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Enhancing Science-Driven Blue Growth with an AI-Enabled Cloud/HPC Platform for Strategic Innovation Policy

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ABSTRACT

SDSN Greece, the Black Sea and the Mediterranean, supported by SDSN Europe, have established the Sustainable Euro-Asian Seas Initiative (SEAs) to accelerate science-driven blue growth and SDG implementation in the Euro-Asian Seas and beyond. Two essential components to provide knowledge, legal certainty and security in the blue economy are the following: ensuring marine knowledge to improve access to information about the sea and enforcing maritime spatial planning to ensure efficient, sustainable, job-based and inclusive management of activities at sea. IntelComp (H2020 project) seeks to build an innovative Cloud Platform that will offer AI-based services to public administrators and policymakers across Europe for data- and evidence-driven STI policy design and implementation. One of IntelComp's focus areas is the climate change challenge, targeting the Blue Growth perspective. Within the project's framework, Living Labs (LLs) will take the role of implementing a co-creation approach and engaging all relevant stakeholders to explore, experiment with and evaluate STI policies at all stages.

Keywords: Blue growth; blue economy; sustainable seas; SEAs initiative; IntelComp; STI policy; living labs.

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1. INTRODUCTION

Worldwide observed and anticipated climatic changes for the twenty-first century and global warming are significant global challenges that have been encountered during the past 65 years [1]. The IPCC 2018 Report warns that exceeding a 1.5 ◦C increase in global temperature above pre-industrial levels will lead to unprecedented effects on health, livelihoods, food security, water supply, human security and economic growth [2,3,4]. Surface water has warmed, on average, by about 0.6–0.8 ℃ from pre-industrial times to 2010. Depending on future emissions scenarios, sea surface temperatures could rise by an average of 0.7 ℃ to 2.6 ℃ by the end of the twenty-first century, according to the most optimistic and pessimistic scenarios [5]. This will be catastrophic for our seas and oceans, which are pillars of the European economy and exhibit great potential for innovation and growth. Two essential components to provide knowledge, legal certainty and security in the blue economy are the following: ensuring marine knowledge to improve access to information about the sea and enforcing maritime spatial planning to ensure efficient, sustainable, job-based and inclusive management of activities at sea [6].

The SDSN Sustainable Euro-Asian Seas (SEAs) Initiative seeks to accelerate science-driven blue growth and the implementation of the United Nations Sustainable Development Goals (Agenda 2030) in the Euro-Asian Seas and beyond. SDSN SEAs Initiative is led by SDSN Greece, SDSN Med and SDSN Black Sea via SDSN Europe [7]. IntelComp (funded by H2020) is setting out to build an innovative Cloud Platform that will offer Artificial Intelligence- based services to public administrators and policymakers across Europe for data- and evidence-driven policy design and implementation in the field of Science, Technology and Innovation (STI) policy [8]. One of the three pilots in the IntelComp project focuses on addressing the challenge of climate change, specifically targeting the perspective of Blue Growth. IntelComp presents a model for a collaborative ecosystem that facilitates the development of policies in collaboration with individuals. The aim is to address the lack of information sharing and enable a wide range of stakeholders to actively engage in creating agendas, making policies, implementing them, and assessing their progress. Living Labs are suggested to execute the co-creation strategy by involving many stakeholders such as public policymakers, academics, industry, SMEs, local actors, civil society, and citizens. The purpose is to research, experiment with, and assess science, technology, and innovation (STI) policies at every level [9].

2. CLIMATE CHANGE IN THE MEDITERRANEAN, CASPIAN AND BLACK SEAS

The Mediterranean Sea is one of the fastest warming ocean regions due to its geographical position between the semi-arid and arid climate of North Africa and the temperate climate of Central Europe, leading to a climate particularly vulnerable to minor modifications of the general circulation [10,11]. Additionally, the Mediterranean's semi- enclosed nature restricts the hydrological exchange with the open ocean, allowing the Mediterranean to store heat. This semi-enclosed nature makes the endemic marine biota extremely vulnerable to alterations to their

environment, as several pieces of research have shown [12,13,11,14]; this has led to significant decreases in local populations of cold-water species, while easing the arrival and adaptation of alien species through the Suez Canal [8].

The mean temperature of the Mediterranean basin has increased by 1.4 degrees Celsius since the late 19th century, compared with the global average of 1.1 degrees. Temperature is projected to increase by an additional 1.5 degrees by 2050 [15] leading to an increased risk of drought, water stress and extreme natural events, such as wildfires and floods. Climate change affects the Mediterranean Sea on multiple levels. The already uneven distribution of water resources will pose a greater challenge as freshwater resources will be less available due to significant expected increases in the length of meteorological dry spells [16]. As a result, river flow and lake levels will be reduced and combined with the sea-level rise and the increased groundwater use for agricultural purposes will aid in salt-water intrusion, which is already a major issue in regions located by the sea. Seasonal changes that already take place in the Mediterranean area in a combination of mixed land use, are responsible for drier lands and a higher fire risk, longer fire seasons and severe fire events, which can already be seen in the latest forest fire events that took place in Italy, Greece and Turkey.
Another major challenge arising from climate change and the interconnection of land and sea is food production, as extreme events may bring losses to crops, while ocean warming, and acidification directly impact fisheries and aquaculture. Finally, due to temperature increases, new challenges in human health are emerging. Increased temperature eases the transmission of vector-, water- and food-borne diseases in the Mediterranean, while droughts, water scarcity, food redundancy and economic instability are expected to increase human insecurity and lead to increased migration rates within the Mediterranean region [17,8]. Similar consequences are expected in the planet's largest inland seas: the Black and Caspian Seas. As is expected, global warming will affect their circulation, temperature and freshwater balance, thus impacting coastal and marine ecosystems.

The Black Sea is a meromictic basin with anoxic conditions below 200 m. As a result, biological life is supported by the upper thin layer (0–200 m), as the deeper and denser water layers are saturated with hydrogen sulfide. An analysis of the circulation patterns in the Black Sea Basin has shown that through the years, a warming trend has been observed in the middle layer of the Black Sea that may alter its stratification. This means that sulfide, noxious and corrosive chemicals from the bottom of the Black Sea will be freed to the upper surface layer, ensuing hazardous consequences on the Black Sea's biota [18]. Furthermore, a reduction in wind stress curl over the basin of the Black Sea is expected, which will lead to a speed decrease of the Rim Current circulation, thus affecting water quality, larvae and pollutant dispersal [19].

In contrast to the Mediterranean and the Black Sea, the Caspian Sea is a closed basin. As an endorheic basin that does not have an outflow, its water levels are determined by balancing precipitation, run-off input from the Volga River and evaporation. Models show that global warming will lead to a freshwater imbalance

that, integrated over 50 years, will result in a 5 m drop in sea level [8]. This will lead to a great retrieval of the shoreline, greatly impacting the Caspian Sea ecosystems [19]. Other studies argue that under medium to high emission scenarios, the projected fall of the Caspian's water level ranges from 9 m to 18 m [20]. This means that a great area will emerge from under the sea's surface, leading to severe stress on biodiversity and the economy [21]. Specifically, shallow-water habitats will disappear, removing a major food source for fish, migrating birds and the endangered Caspian Seal, as well as spawning grounds for endemic and/or endangered species. Moreover, this decline in the water level will directly affect the economies of the region, especially the shipping activity inside and outside of the Sea via the Volga- Baltic Waterway and the Volga-Don Canal [21]. A qualitative assessment has shown that environmental shifts have already made their impact on the Caspian ecosystem structures and functioning [22].

3. SYSTEMS INNOVATION APPROACH

Section 2 provided a detailed description of the situation in the three seas, namely, the Mediterranean, Caspian and Black Seas, and this is an essential starting point for the living labs that will follow. The approach we use to design and run the living labs is the Systems Innovation Approach (SIA) [22]. Systems innovation is defined as an "interconnected set of innovations, where each influences the other, with innovation both in the parts of the system and in how they interconnect" [23]. The SIA represents a fundamental shift in how knowledge generation is perceived, and, as a result, accepted. It turns the focus away from technological breakthroughs and research and onto the entire innovation process, of which research is just one of the components. This framework lays the groundwork for the IntelComp platform's evolution, which will necessitate active engagement in agenda- setting and policymaking, as well as execution, monitoring and collaboration among key stakeholders.

The foundations of the SIA include creating a conducive environment for stakeholders to express their opinions and achieve a holistic understanding of their demands. The first step in deciphering the interactions and thinking about how to solve them is to agree on what the problems are. In this paper, we employ a series of bi-monthly sessions with two stakeholder groups: one for the Mediterranean case study and one for the Black and Caspian case studies, as presented in Fig. 1 [8]. Stakeholders from countries highlighted in yellow will be invited to both living labs and represent the connecting players among the two stakeholder groups. The target groups of these living labs are representatives from the government at the national, regional, and international level, policymakers, academics, researchers, experts, experienced professionals and technology providers, ensuring scientific support, analysis and democratic feedback on the design of commonly accepted metrics and actions for a sustainable future [24].

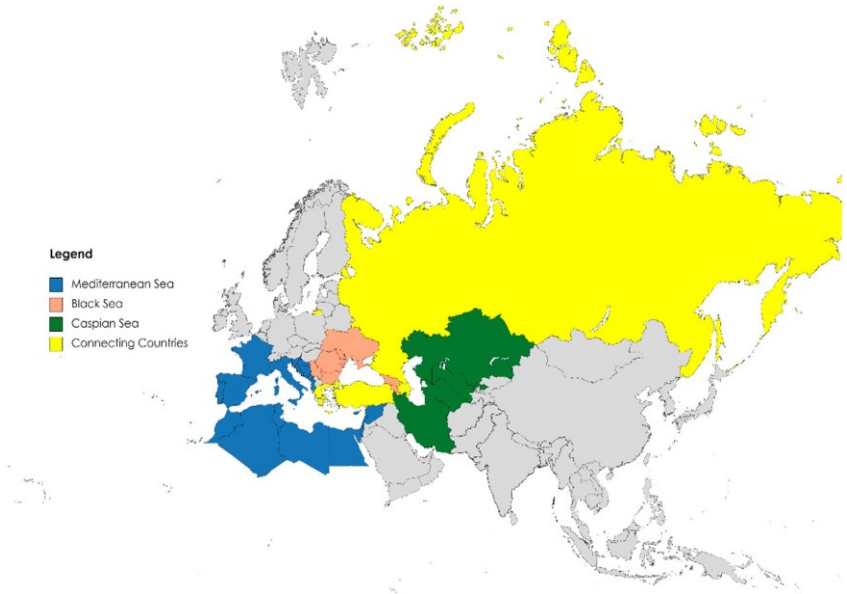

Fig. 1. Division of countries into groups (Map created with mapchart.net)

The first step of the proposed methodology is to present the issue from a scientific perspective based on the literature [8]. The cases of these three Seas are very interesting as the frequency and impact of climate disasters (floods, droughts, extreme weather) will increase within Europe, North Africa and East Asia in the coming decades. To face this challenge and reduce the cost and impact of resulting damage, Europe, North Africa and East Asia need a systemic network offering easily accessible information.

The next step is the stakeholder management process. This process is composed of two steps: stakeholder analysis and stakeholder engagement. Stakeholder analysis aims to identify relevant stakeholder groups, as well as their behavioral patterns, their initial preferences, their requirements and the relationships among them. At this stage, we employ tools to rate stakeholders on two or three essential traits, identify possible synergies or conflictive relationships and create patterns of knowledge and resource flow, which may be interpreted as power flows [25]. Stakeholder engagement refers to both the approach we will utilize to bring all parties together and the level at which they will be fully incorporated into the process. Stakeholders were invited to form the core stakeholder group that will engage in the Living Labs based on their preliminary interest, relevance and expertise in the field, or they will be considered latent [8].

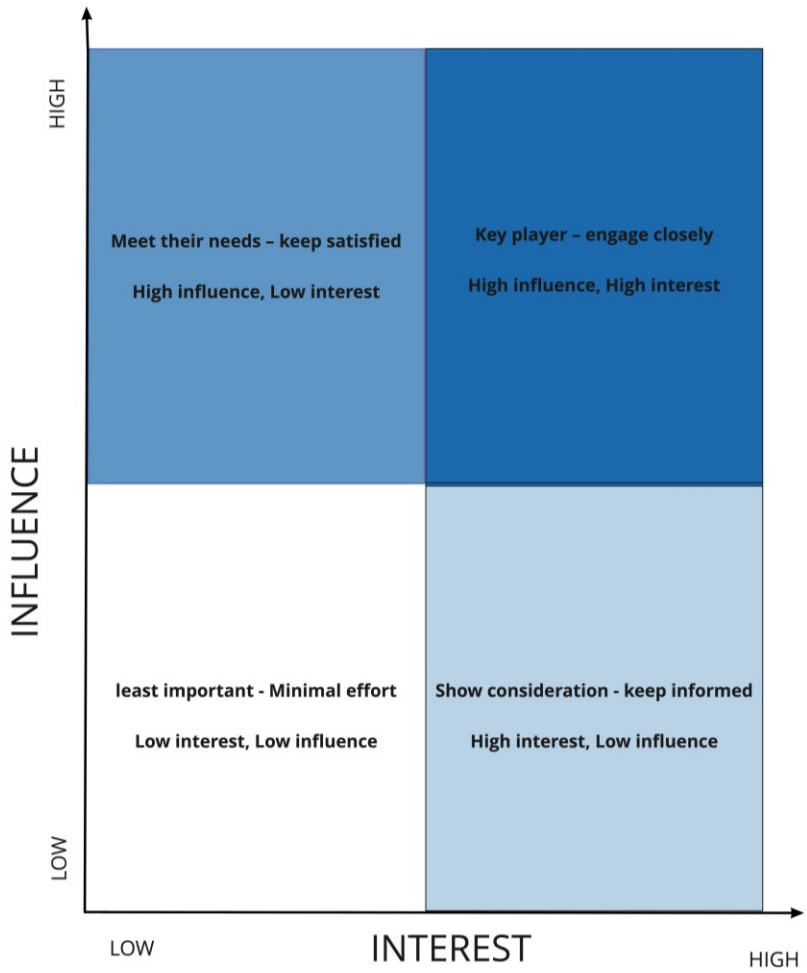

Fig. 2. Influence-Interest Matrix

The stakeholders were assessed and evaluated using the framework of an 'influence/interest' matrix (Fig. 2). In this context, 'influence' refers to the stakeholder's ability and capacity to bring about change, while 'interest' refers to the likelihood of the stakeholder engaging in activities or initiatives related to the focus of the case study. This engagement may be driven by potential benefits or adverse effects [26]. After the plotting process is finished, the map undergoes validation by an external expert, such as members of the project advisory board or other local specialists.

By using this matrix, we were able to assess the position of each stakeholder in reference to these two criteria. The objective of this analysis was to determine the most appropriate group of stakeholders to participate in the LLs. The stakeholders situated in the upper right quadrant, exhibiting substantial influence and interest, will form the central group from whom the LL members will be selected. However, the involvement of stakeholders from the lower right and upper left quadrants (i.e., those with low interest and low influence) is also considered. This is because these groups also include individuals who can play a key role in implementing potential recommendations, and the latter group consists of individuals with significant local expertise but limited decision-making power (i.e., their opinions are often ignored). By following this process for participant selection in the LL, it becomes feasible to identify the stakeholders who are most relevant to the study and are more likely to be engaged in the research efforts. While utilising MAFs can offer advantages in engaging powerful decision-makers, it is also feasible to identify stakeholders who are prepared to commit time and effort to support the study process by assessing their 'Interest' [27,28].

After the identification of stakeholder representatives, we facilitate their active participation in structured workshops, with the goal of comprehensively addressing the issue of climate change in these Seas from multiple perspectives(environmental, political, technological, social, and economic). In this phase, our objective is to analyse the problem by deconstructing it into its individual components. The objective of this stage is twofold: firstly, to reveal concealed underlying causes and issues that are not documented in the literature, and secondly, to facilitate the unimpeded progression of profound listening, to acquire knowledge. The latter has profound consequences, as progressing to the further stages of the SIA, requires stakeholders' ability to understand the viewpoints of the other parties for maximum advantage.

The next concept is the multi-level perspective (MLP), which is an analytical approach designed to determine the process of innovation generation and the key features of transition in socio-technical systems. The MLP categorizes the system into three distinct levels: the macro-level (landscape), the meso-level (regimes), and the micro-level (niches of innovation). At the macro-level (landscape), exogenous, long-term, autonomous tendencies and major crises, such as climate change, urbanisation, and unforeseen calamities, are portrayed. The topography can generate stress, which exerts a significant influence on the remaining two strata. Regimes consist of influential stakeholders who have a vested interest in maintaining the status quo. They determine the elements that shape the structure of the system, including laws, institutions (political, financial, social), user conduct, and cultural norms. Ultimately, the domains of innovation, including universities, research institutions, R&D departments, and the Military, can be seen as the birthplaces of groundbreaking innovations and ideas. We are endeavouring to comprehend the functioning of the system pertaining to the issue to recognise potential chances or significant risks [25].

Once we fully understand the problem, we move forward with the development of the vision. This approach involves seeing a future scenario that is both achievable

and desirable, where the current problem has been resolved. In order to comprehend the influence of a vision, it is necessary to thoroughly examine its underlying basis, which is comprised of expectations. Visions are formed based on collective expectations and, by their very nature, cannot be fully realized, as expectations are adaptable and open to reinterpretation to some extent until the point at which they are realized [29]. Nevertheless, co-developing a vision is essential for agreement on the measures and changes that need to be done.

Finally, to accomplish the co-developed vision, we create change trajectories, that will strive to untangle how the system changes and where innovation originates from [8]. The stakeholders will have the chance to co-develop the needed trade-offs during this phase. We employ methods to aid in the interpretation of sources of resistance and resilience to system changes, as well as the distance between options that co-evolve simultaneously in distinct trajectories and the optimization of co-decided actions under various scenarios using time frames.

Stakeholder co-development of change trajectories can provide credibility to national and sectoral interpretations, while also revealing significant uncertainties or flows. Pecl et al. [30] argue that involving and educating the public on scientific topics may help to transform people's minds, attitudes and behaviours [30]. This strategy aims to ensure stakeholder commitment to the co-developed solutions by testing the hypothesis that a sense of "belonging" and "co-developing" will lead to behavioural change. The SIA process is followed by leading conversations during meetings and the tools mentioned can be applied using visual collaboration platforms, such as MIRO, which allows for the efficient and effective intuitive cooperation of stakeholders.

4. PRIMARY RESULTS AND FUTURE RESULTS

Between June 2021 and February 2022, seven workshops were conducted as part of the Preparatory Living Lab. These workshops aimed to explore the core emphasis of the Climate Change case study within the IntelComp project. These workshops included participants from the Mediterranean and Black-Caspian Seas regions. This was done since climate change cannot be effectively addressed at a local level alone, and the policies being developed are significantly influenced by global trends and occurrences.

The stakeholders who participated in the Preparatory Living Lab (PLL) came from the triangle of knowledge: namely, research, education and innovation, as well as civil society, private sector and public and regulatory authorities. In particular, the following institutions attended the meeting:

- **Institutes and Research Innovation Centres**
- Belgium: Centre for Social InnovationCyprus: The Cyprus Institute
  - Greece: ATHENA Research and Innovation Centre, Hellenic Centre for MarineResearch (HCMR), Solmeyea, Machinor
  - Italy: Eurac Research
  - Kazakhstan: Ban Ki-moon Institute for Sustainable Development

at KazNUNetherlands: KWR Water Research
- Spain: Basque Centre for Climate Change

- **Universities and Educational Institutions**

- Greece: Athens University of Economics and Business (AUEB), Aristotle Univer-sity of Thessaloniki (AUTh), National Technical University of Athens (NTUA), Kazakhstan: Nazarbayev University, Narxoz University
- India: ICFAI Business School (IBS)-Hyderabad
- Italy: University of Siena, Università degli Studi di CagliariMoldova: Academy of Economic Studies of Moldova Norway: UiT the Arctic University of Norway
- Spain: Universidad Carlos III de Madrid, University of Santiago de CompostelaTurkey: Yeditepe University
- U.K.: University of Plymouth

- **Civil Society**
  - France: SDSN Europe
  - Greece: SDSN Greece, SDSN Black Sea, ECOGENIA
  - Italy: SDSN. Mediterranean
  - Kazakhstan: Solar Power Association of Qazaqstan (SPAQ)

- **Public and Regulatory Authorities**
  - Greece: General Secretariat of Research and Innovation
  - Belgium: European Commission, Conference of Peripheral Maritime Regions (CPMR)
  - Kazakhstan: Project Office of the Prime Minister of Kazakhstan
  - Romania: General Secretariat of the Government—Department of Sustainable Development

The participants were divided into two groups. One group focused on matters related to the Black and Caspian Seas, while the other focused on the Mediterranean Sea, save for the initial introductory session. The primary objective of the introductory workshop was to acquaint the participants with the project's goals and the ramifications of climate change on marine ecosystems. During the following two sessions, participants attempted to solve the mystery surrounding data mining, which is the fundamental element of the platform. The panelists discussed the accessibility and availability of commonly used national, regional, and global datasets for policy analysis and research. In addition, they shared national data sources related to the maritime and marine areas. The purpose of this phase of exploration was to understand the gaps in information and monitoring in Greece and its bordering nations.

Following this discussion, a unanimous agreement was established regarding the definition and the basis for further study. Based on our observations, most of the participants in our case comprehended the seriousness and complexity of the data identification problem. They also concurred with most of the various points and details offered during the Living Lab. The participants identified various

deficiencies in the proposed data sources, such as the lack of standardised file formats, availability of daily and publicly accessible data, data validation procedures, reliable and accessible information, geospatial data, data on port facilities, and personnel with the necessary expertise to collect and analyse relevant data.

To overcome data mining and accessibility issues, a multifaceted approach is required, including partnerships with data providers, developing new tools, and establishing clear guidelines. Partnerships with government agencies and public institutions can provide access to high-quality, verified data. Engaging with private sector and non-profits can offer access to proprietary datasets or collaborative opportunities for data sharing. Developing new data collection tools, such as advanced sensors and IoT devices, crowdsourcing platforms, and AI and machine learning algorithms, can help extract meaningful insights from complex data. Standardization of data formats, ethical guidelines, and comprehensive data documentation are essential for easier data integration and interoperability. Education and training programs, such as data literacy programs and workshops, can improve data literacy among stakeholders. Infrastructure investments, such as cloud-based data platforms and open data portals, can also help manage large datasets efficiently. Overall, a comprehensive approach is needed to overcome data mining and accessibility issues.

The energy and agrifood sectors were delineated as the primary areas of focus in the 2nd and 3rd workshops, due to their significant potential for exploitation in response to climate change adaptation and mitigation. During our conversation, we explored the industrial aspects of the energy and agrifood industries. The consortium delved into topics such as incorporating innovation into daily business operations, identifying sources of new research, staying updated on changing regulatory frameworks, and determining if businesses have been involved in EU-funded projects.

During the 4th and 5th workshops, participants from the Mediterranean and Black Sea/Caspian Sea regions showed great interest in the energy industry. The discussions mostly revolved around offshore investments, developing technologies, and wind power. They discussed the challenges of determining the most effective energy balance and the implementation of renewable projects, focusing on the key elements to consider when making energy investments. There is expected to be significant interest in the future on the ideal combination of factors such as climate change, sea level impact, technological advancements, and infrastructure development. The participants had the chance to discuss and share their perspectives on various energy sources, including LNG, hydrogen, methanol, ammonia, and nuclear energy. They also discussed the importance of conducting thorough analytical assessments before investing in renewable energy sources like solar, wind, geothermal, and hydropower.

The Agri-food sector, encompassing food production, distribution, and agriculture, was the central theme of the 6th and 7th workshops. It is closely intertwined with climate change in several ways. Participants emphasised the role of agriculture in generating greenhouse gas emissions, such as methane produced by livestock

digestion, the release of nitrous oxide from the use of synthetic fertilisers (which is a powerful greenhouse gas), and the emissions from agricultural machinery, transportation, and fossil fuel usage in food processing. Additionally, they expressed interest in the topics of food security and distribution, as well as the techniques for adaptation and mitigation. Adaptive measures involve using irrigation technologies that conserve water, choosing crop varieties that are resilient to climate change, and adjusting the timing of planting. Mitigation measures encompass the reduction of greenhouse gas emissions through reforestation, improved land management, and the adoption of sustainable farming practices. Additionally, they expressed interest in understanding the correlation between policy and innovation, the efforts to decrease deforestation, the policies that support sustainable agricultural practices, and the impact of renewable energy on farming operations. These measures aim to reduce the sector's impact on climate change.

The PLL provided the participants with access to a wide range of materials and data that they may not have otherwise come across. It also improved their understanding of the various tactics used by different countries to address climate change. The research undertaken in the PLL has highlighted the energy and agrifood challenges as highly significant subjects in the area. The Living Lab on Adaptation to Climate Change aims to present the Greek STI-Climate Change ecosystem, with a specific focus on the energy and agrifood sectors, in order to support well-informed decision-making. Therefore, they focus their efforts on the environment, society, science, industry, and policy to provide information and knowledge to decision-makers on the consequences of these two domains on climate change.

To summarise, this PLL aimed at increasing participants' enthusiasm for the IntelComp platform, ensure their utilisation of it, and educate them on the energy sector's role in mitigating climate change and relevant regulations. In addition, they conduct technological assessments and forecasts, analyse upcoming advancements and technologies and their impact on policy development, and examine national strategies that form the basis for policy decisions to ensure that the public is better informed, alert, and receptive (especially regarding initiatives related to climate change technologies).

These workshops were supported by the UN SDSN SEAs Initiative, which intends to boost science-driven blue growth in the Euro-Asian Seas and beyond, as well as the realization of the United Nations Sustainable Development Goals (Agenda 2030). The initiative aims at gathering the efforts of SDSN National and Regional Networks on Blue Growth in an interdisciplinary framework [8]. A regular annual report on Technological, Economic and Social Transition Pathways of systemic transformation will be introduced, as it is required for the realization of Agenda 2030 in our seas and oceans, including Science- Technology and Innovation-Policy interface agenda-setting, model design, implementation, monitoring and evaluation. This initiative builds on SDSN Greece, SDSN Black Sea and SDSN Mediterranean, which brought together the 4-Seas Initiative, the Global Roundtable for Sustainable Shipping and Ports, the Plastic Busters Initiative, the

newly formed Global Maritime Accelerator and several Blue Growth research projects.

Each stage is accomplished through monthly workshops. Due to COVID-19 restrictions, the meetings are held online using the Zoom platform and MIRO software is used for the analysis. Each stage is enriched and supported by a variety of tools based on the needs of each workshop and the specificities of the living lab (i.e., what are their interests, needs, conflict points etc.).

A multifaceted approach that addresses resource constraints, ensures stakeholder engagement, and facilitates continuous improvement is necessary to scale and sustain Living Labs over the long term. Initially, it is imperative to obtain a diverse array of funding sources in order to address potential resource constraints. This can be accomplished by establishing partnerships with academic institutions, private investments, and public grants. Private investments and corporate sponsorships can provide ongoing financial support, while public grants can provide initial foundation funding. A symbiotic relationship that benefits both parties can be established by partnering with universities, which can provide access to research funding and resources. For instance, the European Network of Living Labs (ENoLL) frequently employs a variety of funding sources to sustain its diverse initiatives throughout Europe [31].

The long-term success of Living Labs is contingent upon the ongoing engagement of stakeholders. This can be accomplished by cultivating a robust sense of community and ownership among participants. The maintenance of high levels of engagement can be facilitated by the inclusion of stakeholders in key planning and evaluation stages, transparent decision-making processes, and regular communication. Diverse perspectives can be considered by establishing advisory committees that include representatives from a variety of stakeholder groups. Furthermore, stakeholders can be actively engaged and invested in the outcomes by conducting regular seminars, hackathons, and co-creation sessions. For example, the Amsterdam Smart City initiative guarantees sustained interest and participation by engaging a diverse array of stakeholders through ongoing collaboration and co-creation activities.

The implementation of iterative development processes and robust feedback mechanisms is essential for ensuring continuous improvement in Living Labs. The identification of areas for development and the subsequent adaptation of strategies can be facilitated by the regular monitoring and evaluation of projects. The capacity to monitor progress and impact can be improved by utilising digital tools and platforms for real-time data collection and analysis. Encouragement of a culture of experimentation and learning within the Living Lab can also foster innovation and adaptability. For example, the iHub Nairobi Living Lab employs continuous feedback loops and iterative development to continuously refine its solutions and guarantee that they align with the changing requirements of the community [32]. Living Labs can effectively scale, sustain their operations, and perpetually enhance their impact over time by incorporating these strategies.

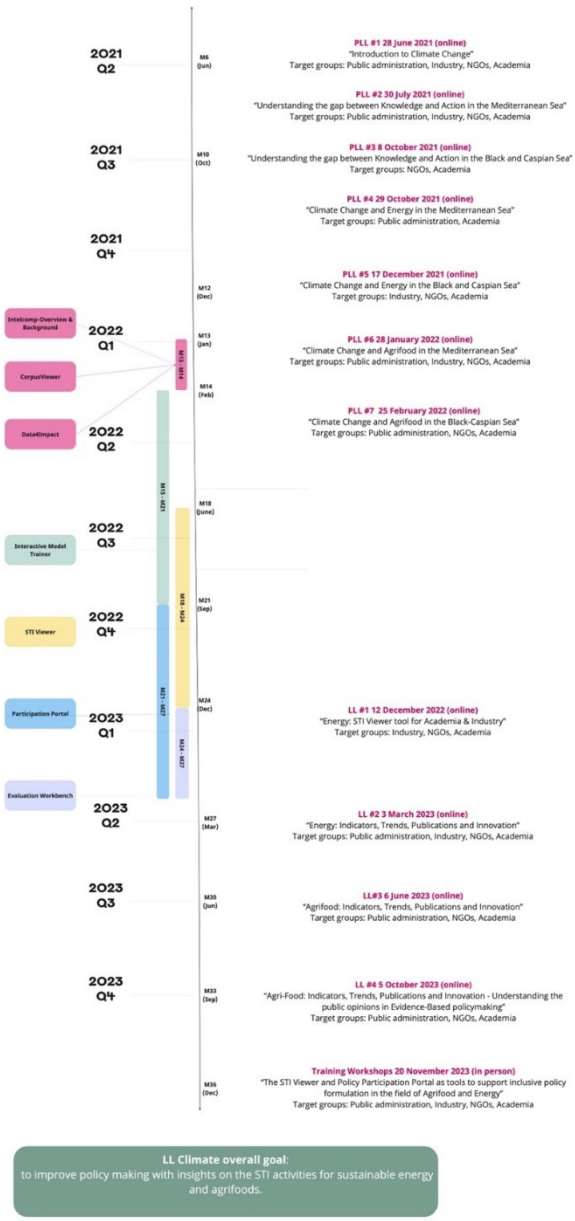

Fig. 3. LL Climate Change – Timeline of preparatory and planned Living Lab workshops

5. CONCLUSIONS

The SIA, or Systemic Innovation Approach, is a potent framework for addressing intricate challenges. It takes into account the dynamics of a given system and issues related to the behaviour of stakeholders to determine the feasibility of tackling the challenge. The process of policy formation, adoption, and implementation is a challenging issue because of the interconnectedness of the stakeholders and their adherence to certain standards, which they rely on to accomplish various social, economic, and environmental objectives. The SIA offers a theoretical framework to enhance comprehension and methodically examine the relationships between the natural and economic environment and human activities. Its goal is to promote more organised management and utilisation of these seas, considering various sectors and scales.

The SIA, when backed by robust scientific evidence, is an influential instrument. The ongoing research in the Mediterranean and Black Caspian Seas contributes to a deeper comprehension of various viewpoints, methodologies, and interconnected systems. Furthermore, it exposes and tackles underlying deficiencies in the institutional framework, the autocratic conduct of the government, misguided notions about the handling of marine resources, and deficiencies in collaboration among different interest groups. The collaborative growth of a shared vision is a crucial catalyst that relies on mutual comprehension and objectives within a collective aim, which surpasses personal interests without diminishing them.

A series of seven workshops were conducted as part of the Preparatory Living Lab (PLL) between June 2021 and February 2022. The primary objective of these seminars was to investigate the fundamental focus of the Climate Change case study within the IntelComp project. The following are the results of these seminars. Participants from the Mediterranean and Black-Caspian Seas regions participated in these seminars. This was necessary due to the fact that climate change cannot be effectively addressed at a local level alone, and the policies that are being developed are substantially influenced by global trends and occurrences. The stakeholders who participated in the PLL were drawn from the triangle of knowledge, which encompasses research, education, and innovation, as well as civil society, the private sector, and public and regulatory authorities.

The workshops focused on the impacts of climate change on marine ecosystems in the Black and Caspian Seas and the Mediterranean Sea. Participants discussed data mining, data availability, and gaps in information in Greece and its neighboring countries. The energy and agrifood sectors were identified as areas of focus, spurring discussions on innovation, research, regulatory updates, and EU-funded projects. The Mediterranean and Black Sea/Caspian Sea regions showed interest in the energy industry, discussing offshore investments, technologies, and wind power. Participants discussed the challenges of determining the most effective energy balance and implementing renewable projects. The agri-food sector, encompassing food production, distribution, and agriculture, was central, emphasizing the role of agriculture in generating

greenhouse gas emissions. Participants discussed adaptation and mitigation measures, such as using irrigation technologies, choosing resilient crop varieties, and adjusting planting timings. They also discussed the correlation between policy and innovation, sustainable agricultural practices, and renewable energy impact on farming operations.

The PLL aimed to present the Greek STI-Climate Change ecosystem, focusing on the energy and agrifood sectors, to support well-informed decision-making. The PLL also aimed to increase participants' enthusiasm for the IntelComp platform, educate them on the energy sector's role in mitigating climate change, and conduct technological assessments and forecasts. The initiative was supported by the UN SDSN SEAs Initiative, which aims to boost science-driven blue growth in the Euro-Asian Seas and beyond, and to realize the United Nations Sustainable Development Goals (Agenda 2030). Monthly workshops were held on Zoom and MIRO software, with tools adapted to each workshop's needs.

To scale and sustain Living Labs over the long term, a multifaceted approach is necessary, including obtaining diverse funding sources, fostering stakeholder engagement, and implementing iterative development processes and feedback mechanisms. This includes establishing advisory committees, conducting seminars, hackathons, and co-creation sessions, and implementing iterative development processes and robust feedback mechanisms. Encouraging a culture of experimentation and learning within the Living Lab can foster innovation and adaptability, ensuring that Living Labs can effectively scale, sustain their operations, and perpetually enhance their impact over time.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Abbass K, Qasim MZ, Song H, Murshed M, Mahmood H, Younis I. A review of the global climate change impacts, adaptation, and sustainable mitigation measures. Environmental Science and Pollution Research. 2022 Jun;29(28):42539-59.
2. European Commission. Consequences of climate change; 2023. Available:https://climate.ec.europa.eu/climate-change/consequences-climate-change_en
3. Masson-Delmotte V, Zhai P, Pörtner H-O, Roberts D, Skea J, Shukla PR., Pirani A, Moufouma-Okia W, Péan C, Pidcock R, Connors S, Matthews JBR, Chen Y, Zhou X, Gomis MI, Lonnoy E, Maycock T, Tignor M,

Waterfield T. Global warming of 1.5°C An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty Edited by Science Officer Science Assistant Graphics Officer Working Group I Technical Support Unit; 2019.
Available:www.environmentalgraphiti.org

4. UNEP. Facts about the climate emergency; 2024.
Available:https://www.unep.org/facts-about-climate-emergency
5. Pedrós-Alió C, Gasol JM, Simó R. Oceans: the impact of global change on the sea. Mètode Science Studies Journal. 2021;11:165-171. University of Valencia.
6. European Commission. Maritime spatial planning; 2024.
Available:https://oceans-and-fisheries.ec.europa.eu/ocean/blue-economy/maritime-spatial-planning_en
7. SDSN Europe. UN SDSN SEAs Initiative; 2024.
Available:https://sdsn.eu/un-sdsn-seas-initiative/
8. Koundouri P, Theodossiou N, Ioannidis Y, Papageorgiou H, Papandreou A, Papadaki L, Stavridis C. Accelerating science-driven blue growth via a competitive intelligence Cloud/HPC platform for AI-Based STI policy making. Environmental Sciences Proceedings. 2022 May 31;15(1):68.
9. IntelComp. Intelcomp; 2023.
Available:https://intelcomp.eu/
10. Giorgi F, Lionello P. Climate change projections for the Mediterranean region. Global and Planetary Change. 2008;63(2–3):90–104.
Available:https://doi.org/10.1016/J.GLOPLACHA.2007.09.005
11. Marbà N, Jordà G, Agustí S, Girard C, Duarte CM. Footprints of climate change on Mediterranean Sea biota. Frontiers in Marine Science. 2015;2(AUG):155437.
Available:https://doi.org/10.3389/FMARS.2015.00056/BIBTEX
12. Calvo E, Simó R, Coma R, Ribes M, Pascual J, Sabatés A, Gili JM, Pelejero C. Effects of climate change on Mediterranean marine ecosystems: the case of the Catalan Sea. Climate Research. 2011;50(1):1–29.
Available:https://doi.org/10.3354/CR01040
13. D'Amen M, Azzurro E. Lessepsian fish invasion in Mediterranean marine protected areas: A risk assessment under climate change scenarios. ICES Journal of Marine Science2020;77(1):388–397.
Available:https://doi.org/10.1093/ICESJMS/FSZ207
14. Occhipinti-Ambrogi A. Global change and marine communities: Alien species and climate change. Marine Pollution Bulletin. 2007;55(7–9):342–352.
Available:https://doi.org/10.1016/J.MARPOLBUL.2006.11.014
15. McKinsey Sustainability. How hot summers and disease could impact tourism in the Mediterranean; 2024.
Available:https://www.mckinsey.com/capabilities/sustainability/our-insights/sustainability-blog/hot-summers-and-disease-threaten-tourism-in-the-mediterranean

16. Schleussner CF, Lissner TK, Fischer EM, Wohland J, Perrette M, Golly A, Rogelj J, Childers K, Schewe J, Frieler K, Mengel M, Hare W, Schaeffer M. Differential climate impacts for policy-relevant limits to global warming: The case of 1.5 °c and 2 °c. Earth System Dynamics. 2016;7(2):327–351. Available:https://doi.org/10.5194/ESD-7-327-2016
17. Cramer W, Guiot J, Fader M, Garrabou J, Gattuso JP, Iglesias A, Lange MA, Lionello P, Llasat MC, Paz S, Peñuelas J, Snoussi M, Toreti A, Tsimplis MN, Xoplaki E. Climate change and interconnected risks to sustainable development in the Mediterranean. Nature Climate Change 2018;8(11):972–980. Available:https://doi.org/10.1038/s41558-018-0299-2
18. Girleanu A, Rusu E. An evaluation of the main physical features and circulation patterns in the black Sea Basin. Journal of Marine Science J. Mar. Sci. 2021;3(1). Available:https://journals.bilpubgroup.com/index.php/jms/article/view/2552/2506
19. Huang L, Lee SS, Timmermann A. Caspian sea and black sea response to greenhouse warming in a high-resolution global climate Model. Geophysical Research Letters. 2021;48(4). Available:https://doi.org/10.1029/2020GL090270
20. Nandini-Weiss SD, Prange M, Arpe K, Merkel U, Schulz M. Past and future impact of the winter North Atlantic Oscillation in the Caspian Sea catchment area. International Journal of Climatology. 2020;40(5):2717–2731. Available:https://doi.org/10.1002/JOC.6362
21. Prange M, Wilke T, Wesselingh FP. The other side of sea level change. Communications Earth & Environment 2020 1:1,1(1):1–4. Available:https://doi.org/10.1038/s43247-020-00075-6
22. Kashkooli OB, Gröger J, Núñez-Riboni I. Qualitative assessment of climate-driven ecological shifts in the Caspian Sea. PLOS ONE. 2017;12(5):e0176892. Available:https://doi.org/10.1371/JOURNAL.PONE.0176892
23. Mulgan G, Leadbeater C. Systems innovation. discussion paper. Nesta; 2013.
24. Alamanos A, Koundouri P, Papadaki L, Pliakou T. A system innovation approach for science-stakeholder interface: Theory and application to water-land-food-energy nexus. Frontiers in Water. 2022;3:744773. Available:https://doi.org/10.3389/FRWA.2021.744773/BIBTEX
25. De Vicente Lopez J, M. C. Visual toolbox for system innovation. A resource book for practitioners to map, analyse and facilitate sustainability transitions. Transitions Hub Series. Climate-KIC; 2016.
26. Eden C, Ackermann F. Analysing and comparing idiographic causal maps; 1998.
27. Brugha R, Varvasovszky Z. Stakeholder analysis: A review. Health Policy and Planning. 2000;15(3):239–246. Available:https://doi.org/https://doi.org/10.1093/heapol/15.3.239
28. Mendelow AL. Environmental scanning-the impact of the stakeholder concept. Association for Information Systems AIS Electronic Library (AISeL); 1981.

Available:http://aisel.aisnet.org/icis1981/20
29. Berkhout F. Normative expectations in systems innovation. Technology Analysis & Strategic Management. 2006;18:299–311.
Available:https://doi.org/10.1080/09537320600777010
30. Pecl GT, Stuart-Smith J, Walsh P, Bray DJ, Kusetic M, Burgess M, Frusher SD, Gledhill DC, George O, Jackson G, Keane J, Martin VY, Nursey-Bray M, Pender A, Robinson LM, Rowling K, Sheaves M, Moltschaniwskyj N. Redmap australia: Challenges and successes with a large-scale citizen science-based approach to ecological monitoring and community engagement on climate change. Frontiers in Marine Science. 2019;6(JUN):448710.
Available:https://doi.org/10.3389/FMARS.2019.00349/BIBTEX
31. ENoLL. European Network of Living Labs , Living Labs network European Network of Living Labs; 2024.
Available:https://enoll.org/
32. iHUB. iHUB – Driven by people, enabled by technology; 2024.
Available:https://ihub.co.ke/

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