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Climate change adaptation in the Arctic through sustainable socio-ecological innovation: Creating opportunities for local communities while preserving ecological value

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Abstract. The Arctic is heating at 4 times the rate than any other region in the planet. Climate change has been so rapid that many species and the native communities that depend on them have been severely affected. Climate change adaptation must be a priority for arctic communities and can be supported by initiatives that are beneficial to both local communities and the ecosystems at risk. This paper presents a framework of conservation using sustainable business models that preserve and augment natural capital to create resilience the Arctic. This model can be used also for other regions vulnerable regions to rapid climate change. In this paper we review the actors and solutions that might be most effective on decarbonization and preservation of natural and social capital in the Arctic. Our results show that the oil and gas industry possess the technology, mechanisms and expertise to more effectively transfer capabilities from high carbon intensity to carbon sequestration activities. These mechanisms go beyond conservation, aiding energy and nutrients transfers and integrate ecology, biodiversity and community building through rural renewal and innovative business models.

Keywords: Arctic, climate change, decarbonization, sustainability, oil and gas, green transition
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Адаптация к изменению климата в Арктике через устойчивые социально-экологические инновации: создание возможностей для местных сообществ при сохранении экологической ценности

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Аннотация. Температура в Арктическом регионе растет в четыре раза быстрее, чем где-либо еще на планете. Климат меняется настолько быстро, что многие биологические виды и коренное население, которое от них зависит, уже испытали на себе серьезные последствия. Именно поэтому приоритетным направлением для арктических сообществ должна стать адаптация к изменению климата. Это возможно реализовать с помощью инициатив, отвечающих интересам как местных сообществ, так и экосистем, находящихся под угрозой. В данной статье представлены общие принципы охраны природы с использованием устойчивых бизнес-моделей, которые сохраняют и приумножают природный капитал для обеспечения устойчивости Арктики. Те же принципы могут быть использованы и для других регионов, подверженных быстрому изменению климата. В статье проанализированы действующие акторы и решения, которые могут быть наиболее эффективны с точки зрения декарбонизации и сохранения природного и социального капитала Арктики. Полученные результаты показывают, что у нефтегазовой отрасли есть необходимые технологии, механизмы и экспертные знания для более эффективного перехода от видов деятельности с высокой углеродоемкостью к деятельности по связыванию углерода. Эти механизмы позволяют не только осуществлять охрану природы, способствуя переносу энергии и питательных веществ, но и объединять вопросы экологии, биоразнообразия и общинного развития через возрождение сельских районов и использование инновационных бизнес-моделей.
Ключевые слова: Арктика, изменение климата, декарбонизация, устойчивое развитие, нефть и газ, зеленый переход
Конфликт интересов: автор сообщает об отсутствии конфликта интересов.
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Introduction

In the last twenty years Arctic has experienced intense effects of climate change, these trends do not seem to be able to slow down neither by geopolitics conflicts nor by instruments like the treaty of Paris, which has shown so far very few results as the precedent Treaty of Kyoto [20]. As many indigenous communities have already experienced, loss of ice, temperature, melting of the permafrost, increase of diseases, should be addressed by practical means while also limiting pollution and the extension of land use. Nature, species and communities, have and can adapt to changing climatic conditions. The conflict is that the rapid nature of this change has precluded enough time for adaptation.

A dialogue between technological solutions and traditional expertise can accelerate this change and produce effects that go beyond simple theatricality and emotionality. Many studies have shown that solutions to ecological problems decided by committees ignoring opinion of local and native communities' risk to fail at implementation [13]. The oil and gas industry has the technological, scientific and cultural expertise to provide for tools for exploration, monitoring and coordination capabilities and to coordinate between knowledge and financial capitals [26].

This paper presents a framework for solution engineering to adaptation problems in the Arctic that are built on stakeholder exchange and cooperation and from n natural mandate on the communal property of assets responsibilities and consequences of economic activity.

Methods

Literature Review and research on the successes and on the failures of existing sustainability initiatives of several initiatives by the artic countries. Most sources are already published literature and sustainability reports, as well as official data from the EU, US, China and Russia.

The sources for Sustainable Strategic management are based on the research by Stead [1] and the Natural capital examinations of Helm [2]. These materials helped authors in the elucidation of the cycle of creation translated on sustainable strategies, to an analysis of the literature and capabilities to the oil industry to propose realistic initiatives that can lead to the preservation of natural, social and knowledge capital that are the sources of economic prosperity.

The first part of the study encompasses qualitative methods of valuation based on the literature while the second part incorporates quantitative and qualitative methods, to result on a recommendation of qualitative nature.

Results

Fundaments of ecological and financial cooperation on the creation of sustainable and long-term value

For the last 70 years the creation of value was wrongly adjudicated to financial capital causing the depletion of natural resources illustrating how natural capital was the fundamental condition for the creation of value [2]. Knowledge and human capital have equally been discarded despite several studies illustrating that quality of natural resources is maintained through intellectual capital flows such as traditional knowledge of indigenous and local communities and innovation [1, 6, 26].

The capture and maintenance of value has a circular nature that has been ignored on more linear models dismissing the inclusion of externalities as possible disruptors on the systems that preserve and capture value later the lifecycle [2].

We propose the following value creation system in the evaluation of capture and maintenance of value. The areas of knowledge creation led to a further refinement that gives way to scientific and social innovation:

The original value given by natural capital can't be increased it can only be degraded but the rate at which it is degraded depends on the factors of rate of depletion and intensity [2]. Externalities degrade natural capital and make it harder for its components to be restored to the natural capital pool, or it can even make them toxic or negative to its integration, for example, the creation of complex carbon molecules that can't be rapidly degraded by ordinary biological processes. After natural capital has fueled human wellbeing, enterprise and labor further create prosperity that enables financial accumulation which if properly directed leads to knowledge creation [6]. The areas of knowledge creation led to a further refinement that gives way to scientific and social innovation. These advances such as those achieved the 4th industrial revolution allow for immediate survival concerns to stabilize which allows us to evaluate the societal progress and problems they have created as externalities accumulate and impact damage natural capital and consequently social capital [4, 19]. These externalities do not always accumulate on a general location but tends to affect some regions that have more delicate ecosystems and societies first [2, 6].

As knowledge creation leads to new technologies, these new technologies might reduce externalities, reincorporate materials into the circle or restore the condition of natural capital. Scientific progress in its earliest stages without a holistic character can damage natural capital by ignorance of the systemic consequences of an input and its intensity [2, 4]. When science exposes the linkages of the value creation, knowledge becomes transformative by reducing externalities and reveal-

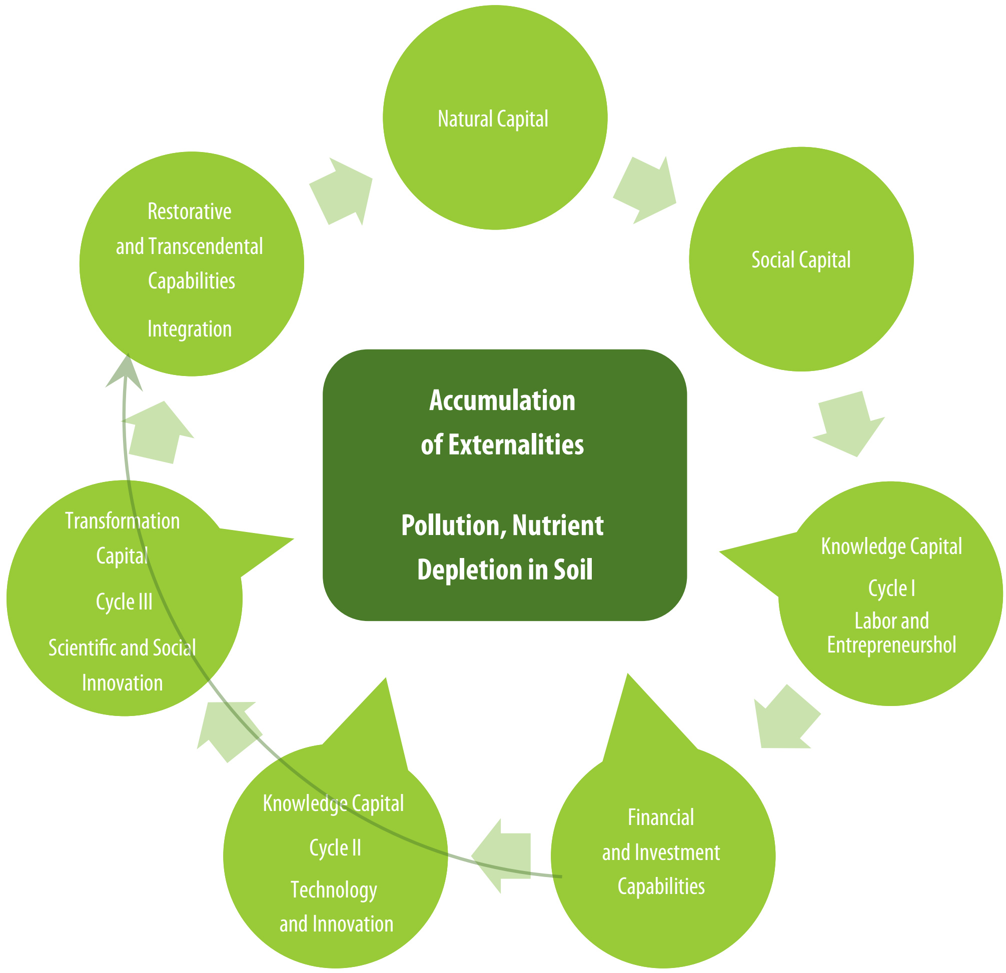

Fig. 1. Amended cycle of value creation (Author)

Рис. 1. Уточненный цикл создания ценности (рисунок выполнен автором)

ing the state of the natural and social linkages. One example is ho under the COP29, 85 % of signatories affirmed investment in energy systems beyond oil and gas. 63 % of companies plan to increase such investments in the future. 2023, the Oil and Gas Climate Initiative. The diversification of energy sources has led to savings, access to markets and reputation improvement, it has also fueled patent surges where knowledge transfer is encouraged [31].

The knowledge capital of industrialization made possible by fossil fuels and its value as a material for the preservation of systemic value

Whether intended or not, every output created is an input from for the next part of the cycle and it is used as an addition or subtraction in the energy of natural capital. Unfortunately, chemicals and carbon taken from the soil or from fossil fuels extraction is now in the atmosphere, yet knowledge created by the access of industrialization might lead to reintegrate these chemicals and excess carbon to natural cycles. Useful examples of natural input reintegration are the filtering of pollutants by wetlands and enhanced soil carbon sequestration. Artificial wetland construction is possible on altered sites, restoring ecosystem services and sequestering carbon to damaged soils [23]. Another example of this is CCS employing the technology and resources already in the possession of oil and gas companies [19].

Oil and gas companies and the refining industry also has vast experience with separation and integration of chemicals and reducing pollutants and waste. They also have a large amount of experience in challenging areas like the Arctic and they have had the largest interaction with Stakeholders. While restoration and green initiatives must gather funds from many different sources, many oil and gas companies are vertically integrated, which is an advantage to material reuse [5]. Oil and gas decarbonization funds are also less vulnerable to destabilizing events as they produce their own income, they own pertinent assets, and they have trained personnel on the regions most affected. Most green energy initiative are still dependent on substantial initial funding and subsidies that can change during crisis as nations elect new governments who have more immediate priorities than green energy development or nature conservation [25]. Technology to detect leaks and to avoid gas flaring has shown to be bring higher ROI. Much of the emissions of the Russian and Chinese oil and gas companies have been already reduced by gasification and further reductions are planned [23, 32, 34].

Nonrenewable resource efficiency has increased every year with the application of new technologies such as digital monitoring of wells, liquified natural gas, EOR, and horizontal drilling. The prosperity that these technologies created can be indirectly linked to the knowledge capital that has been able to increase efficiency and make progress on less toxic materials for solar cells. The recent gains on GDP of China and India have been translated on technological advancement, however. this has incurred damage to their own natural capital flows [6].

Western countries have maintained low level of emissions or reduced them in the last 20 years, independent of resource use [8]. These efficiencies need to be accelerated and exported to developing countries to preserve natural, social and cultural values in a manner which does not cause an accumulation of externalities, forcing sharp and perhaps irreversible decline on the originating natural capital [2, 14].

Some developing countries have not achieved the level of innovation leading to a holistic view of the cycle of value creation, unfortunately their already damaged resource base prolong cycles of poverty that are challenging to break without external financial and intellectual capital [12]. Corruption and lack of enforcement further complicate the preservation of natural capital [5, 14].

Preservation of ecological, social and economic value through sustainable business models in the Arctic

The rarity and vulnerability of Arctic communities culturally and ecologically is based on the principle on which such communities evolved under harsh Arctic conditions. The ecological food web of the Arctic boasts several unique species, with very low threshold for rapid change which makes them particularly vulnerable to climate alterations and invasive species. Some species are adaptable, but they require territorial variety and integrity to withstand challenges, such as with Lemming numbers plummeting due to low cover of snow, redundancy in habitats is useful at times of crisis. Other dangerous changes include nutrients modifying algal composition contributing to extreme ecosystem collapse in the Hudson River [21, 23, 24].

We have identified several factors that might lead to higher resilience to climate change for critical species:

1) the protection of significant ecosystems and their associated territories;

2) preservation of structure and function of biodiversity including corridors;

3) the limitation of human encroachment, including territorial, chemical or noise into areas of high or critical biodiversity;

4) resilience building by preserving water and nutrient processes on which they depend.

Indigenous and local cultures are very dependent on Arctic natural resources for their survival, cultural development in the region is intensely related to natural resources. Participative research and cooperation with large scientific bodies, monitoring technological solutions as well as material resources are keys on creating resilience [2, 7, 17].

We have evaluated several initiatives that can have significant effects on Arctic communities:

1) recording and preserving unique cultural manifestations;

2) establishing communication channels to ensure that the unique cultures can continue evolving while maintaining their traditional traits;

Table 1. Analysis of capabilities between different actors existing in Arctic communities (author)

Таблица 1. Анализ возможностей различных акторов арктических сообществ (таблица выполнена автором)

Quality	Oil companies	V	RF	Governments	V	RF	NGO	V	RF
Existing infrastructure	Vital	5	3	Beneficial	3	3	Not proven	1	0
Local knowledge	Vital	5	3	Beneficial	3	3	Not proven	1	1
Long Term capital	Vital	5	3	Beneficial	3	3	Not proven	1	1
Knowledge capital	Necessary	4	2	Beneficial	3	2	Necessary	4	2
Remediation Means	Vital	5	3	Beneficial	3	2	Necessary	4	0
Transparency	Beneficial	3	3	Beneficial	3	2	Necessary	4	3
Innovative Technologies	Beneficial	3	1	Not proven	1	1	Not proven	1	2
International Cooperation	Beneficial	3	3	Not proven	1	1	Necessary	4	3

Note: We grade the capabilities of different actors in the arctic by the following valuation: 1 — Not proven to be beneficial. 2 — Neutral. 3 — Beneficial. 4 — Necessary. 5 — Vital. Risk factor is the grade the risk of catastrophic failure under Arctic conditions in case of failure for the actor or its point of criticality. 3 High Risk, 2 medium risk, 1 low risk, 0 no risk

Примечание: для оценки возможностей различных акторов Арктического региона используется следующая шкала (Ш): 1 — польза не доказана; 2 — нейтральное влияние; 3 — полезно; 4 — необходимо; 5 — важно. Фактор риска (RF) — оценка риска внезапного отказа в условиях Арктики в случае нарушения нормальной работы или его критичности: 3 — высокий риск, 2 — средний риск, 1 — низкий риск, 0 — нет риска.

3) funding and supporting markets for culturally sensitive products;

4) funding education to support indigenous and local Arctic people to respond to the changes ahead without displacement [20, 27].

The inevitability of the changes taking place in the Arctic because of climate change, means that the loss of ice, the expansion of forest lands and by that the diminishing of Albedo effect will be more likely trends that might strengthen or lower within our lifetime. Establishing mechanisms to safeguard diversity and to lessen or minimize further human interference is essential [24]. The resources that are necessary for this task range from scientific cooperation to technological exchange, and the financial and expertise resources to make such mechanisms possible. The most stable source that can offer these resources is the oil and gas industry that is already situated in these areas and can offer cooperation with local and scientific communities. Protecting large territories might be more expedient for oil and gas companies rather than for NGOs, considering existing financial and knowledge capabilities [18, 36]. The oil and gas industry should make it imperative to minimize interference with vulnerable species, and to establish protocols for rehabilitation of ecosystems with long cycles of recovery with the coordination of Scientific organization and NGOs experienced on conservation and with sufficient experience and stakeholder integration [17, 19, 36].

As we can see from Table 1. The characteristics required to aid adaptation to the Arctic exist on a higher quantity in current oil and gas companies already involved in Arctic operations vs NGO's and governmental organizations that might have at the current time. The benefits of cooperation between governments, NGO's and oil and gas companies currently operating in the Arctic can't be underestimated as the risk index shows. For example, the vital knowledge or an ecological NGO can serve as a good indicator for issues of species health while its possession infrastructure is not its vital capability. The specialization NGO in this provides a vital service to the adaptability of the Arctic [8, 25].

Responsibility over Arctic natural resources

The main goal of sustainability is to create prosperity for this generation without endangering further generations, this includes a duty to protect the biodiversity, ecological and social resources from Arctic communities. Although we can't predict the changes that will occur in vulnerable ecological or social communities, we can establish a procedure to monitor and foresee risks by establishing a system of reviews of data by AI connected to sensors in Arctic communities, these systems can also interpret and mobilize risk minimizing strategies [11]. These assets are more efficiently monitored by the local communities that may be most affected by accidents, such as collapse of infrastructure by permafrost, fires due to the extension of droughts, invasive species expansion, nutrient changes, and susceptibility of animals and plants to illnesses because of environmental changes [22]. Excess flows of earlier melting water can be absorbed by the establishment of artificial wetlands, which have also shown to be prospective on diminishing the effects of permafrost melting [13, 20, 21]. These initiatives need the participation of local and indigenous initiatives from inception, requiring both communication and transparency which can be served by blockchain technologies and the Internet of things [20]. The industries that have profited and stand to profit more on the extraction and utilization of the Arctic natural resources, are oil and gas, mining and the fishing industry, however, the energy and carbon sequestration and albedo effects that the Arctic offer universal benefits in the planet. Accountability should include players that benefit of Arctic ecosystem services indirectly as well and should be directed to the communities that would experience the most damage on their disruption [23]. The oil and gas Industry is already a prolific investor on green technologies CNPC$1.5 billion CNOOC $14.5 billion Sinopec $4.6 billion Hydrogen alone Sinopec [2] and Exxon at $30 billions and Equinor has decided to reduce its investment to $5 billions from its commitment of $10 billions [3]. Shell has committed to low carbon initiatives from $15 billions from 2023 to 2025 [28]. BP has expressed that it intends a reduction of its contribution, but it presented a $3.85billion contribution to a joint venture in Japan [35]. Rosneft $800 millions Gazprom $12.5 millions + $23 millions on two different projects plus several other investments [32].

The oil and gas industry should lead the way to a transition of decarbonization since it has the most to gain from reinvestment and efficiency provoked by a strategy of in innovative technologies as well as redirecting current extractive capabilities to restoration and carbon sequestration, that already showed a high ROI [3, 29, 32, 35]. We suggest the following adaptive mechanisms, which follow many of the most successful programs incorporating SDG objectives to regional development. The Key funding both financial and by knowledge capital should come from Oil and Gas revenues within Arctic territory while scientific institutions and the civil sector can aid on the monitoring of the preservation of natural and socio-economic value

Table 2. Benefits of decarbonization approaches (Author)

Таблица 2. Преимущества подходов к декарбонизации (таблица выполнена автором)

Process in Arctic Conditions	Green Energy (Wind, solar, hydrogen)	Conservation of Ecosystem services through land preservation	Remediation of habitat Including artificial wetlands	Digital And AI	Carbon Capture and Storage	Lowering Emissions	Rural Integration	Circularity
Feasibility	2	5	5	5	5	5	5	2
Affordability	2	5	4	3	2	5	4	3
Social Integration	2	4	5	3	3	3	5	4
Ecological Integration	2	5	5	4	2	4	4	4
Value to the Arctic region	2	5	5	4	3	4	5	3

Note: Where 5 is an option with very positive returns on Investments, 4 positive approach, 3 neutral with no obvious benefits, 2 negative one and 1 a very negative one
Примечание: 5 — высокая рентабельность инвестиций; 4 — конструктивный подход; 3 — нейтральный подход без очевидных преимуществ; 2 — нежелательный подход; 1 — крайне нежелательный подход

of the Arctic ecosystem including penalties for their deterioration [5, 14].

Green energy can be costly in the initial phases, including solar and wind, solar does not work efficiently under arctic conditions, and the weight of wind installation can be dangerous on permafrost soils, hydrogen is prospective, but the cost is still very high [10, 17, 18]. Circularity initiatives in oil and gas are possible but the complex nature of hydrocarbons means that some effluents require costly and complex treatments although there are elements on the process and materials that can be circularly integrated. CCS can have a high cost, if already established pathways are not used [3, 5]. Lowering emissions has had a positive ROI, which is shared by conservation of land, particularly forested one, or wetland which can be translated into the most affordable form of carbon sequestration, as wetland vegetation uptakes the carbon of fens, and wetlands methane emissions under higher temperatures, serving also as valuable renewable resources for local communities [27]. Restoration might be less affordable than conservation and can have the same effects on social integration. Ruralization has shown to have social benefits and be affordable as well as promoting mixed used benefits and economical sustainable growth, digitalization and predictive capabilities have shown ecological, social and economic benefits, but cost and access might be prohibitive where it has not already been incorporated [15, 16].

Discussion

Challenges

The best strategy to make the non-renewable energy sector accountable to future generations is to involve it as a significant stakeholder in the transition to less carbon intensive processes in the Arctic region. Rapid climatic and biological challenges undermine the survival of ecosystem services and the Artic communities that depend on them. These challenges can be resolved with the use of technologies that

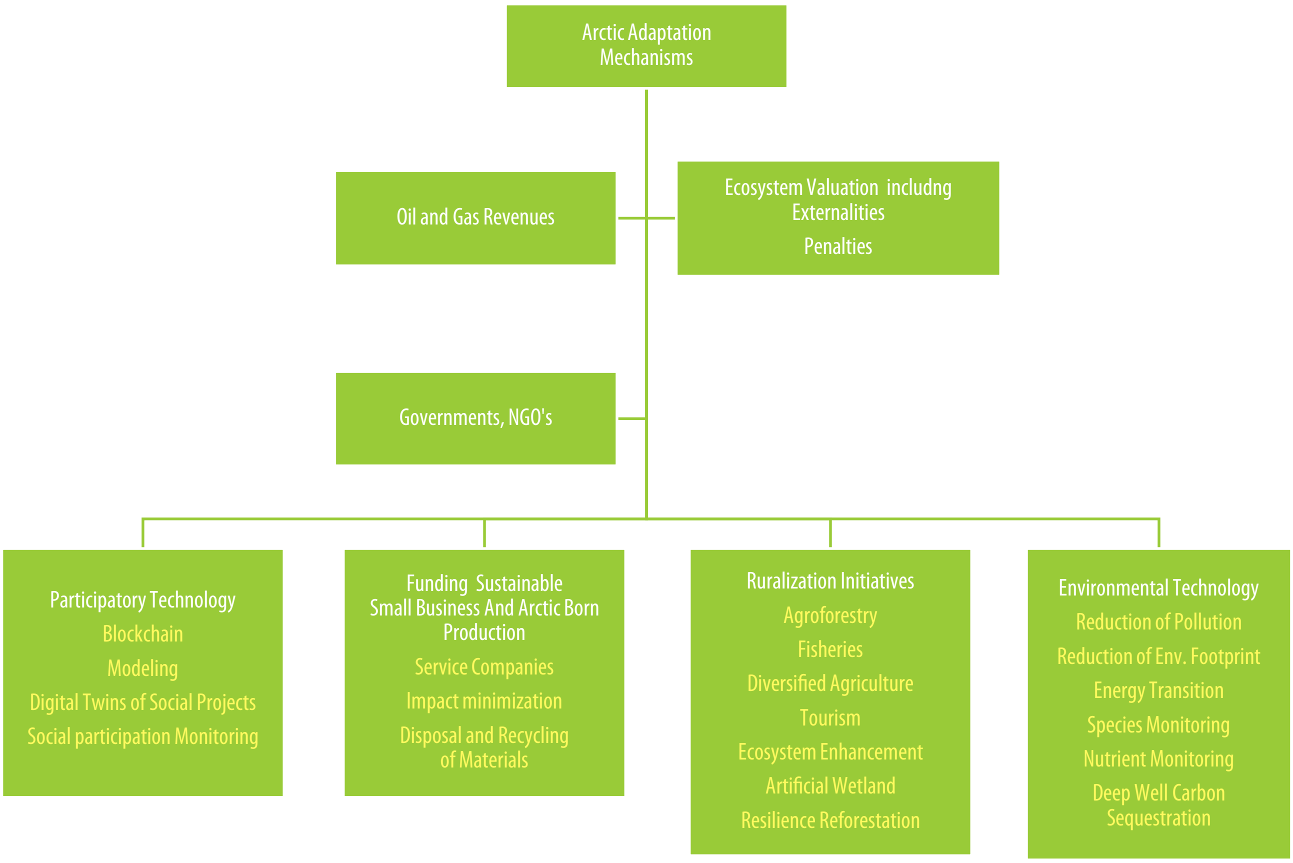

Fig. 2. From strategy to initiatives (Author)

Рис. 2. Переход от стратегии к инициативам (рисунок выполнен автором) we have already been successfully deployed such as AI drones and coordinated sensors [9]. The cooperation with diverse partners should be encouraged from the beginning of development projects through consultations and representation, further facilitating the flow of ecological to social flows including technological innovation [8, 9, 13].

Current geopolitical conditions in the Arctic

The exchange of information and cooperation necessary to address the urgency of the protection of the Arctic natural, cultural and economic capital has diminished in this last 5 years because geopolitical conditions. Since Arctic ecosystems do not recognize national borders or ideologies, all parties should restore scientific as well as social communications for the welfare of the Arctic communities and their future [18].

While transparency in highly contested areas might not occur naturally, there are technological safeguards to ensure that information given by sensors and AI does not conflict with national safety interest but pertain only to those shared scientific interests among Arctic states. Innovative solutions should be set forth by funding cooperative innovation including predictive capabilities [4, 9].

Conclusions

The largest part of clean energy investment support (95 %) since the COVID-19 has been undertaken by advanced economies with private funds through private corporations. According to the IEA, advanced economies have collectively earmarked $1,145 billion. America accounts for around half of this, with the IRA alone directing $370 billion, while 37 % (approximately $45 billion) comes from European Union (EU) investments [29]. NGO's share of the bill has been negligible financially but useful in coordination and facilitation and are significant on EU policy [36].

The Arctic is a very vulnerable region, and it is hard to predict the effects of global warming in an area and with such a mix of unique species and cultures. One of the reasons why our natural resources have been eroded in decades since the industrialization was our poor estimation of the importance of natural capital to ensure long term prosperity. The creation of economic value must respond to the erosion of natural capital and take provisions to effectively reduce waste and integrate processes cradle to cradle. These processes require Technology and participatory integrated monitoring, and significant investment on the health and survival of remaining natural capital by sponsoring sustainable innovation as a partner on the preservation and adaptation of ecosystem services [19, 27].

This responsibility of the oil industry on Arctic health should not be seen as a penalty but as an opportunity for sustainable development and fair redistribution of ecological wealth by the internalization of externalities that damage the transformation of capital to sustainable economic prosperity. Furthermore, it should be valued as a risk minimization strategy for both shareholders and stakeholders. Oil and gas companies can decarbonize and fund ecological stability in the Arctic and around the world by reducing emissions and by protecting, expanding and creating multiple uses carbon sinks for indigenous and local communities.

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Author's contribution

The author confirms his sole responsibility for the study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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