.asp?conferenceID=3796&action=prog_categories

Related publications:

Caló A and Pongrácz E (2014) The role of smart energy networks to support the application of waste-to-energy technologies. Pollack Periodica. An International Journal for Engineering and Information Sciences. 9(Supplement): 61-73.

Suopajärvi H, Pongrácz E and Fabritius T. (2014) Bioreducer use in blast furnace ironmaking – Analysis of CO2 emission reduction potential and mitigation cost. Applied Energy. 124(1 July 2014): 82-93.

Suopajärvi H, Pongrácz E and Fabritius T (2013) The potential of using biomass-based reducing agents in the blast furnace: A review of thermochemical conversion technologies and assessments related to sustainability. Renewable and Sustainable Energy Reviews 25(2013) 511-528. ■

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