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Technological Innovation in the Arctic Region

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Abstract

The Arctic region has attracted attention from all over the globe in recent times not just for its abundance of natural resources but also due to opening up of new trade routes owing to melting of the permafrost. As oil prices are starting to stabilize, corporate from all over the world are investing to planning to invest in the region. Oil and Natural Gas companies are investing heavily in the region. As the permafrost melts due to global warming, new perspective sea trade routes are opening up. However the region is also home to rich biological reserve, flora, fauna and indigenous tribal population. There is a need for immense technological and scientific innovation and R&D in the region. Most of the innovations have taken place in the Nordic countries in the urban regions. New governance policies and regulations have come up and extraction methodologies have become more profitable yet catering to local needs and concerns. Here, analysis of technological development will be done. The paper will focus on new scientific techniques applied by different Arctic countries for tapping and harnessing the abundant natural resources in the region and also would highlight the ecofriendly measures used to promote sustainable development. Focus will also be on development and enhancement of STEM (Science, Technology, Engineering and Mathematics) education at universities to modify and apply technologies for the betterment of Arctic population. There is a stark contrast between innovation in cities of Arctic countries and that in rural areas. This paper will highlight the scientific developmental activities performed by the Arctic countries.

Keywords: Arctic Circle; innovation; technology; research; science

SCIENTIFIC DEVELOPMENT IN THE ARCTIC

International community is taking special interest in scientific and technical development in the Arctic region. Below are few of the initiatives that have been taken:

Arctic Observing Summit (AOS)

The AOS has made recommendations to the Arctic Science Ministry regarding issues such as urgent need to shift short term research funding to long term sustained technical and infrastructure support. Also gaps needs to be identified and corrected for sensors, networks and other instruments used for supervision in the arctic. Data systems should emerge from co-design, co-production and co-management processes which adhere to FAIR (Findable, Accessible, Interoperable, Reusable) data principles. Finally the overall Arctic observation system should be comprehensible, coordinated, and sustainable and must be scalable to the maximum possible extent.

Sustained Arctic Observing

The Sustaining Arctic Observing Networks (SAON) and an US lead group of experts worked on developing the Arctic Observations Assessment Framework. It is a value tree system which aims at accessing the observations made in the region and their social implications. It has 12 societal benefit areas, 41 subareas and 163 key objectives. This framework is supported by the EU's Impact Assessment on a Long Term Investment on Arctic Observations (IMOBAR) which helps in supporting long term sustainable investments in the region. This assessment program will benefit all the countries following the SAON. The Group on Earth Observations (GEO) is trying to coordinate sound and timely environmental information with data and knowledge about the earth so that proper measures can be taken at the proper time. These efforts are aimed at promoting sustainable development in the region.

Regional Observing

Many regional observation programs are evolving and are being developed like the Distributed Biological Observatory and the Svalbard Integrated Arctic Earth Observing System (SIOS).[8] The EU is trying to develop an Integrated Arctic Observation System (iAOS). The World Meteorological Organisation (WMO) is putting best efforts to coordinating global earth observations such as Global Cryosphere Watch which provides detailed and accurate data about Cryosphere or the Polar Challenge which is working for technological advancements.

National Observing activities

An initiative of the US National Science Foundation called the "Navigating the New Arctic" is a major step towards observing and monitoring the climatic changes in the Arctic by way of new technological innovation. The German initiative "Frontiers in Arctic Marine Monitoring (FRAM)" is a network of sensor platforms in Fram Strait and Central Arctic Ocean which helps in observation all round the year. The MIDO project of Germany provides real time data on atmosphere, sea ice and ocean. Spain is working on a Spanish Arctic Observatory. The Czech Republic has been monitoring ice free regions of the Arctic since 2007 related to vegetation and ground temperature. The Faroe Islands too have been surveying the Arctic Marine

Environment. The Republic of Korea's Arctic Ocean Observing System (K-AOOS) has the objective of strengthening international coordination and collaboration. Their Circum-Arctic Permafrost Environment Change Monitoring (CAPEC) project has created new observation centres in Russia and Iceland. Poland is having its R/V Oceania to expand its observation facilities in Hornsund. Norway has a new observation centre focussing on aurora, ionosphere and earth's coupling with space. Russian Cape Baranov and Tiksi station observes various earth system components. US have initiated two new activities to help forecast sea ice and also help in wildlife detection.

Community based observing:

The US has formed a team of 2500 local observers and subject specialists from 552 communities all over the world known as "Local Environment Observer (LEO)" who exchange ideas and impart knowledge on negative climate change, weather, environmental and animal movements using latest software. It is also promoting the "EyesNorth" program to develop best practices for community based observation and services.[1] The "Rangers Ocean Watch" and "Biodiversity Rangers Programme" has been launched by Canada which are to include youth from indigenous communities for overall community development and monitoring activities.

Indigenous Knowledge

The Inuit Circumpolar Council (ICC) and its partners have established a web based atlas infrastructure to inventory and map community based monitoring and indigenous knowledge initiatives all over the Arctic region and have also created the Inuit Mental Health and Wellness map. The Indigenous People's Secretariat (IPS) also functions to enhance and promote indigenous knowledge

Steps that can help innovation in the Arctic Region

The following measures can enhance and help successful implementation of innovation in the Arctic Region

- Houses can be designed more scientifically using better insulation systems and can be made more energy efficient to reduce costs, make them resilient to snow and wind and designed as per family standards.
- Food production can be made more efficient and sustainable using greenhouse farms and grow houses and processing of locally produced goods instead of importing.
- More dependence of off grid power sources such as wind, solar, hydro, biomass and geothermal to reduce carbon footprint. This could also help create employment opportunities for the local population.
- Using more suitable and sustainable materials for development of infrastructure.
- Increased application of telehealth applications
- Increased use of modern technology and innovative ideas in education.

Problems of innovation in the Arctic Region

- The Northern Arctic lacks educational opportunities especially in STEM (Science, Technology, Engineering and Mathematics) technologies, especially the indigenous communities in the rural areas.
- Most of the scientific and technological activities in the region are undertaken by the public sector. The public sector is inherently risk averse and bureaucracy and red tapism adds to the problem.
- The strong presence of traditional indigenous culture and conservative attitude which also deters development to some extent owing to barriers in entrepreneurship and innovation.
- There is lack of economies of scale in the region due to which investments become costly and also risky with no guarantee of returns. For this coordination is very important among the various Arctic countries. By cooperation, investment volume can be increased in the field of technology resulting in hedging of risks and improving chances of returns.
- High environmental regulations also play a negative role. It increases the cost of initial investment in the region thereby filtering out small and medium enterprises from exploring the region.
- Communication systems are also poorly developed. Also internet is highly expensive and has no presence in remote areas.

“Creative Class” in the Arctic region

Andrey Petrov (2014) made a survey of the presence of a creative class in the Arctic region and found some interesting facts. His findings show that the creative class's role in the region is extremely limited and innovative ideas remain low. The following indices are used:

- **Talent Index**: People above 20 years of age having an university degree.
- **Bohemian Index**: The number of population in artistic and creative occupations.
- **Leadership Index**: The number of managerial and leadership occupations available.
- **Entrepreneurship Index**: The number of people involved in business.
- **Applied Science Index**: The number of people involved in occupations related to applied sciences.

The distribution of innovation and developmental activities in the Arctic is quite uneven. Places like Yukon, Murmansk and Yamal-Nenets have education rates much higher than other areas. Communities such as Cape Dorset and Nunavut have high Bohemian Index rating. Also there are communities having high Leadership Index value due to decentralized government operations in the region and dominant role of the public sector.

Some successful steps to promote innovation

Yukon Research Centre Cold Climate Innovation

This research centre is based at Yukon College and is a dedicated centre for cold climate innovation. It produces, commercializes and exports technologies such as alternative fuel and energy, climate specific research and technology and construction of buildings. Even though it is publicly funded, yet it has successfully made profit in several areas and is promoting the culture of innovation in the Arctic region.

Arctic Inspiration Prize

This prize is a brainchild of the S and A Inspiration Foundation of Canada founded in 2012. It's worth is \$1 million and is for teams who portray significant contribution in the field of gaining Arctic information and implementing their knowledge for the betterment of Canadian Arctic and its people.

Canadian Economic Development Agency

The Canadian Economic Development Agency (CanNor) was established in 2009 to promote sustainable and dynamic economic development in the three Northern territories. It has an Entrepreneurship and Business Development Fund which assists funding of Aboriginal business owners who otherwise have no access to funding opportunities. It also maintains a Northern Economic Index to track GDP growth and a Northern Economic Diversification Index to track economic diversification.

Nordic Models

The five Nordic countries of Denmark, Iceland, Norway, Sweden and Finland have been comparatively much more successful in proper management and diversification of their regional Arctic economies. Of the many initiatives, Norden's *Nordic Innovation Project* is of significance. It primarily finances and cooperates with small and medium sized companies operating in the region. It aims at making it easier for smaller organisations to do business and generate profit which leads to growth of entrepreneurship and innovation.

Economic Development Corporations

Economic Development Corporations (EDC) of Canada is also known as Native Corporations in Alaska. EDC is the economic and business development wing of the First Nations, Métis or Inuit government. They invest in and promote businesses that help in development of Aboriginal citizens. Alaskan Native Corporations were established by the 1971 Alaska Native Claims Settlement Act (ANCSA) by which about 44 million acres of land or 10% of Alaska were returned to the native population along with monetary payment of \$962.5 million to 12 regional corporations and 200 village corporations. EDC has a unique way of promoting development in the Arctic by combining capitalism with indigenous traditional ideas. However they focus more on traditional industries that are resource based instead of new innovation. Thus there is always a chance of monopolising markets which further makes it difficult for new enterprises and businesses.

Activities of Space Agencies

Satellite Data Tools

The Polar Thematic Exploitation Platform was initiated by the European Space Agency to access large volumes of Copernicus Sentinel Satellite Data. An EU Earth Observation programme named "Copernicus" is creating an Arctic web page which will have several resources related to portfolios of Sentinel products that scientists can directly access. Finland has its own GEOSS satellite data centre provides wide variety of free data about the Arctic for further study and research. In 2015-2015 Chinese researchers collaborated with Greenlanders to develop a high resolution remote sensing image map which is used for management of local resources and people's welfare.

New and follow on missions

US and Germany collaborated to launch the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) in 2018 to track water movement on earth including ice sheets, glaciers and sea level. The US NASA IceBridge airborne science mission collects geophysical data that relate to the earth's glaciers, ice sheets and Polar sea ice. They also help in analysing forest height in Arctic regions, permafrost and ocean topography for

changes in sea levels.

International access to infrastructure

International agreement

In the Arctic Council's meeting in 2017, the head of states of the Arctic countries signed an agreement by which they agreed to cooperate with each other in areas of development of science and technology, education, research and development, human resource exchange and access to scientific data for study. The agreement known as "Agreement on Enhancing International Arctic Scientific Cooperation" came into force in 2018 which is currently under the supervision of Denmark.

Icebreakers

Strategy for optimal utilization of Arctic icebreakers will be formulated by the EU Arctic Research Icebreakers Consortium (ARICE). It will work in partnership with the marine industry.

INTERACT

The EU's "International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT)" has the objective of proving research infrastructure in the entire Arctic circle including the Alpine regions. Now it has 79 research stations working under it and provides solutions to research projects by giving access of data and services.

EU-PolarNet

It has launched an online European Polar Infrastructure Database which is a repository of information related to vessels, stations, aircrafts and European Logistic capabilities.

National activities

Netherlands conducts the European Polar Board. Canada is establishing the Experimental and Reference Area of the Canadian High Arctic Research Station (CHARS ERA) for assisting international researchers.

National funding

Many countries have increased their budgets and funding for research in the Arctic region. Sweden has increased by 13 million Euros. In 2018, Italy put forward its 2018-2020 Arctic Research Program. Denmark is aiming to monitor long range pollution caused by transport in the region, protection of biodiversity and ecosystem and advancement of international knowledge regarding environmental regulation. Portugal has started its PROPOLAR call in 2013 to encourage increased polar research.

International funding

The EU has allocated 28 million Euros for polar research, GEOSS projects and international coordination. Another 41 million Euros has been added to mitigate risks and uncertainties.[7] There has been an Arctic Bursaries Programme between UK and Canada which allows UK to participate the Arctic projects undertaken by Canada.

New systems for data access and cyberinfrastructure

National Data Efforts

Denmark has developed a web portal named “Isaaffik”, which provides information related to transport and vessels, safety during fieldwork and educational programs. The Italian Data Centre has created an interface that allows download of environmental data. Japan has extended its Arctic data Archive System with option to download data on environment and has plans to include geographic data too by 2020. Sweden is working to modernize its 100 year old land and marine research data.[5] The US National Environmental Satellite, Data and Information Service (NESDIS) Arctic Mission will be providing useful information on water, land and atmosphere. China launched its Earth Big Data Science Project in 2018 to build a big data science centre to promote innovation and new technological development in the region.

International Data efforts

A harmonised base map has been created which provides a unified view of the entire Arctic region. This will help various Arctic countries to share resources among themselves and also coordinate and cooperate. SAON and the International Arctic Science Committee (IASC) aims at establishing a fully open Arctic data resource centre for research and bringing about sustainable development in the region.

New Technologies

Few latest technological developments in the Arctic region include:

- Solar-sky-moon photometry for checking level of aerosols at AWIPEV in Ny-Alesund.
- Chinese scientists have devised a method to measure meltwater run off on the surface of ice.
- An Autonomous Underwater Vehicle (AUV) has been designed by US that has sensors, can travel long distances and can survey oil spills.
- Japan has designed the “Continuous Soot Monitoring System” and has created an AUV for research under sea.
- Italy based Monitor and investigate Arctic along Longitudinal Transects (MELT) is attempting to standardise measurements, terminologies and methodologies for boundary research of different environmental components e.g. ocean and atmosphere interface.

Latest Predictive Technologies

- **MOSAiC**
The international Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) is an all round the year mechanism which has been build for the first time to monitor winter conditions in the Arctic. It has the objective of creating new local and global climate change models. Russia and China will contribute to research and provide logistics support. US is developing instruments that will study the boundary interactions of the atmosphere with the sea or ice surface.
- **YOPP**

The Year of Polar Prediction (YOPP) is an initiative of the WMO and is expected to observe, model, predict and verify knowledge base that plays a key role in the risks and opportunities in the region. The EU APPLICATE program is one of the major contributors to YOPP which will help in prediction and forecasting of weather conditions in Arctic and surrounding areas. China has launched its ninth Arctic Scientific Expedition that will collect and transmit real time climate data to WMO. The Canadian Arctic Prediction (CAP) helps mariners by providing them better and advanced reports on weather, water and ice conditions. The US also has several researchers working in YOPP projects. There are total 22 countries contributing to YOPP.

➤ **Mid Latitude contributions**

The US has a program referred to as the Arctic Monitoring and Assessment Programme (AMAP) which works towards establishing links between Arctic weather changes mid latitude weather conditions. Along with the US, Korea, UK and India has research establishments in the Arctic to study about the climatic conditions in the region.

Country-wise analysis of contributions towards the Arctic

Canada

Canadian Arctic Research Infrastructure

- **Vessels**
 - **CCGS Amundsen**: An icebreaker owned by the Canadian government.
 - **R/V Martin Bergmann**: A research vessel operated by Arctic Research Foundation.
 - **MV Nuliajuk**: A fishing vessel owned by the Government of Nunavut.
- **Satellites**
 - **RADARSAT-2**
 - **RADARSAT Constellation Mission**
 - **SCISAT**

Denmark

Research Vessels

- Dana is the largest of Denmark's fleet.
- The Danish navy owns two ships capable of navigation in the Arctic.

Danish Field Stations

- Zackenberg Research Centre (North Eastern Greenland)
- Villum Research Centre (Disko Island in West Greenland)
- Sermilik Station (South Eastern Greenland)

Finland

Major Research Activities

- The National Research Programme ARKTIKO is under the Academy of Finland. [9]
- University of the Arctic

- The new initiative of NordForsk Arctic Research Programme of Nordic Centres of Excellence.

Initiatives taken for Research

✓ **Research Vessels**

- Aranda (Owned by the Finnish Environmental Institute)
- Ice Model Basins (Owned by Aalto University)
- Icebreakers

✓ **Field Stations**

- Kevo Subarctic Research Institute (Associated with University of Turku)
- Kilpisjärvi Biological Station (Associated with University of Helsinki)
- Pallas-Sodankylä Global Atmospheric and Global Cryosphere Watch Station (Finnish Meteorological Institute)
- Värriö Subarctic Research Station (University of Helsinki)
- Natural Resources Institute Finland

✓ **Satellites**

- Finnish National Satellite Data Centre (Finnish Meteorological Institute)

Greenland

Research Funding Organisations

- Greenland Government
- Danish Public Funding
- Private Organisations such as Oak, Villum and Carlsberg.
- Companies such as Royal Greenland, Sustainable Greenland and even several universities and research institutes.

Research Assisting Institutions

- The government of Greenland
- Greenland Research Council (GRC)

Research Initiatives

- Greenland Climate Research Centre (GCRC)
- Greenland Ecosystem Monitoring (GEM)
- Programme for Monitoring of the Greenland Ice Sheet (PROMICE)
- Maritime Preparedness and International Partnership (MARPART)
- The Fulbright Arctic Initiative, Health and Infrastructure Working Group
- Arctic Monitoring and Assessment Programme (AMAP)

Research Infrastructure

- Vessels such as Sanna and Paamiut
- Field Stations at Nuuk and Kobbefjord (NERO) and at Zackenberg (ZERO)
- Daneborg
- Villum Research Centre

- Niaqornat

Iceland

➤ **Research Initiatives**

- Several collective efforts on study of glaciers and climate involving volunteers and local people.
- An official Climate Change Scenario has been developed which is updated regularly.
- The Marine and Freshwater Research Institute conducts research on marine environment and its surrounding ecosystem.
- The Stefansson Arctic Institute cooperates with the University of Iceland to study the social impacts of change in human livelihood in the region.

➤ **Vessels**

- Árni Friðriksson and Bjarni Sæmundsson (Owned by the Marine Research Institute)
- Þór (Operated by the Icelandic Coast Guard)

➤ **Aircrafts**

- TF-SIF (Owned by the Icelandic Coast Guard)
- TF-FMS (Operated by the Icelandic Aviation Services)

➤ **Field Stations**

- Grimsfjall Field Station (Owned by the Iceland Glaciological Society)
- Rif Research Station, RRS

Norway

Norway's Arctic research is mostly funded by Nordic Ministries and also by universities, research institutes and also by the Research Council of Norway.

Important Research Initiatives include:

➤ **Nansen Legacy Project**

To study the changing Arctic ecosystem and the Ocean. It is owned by the University of Tromsø and The Arctic University of Norway (UiT).

➤ **The Barents Sea and Arctic Ocean Ecosystem Programme**

This programme is owned by the Institute of Marine Research and has partnership with the Russian Institute PINRO. It conducts study on biodiversity and environment.

➤ **The High North Research Centre for Climate and Environment**

It is situated in Tromsø consisting of around 500 scientists from over 200 institutions involved in research related to natural science, social science and technology.

○ **Norwegian Polar Institute's Centre for Ice, Climate and Ecosystems (ICE)**

Gives importance to climate related issues such as sea ice and glaciers and other changes in the ecosystem

○ **Research Centre for Arctic Petroleum Exploration (ARCEX)**

It contributes towards advancement of exploration techniques, knowledge about geological resources and also about environmental risks due to increased petroleum activities in the region.

○ **Centre for Arctic Gas Hydrate, Environment and Climate (CAGE)**

It studies the effect of gas hydrates in the region and their possible global effects on ocean and climate.

- **The Birkeland Centre for Space Science (BCSS)**
This centre is located at the University of Bergen and engages in research on relation of earth with space through the Arctic. It studies aurora and predictability of space weather.
- **Sustainable Arctic Marine and Coastal Technology (SAMCoT)**
This centre is located at Norwegian University of Science and Technology and target development of techniques for effective mining and exploration of the region.
- **The Centre for Integrated Remote Sensing and Forecasting for Arctic Operations (CirFA)**
This centre focuses on development of methods and systems to monitor data received from sensor related to physical environment of the region.
- **Nordic Vessels**
 - Two of the most famous Nordic vessels that are able to navigate in ice filled waters are R/V Kronprins Haakon and F/F Helmer Hansen.
- **Field Stations**
 - **Ny-Ålesund**
It is located in Svalbard and is a permanent research centre for climate and environmental issues and undertakes several projects and hosts many related programmes.
 - **Kjell Henriksen Observatory**
It is also situated in Svalbard and engages in study of upper and middle atmosphere.
 - **The European Incoherent Scatter Scientific Association (EISCAT)**
It does research on lower, middle and upper atmosphere including the ionosphere.
 - **The Climate-ecological Observatory for Arctic Tundra (COAT)**
Located in Svalbard, it is a system designed as a long term territorial ecosystem monitoring system based on food-web theory.
 - **Svalbard Integrated Arctic Earth Observing System (SIOS)**
It is an earth monitoring system that will enhance knowledge about climate and environmental changes in the region.
 - **The Norwegian Satellite Earth Observation Database for Marine and Polar Research (NORMAP)**
It provides information to scientists based on data collected by sensors situated north of 55 degree north.
 - **Infrastructure of Norwegian Earth System Modelling (INES)**
It maintains the Norwegian Earth System Modelling capacity and provides simulations for IPCC assessments.
 - **The Norwegian Mapping Authority's Geodetic Observatory**
It provides reference frames and global observations on earth.
- **Satellites**
 - The Svalbard Satellite Station (SvalSat) is owned by Kongsberg Satellite Service. It is the world's largest commercial ground station for polar satellites. Two important Norwegian satellites are NorSat-1 and Norsat-2.

Russia

Russian Arctic Research Funding bodies include:

- **Ministry of Science and Higher Education of the Russian Federation**

Supports and provides grants to young Russian students and universities.

➤ **Russian Academy of Sciences**

It conducts annual programs on scientific studies and research.

➤ **Federal Service for Hydrometeorology and Environmental Monitoring**

Conducts studies and research related to hydrography, navigation and hydrometeorological support for navigation in the Northern Sea Route.

➤ **Science Foundations**

The Russian Science Foundation and the Russian Foundation for Basic Research promotes and supports research on the Arctic Region.

➤ **Ministry of Natural Sciences and the Environment of the Russian Federation**

It engages in projects and researches that ensure rational and optimum use of Arctic natural resources.

➤ **Ministry of Economic Development of the Russian Federation**

It promotes research on economic studies that aim at more practical and rational use of resources to bring about sustainable development in the region.

➤ **Major Arctic Research Initiatives**

- Enhancement of programs of state initiative aimed at achieving sustainable development of Russian Arctic regions.
- Strengthening the Arctic Scientific cooperation signed in 2018 in accordance with the Arctic Council norms and procedures.
- Modernize and develop infrastructure in the Arctic region to enhance the living standards of the people, availability of education and training and healthcare services. Also to provide employment and protect the rights of the indigenous people.
- Further development of the Northern Sea route as a transport corridor and also strengthen Russian Ice breaking fleet.
- Initiating the Arctic M-Space system to obtain and analyse high resolution hydrometeorological data of the Polar Ice regions.
- Starting the floating observatory called “North Pole” for studies related to Arctic environment and ecology.
- Publishing the “National Atlas of the Arctic” which contains valuable information related to Arctic ecology, economy, and environment, cultural and social aspects.
- A Federal Nature Reserve has been established in Novosibirsk Islands.
- A new railroad is being constructed in the Yamalo-Nenets District called the “New Northern Latitudinal Railway” which will be 707Kms long and will be along the Arctic Circle.

➤ **Arctic Research Infrastructure**

○ **Vessels**

Russia has around 40 ice breaking ships out of which 5 are nuclear powered. It undertakes around 50 Arctic expeditions annually.

○ **Field Stations**

There is a stationary terrestrial network consisting of 52 operating polar stations providing hydrometeorological information. It is located in the coastal regions and on the Arctic Islands and functions almost throughout the year. The most common Russian scientific

institutes in the Arctic include The Russian Research Centre in Svalbard, the research institutes at Samoylovsky Island, the ice base cap Baranov, research centres at Tiksi, Yamal Peninsula etc.

➤ **Satellites**

- **Resurs-P**: To study natural resources
- **Canopus-B-IK**: To study natural and artificial emergency situations.
- **Meteor-M**: To monitor Earth in sun-synchronous orbits.
- **Canopus-B No-3 and Canopus-B No-4**: Also for monitoring natural and artificial emergency situations.

Sweden

Arctic Research Funding bodies in Sweden include:

➤ **The Swedish Research Council**

It funds all kinds of Arctic Research. It has collaboration with the Research Council Formas and the Swedish Polar Research Secretariat.[10] It creates opportunities and supports Swedish scientists to engage worldwide for Arctic research.

➤ **The Research Council Formas**

This council funds research related to climate, agriculture, environment and special planning.

➤ **The Swedish Polar Research Secretariat**

It provides infrastructure for Arctic research expeditions. It operates the icebreaker Oden and the field station “Abisko”.

➤ **Major Research Initiatives**

- Collaboration was done in 2018 with the USA using icebreaker Oden which aimed at study of biochemical process leading to cloud formation in the Arctic region.
- Climate change research centres exist in Universities in Stockholm and Lund. Marine research centres have also been established in many universities. A centre for interdisciplinary research has been established at Umea University.

➤ **Arctic Research Infrastructure**

○ **Vessels**

Icebreaker Oden is 108 metre long and displaces 13 kilotons of ice.

○ **Field Stations**

✓ **Abisko Scientific Station**

It is under the control of the Swedish polar Research Secretariat. It started functioning in 1910. It has already published around 3000 scientific publications and it hosts nearly 200 scientists every year.

✓ **The Tarfala Research Station**

It is under Stockholm University and has been monitoring glaciers since 1910.

✓ **Swedish Infrastructure for Ecosystem Science (SITES)**

It is funded by the Swedish Research Council and is engaged in terrestrial and limnological field research.

✓ **European Incoherent Scatter Scientific Association (EISCAT)**

It controls incoherent scatter radar systems in Northern Scandinavia and studies and analyses interaction between Sun and the Earth. The system is being currently upgraded into EISCAT_3D. It will be multistatic radar with 5 antennas to study the geospatial environment.

The United States of America (USA)

National Aeronautics and Space Administration

NASA undertakes research, analysis and modelling on various subjects such as Arctic Ocean, atmosphere, permafrost, carbon and general ecosystem. This enables it to understand Arctic climate changes and its impact both locally and globally.

National Science Foundation (NSF)

NSF undertakes research on engineering, education, biological, chemical, physical and cultural parameters of the Arctic and also human systems both in the Arctic locally as well as globally.

National Oceanic and Atmospheric Administration (NOAA)

It undertakes research on the following subjects:

1. Sea ice forecasting
2. Promote basic sciences for environmental study
3. Advancement of water and weather forecasting systems
4. Improvement of ocean resources management system
5. Advancement of community health and economics

Department of the Interior (DOI)

It is involved in protecting the rights and heritages of the Alaskan natives and other indigenous people.

Department of Energy

This department is involved in study and research for finding solutions to the country's energy problems. It coordinates with Atmospheric Radiation Measurement (ARM) facilities in Alaska and the Next Generation Ecosystem Experiment- Arctic (NGEE-A).

Department of Defense (DOD)

The US Army Corps of Engineers Cold Regions Research and Engineering Laboratory contribute towards engineering and scientific assistance. For e.g. study related to physical environment of the Arctic.

Department of Health and Human Services (DHHS)

It conducts research and coordinates activities to improve the health conditions of indigenous population in the Alaskan region.

Major Research Initiatives

1. “Navigating the New Arctic” will try to model and analyse physical, chemical and biological changes in the region using advanced tools for assimilation and synthesis.
2. The DOE NGEE-A is working on improving coupled processes in terrestrial ecosystems.
3. The NASA ICESat-2 aims at measuring ice sheet elevation, land structure and vegetation to measure changes in ice thickness and biological changes.
4. The ONR Stratified Ocean Dynamics of the Arctic (SODA) studies ocean heat and buoyancy in the Canadian Basin to analyse upper ocean stratification and circulation.
5. NOAA maintains networks through integrated networks of Arctic Observations.
6. The Marine Arctic Ecosystem Study (MARES) is partnership of US and Canada which focuses on structure and functions of the Beaufort and Chukchi Sea’s ecosystems.

Arctic Research Infrastructure

Vessels

The US has three most important vessels. They are R/V Sikuliaq, USCG Healy and USCG Polar Star. New icebreakers are being planned.

Field Stations

1. Toolik Field Station, Beaufort Lagoon Ecosystem, Bonanza Creek and Northern Gulf of Alaska.
2. Utqiavik in Alaska
3. Summit Station

Satellites

1. MODIS (Moderate Resolution Imaging Spectroradiometer on the NASA Terra and Aqua satellites)
2. ICESat-2 (Ice, Cloud, and Land Elevation Satellite-2)
3. CERES (Clouds and the Earth’s Radiant Energy System)
4. AIRS (Atmospheric Infrared Sounder on the NASA Aqua satellite)
5. VIIRS (Visible Infrared Imaging Radiometer Suite)
6. SSMIS (Special Sensor Microwave Imager/Sounder)
7. NOAA-20
8. Landsat-8

Role of the European Union (EU) in the Arctic Region

Scientific Research measures taken by the EU:

EU-POLARNET

The program aims to create more knowledge about the Arctic that can have relation to the health of the planet. It has a total cost of 2174504 Euros fully contributed by the EU. It had started in March 2015 and will be completed in February 2020. Countries involved include France, UK, Italy, Sweden, Portugal, Netherlands, Norway, Spain, Austria, Bulgaria, Denmark, Belgium, Finland, Poland, Estonia and Greenland.

EU Arctic Research Cluster

This project is a part of Horizon 2020 and the Seventh Research Framework Programme (FP7). It aims at providing support to the EU in developing international cooperation, study the impact of climate change and help bring about sustainable development in the region.

INTAROS

It aims at developing an integrated Arctic Observation System (iAOS) to help overcome challenges and enhance decision making capabilities. It is coordinated by Nansen Environment and Remote Sensing Centre in Norway having a cost of 15490067 Euros completely funded by the EU. It had started in December 2016 and will be over in November 2021.

iCUPE

It aims to achieve coherent and coordinated Polar observations and research activities. It also focuses on quality control. It is coordinated by University of Helsinki at Finland. It has a total cost of 9340000 Euros out of which 2750000 has been contributed by the EU. It had started in September 2017 and will be completed in August 2020.

INTERACT

It aims to study the environmental changes in the Arctic region. It provides scientists, access to work stations for research and analysis. It is coordinated by Lund University in Sweden having a total cost of 10000000 Euros fully provided by the EU. It had started in October 2016 and will be over in September 2020.

ARICE

It aims at providing scientists better access to icebreakers and boost marine research. It also involves collection of marine data which is achieved by commercial ships collecting atmospheric and oceanic data. It has a total cost of 5996567 Euros which is fully funded by the EU. It had started in January 2018 and will be over in December 2021.

APPLICATE

It aims at providing authentic weather forecast and predictions in the Arctic region. Their scientists are trying to make significant changes in climate and weather models so as to acquire accurate climate data. It has a total cost of 8715066 Euros out of which 7999591 Euros are contributed by the EU. It had started in November 2016 and will be over in October 2020.

BLUE-ACTION

This aims at achieving the ability to model and predict climate change in the Arctic by improving the data collection capacities of earth observation satellites. It is coordinated by Danish Meteorological Institute in Denmark having a total cost of 8103125 Euros. 7500000 Euros have been contributed by EU. The program started in December 2016 and will be over in February 2021.

ICE-ARC

This project started in January 2014 and has already been completed in December 2017 by the British Antarctic Survey in UK. It had a cost of 11531469 Euros out of which 8874626 Euros have been contributed by the EU. The program analysed the global cost of Arctic climate change caused by melting permafrost and sea ice.

NUNATARYUK

It aims at determining the effects of melting permafrost and thawing land and coast on both the local Arctic population and the global climate as a whole. Its total cost is 11467318 Euros which is entirely funded by the EU. It had started in November 2017 and will end in October 2022.

GRACE

It aims at studying and analysing the impacts of oil spill control measures in the Arctic environment. It also engages a system of real time monitoring of underwater oil spills. The total cost of the project is 3031648 Euros out of which 2852760 Euros were funded by EU. It started in March 2016 and ended in August 2019.

SEDNA

This project aims at creating an innovative approach towards ship building and navigation in the Arctic region. Its total cost is 6726565 Euros out of which 6498752 Euros were funded by the EU. It started in June 2017 and will end in May 2020.

UK-Russia Research Cooperation

Scientists from Moscow and St. Petersburg have been working closely with the UK Science and Innovation Network. A workshop was held at the Aurora Innovation Centre at Cambridge by 60 researchers for working in the Russian Arctic, do research and analyse critical situations and find out solutions to the existing problems.

Permanent bodies of the Arctic Council

Aleut International Association (AIA)

It is a Non Profit organisation based in Alaska. It has the prime objective of safeguarding and protecting the Aleutians, their culture and traditions and also focuses on environmental protection. Aleutian members are both from America and Russia. It is representative of around 18000 people.

Arctic Athabaskan Council (AAC)

AAC aims at protecting the rights of around 45000 people in Alaska and also in Canadian Northwest Territories and Yukon. It represents itself as a political organisation.

Gwich'in Council International (GCI)

It is also a Non Profit organisation representing the Gwich'in people. It looks into environmental, social, cultural and educational issues. It represents almost 9000 people in Alaska, Canadian Northwest Territories and Yukon.

Inuit Circumpolar Council (ICC)

It aims at protection of the Inuit group of people. It is a political organisation and promotes social, environmental and economic development of the region.[11] It represents around 160000 people of USA, Canada, Greenland and Chukotka.

Russian Association of Indigenous Peoples of the North (RAIPON)

It serves as the parent organisation for around 270000 people in the Russian Arctic. It works for their social, educational and cultural development and also for environmental protection in their local territory.

Saami Council (SC)

SC aims at safeguarding the culture, traditions and language of around 140000 Sami population which is indigenous to Norway, Finland, Russia and Sweden. It provides better representation of the Sami tribe in international bodies and forums.

Arctic “Smart” Cities

In 2019 the Norwegian city of Tromsø held the Arctic Frontiers Conference with focus on “Smart Arctic”. [6] Such discussions must engage local groups and populations and involve governments, corporations and civil societies for technological innovation and development.[4] The city of Oulu in Northern Finland has been declared as an ideal smart city. The city is referred to as the third Silicon Valley and has been the centre for Nokia’s research centre and Oulu Technology Park.[12] It also houses several startup companies including 600 Information and Communication Technology (ICT) companies. Some of the developments include:

1. 5G Test Network
2. Oulu Health (An ecosystem for testing health development products)
3. Free wireless network (panOULU)

Oulu follows a “Public-Private Partnership (PPP) Model” of development. The test user platform PATIO is referred to as “Living Lab”. It is the world’s first combined citizen’s forum. Similar plans are also in place for the Norwegian city Bodø which is to be developed into a modern smart city and a new innovation hub.

Many indigenous groups of people have become aware of technological awareness and development. Demand for digital connectivity is high in places that are least connected. This is because such places lack proper infrastructure such as stores, schools and digital services.

For example, the Inuits in Canada have started an initiative called “Isuma”. In local language, Isuma means “to think”. The organisation started in 1980s and now turned into a connectivity hub and even won international awards. Today, people across Nunavut can access 24/7 community curated programming. It always people from all over Canadian Arctic to participate in various activities such as elections, regulation of activities and tracking road transport infrastructure. It has a live streaming feature which enables monitoring of mining activities and its effect on environment.

Conclusion

In spite of all developments, deploying reliable digital technology stills remains a challenge in the Northern region. There are high costs involved and quality of services is not guaranteed. However there are many local players such as K-Net in Ontario and Tamaani Internet Services in Nunavik. They support education, healthcare and other public services. Broadband based technology and applications are coming up which provides services such as online high schools and access of medical facilities.[2] Other developments include water treatment plants, assisting in exploration operations, GIS enabled services, regulation and protection of marine life. Web design companies are being created for various types of training purposes.

The Arctic Council has created several task forces and special purpose vehicles to improve telecommunications connectivity in the region. Oulu and Isuma are two prime examples of innovation in the region.[3] Societal norms, governments, communities and civil societies continue to be challenged to find and make way for new innovation and changes so as to make the lives of people better and bring about sustainable development in the region. For overall development of the Arctic, the following steps need to be taken:

1. Specialization strategies must be formalized
2. Joining forces of various Arctic countries in a common network
3. Mobilising local players and communities in the process of development

4. Enhancement of inter-regional communication and networking

5. Collaboration among various institutions in various Arctic and Non-Arctic nations.

In spite of all technological advancements taking place, the Arctic needs to be protected and preserved. The permafrost is melting faster than usual and this poses threat to several communities. Imbalance in ecological order and global warming are few of the reasons. Environmental protection and preservation should be the prime focus of the Arctic countries and the international community to a sustainable future.

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