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# Preparatory living lab workshops under the IntelComp platform: An enabler of the solution for sustainability challenges of climate change in Greece

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The phenomena of climate change transcend all national and regional boundaries. To address this complex challenge, we must determine the areas of the country of interest, in this case, Greece, that have been most adversely affected by climate. Greece is surrounded by water, and a significant part of its GDP is derived from the marine and maritime industries, including tourism. Since the start of the IntelComp project, a Preparatory Living Lab (PLL) has been planned and delivered, feeding into the development of the IntelComp platform and the Living Lab on Climate Change Adaptation. The study's results lead to the conclusion that one of the most important challenges in tackling climate change is the decarbonisation challenge, specifically the shift to renewable energy sources and the investments that must be made. Several EU and national policy frameworks, including the European Green Deal, the Climate Law, the National Long-term Strategy for 2050 (on the Climate and Energy), highlight the decarbonisation as one of the major challenges in the climate change pledge. This will be the primary subject of the IntelComp climate change case study. PLLs also led to the identification of policy questions and useful data sources to aid the IntelComp project's launch. While previous research on co-production has primarily focused on involving citizens through public participation processes in order to gain their support, trust, and insights in structured decision-making processes, our approach opens a new channel for incorporating external knowledge into problem-solving processes. The IntelComp project will aid in policy development by providing pertinent tools co-developed with the final users that will provide insights and analysis in the field of STI (Science, Technology, Innovation) encompassing all of the Energy areas mentioned above.

KEYWORDS

**living lab, climate change, IntelComp project, Greece, Mediterranean Sea**

## 1. Introduction

Climate Change is a phenomenon that knows no national or regional limits. Its effects can be seen in both the natural and human spectra such as, human health, agriculture and food, forest fires, alterations in ocean salinity etc. The rising population and disposable income together with the fast and linear consumption model led to skyrocketing the Greenhouse Gas (GHG) emissions in the last century and to a climate crisis which is

accompanied by significant biodiversity losses, extreme weather events and more and more frequent catastrophes all around the world.

Climate change exacerbates pressures on oceans and coasts, bringing to the forefront one of its most serious consequences: global mean sea level rise. Throughout the past century, sea level has been increasing, and recently, the rate has accelerated. The highest annual average in the satellite record, the global sea level in 2023 was 103 mm higher than the average for the year 1993 (NASA, 2023). Sea level rise is primarily caused by two global warming-related factors: the addition of water from melting ice sheets and glaciers, and the expansion of seawater as it warms.

However, there is considerable uncertainty about how the climate will change in the future and what the actual effects on sea level rise will be. The two most important uncertainty factors associated with climate change and, thus, sea level rises are climate sensitivity (i.e., the increase in global mean temperature in response to an increase in atmospheric concentrations) and the rate of heat uptake by the deep ocean. If it is expected that uncertainty will never be completely removed, it is preferable to take action early on the basis of a significantly higher cost of damages compared to the cost of abatement and the precautionary principle (Kontogianni et al., 2014).

Thus, we need to identify the areas most impacted by climate change in the country of interest, in this case, Greece. Greece is surrounded by sea, and it is known for its dense coastline population, with estimates placing coastal areas as home to about 57% of the nation's residents (Polyzos and Tsiotas, 2012). In addition, most of its GDP is dependent on the marine and maritime sectors (including tourism), which are sensitive to the climate crisis, from rising sea levels and water acidification to decreasing fishing stocks and biodiversity loss (Prandeka and Zarkos, 2014; Kyvelou and Ierapetritis, 2019). These effects have a direct impact on the human though five interconnected domains, namely, water resources, ecosystems, food safety and security, health, and human security, which have an impact on the tourism and the agriculture sectors of Greece.

Thus, adaptation to climate change in Greece cannot be addressed without approaching the challenges in the Mediterranean Sea and its neighbor and connected seas, the Black, Caspian and Aral, which see no boundaries. To understand the interreferences of these impacts, we need to gather existing knowledge embedded in the regional fabric by mobilizing and enabling cooperation across key actors in these countries. Living Labs offer a real-life testbed where stakeholders work together in co-designing and co-creating holistic solutions that aspire to solve real challenges.

Living labs have been the subject of academic research for more than a decade (Ballon and Schuurman, 2015; Leminen et al., 2017). The literature that is now available explores living labs as a novel tool, approach, and design for practitioners to overcome a range of issues and demands in today's world, as well as an intriguing topic that offers a wealth of study options for creative researchers (e.g., Voytenko et al., 2016; Rodrigues and Franco, 2018). Living labs are defined by Leminen and Westerlund (2012) as "physical regions or virtual realities in which stakeholders form public-private-people partnerships of firms, public agencies, universities, institutes, and users all cooperating for creation, prototyping, validating, and testing of new technologies, services, products, and systems in real-life contexts."

Living labs are mostly embedded in government structures in the public sector (McGann et al., 2018; Timeus and Gascó, 2018; Lewis et al., 2020). Several drivers and barriers to open innovation processes have been identified in the literature on open innovation in the public sector. Mergel (2018), for example, demonstrates that open innovation processes in government may be constrained by legal considerations or the type of agency involved. In this case, living labs could be used to create an environment in which open innovation processes can be tried out in an experimental manner with fewer costs and risks than open innovation projects organized by a single agency (Leminen et al., 2012).

In the four Seas (Mediterranean, Black, Caspian, and Aral Seas) there are several living labs addressing sustainable development, but none of them addresses climate change as a whole. Table 1 presents a list of the ongoing living labs in several countries located in these regions. Smart cities, sustainable mobility and green energy seem to attract significant interest, with several living labs targeting explicitly these three objectives (e.g., Transilvania Living Lab, SofiaLab, Thessaloniki Smart Mobility Living Lab, SMART Living Lab, Barcelona Living Lab and Smart Santander Living Lab). Among the living labs that aim to address water scarcity, and co-design innovative services and solutions for the agriculture and tourism sectors, are the Living Lab for Water Management (Cyprus), the Santorini Living Lab (Greece), and the Bodrum Living Lab. Finally, the Co-Creation Living Lab in Malta aims to address social challenges such as unemployment, social exclusion, and poverty (ENoLL, 2023).

Climate change is a complex, global issue that necessitates coordinated and concerted action on the part of governments, businesses, and individuals. Climate change policy is inextricably linked to policymaking as governments play an important role in developing policies and regulations that reduce greenhouse gas emissions, promote renewable energy sources, and improve energy efficiency (IPCC, 2018). Carbon pricing or emissions trading schemes, for example, can provide economic incentives for businesses to reduce their emissions. Building codes and energy efficiency standards can encourage the use of energy-efficient technologies and reduce energy consumption in buildings. Renewable energy policies can help to promote the development and deployment of renewable energy sources like wind and solar.

Climate change impacts, such as sea-level rise, more frequent and severe natural disasters, and changes in precipitation patterns, can also be mitigated through policies. Measures to protect vulnerable communities, infrastructure, and ecosystems from the effects of climate change may be included in adaptation policies. Policies could include, for example, land-use planning, building

Abbreviations: CMA, Common Maritime Agenda; EOSC, European Open Science Cloud; HPC, High Performance Computing; LL, Living Lab; MAP, Mediterranean Action Plan; MSSD, Mediterranean Strategy for Sustainable Development; MSP, Maritime spatial planning; PLL, Preparatory Living Lab; SDGs, Sustainable Development Goals; STI, Science, Technology, and Innovation; UNEP, United Nations Environment Programme.

TABLE 1 Living labs in the four seas (Mediterranean, Black, Caspian, and Aral Seas).

| Living lab | City, country | Focus area(s) related to sustainable development |
|---|---|---|
| Barcelona Living Lab | Barcelona, Spain | Smart cities, sustainable mobility and energy |
| Bodrum Living Lab | Bodrum, Turkey | Agriculture, tourism, wellbeing, health and maritime verticals. |
| Co-Creation Living Lab | Valletta, Malta | social challenges such as unemployment, social exclusion, and poverty |
| Digi-Art Living Lab Tunis-Nabeul | Nabeul, Tunisia | Smart cities in North Africa and Euro-Mediterranean area (enhance the transfer of skills, identify new business and funding models, and increase the capacity for transnational cooperation and internationalization) |
| Living Lab for Water Management | Nicosia, Cyprus | Water scarcity and management issues in the Mediterranean region |
| Living Lab Tomsk Network | Russian Federation | Public space design, smart greening, water management, smart management |
| Santorini Living Lab | Santorini, Greece | Sustainable tourism |
| SMART Living Lab | Kozani, Greece | Energy decarbonisation, including smart grids, ancillary services to grid operators, demand side management techniques, photovoltaics and energy storage systems operation optimization. |
| Smart Santander Living Lab | Santander, Spain | Smart cities, including energy efficiency, mobility, and citizen participation |
| SofiaLab | Sofia, Bulgaria | Smart cities |
| Thessaloniki Smart Mobility Living Lab | Thessaloniki, Greece | Sustainable mobility through the provision of novel technologies and innovation. |
| Transilvania Living Lab | Cluj-Napoca, Romania | Smart cities and regions, climate change, earth observation, social innovation. |

Source: ENoLL (2023).

codes, and infrastructure design that considers the projected effects of climate change.

The international regulatory framework, as well as global trends and events, have an impact on national policies (The World Bank, 2023).

In addition to these policy initiatives, global climate negotiations like the Paris Agreement can help shape the global policy landscape for climate change action. The Paris Agreement establishes a framework for reducing greenhouse gas emissions and increasing adaptation efforts in order to keep global temperature rise well below 2°C above pre-industrial levels, and to pursue efforts to keep it below 1.5°C (UNFCCC, 2022).

Public administration at all organizational and geographic levels, STI stakeholders, and civil society produce a significant amount of dynamic, multilingual, and heterogeneous data (such as national STI strategies, plans, and work programmes, calls, projects, reports, scientific publications, patents, dissemination articles, etc.). Understanding and analyzing this data is essential for evidence-based policy making.

The rapid decarbonization challenge together with the broad range of data needed puts an unrealistic demand to policy makers and STI analysts to respond to this great challenge. IntelComp platform, a Horizon 2020 Innovation Action, aims to create a platform that can analyze vast amounts of textual data utilizing services provided by artificial intelligence. It is built in a high-performance computing (HPC) environment, which is a replica of the European Open Science Cloud (EOSC) (Ayris et al., 2016). It analyses Large Science, Technology, and Innovation (STI) datasets and provides three tools, the *STI Viewer*, that will analyze, compare and visualize a comprehensive set of STI related KPIs; the *STI Policy Participation Portal*, that will provide a synthetic list of measurements for participatory STI policy making; and the *Evaluation Workbench*, that will assist in the ex-ante evaluation of STI proposals for funding.

By utilizing open data, services, and computational resources from the EOSC, HPC environments, and federated distributed operations at the European Union, national, and regional level, the platform will support the entire STI policy spectrum, including agenda setting, modeling design, implementation, monitoring, and assessment. The final users of the tool, public administration at all organizational and geographic levels, STI stakeholders, and civil society, will be able to visualize, interact with, and evaluate data.

In our study, we employed Living Labs to co-create the IntelComp platform's tools. A large group of stakeholders was used during the co-development stage to ensure that all aspects of climate change adaptation were addressed. The marine and maritime sectors were the focus of the first round of the Living Lab (Preparatory Living Lab - PLL) on adaptation to climate change in Greece, i.e., the interconnectivity of Greece's surrounding seas, their challenges and policy needs, and what could bridge this gap to ensure blue growth in the region.

The target groups of the living lab on climate change adaptation were public policy makers, academia, industry, SMEs, local actors and civil society, working on the marine and maritime sectors in any of the four abovementioned seas, as they all produce a significant amount of dynamic, multilingual, and heterogeneous data (such as national STI strategies, plans, and work programmes, calls, projects, reports, scientific publications, patents, dissemination articles, etc.). Understanding and analyzing this data is critical for making evidence-based policy decisions. The sections that follow provide an overview of the four seas' sustainability challenges, the methodology, the results of the PLLs, and a discussion of how these results will fit into the IntelComp platform, next steps, and limitations.

## 2. Sustainability challenges in the Mediterranean, Black, Caspian, and Aral Sea

### 2.1. The Mediterranean Sea

The Mediterranean Sea warms faster than other ocean regions due to its geographical position between the semiarid and arid climate of North Africa and the temperate climate of Central Europe, leading to a climate particularly vulnerable to minor general circulation modifications. Its position (semi-enclosed) allows the Mediterranean to store heat, as the hydrological exchange with the open ocean is small. Thus, endemic marine biota is extremely vulnerable to alterations to their environment, while they have to cope with the arrival and adaptation of alien species through the Suez Canal.

The fragility of the Mediterranean Sea is further affected by climate change on multiple levels, such as water distribution, salt-water intrusion, drier lands with higher risk for forest fires and even food production. Extreme events bring losses to crops, while ocean warming and acidification directly impact fisheries and aquaculture. Apart from that, climate change eases the transmission of vector-, water-, and food-borne diseases in the area, while human insecurity is increased due to droughts, water scarcity, food redundancy and economic instability.

The Mediterranean Sea, including the Sea of Marmara, occupies an area of approximately 2,510,000 $km^2$. The Mediterranean region consists of 21 littoral states [Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Jordan, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, Syria (data availability limited to 2007), Tunisia, and Turkey] with a combined population of 529 million, or 7% of the world's population, 205 millions of which live on the northern shore and 324 on the southern and eastern shore, see Figure 1 (Salah and Boxer, 2022; United Nations, 2022).

Given that it is one of the most highly valued seas in the world, the Mediterranean has a variety of significance for the global economy. However, political upheavals and conflicts have frequently impeded the region's progress toward economic integration and growth. The significant north-south component that affects all intra-regional flows, as well as the marked variety of the nations' performance in international commerce, investment flows, and energy (oil and gas) potential, are the two prominent characteristics of the Mediterranean's regional economic links. These traits suggest that, despite a lack of regional integration, there are chances to improve intra-regional ties as the Mediterranean region integrates more fully into the global economy and reaps the benefits of long-standing multilateral and cooperative frameworks in the region (Manoli, 2021).

A complicated security environment, institutional and political variability, uneven economic development, income disparities, and a high degree of variety among the region's coastline nations characterize the region today. Most of the discrepancies can be categorized as a north-south divide, where the northern coasts of the sea have developed, stable societies that have integrated into the EU, while the southern shores have unstable socioeconomic indices.

The Mediterranean Sea, a significant contributor to the regional GDP, today generates enormous economic value through its natural ecosystems and maritime resources. Important maritime-based industries include energy, bioprospecting, deep-sea mining, tourism, fisheries, and aquaculture. Ocean-related industries in the Mediterranean region alone generated US$450 billion in 2017, accounting for 20% of the global yearly gross marine product (GMP) in a region that makes up just 1% of the ocean overall. The Mediterranean GMP's largest contributor was Italy, which was followed by Spain, France, and Turkey (Randone, 2017).

It is safe to conclude that tourism continues to be the main driver of economic growth in the Mediterranean, with 92% of the region's GMP coming from coastal tourism, which is valued at roughly US$300 billion annually, and marine tourist, which is valued at about US$110 billion yearly. According to the Manoli (2021), 16% of the Mediterranean population was employed 409 in the tourism industry in 2016 either directly—by hotels, 410 travel agencies, transportation services, food, and leisure industries 411 directly supported by tourists—or indirectly—by travel and 412 tourism investment spending, government spending, and supplier 413 purchases. After tourism and transportation, fisheries, including aquaculture, are the third most valuable socio-economic sector in the Mediterranean. The Mediterranean has long been a dynamic economic region that allows for the transportation of goods, energy, and people because of its advantageous location (Petrick et al., 2017).

Due to the fact that trade movements within the region account for 25% of all international seaborne trade, the region is significant for global trade. The Mediterranean's shores are home to about 600 ports of various sizes (Plan Blue, 2015). Over the past two decades, the transportation of products has experienced tremendous growth, and the International Transport Outlook 2019 predicts that between 2015 and 2050, the demand for global freight will quadruple, with ships carrying 75% of the freight (ITF, 2019). Overall, the maritime transport and trade sector supports 550,000 local jobs and contributes 20 to 40% of the GDP in the majority of Mediterranean nations (MGI, 2017).

The Mediterranean is the most significant sea region for the EU in terms of short sea shipping (of goods), accounting for 31% of the total EU short sea shipping tonnage for all sea regions in 2018 (followed by the North Sea and the Baltic, which accounted for 23 and 21% of the total EU short shipping tonnages, respectively) (Docks the Future, 2020). The Belt and Road Initiative (BRI), which is being driven by China and is largely a major infrastructure project meant to assist Chinese exports to European markets, now includes the Mediterranean. BRI maritime lines include ports in southern Mediterranean nations, such as Egypt's canal ports, as well as ports on the northern Mediterranean coast (Piraeus in Greece) (Ismailia and Port Said). The BRI also includes Chinese cooperation agreements in other fields like agriculture, renewable energy, water, chemicals, and ports in the Mediterranean (as in the case of Israel).

The Sustainable Development Goals (SDGs) and the Agenda 2030 for Sustainable Development are translated at the regional, sub-regional, national, and local levels in the Mediterranean region through the Mediterranean Strategy for Sustainable Development (MSSD) for the period 2016–2025, which offers an integrative policy framework for all stakeholders, including the Mediterranean Action Plan of the United Nations Environment Programme (UNEP/MAP) partners (UNEP/MAP, 2016, 2022). As the first


FIGURE 1
The Mediterranean Sea Basin. Map compiled from: Geographic Guide (http://www.geographicguide.com/europe-maps/mediterranean.htm).

regional action plan formed under the UNEP Regional Seas Programme, the UNEP/MAP is a regional cooperation platform. UNEP/MAP was instrumental in the negotiation and adoption of the Convention for the Protection of the Marine Environment and Coastal Region of the Mediterranean (COP 21: Barcelona Convention) and its Protocols by the Contracting Partners (21 Mediterranean countries and the European Union).[1]

The MSSD, adopted by all Mediterranean countries at the 19th Meeting of the Contracting Parties to the Barcelona Convention (COP 19) in 2016 in Athens (Greece), acts as a strategic document that aims to adapt international commitments to regional conditions and to guide national strategies and stimulate regional cooperation in the achievement of sustainable development objectives. The vision of the MSSD is "*A prosperous and peaceful Mediterranean region in which people enjoy a high quality of life and where sustainable development takes place within the carrying capacity of healthy ecosystems. This is achieved through common objectives, strong involvement of all stakeholders, cooperation, solidarity, equity and participatory governance*".

1 The 22 Contracting Parties to the Barcelona Convention are: Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, Syrian Arab Republic, Tunisia, Türkiye, and the European Union.

## 2.2. The Black Sea

The Black Sea is a meromictic basin with anoxic conditions below 200 m. As a result, the upper thin layer (0–200 m) supports biological life due to the high hydrogen sulfide concentration in the deeper (and denser) water layers. A warming trend is observed in the middle layer of the Black Sea that may alter the stratification of waters. As a result, sulfide, noxious and corrosive chemicals from the bottom will be freed to the upper surface layer harming the Sea's biota. Moreover, water quality, larvae and pollutant dispersal will be affected as the wind stress curl over its basin is expected to be reduced.

As presented in Figure 2, the Black Sea covers 436,400 km$^2$ (not including the Sea of Azov), has a maximum of 2,212 m depth and 547,000 km$^3$ volume (Murray et al., 1989; Europa – Gateway of the European Union Website, 2022; UDEL, 2022). Romania, Ukraine, Russian Federation, Georgia, Turkey, and Bulgaria are the nations that border the Black Sea. There are around 17.5 million permanent residents in the Black Sea regions, while 6–8 million visitors visit each year (Vespremeanu and Golumbeanu, 2018).

A total of 63 harbors have been recorded in the Black Sea catchment region, with the following numbers: Romania: 18 harbors (including rivers), Ukraine: 18, Bulgaria: 2, Moldova: 1, Turkey: 24 (Black and Marmara Sea) (Golumbeanu and Nicolaev in Study on integrated coastal zone management. Ex Ponto Publishing House Constanta, 2015). The major ports along the Black Sea coast

are Samsun and Istanbul (Turkey), Samsun and Sulina (Romania), Odessa, Mariupol (Ukraine), Tuapse, Poti and Batumi (Georgia), Burgas and Varna (Bulgaria).

As a follow-up to the commitment of the 2018 Burgas Ministerial Declaration, the seven participating Countries[2] set and approved the Common Maritime Agenda (CMA) for the Black Sea on May 21, 2019. To attain Healthy marine and coastal ecosystems is the CMA's first goal. According to this objective, the Black Sea and its marine and coastal ecosystems are in danger. The effects of climate change, such as sea level rise, erosion, ecological changes, acidification, natural meteorological effects, and temperature increases, are partially to blame for this.

The marine and coastal environment is directly impacted by unsustainable past, present, and future maritime, coastal, and terrestrial activities such as pollution, marine litter, wastewater, and unsustainable practices. The biggest obstacle is ensuring environmental sustainability and protection while using coastal and marine resources all along the Black Sea. The environmental conservation of the shared natural heritage must be improved through regional voluntary collaboration and teamwork to accomplish this. CMA seeks to achieve three objectives; Healthy marine and coastal ecosystems; A competitive, innovative and sustainable blue economy for the Black Sea; and Fostering Investment in the Black Sea blue economy.

In the Black Sea region, maritime policy-making has not yet fully absorbed the notion of maritime spatial planning. In compliance with the EU Directive for Maritime Spatial Planning (MSP), Bulgaria and Romania must present their national maritime spatial plans by March 2021. The ICZM Project "Black Sea CBC - Joint Operational Programme" began the first inventory of Black Sea MSP in 2013 with regards to national policies for marine space, data collecting and information exchange, cooperation with Member States, and cooperation with third nations (European Commission, 2022).

## 2.3. The Caspian Sea

The Caspian Sea is a closed endorheic basin that does not have an outflow, meaning that its water levels are determined by balancing precipitation, run-off input and evaporation. Global warming will lead to a freshwater imbalance that over 50 years results in a 5.0 m drop in sea level, retrieval of the shoreline and impacting the ecosystem. Some research shows that the water level drop ranges from 9.0 m to 18.0 m. Any drop in the sea level, smaller or bigger, will lead to severe stress on biodiversity and the economy. For instance, shallow-water habitats will disappear, depriving a major food source for fish, migrating birds and the endangered Caspian Seal, as well as spawning grounds for endemic and endangered species. Furthermore, shipping outside of the Sea will be affected by the water level drop.

The Caspian Sea, the largest inland body of water in the world, is located on the boundary between Europe and Asia. Without outflow, the sea itself has a surface area of 378,400 $km^2$ and a volume of 78,200 BCM, or almost 40% of the world's surface water. The Russian Federation, Azerbaijan, Iran, Kazakhstan, and Turkmenistan all border its coast. Its total catchment area is around 3.1 million $km^2$, and it includes portions of Georgia and Armenia in addition to the five riparian nations (see Figure 3). Approximately 70–80 million people reside within the Caspian Sea watershed as a whole, with 50–60 million of them residing in Russia (The World Bank Group, 2004b).

To address the issues of regulation and prevention of the environmental degradation of the Caspian Sea and for its sustainable development, as well as to ensure the wellbeing of the population, the Caspian Environment Program (CEP) was established in 1998 as a regional umbrella program. Within the framework of the CEP, Strategic and National action plans and various transnational measures are being developed, as well as major regional projects in the field of sustainable use of bioresources, improved coastal zone management, monitoring of seawater quality with the assistance of the GEF, UNDP, EU (UNEP, 2022).

One of the critical strategic documents was the Framework Convention for the Protection of the Marine Environment of the Caspian Sea (Tehran Convention), signed and supported by all five Caspian countries: Kazakhstan, Azerbaijan, Iran, Russian Federation and Turkmenistan. The Tehran Convention, which entered into force on August 12, 2006, serves as a framework legal instrument establishing general obligations and institutional arrangements (CEIC, 2022a). This Convention is the first legal agreement between 5 countries and has become a big step toward implementing the sustainable use of the resources of the Caspian Sea. Four protocols of the Convention have been adopted and signed: Protocol Concerning Regional Preparedness, Response and Cooperation in Combating Oil Pollution Incidents ("Aktau Protocol"); Protocol on the Protection of the Caspian Sea against Pollution from Land-based Sources and Activities ("Moscow Protocol"); Protocol for the Conservation of Biological Diversity ("Ashgabat Protocol"); Protocol on Environment Impact Assessment in a Transboundary Context, and negotiations are underway on the 5th Protocol by now (CEIC, 2022b). The 5th Protocol on Monitoring, Assessment and Information Exchange will greatly facilitate studying the Caspian Sea's environmental state through the adoption of a unified monitoring methodology.

## 2.4. The Aral Sea

Due to regional and local climate change, the countries in the Aral Sea basin that are located in the arid zone are most vulnerable to high hazards and dangers. The temperature is warming over Central Asia, and long-term projections based on climate scenarios show no increase in the region's water resources. Additionally, as water quality, particularly groundwater, deteriorates, countries in the intermediate and lower reaches of transboundary rivers will see a reduction in available water resources and an increase in water scarcity. The population's ability to acquire high-quality drinking water will be the main concern. Rapid desertification, decreasing snow cover, salinization of the land, loss of biodiversity, and increased deforestation are all projected to have a substantial impact on the hydrographic regime of surface waterways.

2 Republic of Bulgaria, Georgia, Republic of Moldova, Romania, the Russian Federation, the Republic of Turkey, Ukraine.

The region's political, food, energy, sanitary, and environmental security will be significantly and permanently impacted by the cumulative negative consequences of climate change, which will increase competition for water among the countries in the region. The frequency of natural emergencies is expected to increase along with the frequency of hazardous and extreme hydrometeorological occurrences, such as hail, drought, excessively high or low temperatures, etc. Heavy downpours, mudflows, landslides, avalanches, floods, and droughts are a few of them. The current ecosystems and biodiversity may also be threatened by climate change (Narbayep and Pavlova, 2022).

The 1.9 million square kilometers ($km^2$) Aral Sea basin is located in Central Asia and is mostly shared by six countries: Kazakhstan, Turkmenistan, Uzbekistan, Afghanistan, Tajikistan and the Kyrgyz Republic (Figure 4). Kazakhstan and the independent Republic of Karakalpakstan in Uzbekistan are on opposite sides of the Aral Sea. The Aral Sea is populated by approximately 35 million people, two-thirds of the combined population of these countries (The World Bank Group, 2004a).

In 1993, the Republics of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan signed an agreement on joint activities related to the Aral Sea. Among others, this agreement seeks to foster, to the maximum extent, scientific research, projects and activities aiming at maintaining the necessary water quality in the rivers, reservoirs, and springs, restoring the balance of the region's devastating ecosystems, assuring the water inflows required to preserve the decreased but stable Aral Sea, and taking action to protect migratory species (International Water Law Project, 1993). The International Fund for Saving the Aral Sea (IFAS) was created based on this agreement.

However, IFAS has shown itself to be inefficient in attracting investments and implementing regional programs. Since the formation of the Fund, new regional problems have arisen related to managing water and energy resources, climate change, and increasing the shortage of water resources. The main reason is that the statutory and other regulatory documents of the Fund do not reflect the interests of all participating countries and their approaches to the solution. And later, in 2016, Kyrgyzstan froze participation in IFAS and its bodies (Azattyk, 2016). Another problem is that the activities of IFAS were primarily supported by funding from Kazakhstan and Uzbekistan. Therefore, in November 2018, Uzbekistan launched the Multi-Partner Human Security Trust Fund for the Aral Sea region in Uzbekistan with the support of the UN (MPHSTF, 2021). The Uzbek-Kazakh joint working group on environmental protection and water quality issues in the Syrdarya River basin proved to be the most successful in its work. The working group conducts joint monitoring and exchange of data on the ecological state of the Aral Sea (Kazhydromet, 2021). Today, the countries of Central Asia agree that it is necessary to reform the IFAS by improving the organizational and legal framework of the Fund.

## 2.5. Summary of the challenges in the four seas

Considering the above, the Mediterranean Sea, the Black Sea, the Caspian Sea, and the Aral Sea face in a way common challenges regarding their future condition, the intensity of which depends on their size and the relationship between inflow and outflow. A common factor in all the four seas directly connected to their sustainability is global warming. The Mediterranean Sea, the largest of the four, is observed to warm faster than other ocean regions, due to its closed geographical position. Impacts of warming are already evident in its biota, by altering their growth and their survival rates, and by allowing the adaptation of alien species through the Suez Canal. Warming also affects the core structure of the Black Sea, which is its stratification of waters. Corrosive chemicals may be freed from the anoxic strata and pollute the upper surface layer directly harming its fragile ecosystem. Furthermore, the closed endorheic basin of the Caspian Sea, is extremely vulnerable to rise of global temperatures, that will lead to a freshwater imbalance, that will lead to severe stress on biodiversity. Finally, long-term projections show decrease in the Aral Sea inflow, due to the rapid desertification of its waterways.

As we see, 34 countries surround these four seas, which seem to face similar environmental challenges, from fast sea warming to acidification, precipitation, evaporation and other extreme events. These emergencies have a strong impact on some of the driving forces of these countries, that include energy, deep-sea mining, shipping, tourism, fisheries and aquaculture. For example, as the shallow-water habitats disappear, a major food source for fish will deprive, birds will migrate as well as endemic and endangered species will be lost leading so, to biodiversity loss. Despite of the common and grave dangers that these four seas face, little policy action has been taken, where only the Mediterranean Sea seems to have a dedicated strategy on sustainable development, while its neighbor seas are in the agenda and program stages. The section below present the living lab approach, a co-design methodology, that enables not only the development of the IntelComp platform, but the better cooperation across the four Seas.

# 3. Methodology, data collection, and results

To address the above-mentioned challenges and support the invention and development process of the IntelComp platform, a Living Lab (LL) on Adaptation to Climate Change comprised of seven PLL workshops and several evaluation and testing workshops was designed and delivered. The Living Lab is a qualitative approach that follows a five-step methodology. During the first stage, *contextual research*, participants look at the surroundings and the areas of focus, i.e., the drivers and challenges the Mediterranean and its surrounding seas face. Then, at the *discovery and co-creation* stages, users are asked to share their knowledge about unforeseen STI policy-based activities and novel service options made available by the IntelComp platform and participate as co-creators. These needs and priorities are further explored and analyzed in terms of data availability and feasibility and fed into the platform. When, this input is available on the platform, we proceed to the *evaluation* of the tools, in which customers assess and confirm brand-new products and services offered by the IntelComp platform. Their feedback is being considered and integrated in the platform. The final stage of the living lab includes the *technical testing*, where final


FIGURE 2
The Black Sea Basin. Map compiled from: https://www.britannica.com/place/Black-Sea#/media/1/68234/612.

users are able to learn and use the tool and provide feedback for its improvement (see Figure 5).

This study presents the results of the Preparatory Living Lab (PLL), which focuses on Greece and the climate change impacts and adaptation opportunities in the Mediterranean, and its neighbor seas, the Black, Caspian and Aral. The PLL covered the first three stages of the presented methodology revealing the most severe challenges and areas of interest, which are to be integrated in the platform. All stages are performed in a collaborative online setting, with each workshop comprised of 20-25 policy makers, STI analysts, and civil society representatives.

In the first phase of the project, June 2021 (Month 6) – February 2022 (Month 14), a total of seven workshops were delivered, comprised of participants coming from the Mediterranean, Black, Caspian and Aral Seas aiming to discuss the dominant challenges in the four seas, unfold the STI indicators and KPIs that can bring value to their day to day business and support the data collection process of the technical team by guiding the data sources available in their countries as well as the gaps in these data pools. These discussions aimed to reveal the sector(s) with the highest impact on climate change adaptation, which will be the starting point of the second phase of the Living Lab, the evaluation phase, during which participants will be presented with the initial developments of the IntelComp tools, discuss, prioritize and provide feedback on their further development. This phase is expected to initiate when the first tool of the IntelComp platform, the STI Viewer, is at the pilot stage - around December 2022 (Month 24) - and thus, stakeholders will be able to comprehend the potential and capabilities of the platform and provide constructive feedback on the missing areas.

To increase the outreach and the results of the PLL, a collaboration with the UN SDSN SEAs Initiative was pursued (SDSN Europe, 2022). The UN SDSN Sustainable Euro-Asian Seas (SEAs) Initiative was created to hasten Science Driven Sustainable Blue Growth and the implementation of the United Nations Sustainable Development Goals (Agenda 2030) in the Euro-Asian Seas and beyond. The SEAs initiative helped the delivery of the PLL of the IntelComp project by connecting it with the appropriate parties as well as by supporting and publicizing its operations.

Apart from the first introductory workshop, participants were divided into two groups, one focusing on issues in the Mediterranean Sea and the other in the Black, Caspian, and Aral Seas. The first workshop aimed at introducing the participants to the goals of the project and the impacts of climate change on the seas. The participants in the following two sessions attempted to solve the mystery surrounding data mining, which is the backbone of the platform. They discussed the availability and accessibility of the global, regional and national datasets that are most frequently used in research projects and policy analysis, and shared national data sources related to the marine and maritime sectors. This discovery phase aimed at understanding the gap between monitoring and information getaways in Greece and its neighbors.

This discussion led to the definition and the establishment of a common ground for further analysis. In our circumstance, the majority of participants appeared to comprehend the seriousness and complexity of the data identification difficulty and to concur with the majority of the various points and specifics brought up during the workshop. The participants reported several issues

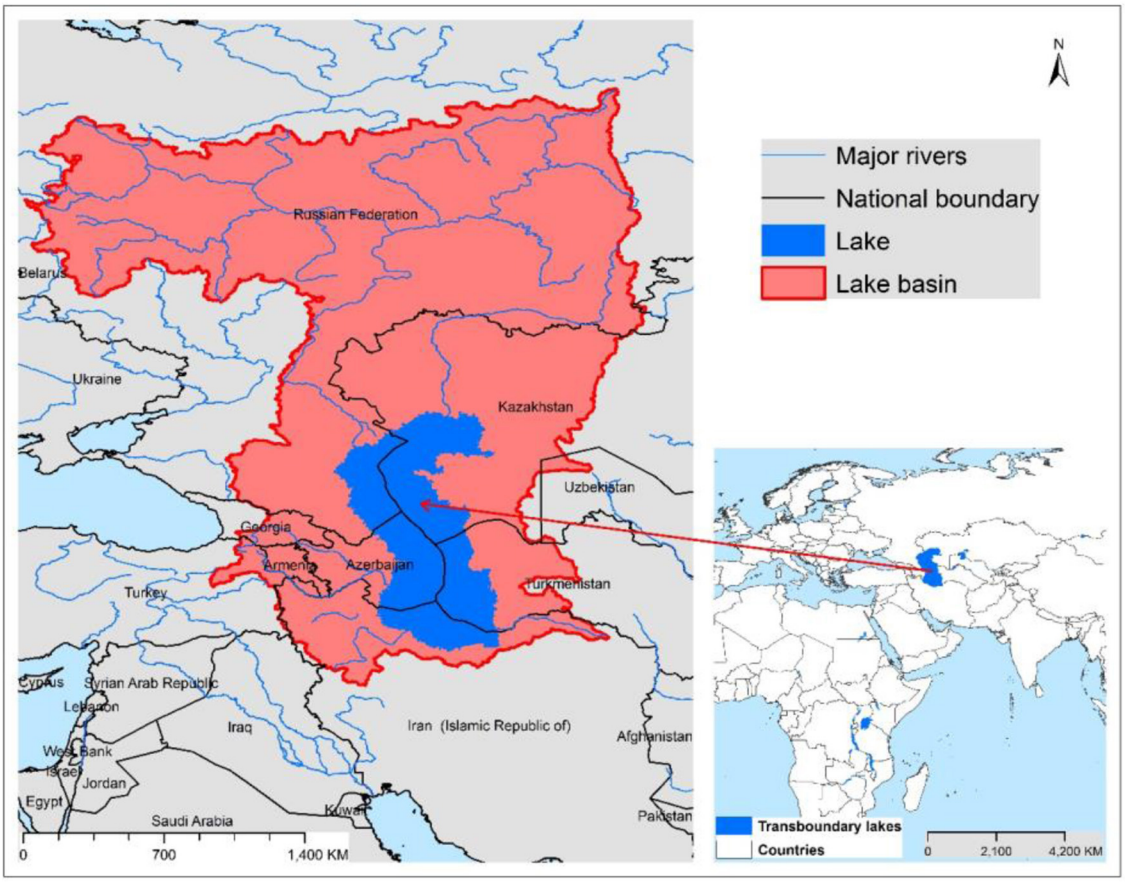


FIGURE 3
The Caspian Sea Basin. Map compiled from ILEC TWAP Lakes Portal (source: http://ilec.lakes-sys.com/portals/lake_detail/28).

with the suggested data sources, including a lack of common file structures, a lack of daily and open data, a lack of data validation, a lack of accessible and reliable data, a lack of geospatial data, a lack of data on port facilities, and a lack of people with the specialized knowledge needed to collect and analyze relevant data.

The energy sector was identified as the primary area of interest and with the highest exploitation potential for adaptation and mitigation to climate change. The participants located in the Mediterranean region and the Black Sea/ Caspian Sea region showed great interest in the energy sector with off-shore investments, new technologies and wind power intrigueing them the most. They focused on the factors to be examined during energy investments, and shared their concerns toward the development of renewable projects and the identification of optimal energy mix. The development of new technologies, as well as the influence of the seas, the infrastructure development and how the optimal mix should alter in regards to climate change, are expected to generate a lot of interest in the future.

The energy sector, which includes the supply of electricity, gas, steam, and air conditioning, was the focus of the fourth and fifth PLLs. The attendees had the chance to discuss their ideas on LNG, hydrogen, methanol, ammonia, and nuclear energy as well as the analytics they should consult before investing in various energy sources, including renewables (solar, wind, geothermal, and hydropower). In the sixth and seventh workshops, we concentrated on the industrial side of the energy sector, talking about topics like how to incorporate innovation into daily business operations, where to look for new research, how to stay informed about evolving regulatory frameworks, and whether or not companies have participated in EU-funded projects.

The PLL's delivery helped participants find several materials and information that they would not have been able to locate on their own and helped them comprehend the various approaches that other nations take to combating climate change. The energy was identified as the topic of most interest in the region as a result of the work done in the PLLs. The Living Lab on Adaptation to Climate Change aims to demonstrate the Greek STI - Climate Change ecosystem, starting with the Energy sector, to enhance decision-making. As a result, they focus on five areas: science, industry, policy, environment, and society to educate and inform decision-makers about the impacts of the energy sector on climate change.

In short, the LLs will seek to increase participant interest in the IntelComp platform, ensure that they use it, and ensure that they are aware of the role that the energy sector plays in combating climate change as well as any rules that may be relevant to that sector. Additionally, they offer technological assessments and foresight, identify future technologies and advances and how they affect policymaking, and examine the national plans as a


FIGURE 4
The Aral Sea Basin. Map compiled from (Micklin, 2007; Gaybullaev et al., 2012); Landsat satellite imagery from USGS/NASA; Digital Elevation Model from USGS EROS; visualization by UNEP/GRID-Sioux Falls.

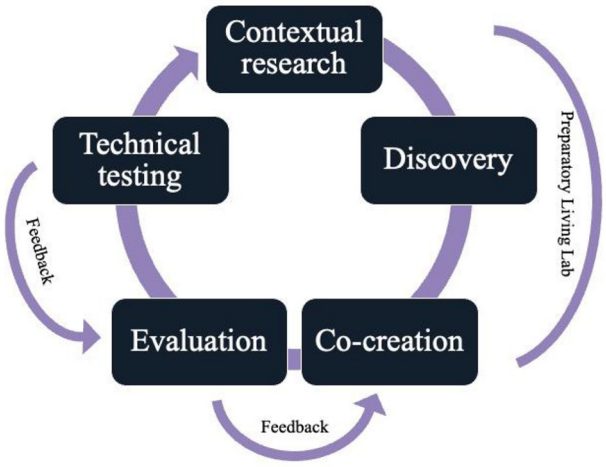


FIGURE 5
IntelComp living lab on adaptation to climate change methodology.

foundation for policy decisions to ensure that the general public is better informed, alert, and receptive (especially in terms of Initiatives related to climate change technologies).

## 4. Discussion

When it comes to climate change, there are no geographical borders. Therefore, it is necessary for stakeholders from various geographic areas to discuss and identify shared concerns. The Preparatory Living Lab, part of the Living Lab on Adaptation to Climate Change, brought together people from different scientific backgrounds, working in the public and private sectors, in academia and in NGOs, in regulatory authorities and in private companies, to discuss already set topics and share their main sources of information, as the climate change itself is a major issue that needs to be addressed interdisciplinary and affects every human activity. The insightful information they provided was assessed and used appropriately to get to the future LL on Adaptation to Climate Change primary focal challenge and initiate the development of the IntelComp platform.

The Energy sector was identified as the initial development area of the IntelComp platform considering the new energy solutions that can be provided using the ocean, such the Offshore wind energy, the infrastructure and policy framework needs to be designed carefully given the dependency on the climate change effects on the seas, described above. The European strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy is strengthened by several EU and National policy frameworks, including the European Green Deal, the Climate Law, the National Long-term Strategy for 2050 (on the Climate and Energy) etc.

As communicated in the European Commission (2018) the road to a net-zero greenhouse gas economy includes energy efficiency maximization and the deployment of renewables and the use of electricity, which are further described in the National Long-term Strategy for 2050 (Ministry of the Environment Energy, 2020). Given that both the energy and climate crises the world is currently experiencing are anticipated to influence future policies,

TABLE 2 Electricity, gas, steam, and air conditioning supply.

| |
|---|
| 1. Production of electricity from solar PV |
| 2. Production of electricity from concentrated solar power |
| 3. Production of electricity from wind power |
| 4. Production of electricity from ocean energy |
| 5. Production of electricity from hydropower |
| 6. Production of electricity from geothermal |
| 7. Production of electricity from gas (not exclusive to natural gas) |
| 8. Production of electricity from bioenergy (biomass, biogas and biofuels) |
| 9. Transmission and distribution of electricity |
| 10. Storage of electricity |
| 11. Storage of thermal energy |
| 12. Storage of hydrogen |
| 13. Manufacture of biomass, biogas or biofuels |
| 14. Retrofit of gas transmission and distribution networks |
| 15. Production of heat/cool using waste heat |
| 16. District heating/cooling distribution |
| 17. Installation and operation of electric heat pumps |
| 18. Cogeneration of heat/cool and power from concentrated solar power |
| 19. Cogeneration of heat/cool and power from geothermal energy |
| 20. Cogeneration of heat/cool and power from gas (not exclusive to natural gas) |
| 21. Cogeneration of heat/cool and power from bioenergy (biomass, biogas, biofuels) |
| 22. Production of heat/cool from concentrated solar power |
| 23. Production of heat/cool from geothermal |
| 24. Production of heat/cool from gas combustion |
| 25. Production of heat/cool from bioenergy (biomass, biogas and biofuels) |

Source: European Commission (2020).

the Technical Annex of the EU Taxonomy Report expands the Energy sector into 25 sectors, as presented in Table 2 (European Commission, 2020).

This study also contributes to the body of knowledge on co-production and co-design of public services (Mergel, 2018). While previous research on co-production has primarily focused on including citizens through public participation processes in order to gain their support, trust, and insights in structured decision-making processes, our approach opens a new channel for incorporating external knowledge into problem-solving processes. It differs significantly from previous waves of co-design in that it encourages innovative ideas and solutions by utilizing online platforms to broaden the inclusion of ideas rather than just local participation and including a diverse group of stakeholders in the co-development process.

Consequently, the IntelComp project will aid in policy making by offering relevant tools that will provide insights and analysis in the field of STI (Science, Technology, Innovation) covering all Energy areas presented above. The demands of the stakeholders will be determined through the Living Lab on Climate Change Adaptation, and regional, municipal, and urban initiatives concentrating on energy, laws, policies, and significant climate change-related challenges will be acknowledged. The participants' desire to join the Platform will grow as a result of this co-creation process, and they will use it actively once the tools are officially released in the future.

## 5. Concluding remarks

Public administration at all organizational and geographic levels, as well as STI stakeholders and civil society, generate a large amount of dynamic, multilingual, and heterogeneous data (such as national STI strategies, plans, and work programmes, calls, projects, reports, scientific publications, patents, dissemination articles, etc.). Understanding and analyzing this data is critical for making evidence-based policy decisions.

Through the Preparatory Living Lab (PLL), climate change in Greece was examined under the lens of sustainability in the Mediterranean and its surrounding seas. Greece is surrounded by sea and is known for its dense coastline population with the marine and maritime sectors (including tourism) account for the majority of its GDP and being vulnerable to the climate crisis, ranging from rising sea levels and water acidification to declining fishing stocks and biodiversity loss. These effects have a direct impact on humans *via* five interconnected domains: water resources, ecosystems, food safety and security, tourism, health, and human security.

Given the foregoing, the Mediterranean Sea, Black Sea, Caspian Sea, and Aral Sea all face similar challenges in terms of future condition, the severity of which depends on their size and the relationship between inflow and outflow. Global warming is a common factor in all four seas that is directly related to their sustainability. Because of its close geographical location, the Mediterranean Sea, the largest of the four, has been observed to warm faster than other ocean regions. Warming is already having an effect on its biota, altering their growth and survival rates and allowing alien species to adapt through the Suez Canal.

Warming also has an impact on the Black Sea's core structure, which is its stratification of waters. Corrosive chemicals may be released from the anoxic strata and pollute the upper surface layer, causing direct harm to the ecosystem. Furthermore, the Caspian Sea's closed endorheic basin is extremely vulnerable to rising global temperatures, which will cause a freshwater imbalance and severe stress on biodiversity. Finally, long-term projections show that the Aral Sea's inflow will decrease due to the rapid desertification of its waterways.

Thus, addressing climate change adaptation in Greece requires addressing the challenges in the Mediterranean Sea and its neighboring and connected seas, the Black, Caspian, and Aral, which have no boundaries. To comprehend the interrelationships of these impacts, we must collect existing knowledge embedded in the regional fabric by mobilizing and facilitating cooperation among key actors in these countries. Living Labs provide a real-world testbed in which stakeholders collaborate to co-design and co-create holistic solutions that aim to solve real-world problems.

The PLL, which was supported by the SEAs Initiative, aimed to co-create the IntelComp platform's tools. During the co-development stage, a large group of stakeholders was utilized to

ensure that all aspects of climate change adaptation were addressed. Its target audiences were public policymakers, academia, industry, SMEs, local actors, and civil society working in the marine and maritime sectors in any of the four above-mentioned seas, as they all generate a significant amount of dynamic, multilingual, and heterogeneous data (such as national STI strategies, plans, and work programmes, calls, projects, reports, scientific publications, patents, dissemination articles, etc.).

Through these fruitful discussions, in which participants presented their concerns and prioritized the main challenges. The study's findings lead to conclusion that one of the most important challenges in addressing climate change is the decarbonisation challenge, particularly, the transition to renewable energy sources and the investments to be made. This will be the central focus area of the IntelComp climate change case study. Furthermore, through the PLL, policy questions were identified, and valuable data sources were gathered to help the IntelComp project start. The following workshops will build on the involvement of stakeholders working on the energy sector, primarily from Greece, and keep informed those who took part in the project's initial phase and are directly impacted by climate change in their local seas.

## 6. Limitations

The research design has limitations that may affect the findings' generalizability. First, the chosen living labs are countries with distinct bureaucratic contexts and administrative cultures. As a result, the findings may not be applicable to living labs in other bureaucratic contexts. Second, the fact that living labs were conducted in English, excludes stakeholders who are not confident in speaking English and did not participate in the discussion. Third, the data collection process limits the internal validity of the findings and thus, its generalizability.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

Ethical approval was not required for the study involving human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants in accordance with the national legislation and the institutional requirements.

## Author contributions

LP, CS, PK, and NT: conceptualization, methodology, and visualization. PK, NT, IG, and HP: validation and supervision. LP and CS: formal analysis and writing—review and editing. PK, NT, HP, and IG: investigation. LP, CS, and MK: writing—original draft preparation. LP: project administration. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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