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# CIVIC UNIVERSITY MODEL AS LIVING LAB - POTENTIAL AND CHALLENGES

## FOR THE OUTPUT "DESIGNING SKILLS AND ROLE FOR "CIVIC UNIVERSITIES"" OF THE ENI CBC MED "MED-QUAD" PROJECT

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## ABSTRACT:

*This article explores the Civic University model's potential as a Living Lab, highlighting its capacity to integrate academia into the societal fabric and promote sustainable development. It examines the concept of Civic Universities, entities that prioritize positive civic impact through engagement with local communities. The study delves into the Living Lab approach, characterized by user-centered, open innovation ecosystems where stakeholders from public, private, and academic sectors collaborate in real-world settings. Further, it discusses the Quadruple and Quintuple Helix frameworks, illustrating how these models facilitate multi-stakeholder collaboration to foster innovation and address complex challenges. The article also connects these concepts with the Sustainable Development Goals (SDGs), emphasizing the role of Civic Universities in achieving these global objectives. Through the lens of the ENI CBC MED 'MED-QUAD' project, the article exemplifies how the integration of these frameworks can lead to impactful societal and economic development, particularly in the Mediterranean region. The findings underscore the significance of Civic Universities as Living Labs in cultivating an innovative, sustainable, and inclusive future.*

**KEY-WORDS:** Sustainable Development Goals (SDGs), Quadruple Helix, Quintuple Helix, Innovation Ecosystem, Community Engagement, Public-Private Partnerships, Stakeholder Collaboration, Urban Living Labs, Sustainability, Educational Integration, Research for Public Good, Place-based Education, MED-QUAD.

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# 1. INTRODUCTION

To construct a dynamic model inside the university that emphasizes its position within society and expedites sustainable development goals, this article discusses the civic university and how it can benefit from emerging concepts like the Living Lab and quadruple/quintuple helix framework.

> "While universities are vital to their places, they also need the active support of their communities in these turbulent and challenging times."
>
> *Lord Kerslake, (FAcSS), awarded the Fellowship of the Academy of Social Sciences (FAcSS), granted by the Academy of Social Sciences to leading academics, policymakers, and practitioners of the social sciences.*

## The Civic University (CU)

A university can be regarded as a ***civic university*** if its purpose, and the strategy that supports it includes making a positive civic impact. On the other hand, universities that only undertake valuable civic activity can be regarded as *civically engaged universities.* (1)

A civic university is a university that recognizes and prioritizes its role in serving and engaging with its local community. This involves working with community members, organizations, and government agencies to address local challenges and create social, cultural, and economic benefits for the community. This can be in the form of ***Community partnerships***, where the university works with local organizations and community members to create programs and initiatives that address local challenges and meet community needs through partnering with local government agencies, non-profit organizations, and businesses to create collaborative solutions. And in the form of ***Service Learning*** by incorporating community service and engaging into their academic programs to give students the opportunity to apply their skills and knowledge to real-world challenges in the local community. The civic university shall be involved in ***Research for the public good*** that addresses local challenges and has the potential to create social, cultural, and economic benefits for the community, which involves partnering with community members and organizations to identify research priorities and co-create solutions. One of the vital features of the civic university is ***Place-based education***, where the universities use their local community as a learning laboratory or as a *Living Lab (LL),* creating opportunities for students to explore and learn from their local environment, culture, and history.

> "If you want to build a great city, create a great university and wait 200 years."
>
> *Senator Daniel Patrick Moynihan*

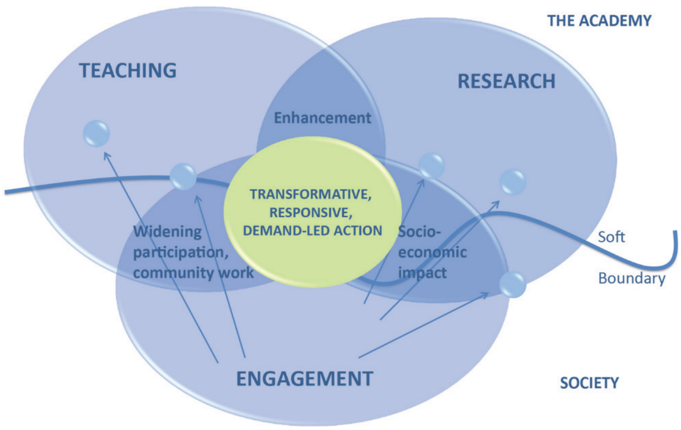


**Fig. (1):** A civic university
*CITATION God20 \l 1033 (9)*

## The University as a Living Lab

William J. Mitchell, Kent Larson, and Alex (Sandy) Pentland at the Massachusetts Institute of Technology are credited with first exploring the concept of a Living Laboratory (2). They are "User-centered, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real life communities and settings" as defined by the European Network of Living Labs (ENoLL). Westerlund and Leminen (3) described Living Labs (LLs) as physical regions or virtual realities where stakeholders form public-private-people partnerships (4Ps) of firms, public agencies, universities, institutes, and users all collaborating for creation, prototyping, validating, and testing of new technologies, services, products, and systems in real-life contexts.

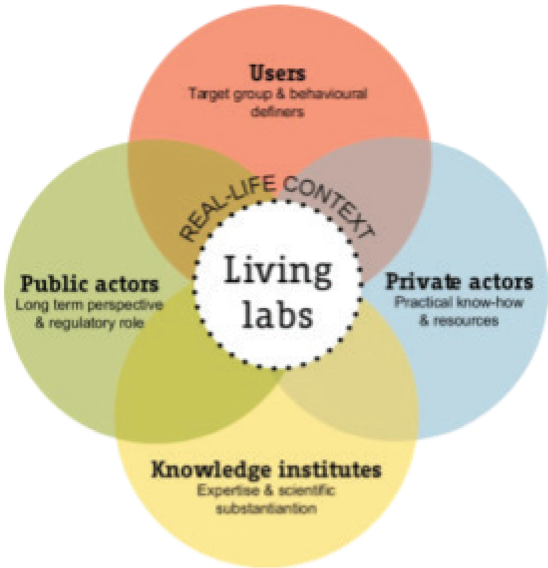


**Fig. (2):** The living lab stakeholders
*CITATION Ste17 \l 1033 (10)*

Living labs are an open innovation ecosystem that involves users, academics, and industry in creating innovative outcomes to match the scientific potential with the real needs on the ground. Either virtual or physical spaces, the Living Labs (LLs) enable the collaboration of multiple stakeholders in a real-life context to co-create solutions, often in urban areas (4).

The basic idea of student engagement for sustainability reinforcements at a university is to offer students the chance to participate in sustainability activities outside the classroom, gain real-world experiences, and learn how to work with various stakeholders from the industry. The campus can serve as a living lab that connects student engagement through education with sustainability outcomes on an urban campus.

## The Quadruple and Quintuple ( Q2H ) Helix Framework

QH framework (Figs 3 & 4) is based on models by Carayannis and Campbell (5) and Galvao (6). The Quadruple helix model emphasizes the importance of collaboration between universities, policymakers, civil society, and industry. The Quintuple Helix model builds on this by including the overall ecosystem in the collaboration. Collaboration between stakeholders is an essential factor in overcoming obstacles and generating innovative solutions through research and development (7). The helix models of innovation highlight the important role universities play in promoting innovation in our knowledge-based society (8).

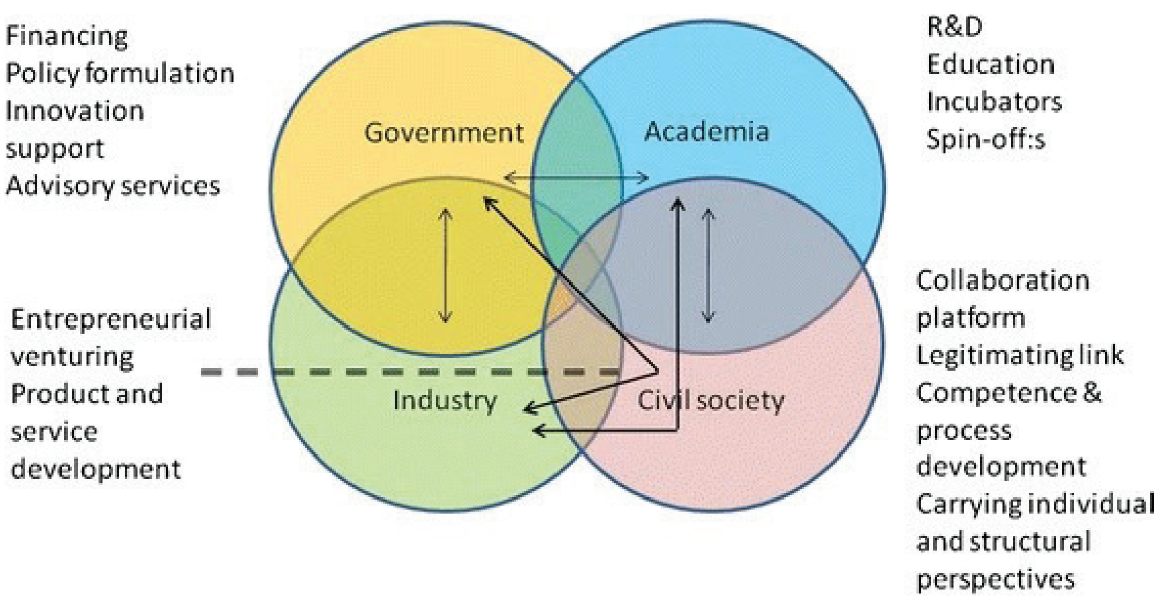


**Fig. (3):** Quadruple Helix framework
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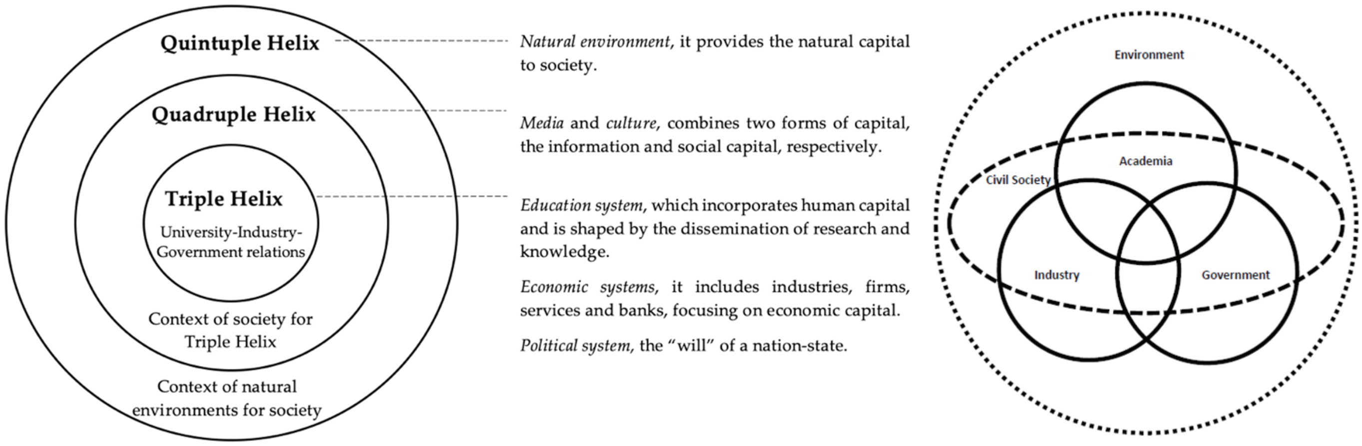


**Fig. (4):** Quintuple Helix Innovation Model for the European Union Defense Industry—An Empirical Research
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## 2. THE CIVIC UNIV. AS A LIVING LAB UTILIZING THE QUADRUPLE/QUINTUPLE HELIX ( Q2H ) FRAMEWORK

The concept of using universities as Living Labs (LLs) using the quadruple/quintuple helix (Q2H) framework is an innovative approach to driving sustainable development and promoting collaboration between various stakeholders.

The Q2H framework involves the collaboration of key stakeholders, namely, academia, industry, government, civil society and the environment. This approach promotes the exchange of knowledge, skills, and resources between these stakeholders to drive innovation and development.

In the context of using universities as LLs, the Q2H framework involves leveraging the resources, expertise, and innovation of universities to address real-world problems in collaboration with industry, government, civil society, and the environment. This approach facilitates the co-creation of knowledge and solutions that are relevant and impactful to society.

By using universities as LLs, students, faculty, and researchers can work with external stakeholders to co-create solutions to real-world problems, and test and validate these solutions in a real-world context. This approach not only promotes innovation but also provides students with practical learning opportunities and industry experience.

Overall, the concept of using universities as LLs using the quadruple helQ2H framework has the potential to drive sustainable development and create a collaborative innovation ecosystem that benefits all stakeholders involved.

## 3. INTEGRATING THE Q2H FRAMEWORK AND THE SDGS

The Agenda 2030 for Sustainable Development Goals (SDGs), adopted by the United Nations in 2015, is a global initiative aimed at addressing pressing global challenges, including poverty, inequality, environmental degradation, and more. Its primary purpose is to promote sustainable development and improve the well-being of people and the planet by 2030.

The UN report (9) explains the 17 Sustainable Development Goals (SDGs) and the 169 associated targets. These goals cover a wide range of social, economic, and environmental issues and provide a comprehensive framework for action at the global, national, and local levels. It emphasizes the importance of multi-stakeholder engagement, including governments, civil society, businesses, and academia, to work together towards achieving the SDGs.

The Agenda 2030 for SDGs and the Q2H Model are related in the sense that both advocate for multi-stakeholder collaboration and emphasize the importance of various sectors working together to achieve common goals. The Q2H Model can provide a conceptual framework for understanding how different actors, including government, academia, industry, civil society, and media, can collaborate to implement and advance the SDGs outlined in

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Agenda 2030 (10).

In practical terms, the Q2H Model can be used as a guiding framework for designing and implementing initiatives that align with the SDGs. It encourages a holistic approach to sustainable development by considering the diverse perspectives and contributions of various stakeholders. Thus, these two concepts can complement each other in efforts to address complex global challenges and promote sustainable development. The Agenda 2030 for Sustainable Development Goals (SDGs) and the Q2H Model are both frameworks designed to address complex societal challenges and promote sustainable development, but they have different focuses and purposes.

Both the Helix framework and the SDGs are powerful instruments for organizing, educating, and integrating future societies.

- Helix models provide abstract, conceptual, and evolutionary frames based on cross-fertilized knowledge and innovation from stakeholders like universities, industry, government, society, and the environment.

- The UN SDGs formulate practical, hands-on, and fine-grained targets in multiple realms (social, educational, economic, environmental, and political) with the goal of implementing more sustainable practices by 2030.


## 4. CIVIC UNIVERSITY ( CU ) ACTING AS LIVING LABS ( LLS ) WITHIN THE Q2H FRAMEWORK

### Potential for CU as LLs using QH Framework

The potential for a civic university as a living lab using the Q2 helix model is significant. By engaging with the community and bringing together multiple stakeholders, a civic university can create a dynamic innovation ecosystem that fosters economic and social development. The Q2 helix model provides a framework for collaboration between academia, industry, government, civil society, and the environment, which can result in more innovative and effective solutions to complex problems.

A civic university can act as a hub for this collaboration, bringing together stakeholders from different sectors and facilitating dialogue, cooperation, and co-creation. By working together, stakeholders can identify common goals and develop solutions that are tailored to the needs of the community.

In addition to the benefits for the community, the engagement of a civic university in a living lab using the Q2 helix model can also benefit the institution itself. It can provide opportunities for interdisciplinary research, student engagement, and networking, and can enhance the university's reputation and profile.

Here are some potential benefits:

1. **Addressing Real-world Challenges:** A civic university can use the living lab approach to identify and address real-world challenges faced by the community. This approach ensures that research and innovation are relevant and useful to society.

2. **Engaging Stakeholders:** The Q2 helix model emphasizes the importance of engagement and collaboration among academia, government, industry, civil society, and the environment. A living lab approach can facilitate stakeholder engagement and ensure that all parties are involved in the innovation process.

3. **Fostering Innovation:** A living lab approach can facilitate the co-creation of innovative solutions by bringing together different perspectives, resources, and expertise. The Q2 helix model ensures that innovation is not limited to academia or industry but is a collaborative effort.

4. **Enhancing Education:** A civic university can use the living lab approach to enhance the education of its students by providing them with opportunities to work on real-world projects and collaborate with stakeholders from different sectors.

5. **Economic Development:** A civic university can contribute to the economic development of its region by promoting innovation and entrepreneurship. The living lab approach can facilitate the creation of new businesses and products that address local needs and create jobs.

A civic university as a living lab using the Q2 helix model has the potential to create a collaborative and innovative ecosystem that addresses real-world challenges, engages stakeholders, fosters innovation, enhances education, and contributes to economic development.


**Fig. (5):** UN 17 Sustainable Development Goals and dominant Helix properties
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### Challenges facing CU acting as LLs within the 2H Framework:

A civic university as a living lab, using the Q2 helix model, faces several challenges. Here are some of them:

1. **Collaboration:** collaboration between the stakeholders can be challenging due to differences in priorities, goals, and communication styles. Building and maintaining strong relationships among the stakeholders is essential to overcome these challenges.

2. **Funding:** Implementing a living lab requires resources, including funding. Universities may struggle to secure funding for their living lab initiatives, especially if they do not have strong partnerships with industry and government.

3. **Ethics and Governance:** Living lab initiatives involve human participants, and thus ethical considerations must be considered. Universities must establish ethical guidelines for their living labs and ensure that they adhere to them. In addition, the governance structure of the living lab must be established, and the stakeholders must agree on how decisions will be made.

4. **Scalability:** Living labs are often focused on a specific geographic area or community. To be successful, the living lab must demonstrate that its results can be scaled up to a broader context. The living lab must also show that it can be replicated in other contexts.

5. **Data Management:** Living labs generate vast amounts of data, and managing this data can be challenging. Universities must establish protocols for data collection, storage, and sharing. In addition, they must ensure that the data is secure and that participants' privacy is protected.

6. **Measuring Success:** Living labs are designed to produce tangible outcomes, but measuring success can be challenging. Universities must establish metrics to measure the success of their living labs and ensure that these metrics are aligned with the goals of the living lab.

Implementing a living lab using the quadruple helix model is a complex undertaking. Universities must navigate a range of challenges to ensure that their living lab initiatives are successful.

## 5. THE MED-QUAD PROJECT

The MED-QUAD project applies the Quadruple Helix (QH) approach to support innovation and sustainable local development among partner countries: Italy, Greece, Egypt, Tunisia, Palestine, and Jordan. The project's partners applied actions to support innovation and sustainable local development based on the QH. Actions were based on the awareness that government, businesses, academia, and citizens will be able to align goals, amplify resources, and accelerate progress by joining forces.

MED-QUAD addressed challenges in project partners' countries by creating the right environment where universities, SMEs, and governments cooperate and promote the innovation of processes and products. The QH approach is applied to the planned cross-border Living Labs focused on two crucial issues:

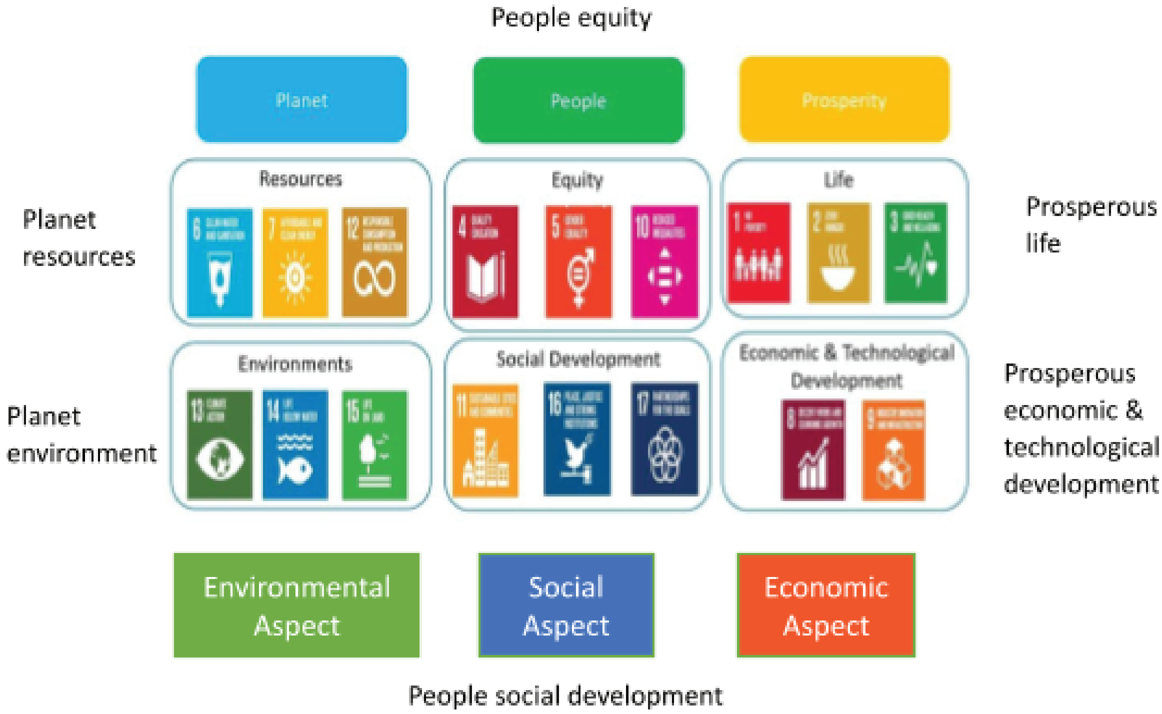
1. **Smart Water Use Applications – SWUAP:** quality traceability for drinking water, quality assessment of water for irrigation, traceability of vegetables from fields to shops, smart packaging and

2. **Applied Research for Cultural Heritage Exploitation-ARCHEO:** Augmented reality applied to archaeology, architecture, and art. Mixed Realities and their concept of cyber-real space interplay. A full appreciation of cultural heritage sites. Virtual and augmented reality technologies that will provide historically accurate reconstructions and relevant contextual information.

## Outcomes of some partners in the Arab Region

- The Arab Academy for Science, Technology, and Maritime Transport "AASTMT", Egypt:

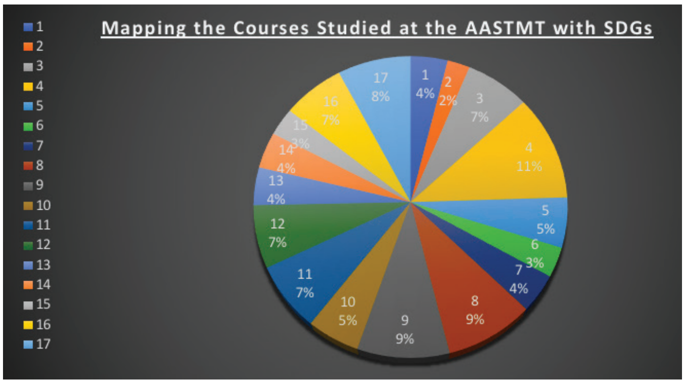
Within the Med- Quad project funded by the EU Horizon, AASTMT applied the CU model acting as LL and using the Q2H Framework. AASTMT gathered forces to become a sustainable campus. They established a community of staff, employees, and students spearheaded to advance the SDGs within the AASTMT campuses. A special link "Sustainable AASTMT" was created to include all the policies, goals, initiatives, news, etc., all concerning sustainable development and the SDGs implemented within the campuses. A committee of officers was assigned the responsibility of advancing the SDGs with an officer for each SDG. The Committee management gathered the SDGs into six clusters according to the related themes within the AASTMT community.




**AASTMT insights towards SDGs**

**Towards SDG4:** Since 2021, the AASTMT has developed mapping matrices that indicate the direct relationship between educational program courses and SDGs, to increase awareness about SDGs and enhance the participation of different stakeholders, such as students, lecturers, employees, and community, in the achievement of SDGs. Each program in AASTMT has a matrix that shows a partial or complete addressing of a certain SDG or group of SDGs within the teaching courses.

The plan is to generalize the evaluation of SDGs in most of the courses within the AAST In order to measure the achievement of SDGs within the teaching course. It has gone further in 2022 to measure the achievement of SDGs within the teaching course in evaluating the understanding of students the SDG concept and practicing activities that support their achievement. The plan of SDGs workforce is to generalize the evaluation of SDGs in most of courses within the AAST starting from September 2023.



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- Palestine Polytechnic Univ.:

Within the framework of MED-QUAD project, the ARCHEO Virtual Reality Laboratory team at Palestine Polytechnic developed a model to preserve and develop the cultural heritage of historical sites in the city of Hebron using 3D scanning techniques and virtual reality software. The model will be adopted by the Ministry of Tourism and Cultural Heritage within the Ministry's plan to develop the Palestinian Virtual Museum.

The team at the Water Quality Laboratory SWUAP developed a process to remotely monitor water quality using the Internet of Things (IoT). They cooperated with the Water Department in Hebron Municipality to install and operate the device to monitor changes in the quality of the water distributed in the city, where the measurements are sent via the Internet to the laboratory in the Biotechnology Center at the university with the aim of making a model that can be applied to ensure public health.

The Palestine Polytechnic University in cooperation with a relative EU project established a network of 5 agro-technological centers in 5 Universities in Jordan and Palestine to develop practical and innovative Vocational Education and Training (VET) courses equipping students with new skills, not addressed in traditional curricula. The AgroTech centers will promote cooperation between companies and VET institutions as well as create links between all stakeholders of the agri-food value chain.

- Al-Balqa Applied University - Jordan:

The Smart Water Use Applications (SWUAP) lab at Al-Balqa Applied University joined forces with industry to enhance water management in the industrial sector. Their collaboration will implement advanced water solutions to ensure top-notch water quality and safety. This partnership addresses challenges, boosts food safety, and drives innovation in industrial water treatment, benefiting the environment and businesses alike.

## 6. ACKNOWLEDGMENT

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# IS COLD IRONING ( ONSHORE POWER SUPPLY, OR ALTERNATIVE MARITIME POWER, OR SHORE-TO-SHIP POWER ) A VIABLE SOLUTION FOR REDUCING GREENHOUSE GAS EMISSIONS IN PORTS? EU / GREEK PORTS PERSPECTIVE

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## ABSTRACT:

*Adaptation to climate change has led Institutional bodies to work relentlessly to find solutions to this progressing problem. European Union has been diligently formulating a comprehensive institutional framework aimed at addressing maritime transport's environmental impact and fostering sustainable practices. Maritime transport, responsible for approximately 75% of the Union's external trade and 31% of its internal trade by volume, plays a pivotal role in the economy of the Union. However, it also accounts for a significant portion of carbon dioxide (CO2) emissions within the EU, contributing around 11% of all EU CO2 emissions from transport and 3 to 4% of total CO2 emissions in the EU.*

*In response to the pressing need to curb emissions, Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law') set a clear objective for the net reduction of greenhouse gas (GHG) emissions by at least 55% compared to 1990 levels by 2030. Moreover, this regulation places the Union on a trajectory towards achieving net zero GHG emissions by 2050. As part of this commitment, complementary policies have been introduced to expedite the adoption of sustainably produced renewable and low-carbon fuels in the maritime transport sector, all while respecting technological neutrality.*

*Regulation (EU) 2023/1804 requires the port to be able to provide shore-side electricity supply for at least 90% of container vessels over 5,000 GT, ro-ro passenger ships and high-speed passenger craft over 5,000 gt, and passenger ships over 5,000 gt, provided the annual average number of ships in each of these categories exceeds 100, 40 and 25 respectively. However, the lack of a common methodology for setting targets and adopting measures in national policies led to significant differences in the levels of ambition between Member States which was perceived as a hindrance to the establishment of a comprehensive network of alternative fuel infrastructure.*

*The paper examines the most important obstacles and towards EU legislative framework implementation and techno-economic challenges.*

**KEY-WORDS:** Maritime Decarbonization, Cold Ironing, Onshore Power Supply, Climate Adaptation in Shipping and Ports, Sustainable Development.

# 1. INTRODUCTION

European environmental legislation has clearly committed the EU to becoming climate-neutral, achieving net-zero greenhouse gas emissions by 2050. The European Green Deal of 2019 is based on four pillars covering issues related to the implementation of the appropriate regulatory framework, financing specialized measures and policies, necessary skills adaptation for the implementation of innovative environmental actions, and the liberalization of global trade to enhance the EU's bilateral trade relations with its partners and avoid unfair competition practices.

In 2021, the European Parliament adopted the European Climate Law, which sets the achievable target of reducing greenhouse gas emissions by 55% by 2030 (compared to 1990 levels) and designates 2050 as the milestone date by which the EU will become entirely climate neutral. The implementation of these targets is institutionally reinforced by the adoption of the policy package known as "Fit for 55."

All productive sectors are included in the measures specified in the "Fit for 55" package, including shipping, which is most directly impacted by the EU Emission Trading System (ETS) as it came into effect on May 16, 2023. Additionally, the shipping sector is affected by the FuelEU Maritime Regulation, which is awaiting finalization and approval by the European Parliament and the European Council, the Energy Taxation Directive, the Alternative Fuels Infrastructure Regulation effective from July 13, 2023, and the Renewable Energy Directive.

As can be understood, the regulatory work at the EU level is continuous, and the institutional bodies of each member state, as well as representatives of sectoral interests within the EU, are working tirelessly to have their views, which reflect their specific interests, adopted institutionally and become EU legislation.

At the same time, the strict timelines set with the milestone years 2030 and 2050 intensify the efforts of entities (both private and public) to comply within these limits, even without waiting for the details and final adaptation requirements.

The shipping industry is in constant pursuit of the prevailing trends in the energy and maritime fuels sector, while the port industry is preparing the zero-emission ports of tomorrow, which now seem very close.

# 2. THE INSTITUTIONAL FRAMEWORK

The prevailing view for reducing greenhouse gas emissions is reported to be the creation of infrastructure for providing electric power to approaching ships, which, according to the most recent legislation (AFIR, 2023), must be supplied at least at ports belonging to the Trans-European Transport Network (TEN-T), with priority given to seagoing container ships and seagoing passenger ships, as these categories are recognized as the most energy-demanding and the most polluting.

The same legislation mentions that ports should be cautious about the underperformance of attempted capital investments. Special attention is also given to island areas that are not connected to the central power grid and rely exclusively on non-renewable sources, specifically conventional fossil hydrocarbons, for electricity production.

The finalization of technical requirements for installing power supply systems on commercial ships is expected in the coming months. Many ports, mainly in mainland Europe, have already installed such systems alongside networks for providing alternative maritime fuels, such as natural gas and hydrogen.

# 3. CONSTRAINTS AND CHALLENGES FOR THE GREEK PORT SYSTEM

In Greece, the ports within the core network of the Trans-European Transport Network with the highest traffic of container ships and cruise ships have initiated studies for the installation of Onshore Power Supply (OPS) systems. Piraeus, Heraklion in Crete, and Igoumenitsa have completed the study phase and are now in the development stage of the related infrastructure.

So, what are the biggest obstacles to developing such systems, and how economically feasible is this transition for port authorities and shipowners?

Obstacles such as infrastructure financing, delays in finalizing technological guidelines, and the issue of continuous power supply are some of the most significant challenges in the effort to decarbonize the port and maritime industry. Specifically:

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- **Port Infrastructure Cost:** The infrastructure cost, including studies and permits, is in the tens of millions, depending on the installed capacity and the prospect of serving primarily cruise ships, which are the most demanding in electrical energy during berthing. Assuming the minimum power requirement per ship is approximately 5-7 MW, then planning to serve two or three ships simultaneously raises the installed power requirement to at least 15 MW, with capital expenditure exceeding 25 million euros, depending on the complexity and technical work requirements within the port area and the cost of creating a substation. Such an investment cannot be supported based on the financial statements of most Greek ports.

- **Cost of Ancillary Works:** This cost pertains to the necessary infrastructure for transmitting electrical energy to the port installation and is considered significant.

- **Capital Investment in Ships:** The requirement for ports to comply with EU environmental legislation makes the corresponding adaptation of ships mandatory, with the cost per installation amounting to hundreds of thousands of euros.

- **Operational Cost – Charge per kWh:** This concerns the cost that each electrically powered ship will have to pay to the electricity provider. It is clear that this cost must be comparable to the opportunity cost created by forgoing the use of the ship's generators, which in turn is influenced by the international prices of MGO (marine gas oil).

## 4. CONCLUSION

Based on realistic figures regarding the cost of infrastructure and current electricity selling prices, and considering the marine gasoil prices in August 2023, we conclude that:

- The EU (as a whole) still lacks practical results compared to its rapidly evolving environmental regulatory framework.

- Issues of internal competition between countries and infrastructures that may, for various reasons, fulfill their environmental commitments at different times have not been sufficiently studied.

- The cost of studies and infrastructure cannot be undertaken by all ports, many of which serve specific and seasonal needs, without substantial subsidies approaching 80%.

- Ports are evolving into hubs for providing electricity, either by investing in energy production themselves or by entering into agreements with existing energy providers.

- The selling price of electricity is a key factor in the project's success, without compromising the quality of service in terms of frequency and regularity.

- The equivalent selling price of electricity compared to marine gasoil (MGO equivalent) is currently around €0.19/kWh, significantly lower than the selling price of electricity (€0.55/kWh), thus creating a significant "financial gap" for the shipowner **(Figure 1)**. With an electricity selling price of €0.55/kWh, the equivalent price of MGO is €2,558.1/tonne **(Figure 1)**.

- The annual benefit from the reduction of greenhouse gas emissions, especially $CO_2$, must be considered, given that $CO_2$ is now a traded commodity (the current price of 1 tonne of $CO_2$ on 11/08/2023 was $92.77) **(Figure 2)**.

- Quantifying the environmental benefit and distributing it among all stakeholders should serve as an incentive and help mitigate the impact of the capital costs of environmental investments.

To sum up, decarbonizing the maritime industry is a complex issue with multiple components and consequences that can affect competition and the viability of critical activities. Therefore, the environmental approach requires a thorough consideration of cost-benefit elements with the ultimate goal of maintaining competitiveness and ensuring that environmental adaptation does not become a destabilizing factor.

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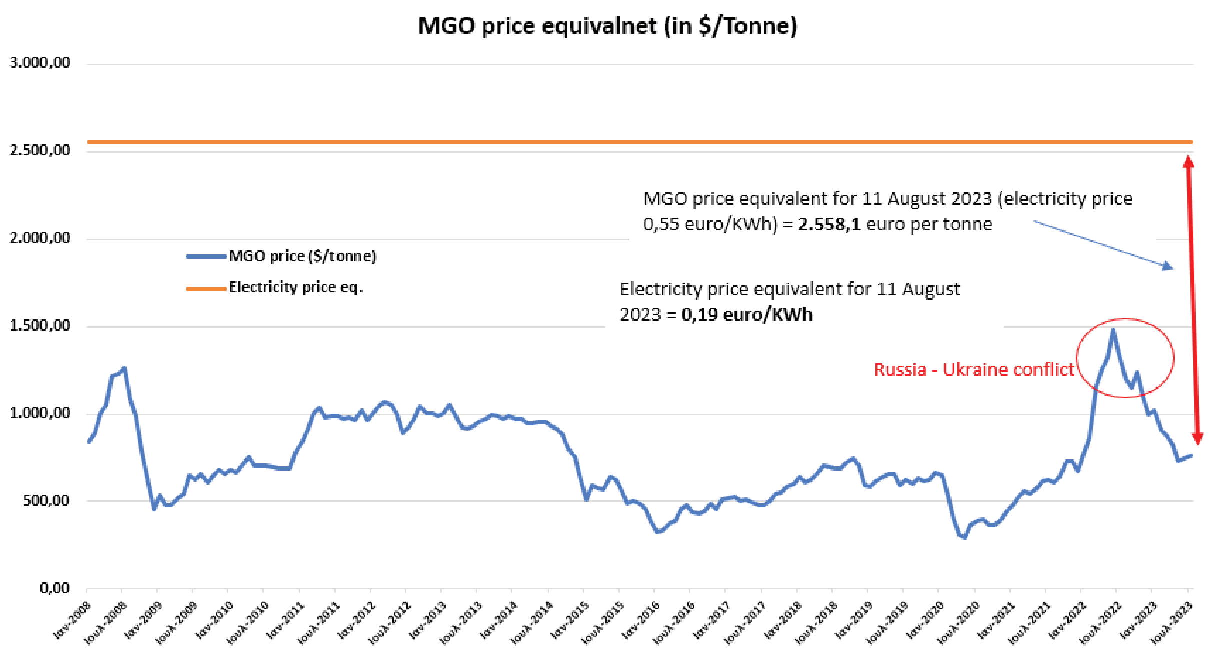


**Fig. (1):** Calculation of Equivalent MGO Price for the Same Period of Electricity Consumption in the Port
*Source: data elaborated by Authors (database Clarksons, August 2023)*

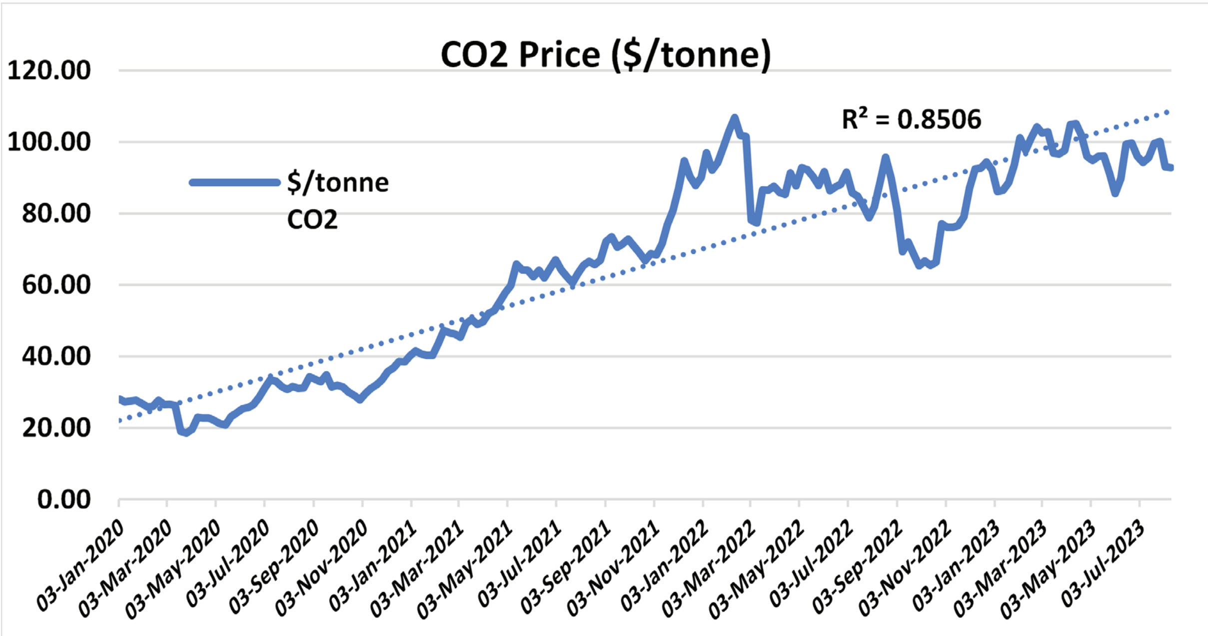


**Fig. (2):** CO2 Price per ton (August 2023) and Long-term Trend
*Source: data elaborated by Authors (database Clarksons, August 2023)*

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