***Laboratory of Operations Research***
***Department of Economics***
***School of Economics and Business***
***University of Thessaly***

***Department of Economics & Sustainable Development***
***School of Environment, Geography and Applied Economics***
***Harokopio University***

**6th Conference**

**"Economics of Natural Resources & the Environment"**

# Conference Proceedings

Friday 11 - Saturday 12 June 2021

**http://envecon.econ.uth.gr/main/**


***University of Thessaly – Department of Economics***

***Harokopio University***

The Laboratory of Operations Research in the Department of Economics at the University of Thessaly and the Department of Economics and Sustainable Development of the School of Environment, Geography and Applied Economics at the Harokopio University organized the 6th Conference "Economics of Natural Resources and the Environment" which was held online on June 11-12th, 2021.

The Laboratory of Operations Research organized successfully under the research project COOPERATION 2011 and the project entitled "Greenhouse Gas Emission Scenarios and Policies to Combat them by the year 2030, of Energy, Transport and Industry in Greece" the first two Pan-Hellenic Conferences on the Economics of Natural Resources and the Environment: Climate change on 26-27th March 2014 and October 31st and November 1st , 2014. Then the successful organization of the 3rd & 4th Pan-Hellenic Conference on Economics of Natural Resources and the Environment followed, on October 30-31st, 2015 and on November 4-5th, 2016. Continuing this effort, the 5th ENVECON Conference was organized on November 1st-3rd, 2018 in the Department of Economics of the University of Thessaly at Volos. This year, the 6th ENVECON Conference was held online, due to the COVID-19 pandemic, on June 11-12th, 2021.

This year's conference aimed to present the main issues that concern the Economics of Natural Resources and the Environment and the recent scientific research on the field. The main focus was given on sustainability and effective environmental management, while research on the environmental and social impacts of the recent COVID-19 pandemic was also presented. The conference aimed to promote the exchange of views and experiences of researchers from different scientific fields and the finding of common components of research approaches, since the environment is governed from interdisciplinarity.

Due to the multidimensional nature of the environment and the interdisciplinarity that is governing the field, the conference covered a lot of the areas associated with the environment, showing once more the importance of the cooperation of different scientific fields when studying about environmental protection and management.

**Conference Scientific Coordinator**

**Professor George E. Halkos (PhD)**

Director of Laboratory of Operations Research
Department of Economics
School of Economics and Business
University of Thessaly, Volos, Greece

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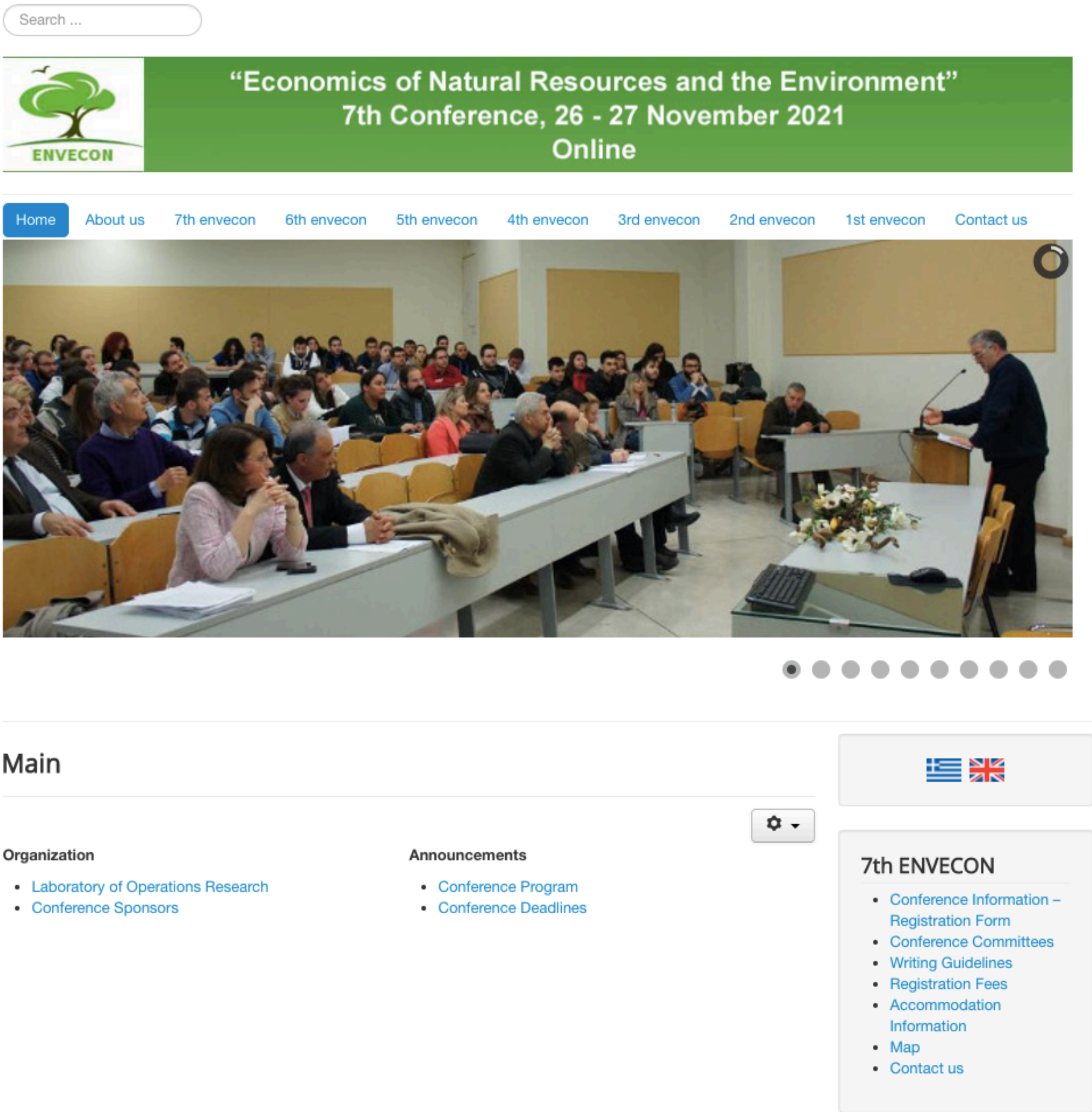
# Conference Website

http://envecon.econ.uth.gr/main/



| Concise Conference Schedule | | |
|---|---|---|
| **Day** | **Time (Greek Time)** | **Sessions-Topics** |
| **Friday 11/06/2021** | **09:00-09:30** | **OPENING – WELCOME** |
| | **09:30-11:00** | **Session 1:** **Environmental Performance** |
| | **11:00-11:30** | **Keynote Speaker** *Professor Phoebe Koundouri* |
| | **11:30-13:00** | **Session 2:** **COVID-19: Environmental and social effects** |
| | **13:00-14:00** | Break |
| | **14:00-15:30** | **Session 3:** **Issues in Biodiversity** |
| | **15:30-16:00** | **Keynote Speaker** *Professor Patrik Thollander* |
| | **16:00-17:30** | **Session 4:** **Energy Issues & Policies** |
| | **17:30-17:45** | Break |
| | **17:45-19:15** | **Session 5:** **Renewable Energy Sources** |
| | **19:15-20:45** | **Session 6:** **Sustainable Consumption** |

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|---|---|---|
| **Saturday 12/06/2021** | **09:15-10:45** | **Session 7:**<br>**Sustainable Development** |
| | **10:45-11:15** | **Keynote Speaker**<br>*Professor Walter Leal* |
| | **11:15-12:45** | **Session 8:**<br>**Quantitative Methods in Environmental & Resource Economics** |
| | **12:45-13:30** | Break |
| | **13:30-15:00** | **Session 9:**<br>**Circular Economy – Sustainable Entrepreneurship** |
| | **15:00-15:30** | **Keynote Speaker**<br>*Professor Thomas Sterner* |
| | **15:30-17:15** | **Session 10:**<br>**Environmental Policies and Assessment** |
| | **17:15-17:30** | **CLOSING & FINAL GIVEAWAYS** |

# CONFERENCE SCHEDULE

# Friday 11 June 2021

**Opening - Welcome** **09:00-09:30**

**1st Session** **09:30-11:00**

**Topic:** **Environmental Performance**

**Chairperson:** **Professor George Halkos**

| | |
|---|---|
| *09:30-9:45* | *Green Growth through Resource Efficiency and Absorptive Capacity under Technology Inequality. Blood Brothers or Distant Relatives?*<br>Nikos Chatzistamoulou & Phoebe Koundouri |
| *09:45-10:00* | *Technological hierarchies and learning: spillovers, complexity, relatedness and the moderative role of absorptive capacity*<br>Nikos Chatzistamoulou, Kostas Tsekouras & Kostas Kounetas |
| *10:00-10:15* | *Assessing the impact of undesirable outputs on industrial productivity growth: A Metafrontier Malmquist - Luenberger index approach across Europe*<br>Eirini Stergiou, Nikos Rigas & Konstantinos Kounetas |
| *10:15-10:30* | *The Impact of CO2 Emissions and Climate on Economic Growth and Productivity: International Evidence*<br>Nikos Rigas & Konstantinos Kounetas |
| *10:30-10:45* | *A comparative analysis of the world's regional green performance: an application of the GIP index*<br>Jaime Moll de Alba & Valentin Todorov |
| *10:45-11:00* | Discussion |

**Keynote Speaker** **11:00-11:30**

Topic: "Sustainable recovery from COVID-19:
Co-Developing the Future Vision for a Sustainable Europe
Co-Designing the Pathways via Research-Innovation-Policy Interface"

Professor Phoebe Koundouri

*Athens University of Economics and Business,*
*President-Elect, European Association of Environmental and Resource Economist,*
*Director of ReSEES Research Laboratory,*
*Director of Sustainable Development Unit, ATHENA RC,*
*Fellow, World Academy of Art and Science.*

## 2nd Session 11:30-13:00

**Topic:** **COVID-19: Environmental and social effects**

**Chairperson:** **Professor George Hondroyiannis**

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|---|---|
| *11:30-11:45* | *Fear of COVID-19 reinforces climate change beliefs. Evidence from 28 European countries*<br>Ádám Stefkovics & Olivér Hortay |
| *11:45-12:00* | *On the relationship among corporate philanthropy, corporate social responsibility and COVID-19: Evidence from the virus' first wave in Greece*<br>Eleni I. Stathi & Konstantinos G. Papaspyropoulos |
| *12:00-12:15* | *The relationships between pollution, economic growth and Covid-19: A literature review*<br>Athanasios Tsadiras |
| *12:15-12:30* | *Internet use, natural resource extraction and poverty reduction in rural Thailand*<br>Trung Thanh Nguyen & Thanh Tung Nguyen |
| *12:30-12:45* | *A conceptual model of psychological resilience to climate change, psychological adjustment, and subjective well-being*<br>Anastasia Gkargkavouzi |
| *12:45-13:00* | Discussion |

**3rd Session** **14:00-15:30**

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|---|---|
| **Topic:** | **Issues in Biodiversity** |
| **Chairperson:** | **Associate Professor Steriani Matsiori** |
| *14:00-14:15* | *Biodiversity reporting: A literature review*<br>Anastasia Naxaki & Konstantinos G. Papaspyropoulos |
| *14:15-14:30* | *What is Biodiversity and How Does Climate Change Affect It?*<br>Sophocles E. Dritsas, Steriani Matsiori & Anastasia Gkargkavouzi |
| *14:30-14:45* | *Comparison of National Strategies for Biodiversity and Forests using the text mining method*<br>Hariklia Liakou & Konstantinos G. Papaspyropoulos |
| *14:45-15:00* | *People and special protected areas: The influence of special protected areas on local communities*<br>George Halkos, Anastasia Gkargkavouzi, Sophocles E. Dritsas & Steriani Matsiori |
| *15:00-15:15* | *The challenges of using Material Flow Cost Accounting in the fish-farming sector*<br>Christos Danatskos & Konstantinos G. Papaspyropoulos |
| *15:15-15:30* | Discussion |

**Keynote Speaker** **15:30-16:00**

*Topic: "Energy management in industry, current status and ways forward"*

*Professor Patrik Thollander*

*Department of Management and Engineering (IEI),*
*Linkoping University & University of Gavle*
*Energy Systems (ENSYS)*

## 4th Session

**16:00-17:30**

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|---|---|
| **Topic:** | **Energy Issues & Policies** |
| **Chairperson:** | **Dr. Jaime Moll de Alba** |
| *16:00-16:15* | *Exploration of energy use in EU 28: Dynamics, patterns, policies*<br>George Halkos & Kyriaki Tsilika |
| *16:15-16:30* | *Proposals for transition of the Western Macedonia to the post-lignite era*<br>Eftimios Zervas & Leonidas Vatikiotis |
| *16:30-16:45* | *Interventions in Existing Buildings and their Environment. Case Study: Environmental - Bioclimatic Upgrade of a School Building*<br>Vasileia Maragkaki & Agisilaos Economou |
| *16:45-17:00* | *Factors determining the intention of citizens to participate and invest in local energy initiatives*<br>Spyridon Karytsas & Eleni Theodoropoulou |
| *17:00-17:15* | *The MOF4AIR European project: Examining the determinants of social acceptance of carbon capture, transport and storage (CCS)*<br>Spyridon Karytsas, Olympia Polyzou, Theoni Oikonomou & Constantine Karytsas |
| *17:15-17:30* | *Discussion* |

## 5th Session 17:45-19:15

**Topic:** **Renewable Energy Sources**
**Chairperson:** **Dr. Trung Thanh Nguyen**

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| *17:45-18:00* | *Optimal sustainability solutions for the location of a floating wind energy farm in the Aegean Sea with the incorporation of wave energy hybrid systems.*<br>Leonidas Tsipouras, George Spiliotopoulos & Vanessa Katsardi |
| *18:00-18:15* | *Renewable biogas energy production from forest biomass accumulated adjacent to forest roads*<br>Vasileios Diamantis, Alexandros Eftaxias, Christodoulos Daoutis, Apostolos Kantartzis & Garyfallos Arabatzis |
| *18:15-18:30* | *The causal relationships among mindfulness, connectedness to nature, mental health, and environmental behavior*<br>Anastasia Gkargkavouzi, Sophocles E. Dritsas, George Halkos & Steriani Matsiori |
| *18:30-18:45* | *The GEORISK European project: Establishing risk mitigation schemes for geothermal projects*<br>Spyridon Karytsas, Ioannis Choropanitis, Theoni Oikonomou & Constantine Karytsas |
| *18:45-19:00* | *A review of biofuels' social acceptance*<br>Spyridon Karytsas |
| *19:00-19:15* | Discussion |

## 6th Session 19:15-20:45

**Topic:** **Sustainable Consumption**
**Chairperson:** **Associate Professor Eleni Sardianou**

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| *19:15-19:30* | *Tracing the effects of the plastic bag levy on consumer behaviour in the case of Greece*<br>Georgios Maroulis, Charalampos Mentis, Dionysis Latinopoulos & Kostas Bithas |
| *19:30-19:45* | *Aspects of environmental policies in Athens in Classical times under an economics perspective*<br>George Halkos, Emmanouil M.L. Economou & Nicholas C. Kyriazis |
| *19:45-20:00* | *Food cycle economy: challenges and prospects*<br>Maria Michmizou & Paschalis Arvanitidis |
| *20:00-20:15* | *The socioeconomic determinants of residential water consumption in Athens. Preliminary results from a micro-econometric analysis*<br>Ioannis Kostakis & Eleni Sardianou |
| *20:15-20:30* | *Recycling of "Waste of Electrical and Electronic Equipment": an Exploratory Data Analysis*<br>Christos Liotiris & Zacharoula Andreopoulou |
| *20:30-20:45* | Discussion |

# Saturday 12 June 2021

## 7th Session — 09:15-10:45

**Topic:** **Sustainable Development**
**Chairperson:** **Professor Vassilios Profillidis**

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| *09:15-09:30* | *Mega Infrastructure Projects and their contribution to Sustainable Development The case of the Athens Metro*<br>Roido Mitoula & Angelos Papavasileiou |
| *09:30-09:45* | *Opinion of citizens about infrastructure privatization*<br>Emmanouil Vougioukalakis, Zoe Gareiou, Leonidas Vatikiotis & Efthimios Zervas |
| *09:45-10:00* | *Comparative assessment of environmental effects of railways with regard to other transport modes*<br>Vassilios Profillidis & George Botzoris |
| *10:00-10:15* | *The road to sustainability through the education of professionals in the field of construction*<br>Sofia Giannarou, Efthimios Zervas & Michael Tsatiris |
| *10:15-10:30* | *Brand Architecture and brand portfolio in tourism destinations: the case of Empordà*<br>Jacinta Gutiérrez Olesti |
| *10:30-10:45* | Discussion |

## Keynote Speaker — 10:45-11:15

*Topic: "Challenges in Adapting to a Changing Climate"*
*Professor Walter Leal*
*Manchester Metropolitan University*
*Department of Natural Sciences*

## 8th Session 11:15-12:45

**Topic:** **Quantitative Methods in Environmental & Resource Economics**
**Chairperson:** **Professor Christos Kitsos**

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|---|---|
| *11:15-11:30* | *Non-farm employment, natural resource extraction, and rural household's welfare: Evidence from Vietnam*<br>Manh Hung Do, Trung Thanh Nguyen, George Halkos & Ulrike Grote |
| *11:30-11:45* | *Kriging Analysis for Atmosphere Pollutants and House Prices: The case of Athens*<br>Polixeni Iliopoulou & Christos Kitsos |
| *11:45-12:00* | *Revisiting the socioeconomic and environmental determinants of health care utilization in European countries*<br>Athina Economou & George Halkos |
| *12:00-12:15* | *The future response of the pollutant adopting Tolerance Regions under different coding systems*<br>Christos Kitsos & Constantinos-Symeon Nisiotis |
| *12:15-12:30* | *Shocks, livelihood diversification, and household consumption: A Comparative evidence from panel data in Thailand and Vietnam*<br>Duy Linh Nguyen, Trung Thanh Nguyen & Ulrike Grote |
| *12:30-12:45* | Discussion |

## 9th Session 13:30-15:00

**Topic:** **Circular Economy-Sustainable Entrepreneurship**
**Chairperson:** **Associate Professor Konstantinos Evangelinos**

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| *13:30-13:45* | *Flood resilience capacity: a structural equation model for Greek small and mid-sized enterprises*<br>Antonis Skouloudis, Konstantinos Evangelinos, Panagiotis Vouros, Ioannis Nikolaou & Thomas Tsalis |
| *13:45-14:00* | *A study for corporate environmental strategy. The interaction between environmental legislation, innovation and intellectual capital*<br>Nikolaos S. Trevlopoulos & Ioannis E. Nikolaou |
| *14:00-14:15* | *Workplace human rights assessment in sustainability reports: An overview of the United Kingdom market*<br>Stefanos Fotiadis & Konstantinos Evangelinos |
| *14:15-14:30* | *Determinants for the withdrawal of companies in the tourism and leisure industry from the UN Global Compact programme*<br>Martin Thomas Falk & Gudrun Helgadottir |
| *14:30-14:45* | *Enriching the "social" in circular economy: the commons perspective*<br>Dionysia Evgenia Paraschi & Paschalis Arvanitidis |
| *14:45-15:00* | Discussion |

## Keynote Speaker 15:00-15:30

*Topic: "Carbon pricing and social acceptability"*
*Professor Thomas Sterner*
*Dept of Economics, University of Gothenburg*

## 10th Session 15:30-17:15

**Topic:** **Environmental Policies and Assessment**
**Chairperson:** **Professor Roido Mitoula**

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|---|---|
| *15:30-15:45* | *Economic Valuation of Honeybee Pollination Services*<br>Simeon Marnasidis, Garyfallos Arabatzis, Chrisovalantis Malesios, Fani Hatjina, Apostolos Kantartzis & Efstathia Verikouki |
| *15:45-16:00* | *Applying Factor Analysis and Structural Equation Models for urban parks in Greece: The relationship between motives and perceived characteristics, satisfaction and future visit*<br>George Halkos, Aikaterini Leonti & Eleni Sardianou |
| *16:00-16:15* | *Hunting Economics as a subdiscipline of Forest Economics*<br>Konstantinos G. Papaspyropoulos |
| *16:15-16:30* | *Modelling the transition dynamics of the socio-technical urban mobility system*<br>Vasiliki V. Georgatzi & Yeoryios Stamboulis |
| *16:30-16:45* | *Methodology approach for the development of an online tourism app: The case of the Greece – Bulgaria Interreg project «Stage for Cross Border Culture – CULSTAGE»*<br>Zacharoula Andreopoulou, Konstantinos Ioannou, Christiana Koliouska, Evangelia Karasmanaki, Georgios Tsantopoulos & Kleanthis Xenitidis |
| *16:45-17:00* | *Vulnerability Assessment to Desertification in Greece Using Composite Indicators.*<br>Demetrios E. Tsesmelis, Efthimios Zervas & Christos A. Karavitis |
| *17:00-17:15* | Discussion |

## Closing 17:15-17:30

*Topic: Closing & Giveaways*
*Professor George Halkos*
*Department of Economics, School of Economics and Business, University of Thessaly*

# ABSTRACTS

# Green Growth through Resource Efficiency and Absorptive Capacity under Technology Inequality. Blood Brothers or Distant Relatives?

**Nikos Chatzistamoulou**[1] **& Phoebe Koundouri** [1,2,3]
[1]*School of Economics and Research Laboratory on Socio-Economic and Environmental Sustainability – ReSEES, Athens University of Economics and Business*
[2]*Director, Sustainable Development Unit, ATHENA Research Center,*
[3]*Co-Chair, UN SDSN Europe*
chatzist@upatras.gr (ή @aueb.gr), pkoundouri@aueb.gr

**Abstract**
The European Green Deal as the new growth strategy of Europe considers resource efficiency as the workhorse towards sustainability paving the way for further investigation on the mechanisms of resource efficiency measures. The latter remains an unexplored area. We explore the drivers of energy and environmental efficiency through feedback loops, absorptive capacity and technological inequality factors by devising a unique balanced panel for the EU-28 from 2010 through 2014. We adopt a production function framework by employing the Data Envelopment Analysis and a Directional Distance Function to estimate productive performance, energy and environmental efficiency of each country. Due to endogeneity concerns and unobserved mechanisms affecting performance measures, we adopt the identification through heteroskedasticity estimator to investigate the drivers of resource efficiency measures. Findings indicate that resource efficiency measures intertwined though feedback loops while productive performance and absorptive capacity exert a significant influence on both. Technological inequality factors exert a differential effect on resource efficiency measures. A rebound effect is documented only for the case of energy efficiency. This is particularly relevant for policy design indicating that there is not a one-size-fits-all policy as green efficiency measures operate through alternative channels responding in an asymmetric manner to candidate drivers.

**Keywords:** Green Growth & Resource Efficiency, Environmental & Energy Efficiency, Productive Performance, Eco-Innovation Index, Data Envelopment Analysis

**JEL Codes**: O44, D2, P18, C50, C60.

# Technological hierarchies and learning: spillovers, complexity, relatedness and the moderative role of absorptive capacity

**Nikos Chatzistamoulou[1,2], Kostas Tsekouras[1] & Kostas Kounetas[1]**
[1] *Department of Economics, University of Patras, Greece*
[2] *School of Economics and Research Laboratory on Socio-Economic and Environmental Sustainability (ReSEES), Athens University of Economics and Business*
chatzist@upatras.gr, tsekour@econ.upatras.gr, kounetas@upatras.gr

**Abstract**
We develop a theoretical framework which facilitates the investigation of spillover effects on productive performance under the lens of technological relatedness, variety, and complexity, which are encompassed in heterogeneous, yet hierarchical, frontier-metafrontier structures. Spillovers are differentiated in terms of the knowledge pool from which they are originated, and the knowledge density of the production space in which they unfold, forming distinct knowledge grids. Concurrently, the counter effects of path dependence on productive performance, and the moderating role of absorptive capacity are in interplay. The theoretical framework is operationalized employing a panel dataset from country specific industrial structures of thirteen manufacturing and transportation industries in seventeen EU countries over an eight-year period. Empirical findings indicate that productive performance path dependence is dominant and catholic for all the examined frontier structures. Technological relatedness proves to be the most influential characteristic on which knowledge exchange is realized and absorptive capacity frames different patterns related to technological complexity and sectoral idiosyncrasies grounded on localization and lumpiness of the employed technology.

**Keywords:** Spillovers & Learning, Technological Complexity, Relatedness & Variety, Absorptive Capacity, Hierarchical structures, Metafrontier & Heterogeneity

**JEL Codes**: C51, D24, L6, L9.

# Assessing the impact of undesirable outputs on industrial productivity growth: A Metafrontier Malmquist - Luenberger index approach across Europe

**Eirini Stergiou, Nikos Rigas & Konstantinos Kounetas**

*Department of Economics, University of Patras, University Campus Rio, 26504, Patras, Greece*

e.stergiou@upnet.gr, nrigas@upatras.gr, kounetas@upatras.gr

**Abstract**

The EU Green Deal sets climate protection and sustainable energy transition on the top of the Agenda for countries and industries creating economic opportunities and strengthening the European economy and resources security. This paper adopts the, environmentally-related, Metafrontier Malmquist–Luenberger productivity growth index (MML) examining the presence of heterogeneity. We incorporate a non-radial approach of the index that is further decomposed into three substantial attributes, namely efficiency change, best practice change and technological gap change. In that endeavor, we integrate undesirable outputs with productivity index on a panel dataset concerning 14 European industries, from 27 countries accounting for years 1995-2014. Our results reveal different levels of environmental productivity across Europe. More specifically, we discover the existence of champions, followers and laggards among European industries and countries. Finally, our results support the non-convergence hypothesis among industries and the creation of discrete clubs with uneven characteristics.

**Keywords:** $CO_2$ emissions, Malmquist–Luenberger productivity growth index, European industries, Metafrontier.

**JEL Codes**: O44, O47, O52, Q56, C61.

# The Impact of CO2 Emissions and Climate on Economic Growth and Productivity: International Evidence

**Nikos Rigas & Konstantinos Kounetas**
*Department of Economics, University of Patras, University Campus Rio, 26504, Patras, Greece*
nrigas@upatras.gr, kounetas@upatras.gr

**Abstract**
The world's climate has already changed measurably in response to accumulated greenhouse gas emissions. These changes, as well as projected future disruptions, such as increase of temperature, have prompted intense research. A significant body of literature on climate change and economic growth signifies a negative relationship between the two. However, considerable uncertainty surrounds the effect of increasing temperatures combined with releases of anthropogenic emissions to the atmosphere. By applying detailed country level data in the 1961-2013 period this paper documents the relationship between weather variables, CO2 emissions, share of renewable energy sources, gross domestic product and total factor productivity in a standard Cobb-Douglas production function by using an instrumental variable approach. Our findings suggest that economic growth has been positively affected by temperature and CO2 emissions, while climate vulnerability varies significantly between rich and poor countries. Furthermore, as soon as we take into account renewable sources as an instrument, the negative effect on CO2 emissions demonstrates its impact for optimal environmental policies design. Finally, our results provide evidence for the existence of an inverted U-shaped relationship for temperature and emissions.

**Keywords:** Countries' TFP; CO2 emissions; Renewable Energy Sources.

**JEL Codes**: Q54, C26, O44.

# A comparative analysis of the world's regional green performance: an application of the GIP index

**Jaime Moll de Alba & Valentin Todorov**

*United Nations Industrial Development Organization (UNIDO), Vienna, Austria*

J.Moll-de-Alba@unido.org, Valentin@Todorov.at

**Abstract**

Bearing in mind the multiple calls for a transition to a green economy and the leading role of the industrial sector in terms of economic growth and environmental sustainability, this paper undertakes a comparative analysis of the green industrial performance of eight world's regions. For that purpose, the paper introduces the latest version of UNIDO's Green Industrial Performance index, which serves to analyse and compare the performance of economies in terms of green manufacturing over time. A unique database derived exclusively from international data sources such as UNIDO's industrial statistics database (INDSTAT) and UN COMTRADE is constructed. The GIP database is then used to compute the GIP composite index and then rank and analyse the green industrial performance of a set of more than 110 countries for the period 2000-2018. The paper then estimates, analyses and compares the relative green industrial performance of the world's regions over time. The paper concludes by putting forward recommendations for future research and analysis of the green performance of the manufacturing sector, with particular emphasis on regional performance.

**Keywords:** Industrial development, Sustainable Development Goals, Green Economy, Composite index.

**JEL Codes**: F63, F64, L60, N60, O25.

# Fear of COVID-19 reinforces climate change beliefs. Evidence from 28 European countries

**Ádám Stefkovics & Olivér Hortay**
*Faculty of Social Sciences, Eötvös Loránd University, Hungary*
*Department of Social Research Methodology*
adam.stefkovics@tatk.elte.hu

**Abstract**
The long-term nature of climate policy measures requires stable social legitimacy, which other types of crises may jeopardize. This article examines the impact of the COVID-19 fear on climate change beliefs based on an autumn 2020 population survey in the Member States of the European Union and the United Kingdom. The results show that deep COVID-19 concerns increase climate change concerns, awareness, and perceived negative impacts of climate change. These effects are more robust among the lower educated Europeans. On the country level, strict governmental measures are also linked to deep climate change concerns. In contrast to the experience following the 2008 recession, the findings show that a secondary crisis can positively impact climate attitudes, which is a promising result for policy actions.

**Keywords:** COVID-19, Climate change beliefs, European Union, Multilevel regression, Survey.

**JEL Codes**: I1, Q54, Q58.

# On the relationship among corporate philanthropy, corporate social responsibility and COVID-19: Evidence from the virus' first wave in Greece

**Eleni I. Stathi & Konstantinos G. Papaspyropoulos**

*MSc Natural Resources: Monitoring, Technology and Bio-economy, Department of Forestry and Natural Environment, Aristotle University of Thessaloniki, 54124*

elenistathi@for.auth.gr, kodafype@for.auth.gr

**Abstract**

The present research explores the relationship between corporate social responsibility (CSR) and corporate philanthropy (CP) given the presence of the COVID-19 pandemic. Taking into account the Greek Fortune 100 corporations that responded or not to the call for help against the first wave of the virus existence, two hypotheses are tested: i) history of CSR practices is a determinant of CP, and ii) history of CP in the proCOVID-19 period is a determinant of CP in the postCOVID-19 period. The findings confirm the first and reject the second hypothesis. The paper is among the first exploring CP in the COVID-19 period and reveals that it presents attributes about the behaviour of corporations that have been already proved in the natural disaster literature, thus they react in a similar way.

**Keywords:** Pandemic, GRI, donations, health system, sustainability reporting.

**JEL Codes**: Q56, M14, Q01, A13, I18.

# The relationships between pollution, economic growth and Covid-19: A literature review

**Athanasios Tsadiras**
*Laboratory of Informatics in Economic Sciences, School of Economics, Aristotle University of Thessaloniki, Greece*
tsadiras@econ.auth.gr

**Abstract**
In the era of Covid-19, one of the main scientific questions regards the relationships that exist between pollution, economic growth and Covid-19. For example, the role that the concentrations of atmospheric Particulate Matter ($PM_{10}$ and $PM_{2.5}$) played in the spread of the virus is examined in various studies, with the correlations to be justified both directly and indirectly. The direct connection can be justified by the fact that the atmospheric particulate could play the role of the virus carrier. The indirect connection can be justified by the fact the effects of respiratory viruses like Covid-19 on humans would be more severe in patients that live and breathe in polluted environment. Moreover, the relationship between economic growth and environmental sustainability in another topic discussed in several studies. In this paper we present the conclusions that we draw from making a survey on the relevant literature that regards the relationships between pollution, economic growth and Covid-19. The paper accumulates the results coming from numerous scientific studies that in most of the cases present findings coming only from regional level (e.g. cities/ regions in China or Italy).

**Keywords:** Pollution, economic growth, Covid-19.

**JEL Codes**: Q53, O44, O47, I18.

# Internet use, natural resource extraction and poverty reduction in rural Thailand

**Trung Thanh Nguyen & Thanh Tung Nguyen**
*Institute for Environmental Economics & World Trade, School of Economics & Management, Leibniz University Hannover, Germany*
thanh.nguyen@iuw.uni-hannover.de, tung.nguyen@iuw.uni-hannover.de

**Abstract**
Understanding the impact of internet use by rural households is useful in facilitating digitalization in rural areas of developing countries. This study uses the data of around 1,912 and 1,815 rural households surveyed in 2016 and 2017 respectively in three provinces of Thailand to examine the impact of internet use on natural resource extraction and poverty reduction. A heteroscedasticity-based instrumental variable regression approach is employed to account for endogeneity concerns. Results show that internet use increases household income, promotes development of non-farm sectors, and reduces the extraction of and reliance on natural resource extraction. However, better-off households are found to benefit relatively more than worse-off households. These findings thus suggest that rural digitalization to be more focused on the rural poor for more inclusive economic growth.

**Keywords:** Rural household, instrumental variable regression, poverty, natural resource extraction, Thailand.

**JEL Codes:** Q12, C25, D13, M15, M12.

# A conceptual model of psychological resilience to climate change, psychological adjustment, and subjective well-being

**Anastasia Gkargkavouzi**
*University of Thessaly, Department of Ichthyology and Aquatic Environment, School of Agricultural Sciences, Volos, Nea Ionia 38446, Greece.*
agkargkavouzi@uth.gr

**Abstract**
This study proposes a causal model of climate-induced psychological resilience, psychological adjustment, and subjective well-being. Based on a literature synthesis, the effect of a series of predictive constructs was considered including climate change coping strategies, subjective well-being, dispositional mindfulness, self-efficacy beliefs, and perceived restorativeness of nature. An online survey with self-complete questionnaire was conducted among Greek adults (n= 552). Data analysis included Confirmatory Factor Analysis and Structural Equation Modeling (SEM). We tested for common method bias (CMB) based on the Common Latent Factor (CLF) technique. The results showed an acceptable fit for the measurement and structural models, while all latent constructs established reliability and construct validity. The main findings showed that mindfulness and self-efficacy positively influence resilience, and the latter has a positive impact on coping appraisals. Resilience has a negative influence on psychological adjustment, and perceived restorativeness has a non-significant effect on resilience. Psychological resilience has a significant positive effect on coping appraisal and subjective well-being as measured by life satisfaction and positive affects, but a negative impact on psychological adjustment. Further research is essential to reassess these relationships and develop an integrative psychological model of climate resilience. Policymakers can draw on relevant research to design and implement informed strategic plans and support sector-specific interventions to increase psychological resilience and improve mental health in the era of climate change.

**Keywords:** Psychological Resilience, Subjective Well-being, Psychological Adjustment, Climate Change, Structural Equation Modeling.

**JEL Codes**: A14, C38, Q00, Q51, Q56, Q59.

# Biodiversity reporting: A literature review

**Anastasia Naxaki & Konstantinos G. Papaspyropoulos**
*MSc. Natural Resources: Monitoring, Technology and Bioeconomy, Department of Forestry and Natural Environment, Aristotle University of Thessaloniki, 54124*
anaxaki96@gmail.com, kodafype@for.auth.gr

**Abstract**
Biodiversity is declining in a rather fast rate, being under threat due to climate change, unsustainable use of natural resources and expanding population. Thus, the concept of biodiversity has evolved in recent years, being an important issue for both businesses and society. Today, there are several efforts for the provision of frameworks for companies to understand how they can incorporate biodiversity loss into their business models. However, many firms seem to be quite reticent to report on the effects that their activities have on biodiversity. Nowadays, under the scope of an ecologically sustainable society, academia is investigating the role of biodiversity accounting and reporting in communicating performance and enhancing accountability towards relevant stakeholders. Under the environmental stewardship theory, business and organizations are accountable to society for protecting and contributing to environmental balance. Thus, the objective of the present research is to explore in detail biodiversity reporting through a literature review and it aims to contribute to the development of a broader theoretical knowledge, as biodiversity reporting and accounting represent issues that need to be explored in more detail. In order to do so, the present research explores five main issues: a) definition of, b) theories for, c) protocols for, d) drivers for, and e) content of existing biodiversity reporting.

**Keywords:** Biodiversity accounting, sustainability, reporting protocols, corporate responsibility.

**JEL Codes**: L22, M41, O50, Q56, Q57.

3rd SESSION: *Issues in Biodiversity*

# What is Biodiversity and How Does Climate Change Affect It?

**Sophocles E. Dritsas, Steriani Matsiori & Anastasia Gkargkavouzi**
*University of Thessaly, Department of Ichthyology and Aquatic Environment, School of Agricultural Sciences, Volos, Nea Ionia 38446, Greece.*
dritsas@uth.gr, steriani@uth.gr, agkargkavouzi@uth.gr

**Abstract**
The need to adopt marine biodiversity conservation policies and adapt them to the needs posed by the effects of climate change has emerged as has emerged as a central and unresolved challenge. People are an important factor in the adoption of the above policies. This paper presents the results of research using a structured questionnaire to capture the views of research participants on the importance of biodiversity and the effects of climate change. A total of 737 were collected to help identify a variety of issues on a range of issues: the economic value of biodiversity and the consequences of its loss, climate change, its consequences, and its causes. In particular, the research findings reveal citizens' concerns about biodiversity conservation and how they relate to their knowledge and attitudes in relation to climate change. The results of the research are analysed both in relation to: (a) the provision of information on the policy adaptation process in the context of biodiversity conservation and (b) the identification of future research needs.

**Keywords:** Marine, ocean, biodiversity, climate change, biodiversity and people.

**JEL Codes**: Q57, Q54, Q56, Q50.

# Comparison of National Strategies for Biodiversity and Forests using the text mining method

**Hariklia Liakou & Konstantinos G. Papaspyropoulos**
*University of West Attica,*
*M.Sc. Applied Environmental Protection Policies and Techniques,*
*University Campus 2, Egaleo 122 44*
hara.laikou@gmail.com, kodafype@yahoo.gr

**Abstract**
In order sustainability to be achieved in the management and protection of natural resources in Greece, national strategies for Biodiversity and Forests with a long-term horizon have been developed in recent years. The Greek Ministry of Environment issued the National Strategy for Biodiversity in 2014 and the Strategic Plan for Forestry Development (National Strategy for Forests) in 2018. Although there is a global distinction between Biodiversity and Forests, there may exist or not differences among the policies described in the texts, since biodiversity among others includes the diversity of forest species, while forest ecosystems protect a significant part of global biodiversity. In order to determine the possible differences, similarities and overlaps of the two texts, in the present research they were compared using the modern tool of text mining. Through the R programming language, the appropriate packages that have developed commands for text mining were used and the two strategies were analyzed in terms of sentiment analysis, word frequency, word relationship and topic modeling. The results show that there are both differences and similarities, and that in the National Strategy for Biodiversity the word biodiversity is related mainly to the word protection, while in the National Strategy for Forests the word forest is related mainly to management.

**Keywords:** Natural resource financing, natural resource policy, content analysis, sentiment analysis, topic modeling, language R.

**JEL Codes**: Q57, Q28, Q23, C55, C38.

# People and special protected areas: The influence of special protected areas on local communities

**Georgios Halkos[1], Anastasia Gkargkavouzi[2], Sophocles E. Dritsas[2] & Steriani Matsiori[2]**

[1] *Laboratory of Operations Research, Department of Economics, University of Thessaly, Korai 43 Volos 38333, Greece.*

[2] *University of Thessaly, Department of Ichthyology and Aquatic Environment, School of Agricultural Sciences, Volos, Nea Ionia 38446, Greece.*

halkos@uth.gr, agkargkavouzi@uth.gr, dritsas@uth.gr, steriani@uth.gr

**Abstract**

Protected areas are vital for biodiversity conservation although some have been criticized for not providing adequate socio-economic benefits to local people. The present study examines the social, economic, and political effects of environmental conservation projects as they are manifested in protected areas. More specific examine the impacts of Lake Karla's surrounding area (welfare, ecological balance, biodiversity conservation, etc). For this reason, a face-to-face survey of 650 respondents randomly selected was carried out. We used descriptive statistics to summarize the demographic and socioeconomic statuses of the households. Then, we estimated the effects of the protected area on the welfare of the households using multicriteria analysis. According to the results of the research, people are interested in the reconstruction of Lake Karla because of its contribution to ecological balance an economic impact on local community.

**Keywords:** Protected Areas, local economies, socio-economic benefits, eco-tourism, ecological balance.

**JEL Codes**: Q28, Q34, Q50, Q57.

# The challenges of using Material Flow Cost Accounting in the fish-farming sector

**Christos Danatskos & Konstantinos G. Papaspyropoulos**
*MSc. Natural Resources: Monitoring, Technology and Bioeconomy, Department of Forestry and Natural Environment, Aristotle University of Thessaloniki*
chrisdanat@gmail.com, kodafype@for.auth.gr

**Abstract**
Animal-source food production industry has developed new intensive farming techniques in order to respond to the growing demand for high protein food, following the population increase. This has resulted in an increased production performance and, sequentially, in environmental impacts and pollution issues. Consequently, environmental accountability is now established by laws and is demanded by various stakeholders, forcing polluting companies to adopt environmentally friendly production processes to avoid high taxes and fines. As a result, various business-level Environmental Management Accounting (EMA) approaches have been developed by academia to address the effects that factors like high environmental cost techniques and usage of polluting materials can have on the financial position and profitability of a company. An EMA method that tracks and analyzes the material and energy flows in a production process, to reveal cost reducing opportunities, both environmental and financial, is Material Flow Cost Accounting-MFCA. Aquaculture industry, as an animal-source food production industry, faces issues regarding environmental impacts, although it is generally considered as a sustainable farming technique. Since aquaculture production process demonstrates material and energy flows, MFCA can be implemented to analyze the production stages and assist an aquaculture company in taking the required management decisions. However, the various aquaculture techniques, regarding the farmed species, the geographical position, and the use of either fresh water or sea, present certain challenges in MFCA application, some of which the current study will attempt to highlight.

**Keywords:** Aquaculture, Environmental Management Accounting, sustainable farming, Material Flow Cost Accounting, environmental cost.

**JEL Codes**: Q22, Q56, Q53, Q51, Q57.

# Exploration of energy use in EU 28: Dynamics, patterns, policies

**George Halkos[1] & Kyriaki Tsilika[1,2]**

[1] *Laboratory of Operations Research, School of Economics and Business, Department of Economics, University of Thessaly*

[2] *School of Social Sciences, Hellenic Open University*

halkos@uth.gr, ktsilika@uth.gr

**Abstract**

Sustainable energy use has become the most critical challenge of the world today. The relationship between consumption and use of different energy resources is an important topic in the regulatory and environmental literature. The paper places emphasis on primary energy resources, their covariation and correlation and aims to provide a systematic analysis of their development over time. The analysis uses evidence from EU country-level data. Different results from same territories show that energy consumption does not always reflect or is due to climatological or meteorological conditions. Our visual exploration includes plotting energy variables with layering information on graphics (concerning geographical zones, GDP levels faceting grouped data, selected energy-use clusters) in order to produce effective comparative plots. We produce visual summaries of data on graphs such as bubble charts, motion charts, boxplots and we visualize confidence intervals for means of energy use; we create maps and correlation matrices. All these for country – or cluster of countries – level data.

**Keywords:** Energy use, exploratory data analysis, correlation analysis, trends, European Union.

**JEL Codes**: C63, Q40, Q42, Q48, C83, C88.

# Proposals for the transition of the Western Macedonia to the post-lignite era

**Eftimios Zervas[1] & Leonidas Vatikiotis[2]**
[1] *Hellenic Open University Parodos Aristotelous 18, 26335, Patra, Greece*
[2] *Small Enterprises of GSEVEE, Aristotelous 46, 10433 Athens, Greece*
zervas@eap.gr, leonidasvatikiotis@gmail.com

**Abstract**
This research text attempts to formulate a coherent and realistic proposal for Western Macedonia, concerning the after de-lignification period. The aim of this proposal is to avoid the economic decline and poverty of the Region. The first part presents the proposals for the necessary environmental restoration of mine lands. Based on the international literature and the best practices, methods and solutions for the restoration of the environment, which has suffered from severe damages, and the development of activities that will not affect the environmental balance, are proposed. Concerning the economic rehabilitation of the Region, a mix of actions referring to the whole production chain: from the primary to the tertiary sector of the economy, is proposed. The action that is expected to ≪unlock ≫ the production potential of this region is the creation of branded products, under a single brand name, which will voluntarily bring together, in the context of synergies, the agri-food and manufacturing activities.

**Keywords:** De-lignitization, Green transition, Just transition, Sustainable growth, Renewable Energy Sources.

**JEL Codes**: Q01, Q26, Q28, Q50, Q56.

# Interventions in Existing Buildings and their Environment. Case Study: Environmental - Bioclimatic Upgrade of a School Building

**Vasileia Maragkaki[1] & Agisilaos Economou[1,2]**

[1] *School of Science and Technology, Hellenic Open University, 26335, Patras, Greece*

[2] *School of Applied Mathematical and Physical Sciences, National Technical University of Athens, 15780, Athens, Greece*

vamaragaki@gmail.com, aghs@mail.ntua.gr

**Abstract**

The high energy consumption of conventional school units and at the same time the important role of bioclimatic design of school buildings in upgrading the educational process makes the need for interventions in the school space in order to upgrade it environmentally and bioclimatically.

The present research refers to the possibilities of upgrading the school units taking into account the Building Energy Efficiency Regulation and the bioclimatic design. Then, the survey focuses on a conventional school unit (Leontio Lyceum in the Patissia area). Research in situ and a method of personal interviews with the teachers of the school unit took place in order to identify the problems of the school unit.

In the end, we propose interventions in the school unit, in order to environmentally and bioclimatically upgrade it, preserve its architecture and improve the conditions of thermal and visual comfort of the students. During the intervention plan, we take into account the characteristics of two bioclimatic school units of the German School in Marousi (Athens). In order to evaluate the interventions in the school unit we use the energy consumption calculation program “Easykenak”, the design program “Autocad”, as well as the 3D design and photorealism programs “Archicad” and “Lumion” to highlight the interventions.

**Keywords:** Bioclimatic design, sustainability, environment, school building upgrade.

**JEL Codes**: Q42, Q43, Q56, Q58.

# Factors determining the intention of citizens to participate and invest in local energy initiatives

**Spyridon Karytsas & Eleni Theodoropoulou**
*Department of Economics and Sustainable Development, School of Environment, Geography and Applied Economics, Harokopio University, 17671 Kallithea, Greece*
skaryts@hua.gr, etheodo@hua.gr

**Abstract**
Collective action is necessary to achieve the restructuring of societies into sustainable production and consumption models. Local energy initiatives can assist the achievement of this goal; however, their success requires citizens' acceptance, support, and participation.
The present paper is part of research that examines the institution of Energy Communities in Greece. Specifically, the research examines the level of information of the citizens and their intention to participate and invest in the Energy Communities, while at the same time examining issues such as the relevant structures, benefits, barriers, and motives. The present paper demonstrates the results of the literature review and the assessment of the aforementioned issues.
The findings of the present work will be further utilized for the definition and examination - through quantitative and qualitative analyses - of research questions targeting the Greek Energy Communities.

**Keywords:** Energy community, participation, investment, barriers, motives.

**JEL Codes**: P18, Q42, Q48.

# The MOF4AIR European project: Examining the determinants of social acceptance of carbon capture, transport and storage (CCS)

**Spyridon Karytsas, Olympia Polyzou, Theoni Oikonomou & Constantine Karytsas**
*Geothermal Energy Department, Division of Renewable Energy Sources, Centre for Renewable Energy Sources and Saving (CRES), 19009 Pikermi, Greece*
spkary@cres.gr, pololi@cres.gr, thoikonomou@cres.gr, kkari@cres.gr

**Abstract**

Carbon Capture and Storage (CCS) is the method of capturing CO2 generated by power plants or heavy industry processes and transferring it to long-term geological storage systems. However, it is a divisive technology that often experiences public opposition when it comes to accepting individual projects. Thus, it should not be ignored that social acceptance of CCS is a requirement for its further development. In this sense, the MOF4AIR European project, which aims to illustrate the efficiency of CO2 capture technologies focused on MOFs (Metal Organic Frameworks), involves relevant activities examining social issues related to CCS.

The findings of the initial stages of these activities are presented in this work. The determinants of social acceptance of CCS, as well as the relationships between them, were defined based on a literature review. Several factors have been identified to affect social acceptance, with perceived costs and benefits, trust in stakeholders, and knowledge of relevant subjects being the most frequently reported. Following the literature review, and based on the identification of relevant research gaps, a questionnaire has been developed for a quantitative social survey that will be performed in seven European countries.

The findings of the social survey, along with the results from interviews with targeted stakeholders, will be used to create public engagement scenarios.

**Keywords:** Carbon dioxide, carbon capture and storage, CCS, social acceptance.

**JEL Codes**: P18, Q49.

# Optimal sustainability solutions for the location of a floating wind energy farm in the Aegean Sea with the incorporation of wave energy hybrid systems.

**Leonidas Tsipouras, George Spiliotopoulos & Vanessa Katsardi**
*Department of Civil Engineering, University of Thessaly, Volos*
ltsipouras@uth.gr, gspiliotop@uth.gr, vkatsardi@civ.uth.gr

**Abstract**
Wind power is an excellent alternative source of energy by being inexhaustible and with zero emissions but until today no wind power is produced offshore in the Mediterranean. However, offshore energy benefits from increased wind energy potential and therefore constitutes the backbone of the Blue Energy at the Blue Economy Sector. Featured in this paper is a methodology for calculating the total life-cycle cost of a floating offshore wind farm. A floating solution is more viable in the deep waters of the Aegean Sea avoiding significant social backlash that is observed against land installations. In addition, using the software "RETScreen Expert", several economic indices are calculated, based on which the economic viability of a floating offshore wind farm is assessed. A hybrid solution combining the use of wave power is also examined. Three potential areas for installation are investigated (offshore Lemnos, Mykonos and Crete), coming to the conclusion that the most cost-effective solution is presented in the area of Eastern Crete. The proposed methodology can be used for the calculation of the economic indices of a floating offshore wind farm in any location.

**Keywords:** Blue Economy, Blue Energy, Floating Offshore Wind Farms, Hybrid Systems, Aegean Sea.

**JEL Codes**: Q01, Q20, Q25, Q28, Q42, Q47, Q48, Q51, Q55.

# Renewable biogas energy production from forest biomass accumulated adjacent to forest roads

**Vasileios Diamantis[1], Alexandros Eftaxias[1], Christodoulos Daoutis[2], Apostolos Kantartzis[2] & Garyfallos Arabatzis[2]**

[1] *Department of Environmental Engineering, Democritus University of Thrace, Xanthi, Greece*

[2] *Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, Orestiada, Greece*

bdiamant@env.duth.gr, apkantar@fmenr.duth.gr

**Abstract**

Regular removal of forest biomass adjacent to forest roads is essential for the prevention of wildfires. In this study we evaluated the quantity of pine needles accumulated onto the forest carpet (litter) and fresh needles collected during pine-tree pruning operations, of a low-altitude Mediterranean *Pinus* forest. Pine needle samples were digested under mesophilic conditions, in batch reactors in order to evaluate the biogas production potential. The pine needle litter was characterized by an average height between 3 and 7 cm, apparent density 400 and 600 g/m$^2$ and low moisture content (12%). The pine needles recovered during tree pruning operations were equal to 2-4 kg/tree having a moisture content between 44 and 54%. Fresh pine needles revealed similar biogas production potential compared to the pine needle litter (140 and 120 L/kg volatile solids, respectively). The data from this study demonstrate that it is possible to recover around 500 m$^3$ of biogas per km of forest road when the collected biomass is disposed of to an anaerobic digestion facility. Under these conditions, the overall economic benefit from electricity introduction to the grid was calculated around 250 € / km forest road that can be used for biomass collection and transportation.

**Keywords:** Forest roads, biogas, forestry solid wastes, anaerobic digestion, environmental economics.

**JEL Codes**: Q53, Q23, Q42.

# The causal relationships among mindfulness, connectedness to nature, mental health, and environmental behavior

**Anastasia Gkargkavouzi[1], Sophocles E. Dritsas[2], George Halkos[3] & Steriani Matsiori[1]**

[1] *University of Thessaly, Department of Ichthyology and Aquatic Environment, School of Agricultural Sciences, Volos, Nea Ionia 38446, Greece.*

[2] *University of Thessaly, Department of Ichthyology and Aquatic Environment, School of Agricultural Sciences, Volos, Nea Ionia 38446, Greece.*

[3] *Laboratory of Operations Research, Department of Economics, University of Thessaly, Korai 43 Volos 38333, Greece.*

agkargkavouzi@uth.gr, dritsas@uth.gr, halkos@uth.gr, steriani@uth.gr

**Abstract**

The current study examines the relationships between dispositional mindfulness, connectedness to nature, aspects of mental health, and environmental behavior. Online- questionnaires were administered in a cross-sectional survey of Greek residents (n=552). We relied on previous research to determine the factorial structure of the constructs and tested the conceptual model using Structural Equation Modeling (SEM). We tested for common method bias (CMB) using the Common Latent Factor (CLF) technique. Both the measurement and structural models had adequate overall fit, high reliability, and established construct validity. Dispositional Mindfulness positively influences nature connectedness, mental health, and environmental behavior. Feelings of nature-relatedness and mental health have a positive impact on environmental behavior. The findings might be relevant to sustainable development and inform social policies aimed at promoting sustainable lifestyles and designing interventions to improve mental health and well-being. Future studies should further investigate the strength and direction of the proposed causal model.

**Keywords:** Mindfulness, Connectedness to Nature, Environmental Behavior, Mental Health, Structural Equation Modeling.

**JEL Codes**: A14, C38, Q00, Q51, Q56, Q59.

# The GEORISK European project: Establishing risk mitigation schemes for geothermal projects

**Spyridon Karytsas, Ioannis Choropanitis, Theoni Oikonomou & Constantine Karytsas**
*Geothermal Energy Department, Division of Renewable Energy Sources, Centre for Renewable Energy Sources and Saving (CRES), 19009 Pikermi, Greece*
spkary@cres.gr, jchoro@cres.gr, thoikonomou@cres.gr, kkari@cres.gr

**Abstract**

Developing geothermal projects contains numerous elements of risk, with the most significant one being the geological resource risk, affecting primarily deep geothermal projects. Beyond the exploration phase, the performance and profitability of a geothermal project are threatened by this risk, which includes: (a) the short-term risk of not finding an economically viable geothermal resource and (b) the long-term risk of natural depletion of the geothermal resource.

Up till the drilling of the first borehole, project developers cannot be definite of the exact parameters of the planned geothermal project. After the first drilling has been carried out, tests and measurements reduce the geological risk and make it possible to attract external capital.

Geological risk is a common issue around Europe, with relevant insurance funds existing in a handful of countries. The GEORISK European project works on the establishment of risk mitigation schemes throughout Europe, focusing on covering the exploration phase and the first drilling. Hence, it deals with activities to be financed before the involvement of financial institutions and energy producers, which participate in the financing of the boreholes and surface systems that follow. The scheme that will limit the potential financial risk must be designed according to the degree of maturity of the market in question.

**Keywords:** Geothermal energy, geological resource risk, risk mitigation schemes.

**JEL Codes**: G32, Q42.

# A review of biofuels' social acceptance

**Spyridon Karytsas**[1,2]
[1]*Geothermal Energy Department, Division of Renewable Energy Sources, Centre for Renewable Energy Sources and Saving (CRES), 19009 Pikermi, Greece*
[2]*Department of Economics and Sustainable Development, School of Environment, Geography and Applied Economics, Harokopio University, 17671 Kallithea, Greece*
spkary@cres.gr, skaryts@hua.gr

**Abstract**
Social acceptance is a crucial aspect related to the successful development of the biofuels market. Besides, the lack of social acceptance can create a significant barrier, hindering the technology's development. Achieving social acceptance strengthens trust between consumers, local communities, and enterprises, thus enhancing project acceptance while preventing time delays and reactions that could lead to increased costs.

The present paper aims to present the different dimensions of social acceptance of biofuels, i.e. acceptance in the socio-political dimension, the local dimension, and the market dimension (including consumer attitudes). In this context, the relevant stakeholders and factors affecting acceptance, the level of public awareness and information, consumers' willingness to pay for and to adopt the technology, the cases of support and opposition towards biofuel applications, the importance of local community engagement, as well as the best practices performed by public authorities and private actors, related to each dimension of social acceptance are investigated and assessed.

**Keywords:** Biofuels, social acceptance.

**JEL Codes**: P18, Q42.

# Tracing the effects of the plastic bag levy on consumer behaviour in the case of Greece

**Georgios Maroulis[1], Charalampos Mentis[1], Dionysis Latinopoulos[2] & Kostas Bithas[1]**

[1]*Panteion University of Social Political Sciences, School of Economy and Public Administration, Department of Economic and Regional Development*

[2]*Aristotle University of Thessaloniki, School of Spatial Planning and Development, Faculty of Engineering*

georgios_maroulis@eesd.gr, x.mentis@eesd.gr, dlatinop@plandevel.auth.gr, kbithas@eesd.gr

**Abstract**

Plastic bags are consumed at an alarming rate on a global level while they also currently pose a significant environmental threat, especially concerning marine and coastal ecosystems, characterized by adverse implications for human health. The purpose of this study is to examine the effects of the plastic bag levy, introduced on January 1st, 2018 and further increasing as of January 1st, 2019, in Greece on the consumer behaviour. In this regard, a web-based survey was conducted on a national level resulting in 841 useful questionnaires in total. Our analysis results suggest that plastic bag consumption has diminished since the environmental levy took effect, though this decrease is mainly attributed to a shift towards pro-environmental behaviour on behalf of Greek citizens and less due to the environmental levy increase. In addition, the majority of consumers replaced plastic bags with more sustainable alternatives, whilst plastic bag demand considerably decreased by comparison of before and after the environmental levy implementation. This suggests that the use of both economic and non-economic measures can prove to be effective in drastically reducing plastic bag consumption along with its deleterious effects on the marine environment.

**Keywords:** Plastic bags, Plastic reduction, Plastic bag charge, Consumer behaviour, Behavior change intervention.

**JEL Codes:** D10, D80, Q50, Q58.

# Aspects of environmental policies in Athens in Classical times under an economics perspective

**George Halkos[1], Emmanouil M.L. Economou[2] and Nicholas C. Kyriazis[2]**
[1]*Operations Research Laboratory, Department of Economics, University of Thessaly*
[2]*Laboratory of Economic Policy and Strategic Planning (L.E.P.S.PLAN), Department of Economics, University of Thessaly*
halkos@uth.gr, emmoikon@uth.gr, nkyr@ergoman.net

**Abstract**
In this paper we present a series of environmental policies that were implemented in the city-state of Athens during the Classical times (508-323 BCE) under an economics perspective. We link these environmental policies to the provision of public goods and we argue that such goods proved to have been beneficial for the Athenian society as a whole. They basically included an efficient water management policy, the implementation of hygiene practices through a system of public baths in both a personal basis and as a collective opportunity for all the residents of the Athenian state, and furthermore, the implementation of a recycling process regarding animal manor and a waste management policy. Using a game theoretical approach we provide an economic assessment regarding the functioning of these institutions. Our results show that the success of these environmental institutions should be attributed to their effectiveness but also, and equally important, to the willingness of the people themselves to accept and adopt them through a spirit of a developing a consistent environmental awareness mentality.

**Keywords:** Environmental public goods, water management and hygiene, recycling and waste management policy, game theory, Classical Athens.

**JEL Codes**: H41, I18, K32, N13, N53, Q53, Q58.

# Food cycle economy: challenges and prospects

**Maria Michmizou & Paschalis Arvanitidis**
*Laboratory of Economic Policy and Strategic Planning, Department of Economics, University of Thessaly, 28th Oktovriou 78, 38333, Volos*
mairamichmizou@gmail.com, parvanit@uth.gr

**Abstract**
Food and Agriculture Organization of the United Nations estimates that about one third of the world's annual food production is lost, discarded and wasted. This loss not only has enormous opportunity costs for humanity, as it could support 12.5% of the malnourished world population, but also has substantial environmental costs, due to the waste of energy and resources but also the degradation of the environment in general. In addition, this chain of waste leads to increased production costs and reduced profitability on the part of companies, exerting upward pressure on the prices of products that reach the final consumer.
A large, and increasing, part of this waste comes from the food industry, giving rise to a growing discussion on the part of the scientific community. Food catering units (restaurants) are considered to be one of the most important factors in the food waste chain that could dynamically intervene to reverse this situation by changing both business and consumer patterns. In this context we can distinguish two ways of dealing with the problem: one is the change of the process of production and management of food "in situ", while the other is the rational disposal of waste.
However, despite the growing interest of researchers, the subject is at an early stage of study and analysis with most research focusing on case studies of specific restaurants, failing to highlight the general attitudes, trends and dynamics in the sector. In this context, the present work attempts to make a presentation of the existing scientific discussion, in an attempt to classify the literature, to identify possible gaps and to highlight potential fields and directions for further research.

**Keywords:** Circular economy, food industry, food waste, food management, waste disposal.

**JEL Codes:** O13, O44, O47, Q18, Q56.

# The socioeconomic determinants of residential water consumption in Athens. Preliminary results from a micro-econometric analysis

**Ioannis Kostakis & Eleni Sardianou**

*Department of Economics and Sustainable Development, School of Environment, Geography and Applied Economics, Harokopio University, El. Venizelou 70, 17671 Athens, Greece*

ikostakis@hua.gr, esardianou@hua.gr

**Abstract**

This paper provides empirical evidence on the effects of socioeconomic characteristics on residential water consumption. The case of Athens is taken as an example for the empirical investigation, using data from the 2019 Household Budget Survey. Employing ordinary, two and three stages least squares, seemingly unrelated regression equations and simultaneous quantile specifications, we found that residential water demand is highly price inelastic. Furthermore, empirical results show that water consumption is positively related to household age while more educated households and unemployed persons seem to follow a more environmentally friendly behavior with respect to water demand. Income, gender, house ownership and population density seem to affect insignificantly residential water demand. The identification of the characteristics of intensive consumers can be a useful tool for policies to achieve sustainability in water consumption amid households. Our empirical findings might also have important national and regional policy implications in the design of sustainable water demand management.

**Keywords:** Residential water demand, sustainability, price elasticity, income elasticity, Greece.

**JEL Codes**: D10, Q25, Q56.

# Recycling of "Waste of Electrical and Electronic Equipment": an Exploratory Data Analysis

**Christos Liotiris & Zacharoula Andreopoulou**
*Forest Informatics Laboratory of the Department of Forestry and Natural Environment, Aristotle University of Thessaloniki*
liotiris@for.auth.gr, randreop@for.auth.gr

**Abstract**
Given the pace and scale of Waste of Electrical and Electronic Equipment (WEEE) generation globally, countries are called upon to tackle their management as drastically as possible in order to maintain the viability of ecosystems. Proper implementation, application and enforcement of EU waste legislation are among the key priorities of EU environmental legislation and policy. In their support, the European Commission has carried out, compliance promotion initiatives to assist Member States with the implementation of EU waste legislation. The complexity of dismantling and recycling, as well as the various hazardous substances in WEEE, constitute a frightful threat to the environment and human health. Subsequently, the EU revised its WEEE legislation to address these challenges more adequately. As a result, Directive 2012/19/EU (WEEE2 Directive) repealed the first WEEE Directive and entered into force in 2012. This paper deals with the screening of WEEE management operations in EU, in terms of technical content and ability to reach the targets of the WEEE2. In addition, a more detailed report on recycling indicators published by the Eurostat, will be based on an Exploratory Data Analysis. Finally, the overall aim of this study is to gain maximum insight into the data and understanding its underlying structure through graphical representation.

**Keywords:** Waste of Electrical and Electronic Equipment, Recycling, European Union (EU), Eurostat, Exploratory Data Analysis.

**JEL Codes**: Q00, Q53.

# Mega Infrastructure Projects and their contribution to Sustainable Development The case of the Athens Metro

**Roido Mitoula & Angelos Papavasileiou**
*Department of Economics and Sustainable Development,*
*School of Environment, Geography and Applied Economics*
*Harokopio University of Athens*
mitoula@hua.gr, apapavasileiou@hua.gr

**Abstract**
The present paper investigates the critical role of significant infrastructure projects in sustainable urban and suburban development by presenting a Sustainable Infrastructure serum analysis supported by primary field research. In the case study of the Athens Metro, we examined the influence of the project on sustainable development through the users' opinions of the project. Thus, the Athens Metro provides a case study to improve our understanding of the concept of Sustainable Infrastructure as a framework for Green Growth. For the needs of the paper, a survey was conducted with questionnaires from October to December 2020. The sample consisted of 266 citizens of the Attica Region. Given the restrictions on movement due to the COVID-19 pandemic, questionnaires were sent and collected online. The organisation and processing of the research results was done through the open free program Microsoft forms. The Stata statistical program was used to process the results. From the data analysis, conclusions emerged, which are summarised at the end of the paper. The research results highlighted the acceptance and necessity of the project by directly correlating the results with sustainable development, the Economy, Society, and the Environment.

**Keywords:** Mega Infrastructure Projects, Sustainable Development, Sustainable Infrastructure, Public Transport, Athens Metro, Greece.

**JEL Codes**: Q01, Q50, Q56, R11, R40, R42.

# Opinion of citizens about infrastructure privatization

**Emmanouil Vougioukalakis, Zoe Gareiou, Leonidas Vatikiotis & Efthimios Zervas**
*School of Science and Technology, Hellenic Open University, 26335, Patras*
zervas@eap.gr

**Abstract**
Nowadays, there is a huge demand on public infrastructure and services worldwide, while the government budget of any country is usually limited. In addition, the public sector often lacks the technologies and expertise required for efficient infrastructure development. As a result, many countries are turning to infrastructure privatization. This study investigates the opinion of the inhabitants of Athens, about infrastructure privatization, on the main sectors: transport, education, health, energy, water supply, telecommunications, public administration and municipal services.
The survey was conducted from January to March 2020 in Athens. The data were collected using a structured questionnaire and the responses were analyzed. For the statistical analysis of the data, simple descriptive statistics, chi-square test and Principal Component Analysis (PCA) were conducted.
The results showed that the majority of respondents want public management in terms of transport, water supply, education, health, energy, public administration and municipal services. On the contrary, the majority of respondents are in favor of the private sector in terms of media, telecommunications and large industries, while maintaining a neutral stance in the case of banks.
Finally, the majority of respondents consider that the quality of infrastructure, which has already become private, has improved, while the cost has deteriorated.

**Keywords:** Privatization, Infrastructure, Opinion of citizens.

**JEL Codes**: Z0

# Comparative assessment of environmental effects of railways with regard to other transport modes

**Vassilios Profillidis & George Botzoris**
*Laboratory of Transportation and Spatial Planning, Department of Civil Engineering, Democritus University of Thrace, Kimmeria Campus, 67100 Xanthi, Greece*
vprofill@civil.duth.gr, gbotzori@civil.duth.gr

**Abstract**
In the present paper it is examined haw can railways contribute to reduce $CO_2$ emissions so as to keep increase of global temperature of the earth below 1.5-2.0 degrees C. First, contribution of the transport sector in $CO_2$ emissions is examined. A causal correlation between GDP and individual consumption for transport is attempted. Specific $CO_2$ emissions from railways and other transport modes are assessed, and other (than $CO_2$) air pollutants are also examined. The energy efficiency of rail transport in comparison with other transport modes is presented. The paper addresses also noise emissions from railways and suggests specific measures and the related costs for the reduction of noise provoked by railway traffic.

**Keywords:** Transportation, $CO_2$ emissions, growth, energy efficiency.

**JEL Codes**: O44, R41, Q53, Q56.

# The road to sustainability through the education of professionals in the field of construction

**Sofia Giannarou[1], Efthimios Zervas[1] & Michael Tsatiris[2]**

*[1] Hellenic Open University, School of Science and Technology, Laboratory of Technology and Policy of Energy and Environment, Parodos Aristotelous 18, 26335 Patras, Greece*

*[2] Democritus University of Thrace, School of Agricultural and Forest Sciences, Department of Forestry and Management of the Environment & Natural Resources, 193 Pantazidou Street, 68 200, Orestiada, Greece*

giannarou.sofia@ac.eap.gr, zervas@eap.gr, tsatiris@fmenr.duth.gr

**Abstract**

The bioclimatic design of buildings is an urgent need that begins with the acceptance of the facts of the reckless use of energy resources, the destruction of the environment and the deterioration of the quality of life of animals and humans and continues with the realization that this is a socio-political rather than a technical issue which requires mainly a change of mentality and a redefinition of the social priorities and goals of humanity.

Therefore, today's society demands the environmental awareness of all citizens and the bioclimatic architectural training of the engineers of the future. To date, ignorance of the goals and benefits of climate-based construction, academic inaction, and rigid curricula in educational institutions, combined with limited expertise, non-social compliance, and a lack of inspiring standards have led to unsustainable ways life and a future doubtful for humanity.

The purpose of this research using structured questionnaires is to investigate the knowledge of professionals in the field of building construction in Greece on bioclimatic design and the causes of the lack of environmental awareness of Greek citizens until recently, which led to a building stock with small number of bioclimatic buildings.

**Keywords:** Bioclimatic design, sustainability, engineering education, environmental education.

**JEL Codes**: O44, O33, Q43, Q52.

# Brand Architecture and brand portfolio in tourism destinations: the case of Empordà

**Dr. Jacinta Gutiérrez Olesti**

*Insetur - Institut de Recerca en Turisme, Universitat de Girona, Girona*

cintagutierrez@telefonica.net

**Abstract**

There is no doubt that we live in a world of brands. Brands are more or less well known, more or less visible. Graphic images, logos and slogans have significant impacts on our daily lives. The brand portfolios of tourist destinations have been growing in the last years. The objective of this paper is to spell out the factors that determine the strategy of the brand portfolio and the brand architecture in tourist destinations. To achieve this goal, it is important to understand the concept of brand and how Place Branding has been applied to countries and territories, as well as Destination Branding in destinations. Understanding the organization of this portfolio and the relationships which different entities or brands establish among and outside themselves, constitutes a focus of analysis for destinations. Destinations, particularly in terms of the human factor, constitute study entities with specific peculiarities that move away from the rigidity and the parameters of a company. For the latter, the concept of brand is well developed. In destinations, brands are born and evolve in different ways and have to reflect all realities. The results of this research include issues related to policy, resources, understanding of the concept of brand, and incapacity to forge alliances between brands and stakeholders.

**Keywords:** Brand, place branding, destination branding, brand architecture, brand portfolio, Empordà.

**JEL Codes**: M31, R11, R58, A13, D04.

# Non-farm employment, natural resource extraction, and rural household's welfare: Evidence from panel data for Vietnam

**Manh Hung Do[1], Trung Thanh Nguyen[1], George Halkos[2] & Ulrike Grote[1]**

[1] *Institute for Environmental Economics and World Trade, Leibniz University Hannover, Königsworther Platz 1, 30167 Hannover, Germany*

[2] *Department of Economics, University of Thessaly, Volos 38333, Greece*

hung@iuw.uni-hannover.de, thanh.nguyen@iuw.uni-hannover.de, halkos@econ.uth.gr, grote@iuw.uni-hannover.de

**Abstract**

Natural resource extraction plays an important role in generating income as a major livelihood strategy of rural households in many developing countries. However, over-exploitation is causing an alarming depletion of natural resources in these countries and posing a major threat to the local environment and ecosystem. Given this problem, we use a panel data of 1780 identical households in 2010, 2013, and 2016 (collected from a country in a hot spot of natural resource degradation) to identify the determinants of rural households' participation in non-farm activities, examine the inter-correlation between non-farm employment and natural extraction, and investigate the impacts of non-farm income on rural households' welfare. Our findings reveal that access to internet or higher quality of roads positively affect households' decision on non-farm employment and non-farm income. The results from the simultaneous equation model show that non-farm income and natural extraction income have a negative inter-correlation. More importantly, non-farm income is significantly contributing to poverty reduction in both relative and absolute terms. Our results have important practical implications for stimulating rural development policies on providing non-farm opportunities, investment in infrastructure and telecommunication to help increase income, improve welfare, and reduce natural resource exploitation of rural households in developing countries.

**Keywords:** Non-farm employment, natural resource extraction, poverty reduction, rural livelihood, rural development.

**JEL Codes**: Q57, Q12, R20.

# Kriging Analysis for Atmosphere Pollutants and House Prices: The case of Athens

**Polixeni Iliopoulou & Christos Kitsos**
*University of West Attica*
piliop@uniwa.gr, xkitsos@uniwa.gr

**Abstract**
In this paper the effect of air pollutants on housing prices in the Greater Athens region is examined employing kriging analysis. Data concerning air pollution in Attica are provided for a network of stations in a time series. Several methods of spatial interpolation can be used in order to create an air pollution surface for the study region, such as polynomials and splines.
These methods are not considered when the measurement depends on time in the sense that $y_i = y(t_i)$, as the Atmosphere Pollution indexes, the prices in any market etc. In such stochastic oriented data, not only Explanatory Dada Analysis (EDA) is needed, but a structural model is required, providing the best estimates, by kriging, as well as the variance of the estimated error.
In this paper the air pollutant surfaces resulting from kriging analysis are used in order to assign air pollution values to houses for sale, employing GIS techniques. The effect of selected air pollutants on housing prices is examined and the results indicate that although structural characteristics of houses, i.e. size, are more important, the effect of air pollutants is not negligible.

**Keywords**: Kriging, interpolation, EDA, Inverse Distance Weighting, air-pollution.

**JEL Codes**: C21, R32, C31, C52.

# Revisiting the socioeconomic and environmental determinants of health care utilization in European countries

**Athina Economou & George Halkos**
*Laboratory of Operations Research,*
*Department of Economics, University of Thessaly*
aeconomou@econ.uth.gr, halkos@econ.uth.gr

**Abstract**
The purpose of the study is to examine the determinants of health care utilization among respondents in selected European countries, by utilizing available information from the SHARE (Survey of Health, Aging and Retirement in Europe). The variable of interest is the number of doctor visits during the past year based on respondents' information linked with the individual demographic, health and socioeconomic characteristics of the respondents. In addition, the country-level environmental effect upon health care utilization is assessed, with the use of the green house emissions annual index, since the environmental burden is found to affect population health in relevant research. Due to the count nature of the dependent indicator, Poisson models are estimated with bootstrapped standard errors. Instrumental variable models with the use of the Control Function Approach are also used to disentangle the endogenous nature between health care and economic position. The evidence supports previous findings regarding the socioeconomic gradient in health care utilization and underline the need to address socioeconomic inequalities that hamper health care treatment. The environmental factor is also found to exert a burden upon health care utilization, mainly in the case of Germany which is the country with the highest greenhouse emissions in Europe.

**Keywords:** Health care utilization, socioeconomic characteristics, greenhouse emissions, European countries.

**JEL Codes**: I11, I12, I14, Q51, Q53.

# The future response of the pollutant adopting Tolerance Regions under different coding systems

**Christos Kitsos & Constantinos-Symeon Nisiotis**
*University of West Attica*
xkitsos@uniwa.gr, cnisiotis@uniwa.gr

**Abstract**
When the future response is needed to be estimated in a chronological data set of pollutants, there is a number of available techniques. In this paper the simple linear regression model is used to fit the data in a given time interval [$T_1$, $T_2$], which can represent a 20, say, year time interval. The coding system adopted to represent the input variable "years" influences the predicted value. We prove that there exists a linear transformation related the coding systems. The 95% of the future responses is asked to lie within an interval with probability .90 or .95. That is a Tolerance Region (TR) is asked to be constructed. The problem that if the TR is influenced by the assumed coding system describing the data, is examined also in this paper.

**Keywords**: Regression, Linear Transformation, Tolerance Region, Affine Tolerance Region.

**JEL Codes**: Q0, Q53.

# Shocks, livelihood diversification, and household consumption: A comparative evidence from panel data in Thailand and Vietnam

**Duy Linh Nguyen, Trung Thanh Nguyen & Ulrike Grote**

*Institute for Environmental Economics and World Trade, School of Economics and Management, Leibniz University Hannover*

linh.nguyen@iuw.uni-hannover.de, thanh.nguyen@iuw.uni-hannover.de, grote@iuw.ini-hannover.de

**Abstract**

In this paper, we use a unique panel data set of around 4,000 households collected in five survey waves from Thailand- and Vietnam during 2007-2016 to investigate the impacts of covariate and idiosyncratic shock on consumption and the mitigating role of land and labor diversification. We employ the System-Generalized Method of Moments estimator to overcome the concerns in controlling for endogeneity. Our results reveal that: (i) rural households in Thailand and Vietnam are able to smooth consumption when facing idiosyncratic shock. However, this is not the case when covariate shock strikes; (ii) livelihood diversification has no significant effect in improving consumption in both countries in general. The higher level of land diversification even negatively affects household consumption in Thailand; (iii) among household with shocks, higher land diversification in Thailand and higher labor diversification in Vietnam helps rural households partially mitigate the negative impacts of covariate and idiosyncratic shocks; and (iv) labor diversification in Thailand and land diversification in Vietnam are ex-post coping strategies to covariate shock but their mitigating role is not statistically significant.

**Keywords:** Livelihood diversification, shocks, household consumption, Thailand, Vietnam.

**JEL Codes**: I310, O120, O130, Q120.

# Flood resilience capacity: a structural equation model for Greek small and mid-sized enterprises

**Antonis Skouloudis[1], Konstantinos Evangelinos[1], Panagiotis Vouros[1], Ioannis Nikolaou[2] & Thomas Tsalis[2]**

[1] *Department of Environment, University of the Aegean, Lesvos*

[2] *Department of Environmental Engineering, Democritus University of Thrace, Xanthi*

skouloudis@aegean.gr, kevag@aegean.gr, pvour@env.aegean.gr, inikol@env.duth.gr, ttsalis@env.duth.gr

**Abstract**

Floods pose unprecedented threats to modern societies and remain a much-debated issue strongly interlinked with current development policies. Small and Medium-sized Enterprises (SMEs) that constitute a driving force of economic growth, employment and total value-added, are highly vulnerable to and ill-prepared for such environmental perturbations. In this study, a model that comprises of factors linked to the resilience capacity of SMEs to flooding is tested. A sample of 343 enterprises from flood-prone areas in Greece was administered a structured questionnaire on cognitive, managerial and contextual factors that influence the ability to shape effective responses to flood challenges. Structural Equation Modeling is employed to identify associations between the various observed items forming the individual latent sub-constructs, as well as the associations between these individual latent sub-constructs with the flood resilience capacity construct (FRCI). By identifying major internal and external attributes explaining resilience capacity, an analytical framework is set forth that could help standardize such assessments, with the overarching aim of reducing SMEs' vulnerability to flooding. Studies such as ours seek to provide essential research findings for practitioners on SME management in relation to flood preparedness and set forth linkages with current mechanisms for policy interventions at regional, national and European levels towards an appropriate flood resilience agenda for SMEs.

**Keywords:** Small & mid-sized enterprises, floods, organizational resilience capacity, structural equation modeling, extreme weather events.

**JEL Codes**: Q01, Q50, Q54, Q56, Q59.

# A study for corporate environmental strategy. The interaction between environmental legislation, innovation and intellectual capital

**Nikolaos S. Trevlopoulos & Ioannis E. Nikolaou**
*Business Economics and Environmental Technology Lab, Department of Environmental Engineering, Democritus University of Thrace, Vas. Sofias, 12, Xanthi, Greece*
ntrevlop@env.duth.gr, inikol@env.duth.gr

**Abstract**
Today more than ever, industries are called to comply with domestic, community and international environmental legislation to ensure sustainable development. In order to achieve these objectives, firms follow a specific strategy that is sometimes accompanied by costs and sometimes by benefits such as new innovations and intellectual capital development. The purpose of this article is to study the interactions between environmental legislation, environmental innovation and green intellectual capital. To do this, a questionnaire-based survey is carried out in a sample of 62 chemical enterprises. The results show that environmental legislation positively affects environmental innovation and green intellectual capital, while green intellectual capital positively affects environmental innovation.

**Keywords:** Corporate environmental strategy, corporate environmental management, environmental innovation, green intellectual capital.

**JEL Codes**: K32, O31, O34, Q50.

# Workplace human rights assessment in sustainability reports: An overview of the United Kingdom market

**Stefanos Fotiadis & Konstantinos Evangelinos**

*Centre for Environmental Policy & Strategic Environmental Management, Department of Environment, University of the Aegean, Mytilene*

sfotiadis@env.aegean.gr, kevag@aegean.gr

**Abstract**

Organizations are responsible for their impacts on human rights directly, through their own actions and operations. They can also impact human rights indirectly, through their interactions and relationships with others, including governments, local communities and suppliers, and their investments. The aim of this study is to assess the level of accountability of Organizations - based in the United Kingdom (UK) - on issues of human rights at work, expressed by nine suggested disclosures of the Global Reporting Initiative (GRI) manual. Our sample consists of all types of Organizations, whose Corporate Social Responsibility (CSR) reports for 2019 were accessed from the GRI database. To date, just over half of the reports have been examined. So far, results show that the sample reveals a very low level of sensitivity to human rights topics at work. At the end of the evaluation, all reports will need a full review.

**Keywords:** CSR, GRI Standards, rights and principles at work, accountability.

**JEL Codes**: G34, M14, O16, Q01, Q56.

# Determinants for the withdrawal of companies in the tourism and leisure industry from the UN Global Compact programme

**Martin Thomas Falk & Guðrún Helgadóttir**
*Department of Business and IT, USN School of Business, University of Southeastern Norway*
Martin.falk@usn.no, Gudrun.helgadottir@usn.no

**Abstract**
Between 2000 and 2020, 818 companies from the tourism and leisure industry signed up to the UN Global Compact guidelines, which cover ten principles in the field of labour, human rights, environment and anti-corruption. Three out of the ten principles refer to the environment (Principle 7: Businesses should support a precautionary approach to environmental challenges; Principle 8: undertake initiatives to promote greater environmental responsibility; and Principle 9: encourage the development and diffusion of environmentally friendly technologies). Over the sample period, 60 per cent of the tourism and leisure businesses are de-listed from the programme. The aim of this paper is to examine to stay active in the UN Global Compact programme. Factors include company-specific factors such as size, ownership (private vs public) and country-specific factors (indicators on CO2 emissions, air pollution, tree cover loss). Other control variables include components that measure various dimensions of the political environment faced by companies operating in a country (political stability and absence of violence, stability of government and control of corruption) as well as GDP per capita as a measure of economic development. This work builds on Rasche et al. (2020) who analyzed delisting status using a survival model. The main contribution is that country-specific factors related to environmental performance and institutional and political factors are included. Estimation results using a Cox proportional hazard model show that the rate of losing the active UN global compact status depends on firm characteristics and environmental performance indicators. Public companies, foundations and NGOS in the tourism sector have a 35 percent lower rate of being delisted, while listed companies have a 64 percent lower rate. The latter is related to the fact that there is more pressure on these companies from investors to do their part in solving societal challenges. The environmental performance indicators are highly important in determining UN Global Compact status. The results imply that tourism businesses in countries that have made progress in decoupling emissions and economic growth are more likely to remain in the UN Global Compact programme. The air quality index indicator is significant at the 1 per cent level. The findings that environmental progress at the country level is the main driver for the decision to join or leave the UN Global Compact programme shows that the commitment of society and government to corporate environmental sustainability goals is of great importance. Three out of ten UN Global Compact goals relate to the environment, and here it is difficult to make progress at the corporate level if there is no general commitment. The findings that institutional and political factors such as levels of corruption and economic development do not matter is a surprising result. This might indicate that this is not the main obstacle to staying in the programme.

**Keywords:** Sustainability, Sustainability reporting, united national global compact programme, Carbon emissions, Air quality.

**JEL Codes**: Q50, Q56, Q01, D22.

# Enriching the "social" in circular economy: the commons perspective

**Dionysia Evgenia Paraschi[1] & Paschalis Arvanitidis[2]**

[1] *MSc Social and Solidarity Economy, Hellenic Open University*

[2]*Department of Economics, University of Thessaly, Hellenic Open University*

deniaparaschi@hotmail.com, parvanit@uth.gr

**Abstract**

The mainstream approach to the issue of circular economy places particular emphasis on the environmental and the economic dimensions disregarding key aspects of social significance, such as collective action, community participation and solidarity building. Yet, these aspects constitute not only desired outcomes of adopting circular practices, but determinants of a truly sustainable circular society, that is a society that embraces in full all circularity dimensions and principles. This transition indicates a movement towards a different lifestyle, consumption sculture and economic behaviour that is based on values of collectivity, cooperation and sharing, all of which are critical elements of the commons as an institution. The commons, which constitutes an alternative, community-based, model of governance and socioeconomic behavior, embraces in full this rich social spectrum of circular economy and therefore is a more appropriate theoretical and analytical concept to explore and assess circular economy initiatives and actions.

With all these under account, the current research draws on the commons in order to explore the social character of a specific sector of circular economy, that of the second-hand clothing. In particular it employs Ostrom's design principles to analyze and evaluate a collectivity that is engaged in the reuse of used clothing in Greece. The research finds that the examined initiative satisfies the Ostromian principles and constitutes a successful commons. It has adopted a governance structure that is prescribed by collective, bottom-up representation, democratic decision-making processes and organizational flexibility, showing a degree of adaptability and continuity that enables it to thrive even during the testing times of COVID crisis.

**Keywords:** Circular economy, commons, second-hand clothing, sustainable development, solidarity economy.

**JEL Codes**: B52, B55, D02, L31, O17, O35, Q56.

# Economic Valuation of Honeybee Pollination Services

**Simeon Marnasidis[1], Garyfallos Arabatzis[1], Chrisovalantis Malesios[2], Fani Hatjina[3], Apostolos Kantartzis[1] & Efstathia Verikouki[4]**

[1] *Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, 193 Pantazidou St., 68200 Orestiada, Greece*
[2] *Department of Agricultural Economics and Rural Development, Agricultural University of Athens, 75 Iera odos St., 11855 Athens, Greece*
[3] *Dep. of Apiculture, Institute of Animal Science— National Agricultural Organization DEMETER, 63200 Nea Moudania, Greece*
[4] *Faculty of Agriculture, Vocational School (EPAL) of Edessa, Melinas Merkouri 28, 58200 Edessa, Greece*

marnasidis@pella.gr, garamp@fmenr.duth.gr, malesios@aua.gr, fhatjina@instmelissocomias.gr, apkantar@fmenr.duth.gr, verikouki@sch.gr

**Abstract**

Honeybees are closely linked with natural and agricultural ecosystems, due to their ability to pollinate many food crops and native plants worldwide, particularly in intensively cultivated areas. Greece is a country where pollination services are hardly developed. Using data from the Regional Unit of Pella in Greece, as well as a number of measurable indicators, the current paper investigates, for the first time in this country the economic valuation and the adequacy of crop pollination services by honeybees. Our results demonstrate that for the 28 insect pollinated crops examined in the study, the commercial value of pollination services was estimated at €89.34 million by means of the net income method; in addition, the economic value of pollination services for the year 2018, that could be attributed to honeybees based on the available number of hives, was found to be equal to €26.9 million. From our analysis it also emerged that apples and kiwifruit plants were the crops with the highest value of pollination services per hectare, which amounted to €10,350.24 and €9,059.23, respectively. Another important finding of the research is that the total hive stocks available are insufficient to cover even half of the demand for honeybee pollinated crops. Especially as sweet cherry trees frequently fail to set fruit, the total hives available at a Regional Unit level were found to be sufficient enough to cover only 66.5% of pollination needs.

**Key words:** Apiculture, honeybees, pollination services, agricultural development.

**JEL Codes:** Q00, Q01, Q50, Q57, Q58.

# Applying Factor Analysis and Structural Equation Models for urban parks in Greece: The relationship between motives and perceived characteristics, satisfaction and future visit

**George Halkos[1], Aikaterini Leonti[2] & Eleni Sardianou[2]**

[1] *Laboratory of Operations Research, Department of Economics, University of Thessaly, 28hs Octovriou 78, 38333 Volos, Greece*

[2]*Department of Economics and Sustainable Development, School of Environment, Geography and Applied Economics, Harokopio University, El. Venizelou 70, 17671 Athens, Greece*

halkos@econ.uth.gr, aleonti@hua.gr, esardianou@hua.gr

**Abstract**

Understanding the motivations for moving to specific locations is a complex process. This article examines the possible relationships between the satisfaction of visitors to two urban parks in Greece and the motivation to visit, as well as their perceptions of the parks. The relationship between visitor satisfaction and future visit is also studied. The total sample consisted of 761 urban parks visitors in Attica. For the purposes of the research, *Exploratory Factor Analysis*, *Confirmatory Factor Analysis* and *Structural Equation Models* were applied. According to the results, three factors were extracted for the motivation to visit the urban parks and five factors for the perceived characteristics of the parks. Motives for the visit were found to affect visitor satisfaction, which statistically significantly affects the probability of revisiting urban parks. It is also interesting the fact that the perceived security provided in the urban parks that were studied as well as the improvements that could be made in the parks have a positive effect on the degree of visitor satisfaction. On the contrary, the perceived negative effects that come from the parks negatively affect the satisfaction.

**Keywords:** Motives, Perceived characteristics, Urban Parks, Factor analysis, SEM.

**JEL Codes**: Q01, Q51, Q58, Z30.

# Hunting Economics as a subdiscipline of Forest Economics

**Konstantinos G. Papaspyropoulos**
*Laboratory of Forest Economics, Department of Forestry and Natural Environment, Aristotle University of Thessaloniki, 54124*
kodafype@for.auth.gr

**Abstract**
The classic forest economics discipline has emerged from Germany's Martin Faustmann who in 1849 presented the Faustmann Formula (FF). But it was until 1970's that the methodology started to become popular when Samuelson presented that Faustmann's Land Expectation Value (LEV) is the unique correct method for finding the optimal rotation age in a forest stand. Forest economics golden rule (FF) says that the optimal rotation age for a forest stand is when LEV is maximized, and the Marginal Revenue Product and Marginal Cost are equal. This approach is timber oriented as it assumes that profit maximization for the forest owner is only derived from the management of wood resources. Thus, other forest values have been usually neglected, although researchers like Hartmann have enhanced FF with non-timber forest products (NTFP), where there is a consumption value (excluding forest ecosystem services without a market price). The consumption of hunted species, as a NTFP and a provisional ecosystem service, can add value to the landowner through hunting activity. This activity may be, sometimes, the only product that can be profitable in forest land where timber is not managed, or non-existent, like areas in the Mediterranean region. Therefore, the purpose of the present research is to find out how hunting has been included and used in the FF, which other approaches of hunting economics have been used in the literature, and to propose further research in the so called in the literature Post-Faustmann Forest Resource Economics.

**Keywords:** Forest resource economics, hunting, Land Expectation Value, optimal rotation age, Faustmann Formula.

**JEL Codes**: Q23, Q57, Q21, Q24.

# Modelling the transition dynamics of the socio-technical urban mobility system

**Vasiliki V. Georgatzi & Yeoryios Stamboulis**
*Department of Economics, University of Thessaly, Volos, Greece*
vageorgatzi@uth.gr, ystambou@uth.gr

**Abstract**
Urban Mobility (UM) is in a state of transition, in an era of digitalization and climate change. Several researchers have analyzed the transition of UM through qualitative and quantitative approaches, focusing mostly on technological change and, less on changes of the mode of mobility. Digitalization and business model disruption have attracted less attention. In this paper, we aim to view change in UM adopting the holistic multi-level perspective of socio-technical transition in combination with a triple helix analysis. More specifically, we present a model of the transition from the current state of the dominant regime based on internal combustion engine technology and private car to a new one where new modes of mobility (ride hailing, car sharing) challenge incumbent ones (private car, taxi, public transport), and new technologies arise as niche-innovations (electric vehicles, ICTs) in the UM system, so as to lead to sustainability. We present a system dynamics model of the transition, based on stock and flow diagrams, facilitating the exploration of different scenarios and policy mixes.

**Keywords:** System dynamics, transition, urban mobility modes, helices, sustainability.

**JEL Codes:** O33, Q56, R40.

# Methodology approach for the development of an online tourism app: The case of the Greece – Bulgaria Interreg project «Stage for Cross Border Culture – CULSTAGE»

**Zacharoula Andreopoulou[1], Konstantinos Ioannou[2], Christiana Koliouska[1], Evangelia Karasmanaki[3], Georgios Tsantopoulos[3] & Kleanthis Xenitidis[3]**

[1] *Laboratory of Forest Informatics, School of Forestry and Natural Environment, Aristotle University of Thessaloniki, Box 247, 54124, Greece*

[2] *National Agricultural Organization –"DEMETER", Forest Research Institute, Vasilika, Thessaloniki, 57006, Greece*

[3] *Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, Pantazidou 193, Orestiada, 68200, Greece*

kleodrama@gmail.com, randreop@for.auth.gr, ioannou.konstantinos@gmail.com, ckolious@for.auth.gr, evagkara2@fmenr.duth.gr, tsantopo@fmenr.duth.gr

**Abstract**

The project "Stage for Cross Border Culture – CULSTAGE" highlights the importance of alternative tourism development in the area of Paggaion Municipality, which is near the Cross Border (CB) area of Greece and Bulgaria. The area is mostly famous among tourists for its natural resources while it possesses a big potential to expand tourism into alternative forms. Many, century old monasteries are located in the region which have visitors on daily basis. The project introduces a well-structured and standardized methodology for promoting effective and sustainable usage of cultural and natural heritage and upgrading tourism in the area. This is achieved through an innovative approach which incorporates religious tourism development including the following activities: improvement of cultural infrastructure (by means of restoration works in monasteries both in Greece and Bulgaria), popularization of religious destinations and development of a Decision Support System (DSS) in the form of a Web application and a Smart Phone application which can help visitors in navigating throughout the region while at the same time it can help the local authorities to improve the offered regions' tourist product. For the investigation of both residents' and visitors' perceptions regarding local development, questionnaires were distributed to the population of the Paggaio municipality as well as the areas' visitors during the summer of 2020. The web application includes detailed statistics regarding the data gathered from the questionnaires as well as real time data created by the application users. The project results include, among other, detailed information regarding tourist behavior, visitor priorities, identification of visitor preferences regarding locations as well as a comprehensive tourist management tool.

**Keywords:** CULSTAGE, alternative tourism, Decision Support System, web application, local development.

**JEL Codes**: O3, Z32, O2.

# Vulnerability Assessment to Desertification in Greece Using Composite Indicators.

**Demetrios E. Tsesmelis[1,2], Efthimios Zervas[1] & Christos A. Karavitis[2]**
[1] *Hellenic Open University, Laboratory of Technology and Policy of Energy and Environment, Parodos Aristotelous 18, 26335, Patra, Greece*
[2] *Agricultural University of Athens, Laboratory of agricultural hydraulics, Iera Odos 75, 11855 Athens*
tsesmelis@aua.gr, zervas@eap.gr, ckaravitis@aua.gr

**Abstract**
The Environmentally Sensitive Areas (ESA) composite index estimates a region's vulnerability to desertification through the analysis of various parameters, such as soil, geology, vegetation, climate, and man-made activities. Each of these parameters is categorized and each factor has weightings for each category. ESAI is divided into four categories: soil quality, climate quality, vegetation quality and management quality. After calculating the four indicators for each quality, vulnerability to desertification is assessed. The Greek area appears degraded with several areas facing significant risk. The period considered for implementation in Greece is from 1971 to 2004. This period, in which there have been various changes, such as the increase in cultivated land in the agricultural distribution, was noted as the driest period of the last 100 years (mainly between 1988 and 1993). in addition, there has been an increase in agricultural water demand due to crop growth and the intensification of agriculture.

**Keywords:** Desertification Vulnerability, Composite Indicators, Spatial Analysis, Natural Resources Management, Environmental Management.

**JEL Codes**: O13, P28, P48, Q24, Q25.

# CONFERENCE PROCEEDINGS

# Proceedings Summary

The 6th Conference program consisted of 10 sessions and 4 Keynote speakers. The 10 thematic sections presented concerned environmental performance, COVID-19: environmental and social effects, issues in biodiversity, energy issues and policies, renewable energy sources, sustainable consumption, sustainable development, quantitative methods in environmental and resource economics, circular economy-sustainable entrepreneurship and environmental policies and assessment. In total, 25 studies were included in the conference proceedings, however, a number of papers has not been included in the book of proceedings since they have already been submitted to the conference special issues journals.

The 1st work by Stathi and Papaspyropoulos explores the relationship between corporate social responsibility (CSR) and corporate philanthropy (CP) under the COVID-19 pandemic, finding that the history of CSR practices is a determinant of CP, while the history of CP in the proCOVID-19 period is not a determinant of CP in the postCOVID-19 period. The 2nd work by Tsadiras presents the results of a survey on the relevant literature, regarding the relationships that exist between pollution, economic growth and COVID-19, taking into consideration numerous scientific studies of regional-level findings.

The 3rd work by Naxaki and Papaspyropoulos explores biodiversity reporting, contributing to the development of a broader theoretical knowledge through a literature review. The 4th work by Danatskos and Papaspyropoulos focuses on Material Flow Cost Accounting (MFCA) in the aquaculture industry and highlights certain challenges in MFCA application that are presented due to various reasons, including the various aquaculture techniques, the geographical position and the use of either fresh water or sea.

The 5th work by Halkos and Tsilika explores energy use in EU 28, focusing on primary energy resources, their covariation and correlation, as well as their development over time. The results show that energy consumption does not always reflect or is due to climatological or meteorological conditions. The 6th work by Maragkaki and Economou focuses on the possibilities of upgrading a school unit based on the bioclimatic design and the Building Energy Efficiency Regulation. The authors studied a certain conventional school unit, identified its problems and proposed various interventions, so that the unit is environmentally and bioclimatically upgraded. The 7th work by Karytsas and Theodoropoulou examines Energy Communities in Greece and, more specifically, the level of information that citizens have, their intention to invest in the Energy Communities, as well as relevant motives, benefits and barriers. The 8th work by Karytsas, Polyzou, Oikonomou and Karytsas focuses on the MOF4AIR European project, a project aiming to highlight the efficiency of $CO_2$ capture technologies, and presents the findings of the initial stages of activities that examine social issues related to Carbon Capture and Storage (CCS).

The 9th work by Tsipouras, Spiliotopoulos and Katsardi examines the total life-cycle cost of a floating offshore wind farm, while assessing its economic viability. After examining three different potential areas for installation, the authors conclude that the most cost-effective solution is the one in Eastern Crete. The 10th work by Karytsas, Choropanitis, Oikonomou and Karytsas focuses on the GEORISK European project, a project for the establishment of risk mitigation schemes in Europe. The authors focus on developing a new risk mitigation scheme that will limit the potential financial risk for Greece.

The 11th work by Maroulis, Mentis, Latinopoulos and Bithas examines the effects that the plastic bag levy has on the consumer behavior in Greece, with the findings suggesting that the consumption of the plastic bag has diminished since the application of the environmental levy, even though the authors highlight that this decrease is mainly due to the Greek citizens' shift towards a pro-environmental behavior. The 12th work by Halkos, Economou and Kyriazis focuses on environmental policies implemented in Athens in 508-323 BCE (Classical times) under an economics perspective, linking them to the provision of public goods and using a game theoretical approach to provide an economic assessment of their functioning. The 13th work by Liotiris and Andreopoulou focuses on Waste of Electrical and Electronic Equipment (WEEE) and on WEEE management operations in the EU, providing also details based on Eurostat recycling indicators, aiming to gain insight into the data.

The 14th work by Mitoula and Papavasileiou investigates the role that infrastructure projects have in sustainable urban and suburban development, focusing on the case of the Athens Metro and examining its influence on sustainable development, through the user's opinion and through a survey conducted with questionnaires. The 15th work by Vougioukalakis, Gareiou, Vatikiotis and Zervas investigates the opinion that Athens' inhabitants have on infrastructure privatization, regarding the sectors of transportation, education, health, energy, water supply, telecommunications, public administration and municipal services, through a survey conducted with questionnaires. The 16th work by Profillidis and Botzoris focuses on railways and examines how they can contribute to the reduction of $CO_2$ emissions. The authors examine the contribution of the transport sector in $CO_2$ emissions, as well as the emissions specifically from railways, and present the energy efficiency of rail transport. The 17th work by Giannarou, Zervas and Tsatiris investigates the knowledge of professionals that are the field of building construction regarding bioclimatic design, as well as the causes of the lack of environmental awareness of Greek citizens that has led to a small number of bioclimatic buildings.

The 18th work by Iliopoulou and Kitsos examines the effect that air pollutants have on housing prices in the Greater Athens region, using kringing analysis, and the findings indicate that the effect of air pollutants is not negligible, even though structural characteristics of houses (such as size) are more important.

The 19th work by Trevlopoulos and Nikolaou focuses on the interactions between environmental legislation, environmental innovation and green intellectual capital, through a survey conducted with questionnaires. The findings indicate that environmental legislation has a positive impact on environmental innovation and green intellectual capital, while green intellectual capital has a positive impact on environmental innovation. The 20th work by Paraschi and Arvanitidis explores the social character of second-hand clothing, a sector of Circular Economy, based on the commons, a community-based model of governance and socioeconomic behavior.

The 21st work by Marnasidis, Arabatzis, Malesios, Hatjina, Kantartzis and Verikouki focuses on honeybee pollination services and on their economic valuation, investigating their adequacy. The authors investigated, among others, and estimated the commercial value of pollination services, the economic value of pollination services attributable to honeybees and the crops with the highest value of pollination services. The 22nd work by Halkos, Leonti and Sardianou examines the relationships that may exist between visitors' satisfaction to two urban parks in Greece, as well as their motivation to visit and their perceptions of the parks, using Exploratory Factor Analysis, Confirmatory Factor Analysis and Structural Equation Models. The 23rd work by Georgatzi and Stamboulis focuses on Urban Mobility and presents a model of transition from the current state (internal combustion engine technology, private car) to a new one that is based on new modes of mobility and new technologies, in order to lead to sustainability. The 24th work by Andreopoulou, Ioannou, Koliouska, Karasmanaki, Tsantopoulos and

Xenitidis focuses on the project “Stage for Cross Border Culture – CULSTAGE” that highlights the importance of the development of alternative tourism in the area of Paggaion Municipality. The perceptions of residents and visitors on local development were investigated through the distribution of questionnaires to the population of the Paggaio Municiapality. The 25th work by Tsesmelis, Zervas and Karavitis focuses on the Environmentally Sensitive Areas (ESA) Index that estimates the vulnerability of a region to desertification by analyzing various parameters. The findings indicate that the Greek territory seems to be degraded and that several areas are facing a significant risk.

As a conclusion, I would like to mention that in this conference we also had interesting presentations and in-depth discussions both by the invited speakers and by the participating academics and researchers. The publication of these practices is based on the responsibility of the research teams and any mistakes, omissions, ambiguities and any similarities with other scientific work are the responsibility of the authors alone.

**George E. Halkos**
Scientific Coordinator of the Conference
Professor of Natural Resources Economics
Director of Laboratory of Operations Research

# Conference Papers

# On the relationship among corporate philanthropy, corporate social responsibility and COVID-19: Evidence from the virus' first wave in Greece

**Eleni I. Stathi & Konstantinos G. Papaspyropoulos**
*MSc Natural Resources: Monitoring, Technology and Bio-economy, Department of Forestry and Natural Environment, Aristotle University of Thessaloniki, 54124*
elenistathi@for.auth.gr, kodafype@for.auth.gr

**Abstract**
The present research explores the relationship between corporate social responsibility (CSR) and corporate philanthropy (CP) given the presence of the COVID-19 pandemic. Taking into account the Greek Fortune 100 corporations that responded or not to the call for help against the first wave of the virus existence, two hypotheses are tested: i) history of CSR practices is a determinant of CP, and ii) history of CP in the proCOVID-19 period is a determinant of CP in the postCOVID-19 period. The findings confirm the first and reject the second hypothesis. The paper is among the first exploring CP in the COVID-19 period and reveals that it presents attributes about the behaviour of corporations that have been already proved in the natural disaster literature, thus they react in a similar way.

**Keywords:** Pandemic, GRI, donations, health system, sustainability reporting.

**JEL Codes**: Q56, M14, Q01, A13, I18.

## 1. Introduction

The year 2020 started with the COVID-19 outbreak, which overwhelmed health systems on a worldwide scale, firing concerns about how the system should be organised to properly deliver health services during the dramatic situation (WHO, 2020a). According to the WHO Coronavirus Disease Dashboard (WHO, 2020b), there have been more that 10,2 million confirmed cases of COVID-19 and more than half a million deaths until the end of June 2020. In the case of Greece, a general lockdown took place on time in March 13th, 2020, in order to limit the virus' spread and support the weak health system. A total of 3,409 cases and 192 deaths were recorded since the first time (27 February 2020) COVID-19 appeared in the country (WHO, 2020b), and until June 30th, when Greece opened fully the country again. This was the first wave of COVID-19 in Greece.

As in other cases of emergency, such as natural disasters or the HIV/AIDS crisis (Twigg, 2001; Johnson et al., 2011), support to the system is not only provided by governments and NGOs, but also by the private sector. Principles for Responsible Investment (2020) timely indicated the way investors should act to help reduce the harmful impacts of the COVID-19 pandemic. Meanwhile in Greece, corporations responded to this health care crisis by acting Corporate Social Responsibility (CSR) practices. Contributions to the National Health System including Intensive Care Units (ICU) donations, equipment and consumables donations, financial or in-kind contributions were some of the spontaneous support mechanisms developed by them.

This voluntary giving of private firms for public purposes is linked to Corporate Philanthropy (Gautier and Pache, 2015). Philanthropy actions, according to Carroll (1991) "are in response to society's expectation that businesses be good corporate citizens". Corporations, in turn, act that way because they are highly depended on their stakeholders (Mc Knight and Linnenluecke, 2016), to maintain their legitimacy (Chen et al., 2008), or due to the institutional environment/industry they are in (Brammer and Millington, 2004; Jackson and Apostolakou, 2010). In other cases, CSR practices, like philanthropic activities, are part of a corporation's strategy (Brammer et al., 2006) and can be communicated by annual Sustainability Reports.

Unlike financial reporting, Sustainability Reporting (SR) includes social as well as environmental issues along with financial information (Herzig and Schaltegger 2006, Kolk 2003). The reporting framework is set by international standards, mainly developed by Global Reporting Initiative (GRI), and its content can become a tool for managers or the corporation's external stakeholders (Willis, 2003).

Corporate philanthropy is linked to sustainability reporting (Kolk, 2003), but their relationship is not mutual. Research has shown that the former can be present without the presence of the latter (Godfrey, 2005). On the other hand, CSR practices published under the name of Sustainability Reports often include corporations' social and environmental funding, and it is usual when a natural disaster takes place (Mc Knight, B. and Linnenluecke, 2016).

As COVID-19 is an unprecedent disaster for the global society, it is worth investigating how the corporations reacted to this pandemic, and if it is considered by the corporations as a natural disaster. This investigation took place by forming two hypotheses based on the existing theory.

The next section presents the theories which are the basis for the hypotheses of the research, and it states these hypotheses. Then the methodology is presented, followed by the statistical analysis and the results. Finally, a brief discussion takes place, and the conclusions of the research are presented.

## 2. Literature Review

In this section, the main theories that apply to the research are presented, in order to form the hypotheses of the paper.

### *2.1. Corporate Philanthropy*

In the literature, Corporate Philanthropy is the way organisations act after they have fulfilled their economic, legal and ethical responsibilities (Carroll, 1991) or reversely (Kang, 1995; Wood, 2010, Chen and Cao 2016) after fulfilling first their moral, social and then their economic responsibilities. Either it is called 'commitment to the common good', 'community investment' or even 'social marketing' (Gautier and Pache, 2015), philanthropic efforts are linked to society's well-being.

It can be expressed through charitable actions like donations and grants either in cash or in kind (good, services and facilities) (Twigg, 2001). According to Johnson et al. (2011) in cases of emergency, charitable giving can also include employee volunteers, employee cash donations and treatment programmes· while in the long run, corporate philanthropy is directed toward mitigation and planning through educational and disaster preparedness programmes. Collaborations with NGOs and governments are common and indicate the altruistic characteristics of corporate philanthropy (Twigg, 2001; Johnson et al., 2011). During emergency cases, private sector philanthropy can be either 'corporation-centric', strategically directed to the salient stakeholders, such as customers or suppliers, or 'community-centric' with a stronger engagement with community (Mc Knight and Linnenluecke, 2016).

### *2.2. Sustainability Reporting*

CSR is inseparable from sustainability. The Society, Environment and Economy triptych expresses sustainable development in general (Giddings, et al., 2001), as well as sustainability accounting and reporting (Schaltegger et al., 2006). These three aspects are integrated and should not be examined separately. With the help of triple bottom line model (Elkington, 1998; Schaltegger et al., 2006, Gray and Hermans, 2012), the conventional economic accounting and reporting have come in line with social and environmental aspects and have formed the modern corporate responsibility reporting.

Nowadays, 'reporting integration is the new normal and "non-financial" is the new financial' according to the KPMG's (2017) latest survey.

In a worldwide scale, the Global Reporting Initiative (GRI) provides corporations with a framework for creating sustainability reports that integrate social, environmental and economic impacts of business. There are three main categories of the GRI- G4 guidelines: 1) Economic 2) Environmental and 3) Social, with the last including four sub-categories: 3.1) Labour Practices and Decent Work, 3.2) Human Rights, 3.3) Society and 3.4) Product Responsibility (GRI, 2013).

The GRI- G4 Standards indicators that relate Corporate Philanthropy and CSR are the following (Table 1).

**Table 1:** Indicators relating CSR and Corporate Philanthropy

| **Category** | **GRI Standard Number (G4 Disclosure)** | **Description** |
|---|---|---|
| Management Approach | GRI 103 | Explanation of the material topic and its Boundary |
| Economic | GRI 201-1 (G4-EC1) | Direct economic value generated and distributed |
| | GRI 203-1 (G4-EC7) | Infrastructure investments and services supported |
| | GRI 203-2 (G4-EC8) | Significant indirect economic impacts |
| Social- Society | GRI 413-1 (G4-SO1) | Operations with local community engagement, impact assessments, and development programs |

*2.3. Corporate philanthropy, CSR, natural disasters, and COVID-19*

According to Tilesic and Marquis (2013), corporate philanthropy takes place during or after natural disasters which are considered as "exogenous destructive shocks to communities", and cause death, injuries, physical and economic damage. The authors find mixing results on the relationship between corporate philanthropy and natural disasters; there are corporations which donate voluntarily because of the magnitude of the effect and its big impact on the society, while there are corporations which are greatly impacted by the natural disaster and are unable to respond, because there is a limitation to their philanthropic capacity. They also found that the history of corporate philanthropy may play a significant role for donating to small-scale disasters, but not to large scale ones, while Crampton and Patten (2008) suggest that CSR practices of history of CP are determinants of corporate giving after a natural disaster.

Research about COVID-19 and its relationship to corporations is rich, though it has only been one year since it begun (Verma and Gustaffson, 2020). Garcia-Sanchez and Garcia Sanchez (2020) show that Spanish corporations reacted through a typology that has already been analyzed by Mc Knight and Linnenluecke (2016). Their response was either community centric, firm centric, or both. However, no research seems to investigate how the history of CSR practices and corporate philanthropy have influenced corporations to respond to societal relief. Although Verma and Gustaffson (2020) identified four main research themes and 18 sub-themes in 107 articles for COVID-19 and businesses, there is no sub-theme that relates the influence of COVID-19 to CP of CSR and CP adopters or non-adopters.

*2.4 Research hypotheses*

Taking into account the previous theoretical framework, two research hypotheses are tested:

H1: history of CSR practices is a determinant of CP, that is previous general CSR practices as revealed through a GRI sustainability report is a determinant of corporate philanthropy during COVID-19

H2: history of CP in the proCOVID-19 period is a determinant of CP in the postCOVID-19 period, that is corporate funding to past disasters is a determinant for CP during COVID-19

## 3. Methods and Data

The current study took place during the COVID-19 outbreak and the first general lockdown in Greece, that is March and April 2020. The first researcher collected all the data available on the internet about the funding of the Fortune 100 corporations in Greece to health system and the customers. The data were found both in daily news pages, or straight from the corporation's webpage, after the use of Google Search was taking place with the suitable key words: COVID-19, donations to NHS (in Greek), donations (in Greek) AND COVID-19. A Microsoft Excel file was created including the data base of the variables that were recorded.

The variables shown in Table 2 were. They were collected by conducting a content analysis research (Landrum and Ohsowski, 2018) to the last available annual, integrated and/or sustainability reports (2018 fiscal year, with some 2017 exceptions) and to the aforementioned collected information.

**Table 2:** Variables used in the research

| Variable name | Variable type | Levels |
|---|---|---|
| Donation (help) | Binary | 0: No, 1: Yes |
| GRI reporting (gri) | Binary | 0: No, 1: Yes |
| Previously used GRI philanthropy related indicators (proCovid) | Categorical and Binary variables | Categorical: the levels of Table 1<br>Binary: 0: No, 1: Yes |
| Donation type | Categorical | 1: towards NHS, 2: towards customers, 3: Both 1 and 2 |

In order to test the first and second hypotheses, the McNemar test was used (Gray and Kinnear, 2012; Hashmi et al., 2015). Mc Nemar test is applied to a sample of research units which is tested under two conditions (before and after the condition) (Weber et al., 2010). Cohen (1988) described also how one can calculate the effect size of the condition, the so-called Cohen's measure $g = |P-p|$. g is the difference between P, the proportion of outcomes in the target category and p is the probability of the outcome under the null hypothesis (Kinnear and Gray, 2012).

The statistical analysis was performed in SPSS 25.0 with significance lever 0.05.

## 4. Empirical Results

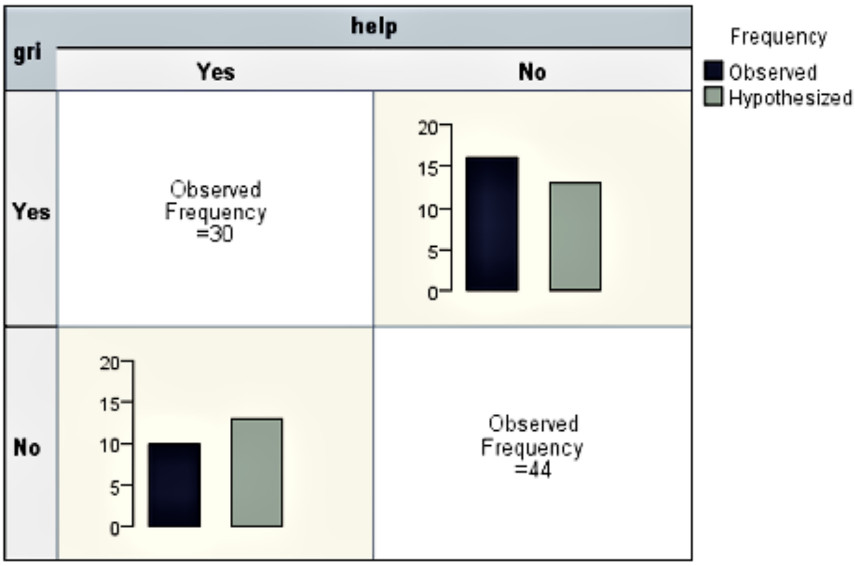
Forty (40) out of Fortune 100 organizations contributed to the fight against COVID-19 in Greece, during the first wave of the crisis. The median value of their total assets was 728 million €. Most of the corporations (17.5%) came from the banking and insurance sector. The 95% of them donated to the NHS while 78% donated material that was not produced in their production process (money are included in this percentage).

From the Fortune 100 list in Greece, it was found that previously 46 corporations had adopted GRI sustainability reporting, thus general CSR practices. This may or may not include corporate philanthropy. Additionally, 40 corporations out of 100 helped with a donation the fight against the virus. The cross relation of these two variables (gri and help respectively) is shown in Figure 1.

Figure 1 reveals that 30 out of the 46 corporations which in the past had adopted general CSR practices (including philanthropic donations or not), helped with a donation the fight against COVID-19, while 16 corporations didn't. On the other hand, 10 corporations which never had disclosed CSR practices with a GRI sustainability report, helped against the virus, while the remaining 44 corporations acted as usually, that is they didn't donate.

The Related-Samples McNemar Change Test tested the null hypothesis that the distributions of different values across previous general CSR practices and help against COVID-19 are equally likely. The test statistic was equal to 0.962 (df=1) and the asymptotic 2-sided test significance 0.327. This means that the null hypothesis is retained

**Figure 1:** Cross relation of CSR practices and help against COVID-19 from Greek Fortune 100 corporations




This result confirmed that history of CSR practices is a determinant of CP, thus Corporate Philanthropy is positively related to CSR practices. As shown by the McNemar test, the majority of CSR practices adopters donated to the fighting against the virus, while the majority of the non-adopters did not.

For the second hypothesis, the Fortune 100 list showed that 23 corporations had previously published a GRI sustainability report using the Table 1 indicators, meaning that they had made at the past donations about social or environmental issues. On the other hand, 77 corporations either hadn't made donations, or didn't issue a GRI sustainability report. The cross relation of this (proCovid) variable with the variable showing the number of Fortune 100 listed corporations helping against COVID-19 (help), as analyzed in the previous section, is presented on Figure 2.

**Figure 2:** Cross relation between previous philanthropy and help against COVID-19

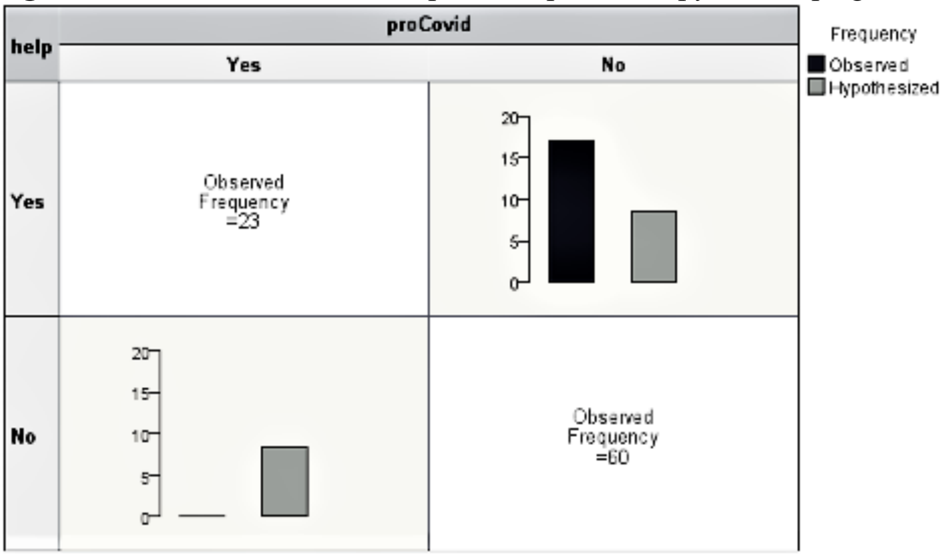



Figure 2 shows that all the Fortune 100 listed corporations which had previously practiced corporate philanthropy did also donate during the first wave of COVID-19 in Greece. There were zero corporations that did not help. On the other hand, out of the 77 corporations that hadn't previously practiced corporate philanthropy, 17 donated against COVID-19 and 60 didn't donate.

The Related-Samples McNemar Change Test tested the null hypothesis that the distributions of different values across help and proCovid are equally likely. The test statistic was equal to 15.059 (df=1) and the asymptotic and exact 2-sided significance <0.001. This means that the null hypothesis is rejected.

The result of the McNemar test means that the corporate philanthropy practices after the COVID-19 period are increased statistically significantly, and that many corporations with no history of corporate philanthropy voluntary donated so that society manages to combat the virus.

Those corporations that changed their strategy after the COVID-19 appeared were in total 17+0=17. Those that changed in favor of the philanthropy compared with total was 17/17 = 1. The proportion expected under the null hypothesis was 0.5 (Kinnear and Gray, 2012). Thus, Cohen's measure g = |P-p| = 1-0.5=0.5. According to Kinnear and Gray (2012) this is a large effect, thus the sudden crisis of COVID-19 forced organizations with no CP history to act responsively and donate to society.

## 5. Conclusions

Public Health has been an issue of concern since the Doha Round (WTO, 2001). Nowadays, the Goal 3 of the Sustainable Development Goals (SDG) is to 'ensure healthy lives and promote well-being for all at all ages' (UN, 2015; UNGC 2020). According to the Agenda (2015), actions should not only focus on medical and pharmaceutical research and development, but also on the early warning, risk reduction and management. The outbreak of the coronavirus disease led to a global health crisis that attacks 'societies at their cores' affecting all aspects of human life and consequently all SDGs (UNSDG, 2020). The private sector needs to take action through CSR activities, in this unprecedented situation in cooperation with public sector and NGOs, to develop new structures and institutions for the good of the society (Dobers and Halme, 2009).

Although the private sector needs to respond to the society relief from COVID-19, the virus has a significant impact on how they operate. Most of the papers published until now show mainly how COVID-19 impacts on the corporate functions, such as value chain, employment, technology, supply chain etc (Verma and Gustafsson, 2020), or the shift of CSR to more societal issues and funding, thus neglecting the environmental aspect of sustainability (Barreiro-Gen et al., 2020; Zhang et al., 2020). CSR is used only as a predictor for the corporation resilience to COVID-19 (Huang et al., 2020).

This paper was among the first which tested how the history of CSR and CP practices are affecting CP during COVID-19 period. Previous research on natural disasters and corporations literature has shown mixed effects of these factors. Our research has confirmed that history of general CSR practices, which may include or may not include past donations to society or the environment, is a reliable determinant for CP in the COVID-19 period. However, if we test only those organizations with history on corporate giving, then history of corporate funding is not a determinant of CP for combating the virus. Thus, previous literature (Tilcsik and Marquis, 2013) is confirmed if COVID-19 is considered as a small scale natural disaster, thus more than usual corporations donate to society for combating the disaster, but not confirmed if COVID-19 is considered as a large scale natural disaster; Tilcsik and Marquis (2013) find that on large scale disaster there is less or not more corporate philanthropy.

Perhaps, due to the fact that corporations were unaware of what COVID-19 will mean to their business and to society have perceived that the virus would stay for a short time. Thus, they decided to fund NHS and their customers and offer some relief. It would be interesting for future research to examine what this prolonged period of the virus means for the Greek corporations. How would the managers have responded if they knew that COVID-19 is one of the major disasters of the global economies for more than a century now?

Additionally, it would be interesting for future researchers to examine the long term actions that are going to take place in the following months. Corporations are expected to proceed to new forms of CSR, for the prevention of the disease, as well as for society's education and awareness.

The results of this paper have shown a mobilisation by Greek private corporations, mostly towards society and by all means within the first two months after the COVID-19 outbreak. A question that could also be answered based on these results, is if there will be a positive influence on community resilience in the near future. Will this CP action contribute to effectively manage the COVID-19 pandemic in Greece? And finally, which are going to be the benefits for the corporations that proceeded to charitable action?

The current study can become a useful tool for CSR studies, as it has recorded the response of the Greek corporations in the unexpected case of the COVID-19 outbreak, which shacked the whole society and changed millions of lives. Our results should be also confirmed by similar research in countries with high CSR rankings and history of strong corporate philanthropy. As presented here, they give a good indication that when society is in need humanitarian attributes are emerged among corporations with less or no history of CSR and CP practices.

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# The relationships between pollution, economic growth and Covid-19: A literature review

**Athanasios Tsadiras**
*Laboratory of Informatics in Economic Sciences, School of Economics,*
*Aristotle University of Thessaloniki, Greece*
tsadiras@econ.auth.gr

**Abstract**
In the era of Covid-19, one of the main scientific questions regards the relationships that exist between pollution, economic growth and Covid-19. For example, the role that the concentrations of atmospheric Particulate Matter ($PM_{10}$ and $PM_{2.5}$) played in the spread of the virus is examined in various studies, with the correlations to be justified both directly and indirectly. The direct connection can be justified by the fact that the atmospheric particulate could play the role of the virus carrier. The indirect connection can be justified by the fact the effects of respiratory viruses like Covid-19 on humans would be more severe in patients that live and breathe in polluted environment. Moreover, the relationship between economic growth and environmental sustainability in another topic discussed in several studies. In this paper we present the conclusions that we draw from making a survey on the relevant literature that regards the relationships between pollution, economic growth and Covid-19. The paper accumulates the results coming from numerous scientific studies that in most of the cases present findings coming only from regional level (e.g. cities/ regions in China or Italy).

**Keywords:** Pollution, economic growth, Covid-19.

**JEL Codes**: Q53, O44, O47, I18.

## 1. Introduction

The relationships that exist between Pollution, Economic Growth and Covid-19 is a main scientific question in the era of Covid-19. Various studies examined the role that the concentrations of atmospheric Particulate Matter ($PM_{10}$ and $PM_{2.5}$) played in the spread of the virus. Their source are cars and motorcycles, plants for production of electricity, wood burning for domestic heating, forest fires etc. They can be inhaled and reach the deepest part of the human respiratory system and lungs.
The hypotheses of correlations between PM and Covid-19 can be justified both directly and indirectly.

a) The direct connection can be justified by the fact that PM could play the role of the virus carrier.
b) The indirect connection can be justified by the fact the effects of respiratory viruses like Covid-19 on humans would be more severe in patients that live and breathe in polluted environment.

Moreover, the relationship between economic growth and environmental sustainability is another topic that is discussed in several studies.

The aim of this study is to:

a) Perform a survey on the relevant literature that regards the relationships between pollution, economic growth and Covid-19.
b) Accumulate the results coming from numerous scientific studies.
c) Unify results that in most of the cases, present findings coming only from particular regional areas (e.g. cities/regions in China or Italy).

d) Examine if there are contradicting results or skepticism on them.
e) Point out areas that deserve more study.

## 2. Literature that regards the relationships between Pollution, Economic Growth and Covid-19.

*2.1 Studies that regards areas in China*

China was the first country to face the COVID-19 pandemic and for this reason various studies regards areas and cities in that country.

The study of Magazzino et.al. (2021) regards the Hubei area in China, the epicenter of the COVID-19 pandemic. The aim of the study was to assess the relationship between economic growth, air pollution and deaths from COVID-19 in that particular area. The study is based on data that includes confirmed COVID-19 deaths, air pollution ($PM_{2.5}$, $PM_{10}$, and $CO_2$), and per capita economic growth, from the main cities in the Hubei province. The methods that were used were artificial neural networks and other deep learning methods. The results of the study were that:

a) There is a strong predictive relationship between changes in the economic growth, fine particles, and deaths from COVID-19, for the Hubei area.
b) Advice should be given to policymakers to recommend adequate environmental reforms (e.g. in transportation) to restrain the spread of the virus.

Another study that regards China, is that of Zhu et al., (2020). The authors examined data from 120 cities in China in order to explore the relationship between air pollutants and Covid-19. The data that was used are Covid 19 cases, air pollution concentration and meteorological variables from the 120 cities in China. The researchers used a generalized additive model to investigate the associations of six air pollutants ($PM_{2.5}$, $PM_{10}$, $SO_2$, CO, $NO_2$ and $O_3$) with COVID-19 confirmed cases. The main findings of the study were:

a) significantly positive associations of $PM_{2.5}$, $PM_{10}$, $NO_2$ and $O_3$ with COVID-19 confirmed cases were found.
b) A 10-μg/m$^3$ increase in $PM_{2.5}$, $PM_{10}$, $NO_2$ and $O_3$ was associated with a 2.24%, 1.76%, 6.94% and 4.76% increase in the daily counts of confirmed cases, respectively (involving a time lag between 0–14 days).
c) On the other side, a 10-μg/m$^3$ increase in $SO_2$ was associated with a 7.79% decrease in COVID-19 confirmed cases (involving a time lag between 0–14 days).
d) Overall, there is a significant relationship between air pollution and COVID-19 infection.

Yao et al., (2021) also performed a similar study in 63 cities in China. Its aim was to explore the relationship between $NO_2$ levels and the transmission ability (basic reproductive number, $R_0$) of COVID-19 in 63 Chinese cities. To do that, the following data was used: a) concentrations of various air pollutants, b) COVID-19 confirmed cases and c) meteorological data including mean temperature and relative humidity, in the 63 cities in China. Statistical analysis, correlations, principal component analysis was used to explore the relevance of the various factors. The conclusions drawn from that study are that:

a) $R_0$ was positively associated with $NO_2$ concentration at city level.
b) All the 11 Hubei cities (except Xianning City) had significant positive correlations between $NO_2$ concentration (with 12-day time lag) and $R_0$.
c) $NO_2$ is also an indicator of traffic-related air pollution.

d) The association between $NO_2$ and COVID-19′s spreadability suggest that reduced population movement may have reduced the spread of Covid-19.

*2.2 Studies that regards areas in Italy*

Italy was a country that was heavily affected by COVID-19, and several studies regards Italian regions and cities.

Conticini et al., (2020) contacted a study that concerned Northern Italy and more specifically the area of Lombardy and Emilia Romagna which is Europe’s most polluted area and also had the highest level of virus lethality in the world. Once again, the aim of the study was to analyze the possible link between pollution and COVID-19. This was done be finding correlations between pollution and the Covid-19 deaths. The study found that:

a) There is evidence that people living in an area with high levels of pollutants are more prone to develop chronic respiratory conditions, suitable to infective agents.
b) Air pollution can partially explain the differences in mortality in this region.

The authors concluded that the high level of pollution in Northern Italy should be considered an additional co-factor of the high level of lethality recorded in that area.

Coccia (2020) studied data from 55 Italian province capitals a) to explain the geo-environmental determinants of the diffusion of COVID-19 and b) to suggest a strategy to cope with future epidemic threats. The data that was used for the study included air pollution data, Covid-19 cases, meteorological information and the density of population of 55 Italian province capitals. The author studied correlations, log-log linear models, quadratic models to draw the following conclusions:

a) Cities with more than 100 days of air pollution have a very high average number of infected individuals.
b) Transmission dynamics of COVID-19 has a high association with air pollution of cities in the presence of low wind speed.
c) Polluted cities in hinterland with low speed of wind have a high number of infected individuals than coastal cities.

The study of Frontera et al., (2020) regards various Italian regions. The purpose of this study was to analyse the relationship between air pollutants concentration and COVID-19 outbreak, in terms of transmission, number of patients, severity of presentation and number of deaths. To do that, the study used data that contains emissions of air pollutants and confirmed COVID-19 cases and deaths, in the specific Italian regions. After performing correlation studies, the authors reached the following conclusions:

a) The highest number of COVID-19 cases were recorded in the most polluted regions with patients presenting more severe forms of the disease.
b) In these regions, mortality was two-fold higher than the other regions.

A study that regards Italy in national level is that of Setti et al., (2020). The aim of this study was to assess the relationship between PM concentration levels and COVID-19 diffusion rate in Italy. The authors collected $PM_{10}$ daily concentration levels from Italian environmental monitoring stations at national level. After that they studied the correlation between COVID-19 cases and the average number of exceedances of $PM_{10}$ daily limit. A delay time of 14 days was also taken into account. A positive correlation was found, and the study concluded that the rapid COVID-19 infection spread observed in selected regions of Northern Italy is related to $PM_{10}$ pollution due to airborne particles able to serve as carrier of pathogens.

*2.3 Studies that regards areas in USA*

Various studies concern USA where Covid-19 had a serious impact.

In 2020 Wu et al. performed a study that regarded 3087 counties in the USA. The purpose of this study was to explore whether long-term exposure to $PM_{2.5}$ can be associated with an increased COVID-19 fatality in the USA. Apart from $PM_{2.5}$ and COVID-19 deaths from 3087 counties in the USA, another 20 potential confounding factors were adjusted to be examined in the study. The factors include population size, age distribution, population density, time since the beginning of the outbreak, time since state's issuance of stay-at-home order, hospital beds, number of individuals tested, weather, and socioeconomic and behavioral variables such as obesity and smoking. A negative binomial mixed model was used for the study and the results were that:

a) an increase of only 1 μg/m$^3$ in $PM_{2.5}$ is associated with an 8% increase in the COVID-19 death rate.
b) A small increase in long-term exposure to $PM_{2.5}$ leads to a large increase in the COVID-19 death rate.

Magazzino et al., (2021) contacted a study that regarded New York state. Its purpose was to assess the relationship between COVID-19-related deaths, economic growth, $PM_{2.5}$, and $NO_2$ concentrations in New York state. The authors collected data that regarded confirmed deaths due to COVID-19 and air pollutant ($PM_{2.5}$ and $NO_2$) concentrations levels. The methods that they followed were a) Artificial Neural Networks, b) a Deep Learning approach and c) a D2C causality model. The conclusions were that:

a) A unidirectional causal effect is found from $PM_{2.5}$ to Deaths, $NO_2$ to Deaths, and economic growth to both $PM_{2.5}$ and $NO_2$.
b) Unsustainable economic growth could increase environmental pollution by escalating emissions of pollutant agents ($PM_{2.5}$ and $NO_2$) in New York state.
c) Evidence was found that unsustainable economic growth predicts the dynamics of air pollutants.

*2.4 Studies that regards areas in Europe (except Italy)*

Except Italy (presented above), similar studies that regards other European countries have been contacted.

The study of Travaglio et al., (2021), regarded 120 sites in England. The purpose of this study was to explore potential links between major air pollutants related to fossil fuels and Covid-19 mortality in England. The data that was used for this study included Covid-19 cases and deaths and air pollution data monitored at the 120 sites across England. A negative binomial regression model was created, showing that the levels of nitrogen oxides ($NO_x$) and $SO_2$ are associated with increased numbers of COVID-19-related deaths throughout England. The authors concluded that there is a significant relationship between air pollution and COVID-19 infection.

A study that regards three major French cities, that of Paris, Lyon, and Marseille was contacted by Magazzino et al., (2021). The authors investigated the relationship between COVID-19 outbreak and air pollution in three major French cities. They also wanted to determine particulate concentration threshold levels of $PM_{2.5}$ and $PM_{10}$ that can foster COVID-19 and make the respiratory system more prone to this infection. They gathered pollution data and COVID-19 deaths from Paris, Lyon, and Marseille.
Artificial Neural Networks and a Causal Direction from Dependency (D2C) algorithm was applied to check the consistency of the findings. The results were that:

a) Particulate concentration threshold levels were found for each city.
b) All threshold values identified are lower than those imposed by the European Parliament.

In a study that regards Catalonia, Spain, Marquès et al., (2021) investigated the potential association of COVID-19 with $PM_{10}$, $NO_2$ and $O_3$, as well as the differences in the incidence and lethality of this disease in that area. Daily average air pollutants $PM_{10}$, $NO_2$ and $O_3$ and daily COVID-19 cases from Camp de Tarragona (an industrial area) and Terres de l'Ebre (an agricultural area) were collected. Using correlations and other statistical methods the authors reached the following conclusions:
a) Preliminary findings indicate that the industrialized/urban areas of Tarragona Province show a higher incidence and mortality of COVID-19 than the agricultural/rural zones.
b) If air pollutants such as PM can act as carriers of the SARS-CoV-2 then the recommendation on keeping the "social distance" (1.5–2.0 m) might need to be adapted to polluted areas.

*2.5 Studies that regards areas in India or multinational studies*

Mele & Magazzino, (2020) performed a study that regarded 25 major cities in India.
They wanted to explore the relationship between pollution emissions, economic growth, and COVID-19 deaths in India. To do that, they collected air pollution data and data that regards Covid-19 deaths in India. The authors followed a time series approach, performed causality tests, and applied machine learning methods to reach the following conclusions:
a) A unidirectional causality between economic growth and pollution was found.
b) A unidirectional causal link between economic growth and $PM_{2.5}$, $CO_2$, and $NO_2$.
c) The D2C package implements a supervised machine learning approach, showed a direct relationship between concentration of $PM_{2.5}$ and COVID-19 deaths.

A study that concerns 8 different countries (China, Iran, Italy, Spain, France, Germany, U.K. and U.S.A) was contacted by Pansini & Fornacca, (2020). Its aim was to investigate the geographical character of Covid-19 and correlate it with several annual satellite and ground indexes of air quality. The data that this study is based on was satellite-derived $PM_{2.5}$ distributions and COVID-19 cases or deaths in these eight countries. They measured correlation coefficients between Covid-19 cases or deaths and air quality variables. The results were that:
a) More viral infections were found in areas afflicted by high $PM_{2.5}$ and $NO_2$ values (significant correlations in China, Italy, U.K., Iran, France, and U.S.A, not in Spain and Germany). Higher mortality was also correlated with relatively poor air quality.
b) In Italy, the correspondence between the most polluted European valley and Covid-19 infections and mortality was clear.
c) Air pollution appears to be a risk factor for Covid-19 (similar to smoking).

**3. Research results that express skepticism**

There are several studies that express skepticism on, or even contradict, the results of the studies presented in section 2 above.

For example, E. Bontempi, (2020a) investigated the potential association of COVID-19 with $PM_{10}$ during the severe cases of COVID-19 infections in Lombardy area, Italy. Statistical tools were used to examine the data of $PM_{10}$ daily mean concentrations and daily COVID-19 cases. The outcome was that:
a) There were no evident of direct correlations between the presence of high quantities of $PM_{10}$ and the diffusion of the COVID-19 virus.

b) Cities that suffered of the most severe event of $PM_{10}$ pollution (Torino and Alessandria), in the 20 days before the Italian sanitary crisis, had low infections cases. On the contrary, Bergamo, where the limit of 50 μg/m$^3$ for $PM_{10}$ concentration was exceeded only few times, presented the highest infectious cases.

Another study that expressed a skepticism on the topic is that of Contini & Costabile, (2020). The authors state that the current data on mortality (and contagions) could be affected by relevant uncertainty due to the different strategies used for counting deaths related to COVID-19 and infected people. Furthermore, they mention that the relationships between $PM_{2.5}$/$PM_{10}$ concentrations and COVID-19 should be studied with caution since airborne transmission aerosols have low probability in outdoor environments but increased probability in specific indoor environments, like hospitals and areas where patients are quarantined.

Moreover, in the study of E. Bontempi, (2020b), the author states that:

a) There is lack of suitable interdisciplinary research (even airborne has a different meaning for medical and environmental scientists).
b) Further studies should be done to examine other parameters that can better justify the difference in the initial diffusion of virus in Italy. For example, to investigate commercial exchanges and the financial relationships of different parts of Italy with China, that wasn't considered before in COVID-19 literature.

It should be also mentioned that there are also studies that investigate the change in atmospheric pollution from public Covid-19 lockdown. Such a study is that of Varotsos et al., (2021) and regards Greece. Using data from $NO_2$, $O_3$, $PM_{10}$, and $PM_{2.5}$ pollutants and ground-based and satellite observations, the applied statistical methods to find that:

a) In most cases, the change in atmospheric pollution is not statistically significant.
b) The above result is probably an artifact of the meteorological conditions that contributed significantly to the long-range transport of air pollutants over Greece during the shutdown period.

## 4. Conclusions and Future Work

From the above literature review there is several conclusions that can be drawn. First, that there are many studies that have been done on the topic, but according to their results, the subject is still open. A second conclusion is that accord to them, there is evidence of relationships between Pollution, Economic Growth and Covid-19. Another conclusion is that more extensive studies should be done to investigate the topic, not in regional or national level but on a global scale. Furthermore, additional interdisciplinary research should be done to get more solid results. Several studies show that Machine Learning & Deep Learning techniques can assist the research on this subject. Our future plan is to apply such methods in data e.g., from Greece, Europe or even in a more global scale to perform an in-depth investigation of the underling relationships between Pollution, Economic Growth and Covid-19.

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# Biodiversity reporting: A literature review

**Anastasia Naxaki & Konstantinos G. Papaspyropoulos**
*MSc. Natural Resources: Monitoring, Technology and Bioeconomy, Department of Forestry and Natural Environment, Aristotle University of Thessaloniki, 54124*
anaxaki96@gmail.com, kodafype@for.auth.gr

**Abstract**
Biodiversity is declining in a rather fast rate, being under threat due to climate change, unsustainable use of natural resources and expanding population. Thus, the concept of biodiversity has evolved in recent years, being an important issue for both businesses and society. Today, there are several efforts for the provision of frameworks for companies to understand how they can incorporate biodiversity loss into their business models. However, many firms seem to be quite reticent to report on the effects that their activities have on biodiversity. Nowadays, under the scope of an ecologically sustainable society, academia is investigating the role of biodiversity accounting and reporting in communicating performance and enhancing accountability towards relevant stakeholders. Under the environmental stewardship theory, business and organizations are accountable to society for protecting and contributing to environmental balance. Thus, the objective of the present research is to explore in detail biodiversity reporting through a literature review and it aims to contribute to the development of a broader theoretical knowledge, as biodiversity reporting and accounting represent issues that need to be explored in more detail.

**Keywords:** Biodiversity accounting, sustainability, reporting protocols, corporate responsibility.

**JEL Codes**: L22, M41, O50, Q56, Q57.

## 1. Introduction

There are plenty of definitions of biodiversity varying from the narrow to the broad (Grabsch et al., 2012). A narrow and scientific meaning of biodiversity is "the number of species and genetic variety within species" (F & C, 2004). Alho (2008) noted that "life forms should be conserved with a simple way, constituting an altruistic or non-humanistic value to support the intrinsic value of biodiversity". The Convention on Biological Biodiversity (CBD) was launched in 2002, recognizing that biological diversity, except from plants, animals and microorganisms and their ecosystems, concerns also people and a healthy environment in which to live, including the need for food security, medicines, fresh air and water (GRI, 2007).

However, biodiversity is declining in a distressing fast rate, being under threat due to climate change, unsustainable use of natural resources and expanding population (Daly & Friedman, 2016, Usher & Maroun, 2018). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in its annual report in 2019, highlighted that the condition and the extent of natural ecosystems was declined at an amount of 47 %, compared to primary research (IPBES, 2019). So, it was agreed at the World Summit on Sustainable development to be achieved a significant reduction in the current rate of biodiversity loss (CBD, 2012, Potdar et al, 2016). By 2050, European Union aims to protect, value and restore biodiversity and ecosystem services that it provides (European Commission, 2011).

Ball and Milne (2005) had supported that businesses unwillingness to sacrifice current earning in the interests of future generations and also a general lack of ecological conscience, have contributed to an absence of environment-related disclosures (Samkin et al., 2014). However, Limited (2011) claimed that the protection of species, habitats and general the conservation of biodiversity and natural resources are included in the business's main environmental goals and objectives (Samkin et al., 2014). So, due to the fact that biodiversity is very important for assessing sustainability, academics have begun to evaluate reporting on biodiversity-related issues by some of the most well-known and noticeable companies (Adler et al, 2018).

Industrial processes depend on critical resources that are provided by biodiversity. In negatively impacting biodiversity, businesses risk losing these resources (ABMB, 2019). Thus, the last 20 years has seen an increase in environmental data that are included in sustainability and integrated reports, but a few details on biodiversity conservation and management (Jones & Solomon, 2013). However, more and more companies have begun considering their social integration as an important commitment and are concerned that their activities appear legitimate to their stakeholders (IUCN, 2014). These activities now include corporate environmental measures, such as countermeasures about waste, water and air pollution (Oka et al., 2019). Primary business sectors, such as agriculture, forestry and fisheries rely on biological resources, which underline an influential value to investigating to natural capital enhancement (Skouloudis et al., 2019).

Thus, there is a need to create a holistic accounting, which combines biological diversity and ecosystems with the key areas of accounting (Jones, 2010). The global biodiversity crisis that exists today, requires immediate action from all parts of society, so it is very important for the private sector and its stakeholders to demonstrate an improved performance on biodiversity (EU Business, Biodiversity Platform, 2019). For organizations to take biodiversity and ecosystem services into consideration for decision-making, they need specific tools to identify and monitor their interactions with Biodiversity and Ecosystem services (BES). It is argued by The Economics of Ecosystems and Biodiversity (2010) that for Business Report "the challenge is to establish information management and accounting systems that can provide relevant information on BES to support operational decisions, to inform financial valuations or project assessments and also for internal and external reporting (Ring et al., 2010).

Aligning Biodiversity Measures for Business Initiative (ABMB) being a collaboration of twenty organizations with expertise in corporate biodiversity measurement approaches, aims to form a common view between key stakeholders to measure, monitor and disclose the impact of businesses activities on biodiversity. This will help incorporate more credible indicators of corporate contribution to global biodiversity goals into corporate reporting and accounting and identify also common elements between measurement approaches (ABMB, 2019).

So, many researchers nowadays, under the scope of an ecologically sustainable society, are investigating the role of biodiversity accounting and reporting in communicating performance and enhancing accountability towards relevant stakeholders (van Liempd & Busch 2013, Atkins et al. 2014, Schneider et al. 2014, Mansoor & Maroun 2016, Skouloudis et al, 2019). Under the environmental stewardship theory, business and organizations are accountable to society for protecting and contributing to environmental balance (Papaspyropoulos et al. 2012, Siddiqui 2013)

Thus, the objective of the present research is to explore biodiversity reporting through a literature review and it aims to contribute to the development of a broader theoretical knowledge, as biodiversity reporting and accounting represent issues that need to be explored in more detail. In order to do so, the present paper in the following, after the methodology, sections, three main issues explores: a) definition of, b) protocols for, c) attributes of corporations that report on biodiversity.

## 2. Methodology

The research was conducted via a literature review. According to Seuring et al. (2005) literature review is an explicit and reproducible design for identifying, evaluating and interpreting existing knowledge on a particular subject. Literature review is a valid approach and a necessary step towards the structure of a research field, being an internal part of any research conducted (Easterby- Smith et al., 2002).

Major databases were used such as (Elsevier (www.sciencedirect.com), Emerald (www.emeraldinsight.com), Springer (www.springerlink.com), Wiley (www.wiley.com) and Taylor & Francis (www.tandfonline.com)) and library services (Scopus and Web of Science) (Stechemesser and Guenther, 2012). Additionally, Google Scholar was used to find literature that has been published in conference proceeding and/or technical reports (Bergman, 2012).

The terms that were used were "biodiversity reporting", "biodiversity accounting", "reporting on biodiversity", "sustainability reporting" AND biodiversity, "environmental reporting" AND biodiversity. In order to limit the results, the term "biodiversity" was not used alone because a very broad of results would have appeared.

## 3. Results

### *3.1 Definition*

Biodiversity reporting refers to the information on biodiversity that a company discloses to its stakeholders. However, there is no explicit definition of biodiversity reporting in the literature. The term is considered as a subdiscipline of sustainability or social and environmental reporting, especially when seen as part of GRI reporting (Atkins et al. 2014, Bhattacharyya & Yang 2019).

An explicit definition of the term "biodiversity reporting document" can be found in the technical report of IUCN French Committee (2014), where it is defined as "the various 'reporting documents' or parts of 'reporting documents' published by companies and containing information on biodiversity, both obligatory information and information provided voluntarily" (p. 13). It is considered as a multipurpose text, directed to the stakeholders (IUCN French Committee, 2014).

Implicitly defined, according to Jones & Solomon (2013), corporations through reporting on biodiversity have the ability to inform more the people, engender the evolution of understanding biodiversity impact and transform attitudes in relation to biodiversity (Adler et al, 2018). The aim of biodiversity reporting is not only the transparency but also how the enterprises and their stakeholders will use the reports.

Khan (2014) defines what biodiversity reporting isn't: "…biodiversity reporting cannot be restricted to the rigid economic definitions of the accounting framework. Measurement methods developed in the non-accounting sciences that are based on more than narrowly defined economic values need to be incorporated into biodiversity reporting"., while Gaia and Jones (2019) cite Jones (1996) who states that "Biodiversity reporting allows the society and interested stakeholders to assess management's stewardship of the natural environment".

### *3.2 Protocols for reporting*

According to Dumay et al. (2010), there are a lot of and different national and internationals standards dealing with the meaning of sustainability reporting, but the general rules issued by the Global Reporting Initiative (GRI) are the most well-known (Usher & Maroun, 2018). More than 90% of the worlds' largest companies use GRI, which includes guidance on issues and challenges in order to prepare their sustainability, biodiversity and other kind of reports. GRI 304 being a part of the set of GRI Sustainability Reporting Standards (GRI 304: Biodiversity 2016), was published in 2018 and it includes disclosures on the management approach and topic-specific disclosures as follows:

**Table 1**: GRI 304

| | |
|---|---|
| •Disclosure 304-1 | Operational sites owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas |
| •Disclosure 304-2 | Significant impacts of activities, products, and services on biodiversity |
| •Disclosure 304-3 | Habitats protected or restored |
| •Disclosure 304-4 | IUCN Red List species and national conservation list species with habitats in areas affected by operation |

These biodiversity indicators can be combined with some of the UN Sustainable Development Goals (SDGs), such as the 6th (Clean water and sanitation), the 14th (Life bellow water) and the 15th (Life on land) (Michalczuk & Konarzewska, 2018).

The System of Environmental-Economic Accounting consists another international statistical standard which aims to define the linkage between the environment and the economy, providing information in physical and monetary terms too (SEEA and the Post-2020 Biodiversity Agenda). The distinctiveness of SEEA is that it includes the perspective of natural resources, which is based on the concept of individual environmental assets, analyzing the way that natural resources are used in consumption (Natural Capital Accounting For Integrated Biodiversity Policies, 2020) and the one of ecosystems. The second one represents the main way that SEEA accounts for biodiversity, which is through experimental ecosystem accounting (EEA), incorporating the ecosystem extent, ecosystems' condition and health, social and economic benefits of ecosystem services and asset accounts. Last but not least, SEEA-EEA incorporates distinct species accounts, revealing information on species conservation and monitoring.

A global alliance of regulators, investors, firms, standards setters, the accounting sector, and nongovernmental organizations (Busco et al., 2013) called International Integrated Reporting Council (IIRC) was published and developed in 2013, focusing on value creation (Dumay et al., 2017) The destructiveness of the integrated report is that except from the reporting information, such as sustainability reports, explains the connection of the variety of information. Also, IIRC Framework indicates to a company how to react to different circumstances. A current example is the pandemic of covid-19 that has an evident impact on natural capital. According to IIRC (2021), The covid-19 pandemic has highlighted that environment, humanity and our economy need to be interconnected and interdependent, showing that if these sectors collaborate, humanity will make fundamental changes.

*3.3 Attributes of corporations that report on biodiversity*

Social constituents can make enlightened decisions with regards to corporate performance and environmental stewardship methods, by providing important information on pressures to ecosystem functioning coming from corporate activities. In this setting, corporate biodiversity accounting and reporting aims to capture information relevant to biodiversity management by employing a certain amount of valid and credible quantitative and qualitative indicators (Skouloudis et al, 2019).

Potdar et al. (2016) have selected 101 business in order to find which of them report biodiversity indicators, either fully or partially. It was found that 77 of them reported on at least one of the biodiversity indicators, representing sectors as chemicals, energy, financial services, forest and paper products. One of the GRI indicators, EN15 showing 'the number of IUCN Red List species and national conservation list species with habitats in areas affected by operations, by level of extinction risk' was reported only from the 25% of them. (Potdar et al., 2016).

South Africa is one of the most biodiverse regions all over the world (Mayes, 2012, Usher & Maroun, 2018), with a high contribution of its resources to the economy. Under the GRI's principle of clarity, a detailed biodiversity reporting can be achieved, for example about which species of fish are at risk of being overexploited and the assessed impact of over-exploitation on the business model (Atkins et al, 2016, Usher & Maroun, 2018). Usher and Maroun (2018), were based on 7 companies in farming and fishing sector listed on the Johannesburg Stock Exchange (JSE) in South Africa. and included in the farming and fishing sector. Sections of the reports dealing with issues relating to biodiversity were analyzed in more detail and the disclosure themes were used as Scene- setting, Species related disclosures, Partnership engagements, Stakeholder engagements, Performance evaluation, Risk or policy disclosure, Internal management and as External reports. Finally, the results have shown low levels of reporting on biodiversity-related issues. Particularly, over the 3-year period, social engagements account for 20% of the 140 disclosures, followed by species-related disclosures and external reports accounting for 14%.

Management reporting and accounting of impacts except from the financial domain, is a very important point in business' engagement with the environmental stewardship agenda (Gray, 2010). Skouloudis et al. (2019), described the role of businesses entities in mega-diverse countries, as Bolivia, Brazil, Colombia, China, India, Indonesia, Malysia and Philippines about biodiversity conservation and management. In particular, GRI indicators (EN11, EN12, EN13 & EN14) and another indicator, called DMA-BIO, showing the integration of biodiversity considerations in detailed tools applied by the business, were used about 2017 reporting cycle, utilizing Poisson and Gaussian Bayesian modeling. Their assessment was based on 182 reports and some of the results are the following:

- Businesses sectors that present the highest biodiversity indicators (BIs) are materials, energy, industrials, consumer staples and utilities sectors.
- In Brasilia, Bolivia and Malaysia are observed the highest levels of BIs and in Philippines the lowest.
- The majority of businesses biodiversity indicators being a part of the management accounting system, are underreported. In particular, data that are disclosed are unclear and the majority of narratives are qualitative.

Bansal and Kistruck (2006) support that information which is disclosed, rarely can be considered as unbiased. The reason that boosts businesses to report a symbolic commitment is just for influence positively stakeholder impressions (Milne and Gray, 2013). So, companies dissemble biodiversity management information within corporate social responsibility and environmental management activities (Fonseca et al., 2014, cited in Skouloudis et al., 2019).

From 2013 until 2017, Japanese companies have begun to look into the impact of their activities on environment and biodiversity, with an increase of 2,9% of businesses in 5 years (Oka et al., 2019). Nikkei Environmental Management Survey presented some specific questions to all these Japanese companies, as if they promote activities for biodiversity conservation and sustainable use, if the guidelines for these activities have been published, as also if they promote actions for biodiversity conservation.

More than 70% have created targets for biodiversity conservation and more than 85% have established an organization for that. Furthermore, based on a questionnaire survey of Nikkei in 2017, 51,8% of an amount of 396 firms support that they are going to start implementing and calculating Natural Capital Accounting from now. Only 24 of them (6,1%) stated that they have already incorporated and calculated the value of natural capital in the company.

## 4. Discussion

There is a view that organizations are human constructs, so they are accountable to society as large as well as to the stakeholders for their guidance of the environment. If it is true, it is reasonable to expect that a big amount of information of their activities' impact on biodiversity would be disclosed (Jones, 2003).

Until now, there is an extensive academic literature relating to social and environmental reporting (SER), but biodiversity reporting has received little attention from researchers. Only a few attempts have been done to develop frameworks for biodiversity audit and accounting too (Samkin et al., 2014). There are specific problems associated with the measurement and quantification of biodiversity information in order to be incorporated into corporate accounts and financial accounts. According to Grabsch and his colleagues (2012), except from the difficulty to settle on a widely accepted definition of biodiversity, there are difficulties also in measuring biodiversity, as a consequence causing problems for companies, which attempt to report biodiversity. Management accounting and reporting for biodiversity is an aspect omitted in the sustainability disclosure research stream (Boiral, 2014).

Until now, several studies have been done to develop an approach to environmental and biodiversity accountability in order to be created a discussion on the linkage between humanity and nature. The majority of firms that report on biodiversity represent sectors from energy, financial services and chemicals, but without revealing more specific information about the environment and biodiversity exploitation, as for the species which are by level of extinction risk. Prior environmental reporting and accounting research lacks a real ecological element (Russell et al., 2017, cited in Atkins and Maroun,2018). Research into the practice of accounting for biodiversity disclose reports that are anthropocentric, concerning species that people are interested in and not species as insects that are more unpleasant (Jones and Solomon, 2013; Atkins et al., 2014). In particular, biodiversity reporting and accounting literature have been mainly fixated with a critique in the anthropocentrism underpinning of corporate reporting. Actually, is needed a semantic framework for using the variety of types of biodiversity and extinction accounts to provide a review of human impact in the planet and the efforts that are now or should be taken in the future to prevent mass extinction. As Atkins et al. (2014) highlighted, biodiversity and extinction accounting have to be incorporated into the internal or management control system of a firm. In general, it seems that the majority of narratives are for unsustainability, rather than attempts just for report the term of sustainability (Spence and Gray, 2008). As Gray noticed (2010), sustainability is a notion promptly linked to eco-systems and biodiversity, so is quite difficult to incorporate it into an organizational level. In order to make the biodiversity reporting more detailed, businesses have to start distinguishing it from the sustainability reporting. Until now, the variety of frameworks such as Global Reporting Initiative (GRI) have contributed to reveal the term of environmental and biodiversity reporting. However, it seems that they are insufficient for businesses to report thoroughly and quantitively on biodiversity. Thus, it is an urgent need not only to do something because it helps the survival of human being, but also for protecting the natural resources and biodiversity, adopting the philosophy that views nature as having intrinsic value, the deep ecology (Glasser, 2011).

## 5. Conclusions

Biodiversity can be simplified to describe the variety of life on earth. Measurement of biodiversity performance by businesses and financial organizations is continuously gaining attention. From the literature review in this paper, it seems evident that corporations, in order to implement biodiversity conservation activities, they have to install within the organization a detailed reporting and accounting system. Biodiversity reporting initiatives aim to encourage these organizations to look into and reveal the impact that their activities have on biodiversity.

Today, there are a lot of industries and factories that harm the environment and the biodiversity in a distressing way, and as biodiversity loss is referred as one of the top five global risks to society, businesses are critical actors in supporting international efforts to halt biodiversity loss (Addison et al., 2020). So, in order to contribute to the term of sustainability, they have to report on biodiversity and extinction species with quantitative analysis and indicators. In particular, in order to be formulated policies on conserving biodiversity, is essential the ability to report on specific biodiversity indicators. So, it seems that the companies are beginning to recognize the importance of the impact that their businesses activities have on biodiversity.

However, the majority of firms disclose information which is biased, because businesses report a simple and symbolic commitment in order to influence with a positive way stakeholders' impression. Namely, mission statements and firm policy commitments are mainly avoided.
The present research, by mainstreaming biodiversity reporting, has tried to guide practitioners and academics in why it is needed to report on biodiversity and recognize the harmful impacts of businesses processes, putting practices into action that mitigate these negative effects.

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# The challenges of using Material Flow Cost Accounting in the fish-farming sector

**Christos Danatskos & Konstantinos G. Papaspyropoulos**
*MSc. Natural Resources: Monitoring, Technology and Bioeconomy, Department of Forestry and Natural Environment, Aristotle University of Thessaloniki*
chrisdanat@gmail.com, kodafype@for.auth.gr

**Abstract**
Animal-source food production industry has developed new intensive farming techniques in order to respond to the growing demand for high protein food, following the population increase. This has resulted in an increased production performance and, sequentially, in environmental impacts and pollution issues. Consequently, environmental accountability is now established by laws and is demanded by various stakeholders, forcing polluting companies to adopt environmentally friendly production processes to avoid high taxes and fines. As a result, various business-level Environmental Management Accounting (EMA) approaches have been developed by academia to address the effects that factors like high environmental cost techniques and usage of polluting materials can have on the financial position and profitability of a company. An EMA method that tracks and analyzes the material and energy flows in a production process, to reveal cost reducing opportunities, both environmental and financial, is Material Flow Cost Accounting-MFCA. Aquaculture industry, as an animal-source food production industry, faces issues regarding environmental impacts, although it is generally considered as a sustainable farming technique. Since aquaculture production process demonstrates material and energy flows, MFCA can be implemented to analyze the production stages and assist an aquaculture company in taking the required management decisions. However, the various aquaculture techniques, regarding the farmed species, the geographical position, and the use of either fresh water or sea, present certain challenges in MFCA application, some of which the current study will attempt to highlight.

**Keywords:** Aquaculture, Environmental Management Accounting, sustainable farming, Material Flow Cost Accounting, environmental cost.

**JEL Codes**: Q22, Q56, Q53, Q51, Q57.

## 1. Introduction

Animal-source food production industry, in order to respond to the growing demand for high protein food, following the population increase, has developed new intensive farming techniques that increased production performance and, regrettably, environmental impacts and pollution issues. Consequently, environmental accountability is now established by laws, obliging companies to adopt environmentally friendly production processes, enforcing high taxes and fines to polluting enterprises. As a result, business-level Environmental Management Accounting (EMA) approaches developed to address the effects that factors like high environmental cost techniques and usage of polluting materials can have of the financial position and profitability of a company (Bartolomeo, 2000). An EMA method that tracks and analyzes the material and energy flows in a production process, to reveal cost reducing opportunities, both environmental and financial, is Material Flow Cost Accounting-MFCA (Asian Productivity Organization 2014). Aquaculture industry, as an animal-source food production industry, also faces issues regarding environmental impacts, although it is generally considered as a sustainable farming technique. Since aquaculture production process demonstrates material and energy flows, MFCA can, by definition (ISO 14051:2011), be implemented to analyze the production stages and assist the aquaculture company in taking the required management decisions. However, the various aquaculture techniques, regarding the farmed species, the geographical position, and the use of either fresh water or sea, present certain challenges in MFCA application, some of which the current study will attempt to highlight.

## 2. Background

### *2.1 Synopsis of European Aquaculture sector and the importance of Environmental Management Accounting in aquaculture.*

In Europe, the aquaculture sector accounts for about 20% of fish production and employs 70,000 people while the sector is mainly composed of SMEs or micro-enterprises in coastal and rural areas (European Commission, 2020).According to the Economic Report of the EU Aquaculture sector (STECF-18-19) of Scientific, Technical and Economic Committee for Fisheries (STECF), in 2016 the EU aquaculture sector reached 1.4 million tonnes in sales volume and €4.9 billion in sales value and its economic performance has been improving on almost all economic indicators in 2016 compared to 2014 and 2015. According to Jasch (2009), to realize and comprehend environmental costs of an economic activity and to achieve cleaner and less wasteful production processes, one can apply Environmental Management Accounting (EMA) to recognize produced wastes and ensure a cleaner and less wasteful production process (Jasch, 2009).

### *2.2 Methodology of Material Flow Cost Accounting process*

Underestimating material and environmental flow costs in production process proves to be an important issue regarding hidden opportunities for lowering production costs and minimizing the resulting environmental impact. Environmental Management Accounting (EMA) contributes to the identification, assessment, and allocation of those flow costs during production and allows management to identify those opportunities by either replacing materials that prove to be causing wastes or by applying more efficient techniques thus minimizing environmental costs. Since the principle of EMA application is that all materials purchased for production exit the process either as products or wastes and emissions, the identification of wastes proves an insufficient production line (Jasch, 2009). The aquaculture production includes material and energy flows, since, depending on the geographical position of farms, the effort to stabilize optimum temperatures regarding fish well-being and nursing processes (in establishments operating hatcheries and nurseries), is particularly energy demanding.

MFCA is a material and energy flow-oriented accounting approach that considers corporate material and energy flows as cost objects. This is because all impacts on the environment by a manufacturing company are related to energy and material use and also because both material and energy are considered the main portion of a company's operating costs. Since their reduction can lead to both environmental and economic gains, it is assumed that the purpose of implementing MFCA in a production system, is to increase its resource efficiency (Prox 2015, Jasche 2009). As a management tool, MFCA can be used not only in manufacture procedures but also in the service sector (Jasch, 2009) and it has been proved that it can be a useful tool to partially augment the accountability of the non-profit sector (Papaspyropoulos, 2012). The MFCA process is based on the input-output analysis aspect of sustainability accounting (Papaspyropoulos, 2012) and, according to ISO 14051 begins with the involvement of the company's management into the MFCA implementation. The management assigns and distributes the required expertise to fully interpret and identify the energy and material flow of the production, process issues related to material flow, product rejects and maintenance issues, environmental impacts and loss of accounting data. (ISO 14051:2011) (Asian Productivity Organization, 2014)

The first step is the development of a flow model, to comprehend and distinguish the material and energy flow in an organization and that applies for each company's activity. Material refers to any raw material, auxiliary material, component, catalyzer, or part and any material that does not become part of the final product and is considered material loss. In any process, waste and resource loss occur in different steps of the process, including:

- Material loss during processing, defective products, impurities
- Materials remaining in manufacturing equipment following set-ups
- Auxiliary materials such as solvents, detergents to wash equipment, water
- Raw material that becomes unusable for any reason (Asian Productivity Organization, 2014)

The next step is to assign values to the materials and energy that participate in the production or are stored in the enterprise. All parts of the flow must be converted into comparable units of measurement. That leads to a "material balance" (Jasch 2009, Asian Productivity Organization 2014, Christ & Buritt 2015), in the sense that energy and material cannot be lost in a process so input equals output. Following the material balance, monetary values must be assigned for every input and output and all costs must be identified and acknowledged. The cost categories include material costs, system costs that include energy, material handling, labour, depreciation, and transport costs and finally waste management costs (Christ & Buritt 2015, Asian Productivity Organization 2014, Jasche 2009). The material balance cost is calculated for every activity undertaken by the company. The total input that enters the process equals the total final products of every activity plus the corresponding total material losses.

The final step of the MFCA process is the interpretation of the results by the management and the identification of opportunities to increase the material use efficiency, to lower costs both monetary and environmental and to increase company's performance (ISO 14051:2011) (Asian Productivity Organization, 2014).

## 3. Research method

The research method that was used to highlight possible challenges of MFCA implementation to aquaculture techniques, included the following steps:

a. Literature review of MFCA and certain LCA methodology, focusing on the construction of the material balance regarding aquaculture farming techniques.
b. Review of aquaculture waste estimation methods and techniques along with environmental cost quantification methods, to demonstrate a range of possible pollution issues that can be revealed under MFCA method.
c. Review of aquaculture production cost analysis including operation of parallel activities like fish processing and packaging, to demonstrate in those cases the need of establishing separate material flow processes for effective MFCA implementation.

## 4. Applying the MFCA method and material flow balance of ISO 14051 in a typical aquaculture production cycle to point out challenges of MFCA implementation in aquaculture

### *4.1 Specification of aquaculture environmental costs and possible hazards*

Aquaculture is an animal-source food production technique that includes an input and output material and energy flow and to apply the methodology of MFCA on the specific process, a specification of possible aquaculture environmental costs and hazards is required since MFCA implementation demands characterization and quantification of waste and non -product output. Aquaculture shares the environmental impacts of other animal-source food productions, and they include environmental emissions, land use and water use. Although aquaculture systems perform well with respect to the emissions produced from beef and pork production, there are issues regarding the environmental costs of aquaculture since, especially for extensive systems, there is a great demand of land use, fresh water, and energy since it is a farming process of cold-blooded product. The environmental emissions include emissions of waste nitrogen and phosphorus, and the levels of the emissions depend on the aquaculture technique and the farmed species. Water use also depends on the aquaculture technique (extensive, semi-tentative etc.) (Hall, 2011). To list the possible environmental costs of an aquaculture, a categorization of four types of costs will follow, by a study assessing the environmental costs of Atlantic salmon cage culture by Food and Agriculture Organization of the United Nations (FAO):

Category 1 environmental costs are common to coastal aquaculture activities and are costs that can be avoided through proper engineering, worker training, inspection of infrastructure, etc. They include material and equipment waste from collision of boats with aquaculture structures, fuel spills, disposal of trash including feed bags and disintegration of anchoring systems and containment nets, among others. Category 2 environmental costs include organic enrichment from fed aquaculture (shrimp and piscivorous fish) and organic depletion associated with extractive aquaculture (bivalves, carp, etc). Category 3 costs are associated with contaminants releases including sediment accumulations of trace metals, antibiotics and pesticides, organic inputs from net cleaning and mortalities disposals. Finally, Category 4 environmental costs involve disease transfer in both directions. They include ecological interactions (competition for habitat and food) associated with cultured shellfish and escaped finfish and genetic interactions between cultured and wild species (FAO- Kenneth M. Brooks, 2006).

*4.2 Introducing MFCA into aquaculture*

Using the salmon farming as an example of introducing MFCA method into aquaculture, a typical two-processes type of farm includes a hatchery, where the fry is produced and the grow-out site. The material and energy flow includes material and energy input to its two processes. The releases/environmental costs, include waste feed and feces, escaped fish, pathogens, antibiotics etc.

Regarding the salmon farming cost structure, according to the European Commission's science and knowledge service, Joint Research Centre (JRC), for the year 2016, the most important costs to the EU salmon aquaculture sector are feed costs (39% of total costs). Other operational costs constitute the next highest outgoing (34%), followed by labour (10%), consumption of fixed capital (6%), repair and maintenance (4%), livestock (4%), and energy costs (3%) (Nielsen, 2018).

According to MFCA method, an input-output balance must be created to identify all possible wastes in every step of the aquaculture process. Following the EMA Assessment Table, the creation of a material flow balance – input/output would include the following cost categories: As input, material inputs that include raw and auxiliary materials, packaging materials and merchandise, operating materials and water and energy, including electricity and fuels. As output, non-product output as solid and hazardous waste, waste oil, wastewater and air emissions. It is apparent that the conventional available accounting information of aquaculture companies is not adequate to successfully fulfill a material flow balance as it is described in MFCA method. The missing environmental costs must be identified and quantified to create the desired input/output balance.

*4.3 Challenges of MFCA implementation into aquaculture processes*

According to the MFCA method, an input-output material flow balance is required for an MFCA implementation into a production process. For an aquaculture unit, a basic balance could include the following flows:

As inputs, raw and auxiliary materials, operating materials, energy, and water. Outputs will include product output, products and by-products, non-product-output (NPO), solid waste, wastewater and air emissions (Jasch, 2009). The inputs will include broodstock and fry as raw materials, aquaculture operating materials (cages, tanks, raceways, egg jars for the hatcheries etc.), nets and buoys, to mention the basic aquaculture equipment, always depending on the farming species and their specific rearing and on growing needs. Depending on the species, the inputs will also include water (sea water or fresh water), energy/fuels for heating and transportation (boats and trucks). In case of a parallel seafood processing activity operation in the aquaculture company, an additional flow chart will have to be produced, to list and quantify the material flows in that activity. Outputs like products and by-products will include harvest of full-grown fish and, in case of fish processing, trimmings, fish heads, skins and belly flaps, viscera and blood to name a few. Non-product outputs will include solid waste (excessive feed, excreta, escaped fish), waste water and air emissions (Stevens 2018, FAO 2020, Nguyen 2018).

1. To apply the MFCA method, expertise on biomass estimation is needed to create the material balance at any given moment. A challenge regarding the accurate estimation of the organic input and output flow of an aquaculture unit, is the quantification of the biomass that is handled during the various stages of the farming process with techniques that not only accurately calculate the fish biomass, especially in large scale farms with high fish densities, but also reduce their harmful impacts on the fish population.
2. Another challenge that MFCA implementation may encounter is the quantification of solid and hazardous wastes as well as wastewater and air emissions (GHG) of aquaculture units, where estimation and quantifying techniques must be applied to attribute respective values. The concentration of wastes in aquaculture activity can be addressed with various methods and can also be measured as shown in studies and research works (Mara and Cairncross 1989, Dosdat 2001, Lin 2002). Additionally, the development of intensive aquaculture has created serious environmental problems. An important environmental issue is the accumulation of toxic inorganic nitrogen species (especially, NH3 and NO2) in the aqueous phase (Zhen Hu, 2014). Nutrient pollution as an issue in aquaculture has been addressed by technical papers which have used nutrient-balance models for measuring the nutrient emissions results. On quantifying aquaculture environmental emissions, as in nutrient or GHG emissions, international bibliography provides various technical papers and publications to address the possible environmental costs especially in intensive aquaculture techniques (Thakur 2003, Rakocy 2006). Studies have also covered aquaculture wastewater issues, on quantification and treatment of environmental impact from wastes in water (Ying-Feng Lin 2002, Mara 1989, Van Rijn 1996).
3. Quantification of energy input in aquaculture processes is another challenge, especially in aquaculture units that operate hatcheries with increased energy demands due to the temperature controlling requirements and in semi-intensive and fully intensive techniques. Various practices on quantification of energy input in aquaculture have been reviewed, as well as development of models and software to monitor and estimate material and energy inputs and waste outputs (Troell et al. 2004, Bureau 1998, MacLeod et al. 2019).

4. Another challenge lies in the environmental impact regarding the issue of ecological and genetic interactions between cultured and wild species. Since the severity of these environmental effects depend on the local area's assimilative capacity, it is difficult to estimate their value especially because these hazards can result in either positive or negative effects (diversity of wildlife but also eutrophication) (FAO- Kenneth M. Brooks, 2006). Another similar issue is the general ecological impact of aquaculture units in coastal areas, where aquaculture activities show not only negative impacts like altered landscape aesthetics, coastal sea pollution and disturbance may emerge, but may also have positive effects in the area like creation of new jobs and increased supply of fish (Katranidis 2010, Jones 2001, Ethier, 2005).
5. Regarding the hidden environmental costs of non-product-outputs, the required expertise that was mentioned in the MFCA process analysis, must be applied in order to distinguish the waste costs from the production costs. Parts of the containment nets that are released to the sea due to poor maintenance or disintegration must be separated from the general equipment restocking costs and redefined and registered as environmental costs. The same registration will apply for the cost of material wastes including buoys on floating sea cages that disintegrated or were disconnected due to weather conditions and for fuel spills from malfunctioning boat engines to name a few.

## 5. Conclusions

Since aquaculture is a process with material and energy flow, it can implement Material Flow Cost Accounting because MFCA is applicable to any activity that uses materials and energy, regardless of their products, services, size, structure, location, and existing management and accounting systems (ISO 14051:2011) (Jasch, 2009). To set up the required boundary of material flow in an aquaculture company, an identification of every production step and every material an energy cost is required that involve both product and non-product results, to efficiently quantify the material balance. The challenges that an MFCA approach can face are the possible and often reviewed in current bibliography environmental costs of aquaculture techniques. They include identification and quantification of emissions, solid or not, wastewater, wastes from handling or maintenance hazards or deficiencies in use of resources. An MFCA implementation not only can distinguish deficiencies in a process but can also discover cost reducing opportunities that can be combined with lower emissions to the environment, making it a useful management tool for an already highly sustainable animal-source food production sector, in an intensification process, nonetheless.

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# Exploration of energy use in EU 28: Dynamics, patterns, policies

**George Halkos[1] & Kyriaki Tsilika[1,2]**
[1] *Laboratory of Operations Research, School of Economics and Business, Department of Economics, University of Thessaly*
[2] *School of Social Sciences, Hellenic Open University*
halkos@uth.gr, ktsilika@uth.gr

**Abstract**
Sustainable energy use has become the most critical challenge of the world today. The relationship between consumption and use of different energy resources is an important topic in the regulatory and environmental literature. The paper places emphasis on primary energy resources, their covariation and correlation and aims to provide a systematic analysis of their development over time. The analysis uses evidence from EU country-level data. Different results from same territories show that energy consumption does not always reflect or is due to climatological or meteorological conditions. Our visual exploration includes plotting energy variables with layering information on graphics (concerning geographical zones, GDP levels faceting grouped data, selected energy-use clusters) in order to produce effective comparative plots. We produce visual summaries of data on graphs such as bubble charts, motion charts, boxplots and we visualize confidence intervals for means of energy use; we create maps and correlation matrices. All these for country – or cluster of countries – level data.

**Keywords:** Energy use, exploratory data analysis, correlation analysis, trends, European Union.

**JEL Codes**: C63, Q40, Q42, Q48, C83, C88.

## 1. Introduction

In the sections that follow extensive use of visualization is adopted as a means of contributing to the understanding of energy use, some involved problems and concepts and energy consumption trends over time (Jones and Warner, 2016). Different results from same territories show that energy consumption does not always reflect or is due to climatological or meteorological conditions. For the analysis, countries are grouped in clusters in order to examine energy use in a general context and avoid the bias caused by the country-level circumstances.

The exploratory data analysis is done for having a picture for the energy use state in EU-28. Box plots are utilized to determine the energy data distributions and the outliers in each cluster of countries. The outliers are determined using the following rule: the outliers are the values 1.5 times greater than the difference between the third percentile and the first percentile. The box plots for clusters of countries according to the energy use/consumption classification show the differentiation between clusters. It is also a way to pinpoint the extreme values of energy consumption on the graph.

In this direction, circle packing graphic is created with countries being represented by circles was realized in RawGraphs (Mauri et al., 2017). The area of each circle is proportional to the value of the selected energy variable. The variables under study are energy use per capita, fossil fuel consumption per capita, renewable energy per capita.

A motion chart is a dynamic bubble chart which allows efficient and interactive exploration and visualization of longitudinal multivariate data. Here, with dynamic bubble charts, 4 dimensions are represented simultaneously (namely CO2 emissions, energy variables per capita, time, and in color, GDP per capita) using Gapminder offline tool (www.gapminder.org).

To highlight the relationship between the values observed of X (variable expressing the energy consumption: total, fossil fuel, renewables) and Y (CO2 emissions per capita, GDP per capita) we plot X versus Y on a Cartesian graph detecting for each one of the four clusters evidence about the form of the function g connecting the variables. Next, we provide a graphical display of the correlation matrix to illustrate the linear associations of the energy variables with pollution and social variables. To do this we used R packages “Hmisc” (Harrell, 2020) and “corrplot” (Wei and Simko, 2021) in statistical programming language R (R Development Core Team, 2011).

This article is structured into three sections, including this introduction. In section 2 the methodological approach and the empirical implementation are given. Section 2 presents the EU 28 policies considered and the relationship among energy consumption, CO2 pollution, economic growth, and time. Finally, section 3 includes the main conclusions of the analyses.

## 2. Methods and Data

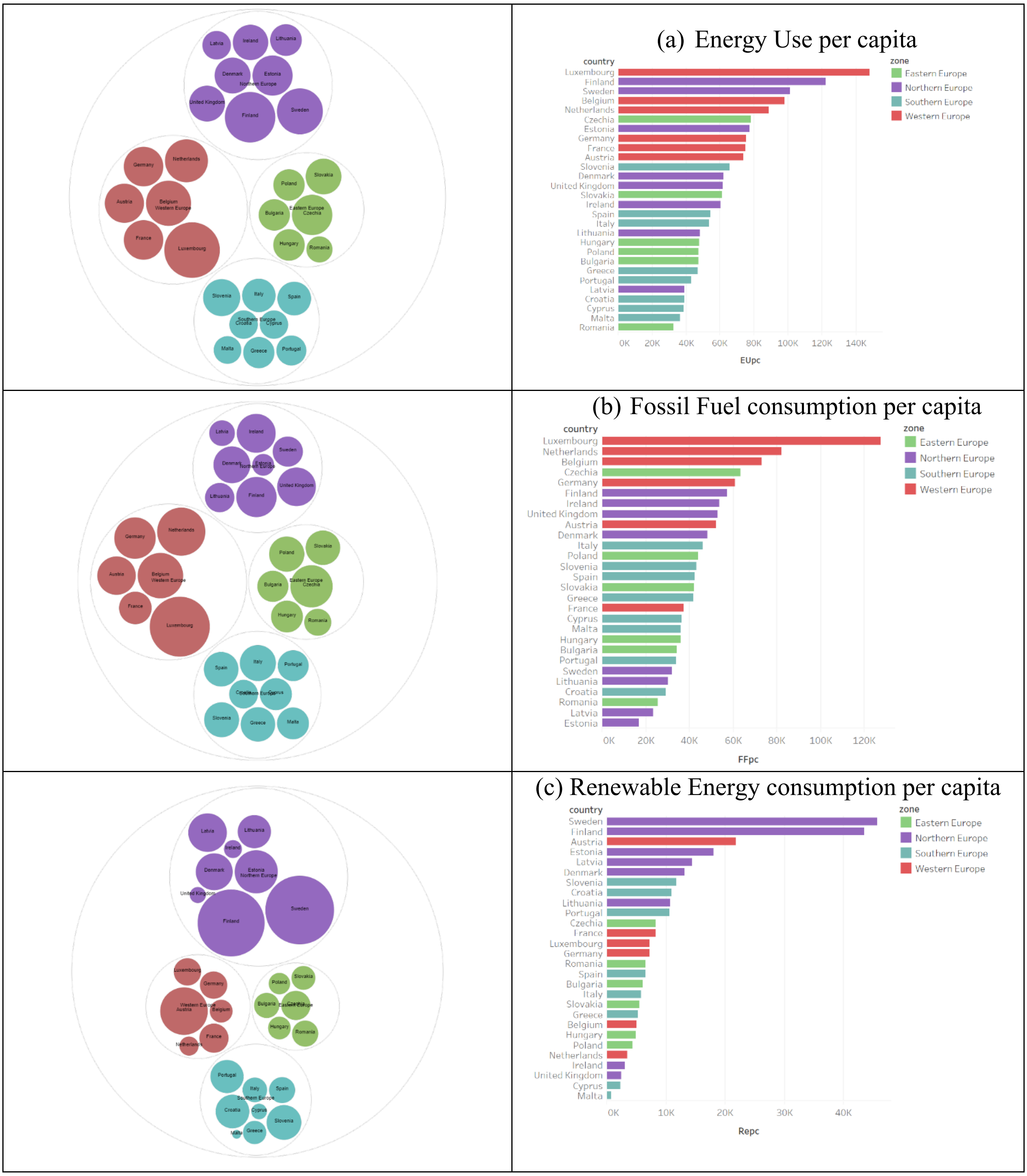
### *2.1 Data acquisition*

Data is adopted from World Bank database (https://data.worldbank.org/), for 28 European countries from 4 geographical regions (defined by the United Nations Geoscheme, see below). Data include valid measurements of direct and sustainable energy use per country and per geographical region, according to the geographical clustering proposed by the UN. Specifically we deal with collections of time series on energy use per capita (measured in Kg of oil equivalent per capita), fossil fuel energy consumption (% of total), and renewable energy consumption (% of total final energy consumption) (World Bank 2021a, d-f). Pollution data involve CO2 emissions (measured in metric tons per capita) and social data concern gross domestic product (in current US$) and population density (people per sq. km of land area) for the same period (World Bank 2021b, c). Time series for fossil fuel consumption per capita (resp. renewable energy consumption per capita), were calculated by multiplying energy use per capita by the percentage of fossil fuel energy consumption (resp. the percentage of renewable energy consumption) and diving by 100.

The UN Statistics Division has created the UN Geoscheme for Europe that subdivides the continent into four divisions for statistical convenience. These divisions put European countries in one of four groups: Eastern Europe, Western Europe, Northern, and Southern Europe. The UN Geoscheme[1] specifies the countries included in each of these divisions. Although one could assume that regional circumstances strongly modulate the development of energy use attitudes, no similarities or uniformity within geographical regions is observed. According to the UN, Eastern Europe is the largest and most populous subregion of Europe. However, no differentiation concerning the energy use is observed (see figures 1a-c).

[1] https://en.wikipedia.org/wiki/United_Nations_geoscheme_for_Europe, https://www.worldatlas.com/articles/the-four-european-regions-as-defined-by-the-united-nations-geoscheme-for-europe.html

**Figure 1:** The regional distribution of energy use (according to the United Nations Geoscheme). Sums over 2000-2018 period.

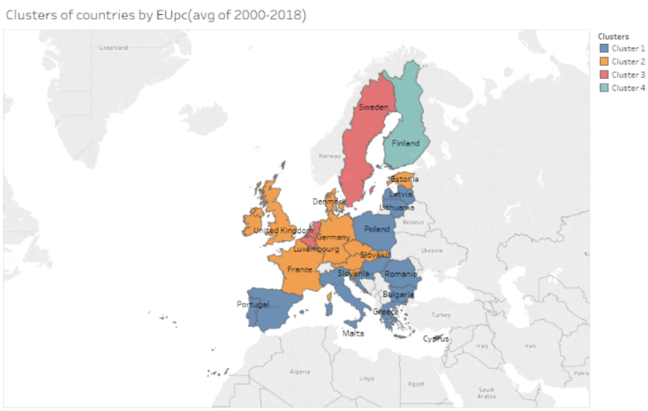



*2.2 Cluster Analysis*

Cluster analysis partitions countries into clusters, where countries within each cluster are more similar to one another than they are to countries in other clusters. In the European district we identify four clusters of countries which classify separately (a) average energy use pc, average fossil fuel consumption pc, (b) average renewable energy consumption pc (c). The four groups of countries in all maps are denoted with numbers from 1 to 4, corresponding to different levels of average energy variable pc. Clusters classify countries in ascending order of their average energy use. The present classification will enable us to clearly indicate the effects of energy consumption. A spatial represenation of energy variables in EU-28 follows in figure 2. For each energy variable a map was created in Tableau software[2] (Tableau 2020) to visualize the four groups of countries according to the energy use pc (figure 2a), fossil fuel consumption pc (figure 2b), renewable energy pc (figure 2c), based on average levels through 2000-2018.

Energy data distributions per cluster are given in boxplots of figure 3a-c.

**Figure 2:** Clusters of countries in Europe according to (a) energy use pc (average of 2000-2018) (b) fossil fuel consumption pc (average of 2000-2018) (c) renewable energy pc (average of 2000-2018)

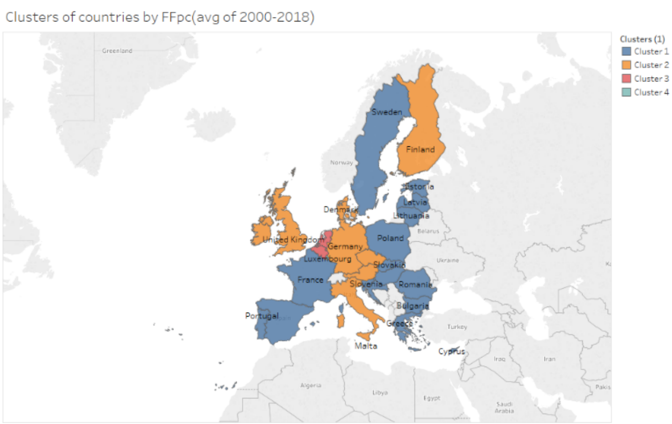



(a)

Summary Diagnostics

| | |
|---|---|
| Number of Clusters: | 4 |
| Number of Points: | 28 |
| Between-group Sum of Squares: | 1.3914 |
| Within-group Sum of Squares: | 0.10856 |
| Total Sum of Squares: | 1.5 |

| Clusters | Number of Items | Centers Avg. EUpc |
|---|---|---|
| Cluster 1 | 13 | 2319.7 |
| Cluster 2 | 10 | 3632.7 |
| Cluster 3 | 3 | 5049.8 |
| Cluster 4 | 2 | 7116.7 |
| Not Clustered | 0 | |




(b)

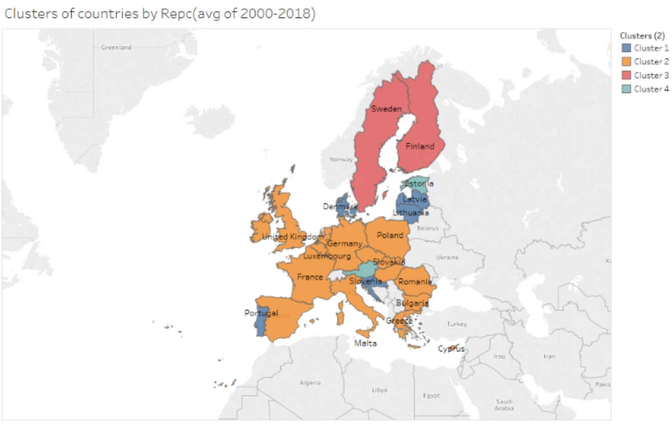
Summary Diagnostics

| | |
|---|---|
| Number of Clusters: | 4 |
| Number of Points: | 28 |
| Between-group Sum of Squares: | 0.93732 |
| Within-group Sum of Squares: | 0.098558 |
| Total Sum of Squares: | 1.0359 |

| Clusters | Number of Items | Centers Avg. FFpc |
|---|---|---|
| Cluster 1 | 17 | 1810.5 |
| Cluster 2 | 8 | 2859.2 |
| Cluster 3 | 2 | 4089.5 |
| Cluster 4 | 1 | 6715.0 |

[2] Tableau uses the K Means clustering algorithm.

| | |
|---|---|
| Not Clustered | 0 |



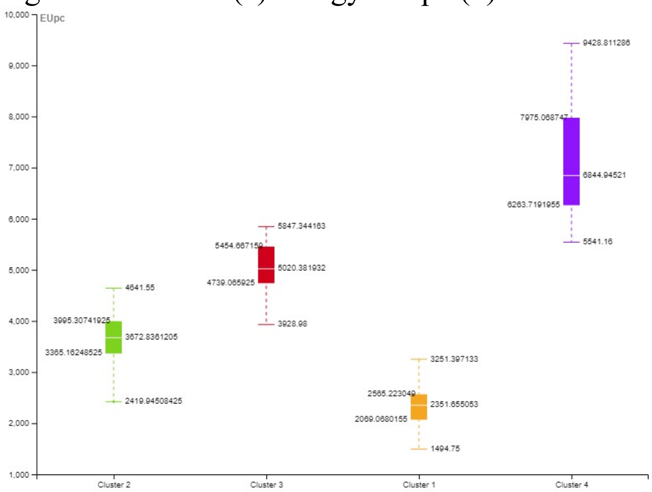

(c)

Summary Diagnostics

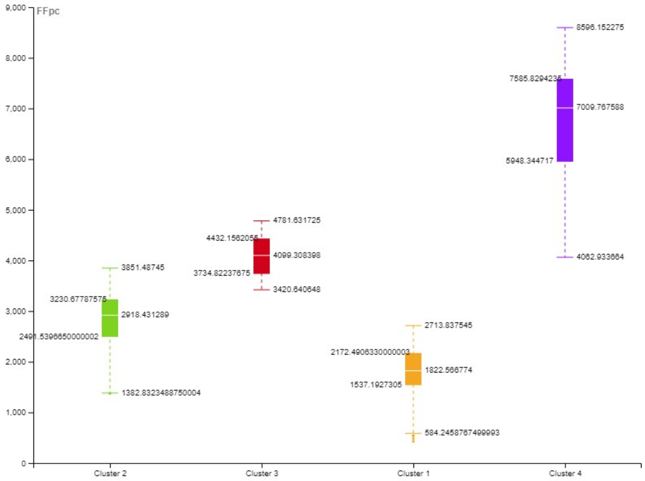
| | |
|---|---|
| Number of Clusters: | 4 |
| Number of Points: | 28 |
| Between-group Sum of Squares: | 1.4934 |
| Within-group Sum of Squares: | 0.048059 |
| Total Sum of Squares: | 1.5415 |

| Clusters | Number of Items | Centers<br>Avg. Repc |
|---|---|---|
| Cluster 1 | 6 | 626.89 |
| Cluster 2 | 18 | 272.83 |
| Cluster 3 | 2 | 2343.1 |
| Cluster 4 | 2 | 1048.4 |
| Not Clustered | 0 | |

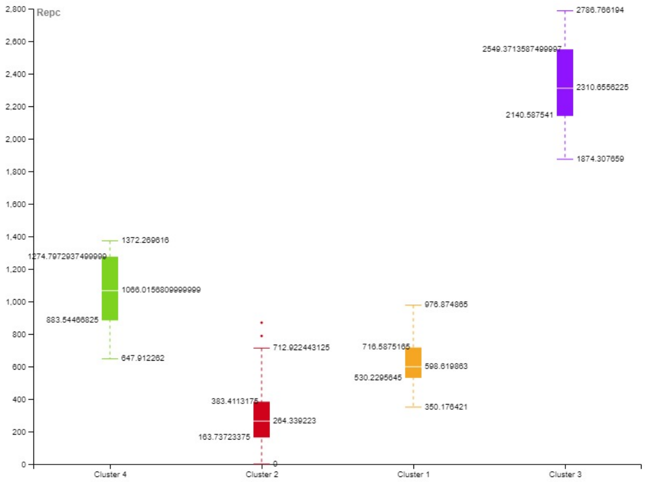
**Figure 3:** Range of values for (a) energy use pc (b) fossil fuel consumption pc (c) renewable energy pc




(a) Clusters of countries according to energy use pc (average of 2000-2018)




(b) Clusters of countries according to fossil fuel consumption pc (average of 2000-2018)




(c) Clusters of countries according to renewable energy pc (average of 2000-2018)

*2.3 The situation at a country level*

To present the situation at national level, two views are adopted in figures 4 and 5. Error bars (in figure 4) are a graphical enhancement to visualise the variability of energy data on a comparative graph. Bars represent confidence intervals for mean of energy variables (namely energy use, fossil fuel consumption, renewable energy consumption, which correspond to EUpc, FFpc, Repc variables). A main observation is that renewable energy consumption is significantly low in all countries and only in Finland and in Sweden reaches the levels of fossil fuel consumption pc of most countries.

In order to identify which countries are leading the race to energy use, the boxplots of figure 5 indicate energy use outliers, that is countries with higher values than the quartiles of energy use pc, fossil fuel consumption pc, and renewable energy pc among EU 28. Figures 4 and 5 were created in IBM SPSS (IBM Corp. Released 2019).

**Figure 4:** Energy use in EU 28 (confidence intervals for means over 2000-2018) – disaggregated results

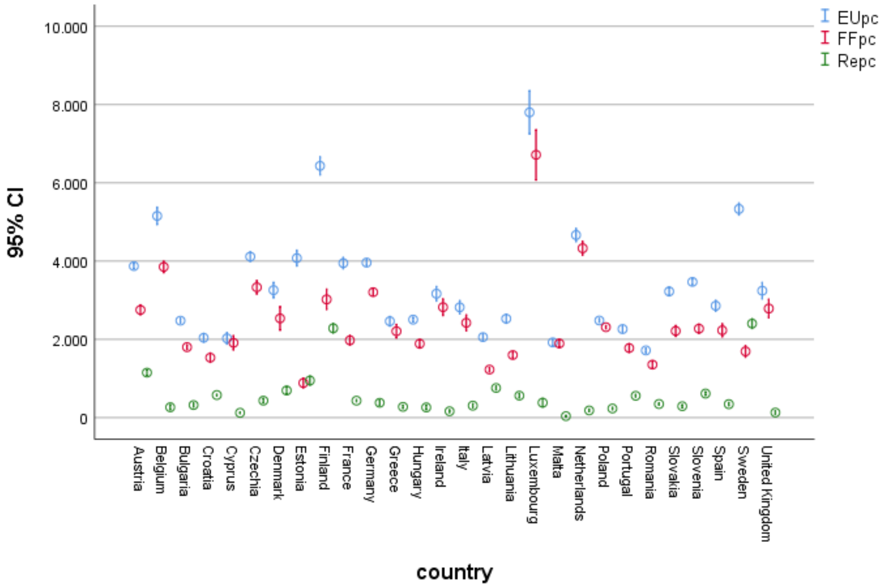
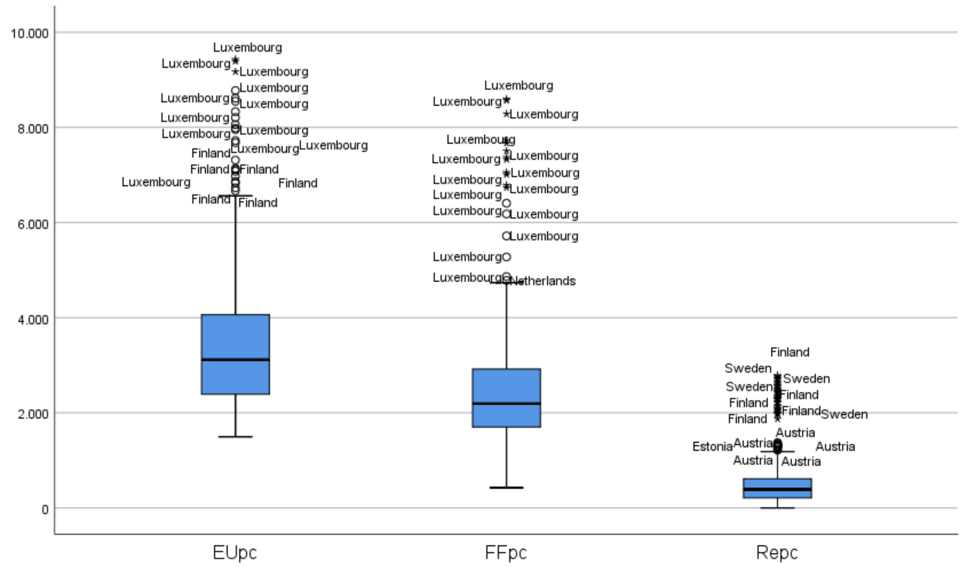



**Figure 5:** Outlier countries (from left to right) in energy use pc, fossil fuel consumption pc, and renewable energy pc of EU 28

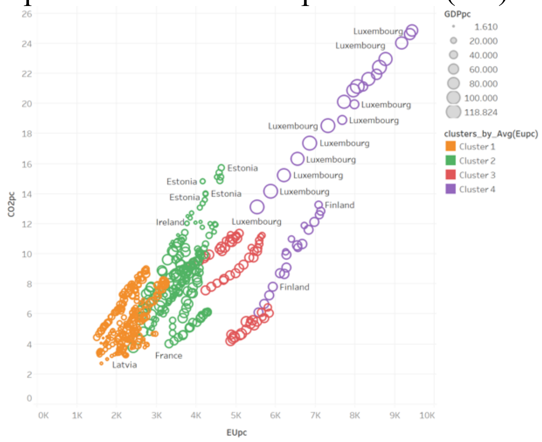



Let us now examine in more detail the relationship between the values of energy variables and CO2 emissions through time. To achieve this, we use bubble charts to represent four dimensions simultaneously (corresponding to variables CO2, EUpc, time, GDPpc in the charts). Figure 6b suggests a strong correlation between CO2 emissions and energy use pc for all clusters. Comparing the situation in EU 28 in 2000 and in 2018, figures 6(a) suggest weaker correlation of the two variables in 2018.

By observing the bubble chart in motion, we can monitor the dynamic evolution of the biggest energy consuming countries (which are Luxembourg and Finland). Luxembourg energy bubble reaches its highest position in 2005 and ends at the lowest position in 2018. Finland energy bubble reaches its highest position in 2003 and ends at the lowest position in 2018. The motion cart reveals an upward trend in the first years of study and a downward trend after the turning point of 2004, 2005.

**Figure 6:** The relationship between energy use pc and CO2 emissions pc in EU-28 (2000-2018). Bubble color is categorized by clusters of average energy use pc level. Bubble size is analogous to the corresponding economy's gross domestic product per capita.


(a) Energy use pc vs CO2 emissions pc in 2000 (left) and in 2018 (right).



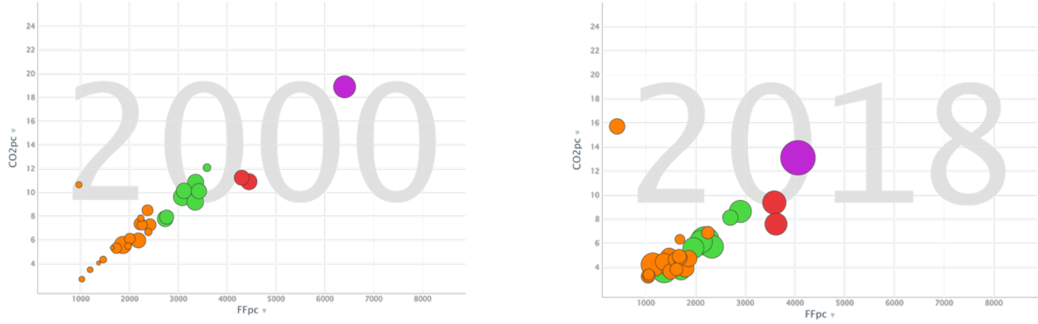

(b) The relationship between energy use pc and CO2 emissions pc in EU-28 (all years of period 2000-2018).

In figure 7(a), the initial and the final situation for the fossil fuel consumption pc is depicted. Obviously both levels, fossil fuel pc level and CO2 pc level have decreased in 2018. The bubble chart in figure 7(b) suggests a strong correlation between CO2 emissions and fossil fuel consumption pc for all clusters.

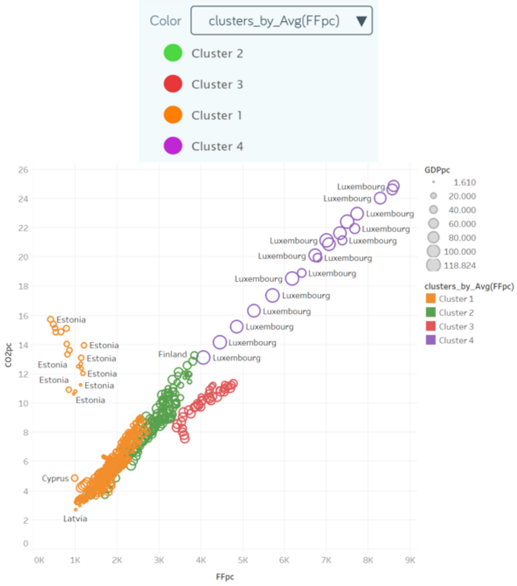
In the motion chart, we highlight the leaders in fossil fuel consumption pc: Luxembourg and The Netherlands. Luxembourg energy bubble reaches its highest position in 2005 and ends at the lowest position in 2018. Netherlands' energy bubble reaches its highest position in 2004 and ends at the lowest position in 2018. The motion cart reveals an upward trend in the first years of study and a downward trend after 2005. It seems that in 2005, an era of change starts.

In the comparative scheme of figure 8(a), all bubbles of the chart have moved to the right, indicating increased levels of renewable energy use in later years. Figure 8(b) is the first chart to present an inverse relation between energy use and CO2 emissions (with the exception of Estonia), in all clusters.

**Figure 7:** The relationship between fossil fuel energy consumption pc and CO2 emissions pc in EU-28 (2000-2018). Bubble color is categorized by clusters of average fossil fuel energy consumption pc level. Bubble size is analogous to the corresponding economy's gross domestic product per capita.

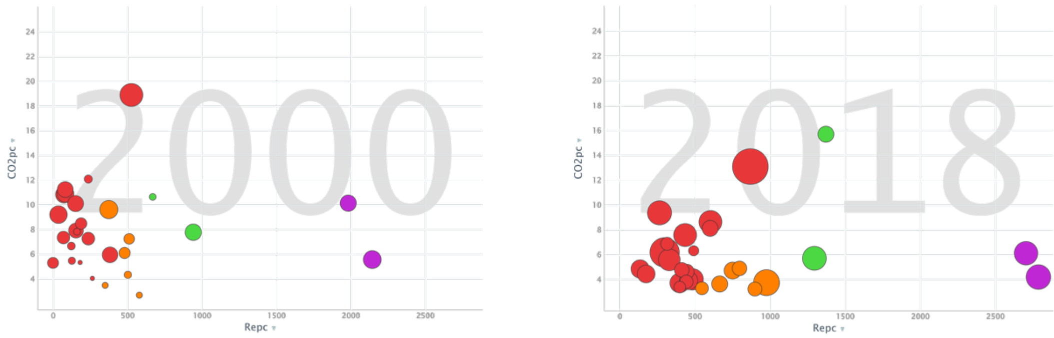



(a) Fossil fuel energy consumption pc vs CO2 emissions pc in 2000 (left) and in 2018 (right).

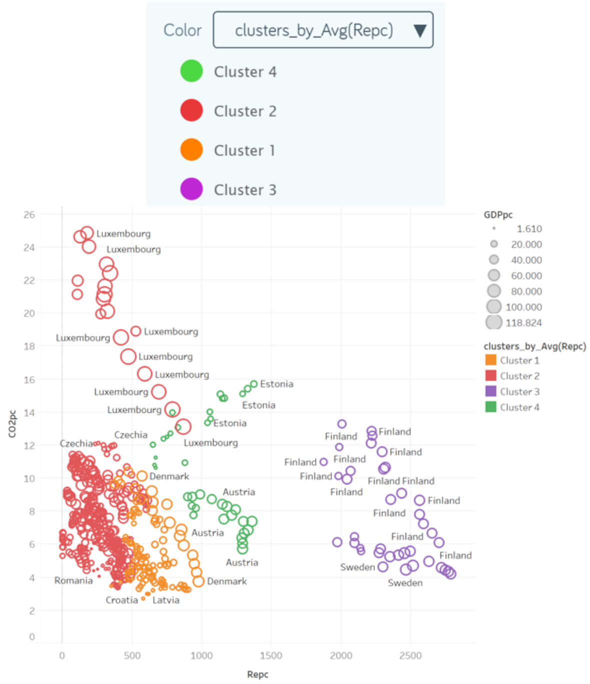



(b) The relationship between fossil fuel energy consumption pc and CO2 emissions pc in EU-28 (all years of period 2000-2018).

**Figure 8:** The relationship between renewable energy consumption pc and CO2 emissions pc in EU-28 (2000-2018). Bubble color is categorized by clusters of average renewable energy consumption pc level. Bubble size is analogous to the corresponding economy's gross domestic product per capita.




(a) Renewable energy consumption pc vs CO2 emissions pc in 2000 (left) and in 2018 (right).




(b) The relationship between renewable energy consumption pc and CO2 emissions pc in EU-28 (all years of period 2000-2018).

*2.4 Correlation analysis*

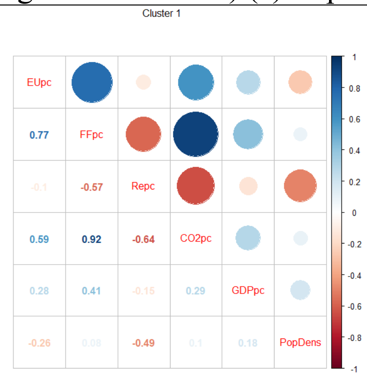
In the present section, we assess the dependence structures between energy variables (resp. EUpc, FFpc, Repc variables) and pollution (expressed with CO2pc variable), growth variable (GDPpc) and population density, for each one of the four clusters of countries, in correlation matrices (figure 9a-c). In all cases of clusters, we notice strong correlations of energy variables per capita with CO2 pollution pc, GDP pc, population density. It is impressive that in all cases, correlations are stronger in clusters of higher levels of energy use. The higher the level of average energy use during the study period, the more intense the correlation among energy, pollution, and growth variables.

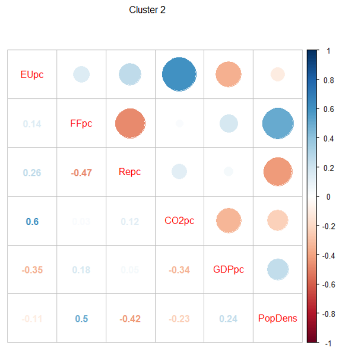
Figure 9 suggests that levels of energy consumption (total energy use, fossil fuel consumption pc, renewable energy use pc correspond to EUpc, FFpc, Repc variables in the correlation matrices respectively) and CO2 emissions per capita (CO2pc variable) are negatively correlated only in the case of renewable energy consumption pc.

In all clusters by energy variable classification (average value used over 2000-2018) a direct relationship between the energy use pc / fossil fuel consumption pc and CO2 emissions pc is observed, except for cluster 4 in classification by renewable energy consumption pc (figure 9c), where fossil fuel consumption pc and CO2 emissions pc are having a reverse relationship.

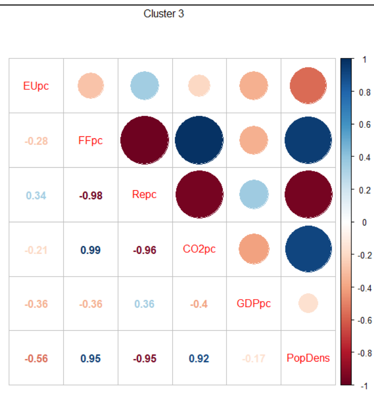
Negative correlations are observed for GDP with energy use pc / fossil fuel pc for cluster 3 in classification by average energy use pc (figure 9a), for clusters 2,3,4 in classification by average fossil fuel consumption pc (figure 9b), and strong negative correlation for cluster 3 in classification by average renewable energy pc (figure 9c).

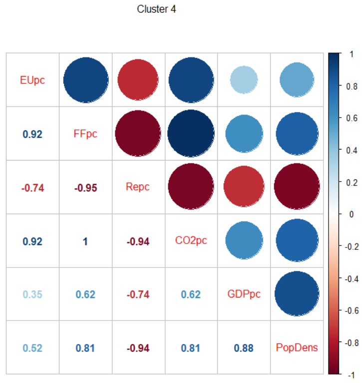
**Figure 9:** Clusters of countries in Europe according to (a) EUpc level (average of 2000-2018) (b) FFpc level (average of 2000-2018) (c) Repc level (average of 2000-2018)



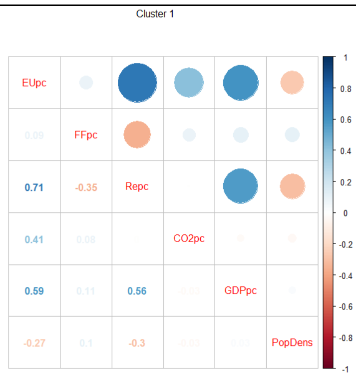

| Cluster | No of items: | Centers of Avg EUpc: | Cluster | No of items: | Centers of Avg EUpc: |
|---|---|---|---|---|---|
| 1 | 13 | 2319.7 | 2 | 10 | 3632.7 |

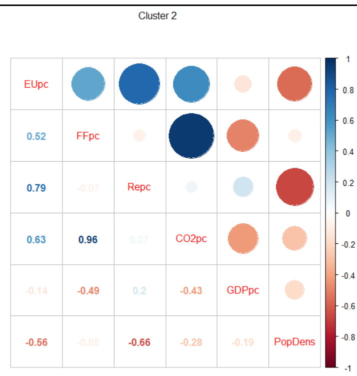


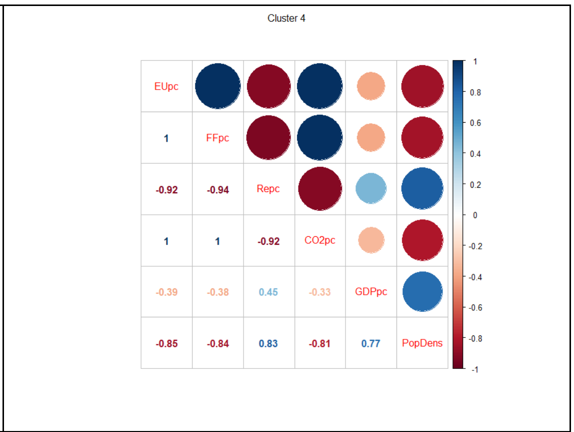

| Cluster | No of items: | Centers of Avg EUpc: | Cluster | No of items: | Centers of Avg EUpc: |
|---|---|---|---|---|---|
| 3 | 3 | 5049.8 | 4 | 2 | 7116.7 |

(a) Clusters of countries. Classification by energy use pc (average of 2000-2018)



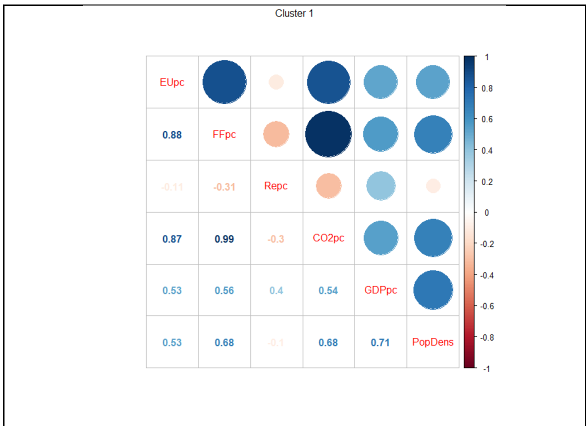



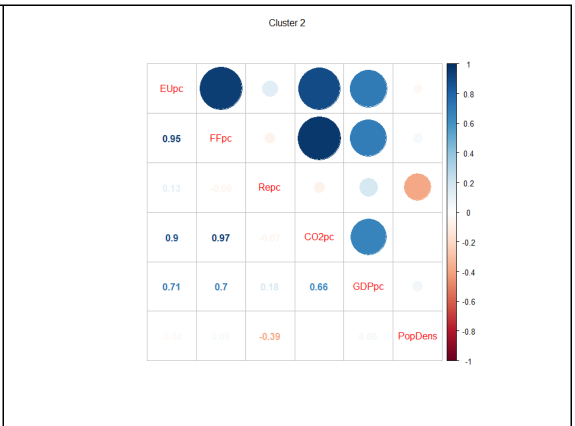

| Cluster | No of items: | Centers of Avg FFpc: | Cluster | No of items: | Centers of Avg FFpc: |
|---|---|---|---|---|---|
| 1 | 17 | 1810.5 | 2 | 8 | 2859.2 |

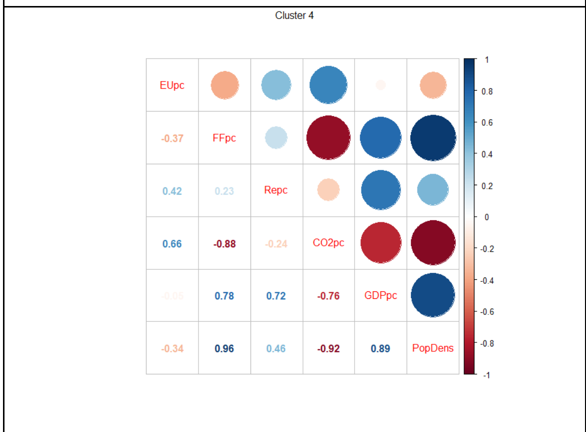

| Cluster | No of items: | Centers of Avg FFpc: | Cluster | No of items: | Centers of Avg FFpc: |
|---|---|---|---|---|---|
| 3 | 2 | 4089.5 | 4 | 1 | 6715.0 |

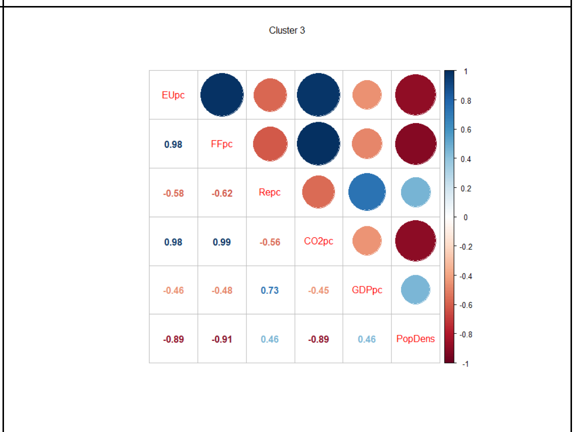
(b) Clusters of countries. Classification by fossil fuel consumption pc (average of 2000-2018)




| Cluster | No of items: | Centers of Avg Repc: | Cluster | No of items: | Centers of Avg Repc: |
|---|---|---|---|---|---|
| 1 | 6 | 626.89 | 2 | 18 | 272.83 |




| Cluster | No of items: | Centers of Avg Repc: | Cluster | No of items: | Centers of Avg Repc: |
|---|---|---|---|---|---|
| 4 | 2 | 1048.4 | 3 | 2 | 2343.1 |

(c) Clusters of countries. Classification by renewable energy consumption pc (average of 2000-2018)

*2.5 Trend analysis over time*

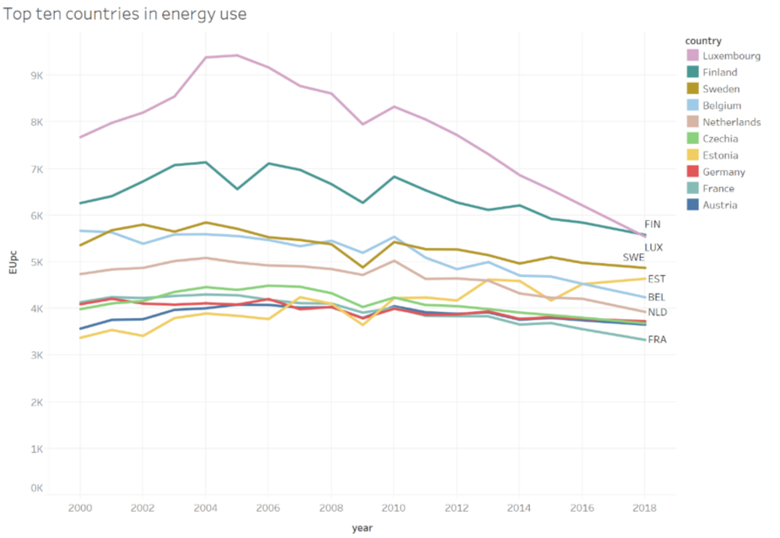
Figure 10a-c depicts the evolution of the consumption of different energy resources in top 10 energy consuming countries in a comparative time series plot for 2000-2018. The same top energy consuming countries are present in both non-renewable and renewable energy categories (with different rankings within each category).

Annual energy use pc and fossil fuel consumption pc of top 10 consuming countries have experienced a downward or slight downward trend from 2004 to 2018. The only upward trend observed is reported in Estonia in energy use pc consumption. Annual renewable energy consumption pc of top 10 consuming countries has experienced a constant upward or slight upward trend from 2003 to 2018. Years 2004-2006 seem to signal the change in the non-renewable energy consumption trend.

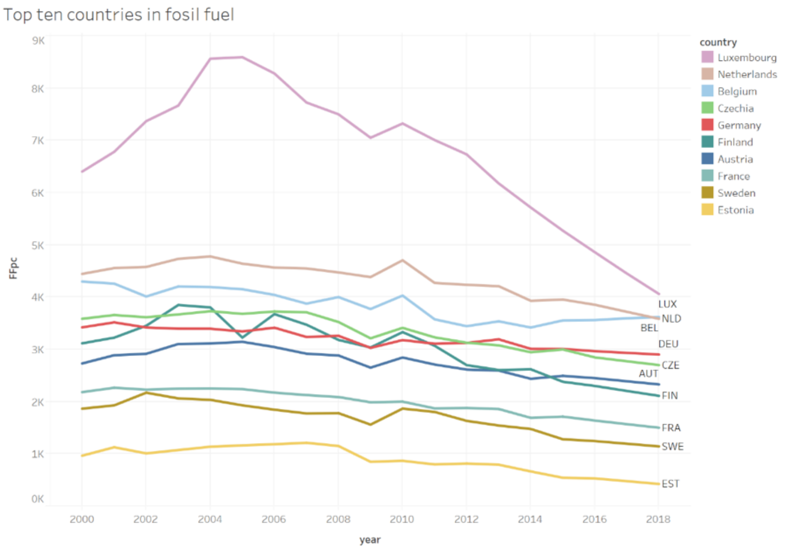
Moving towards renewable energy directives for 2020 and 2030, 6 countries have already exceeded the 2030 target for renewable energy consumption which is at least 32% share for renewable energy (https://ec.europa.eu/clima/policies/strategies/2030_en) (figure 11). 11 countries are well above 2020 renewable energy target (figure 11). The European Union's current target is for a 32% share of renewable energy across the bloc by 2030, and 20% in 2020.

Time series plots were visualized using Tableau Software (Tableau 2020).

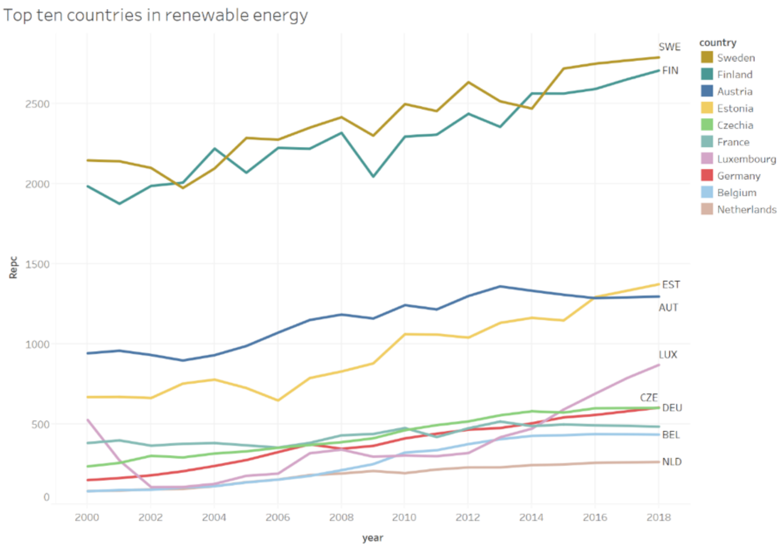
**Figure 10:** Top 10 energy consuming countries




(a) energy use pc

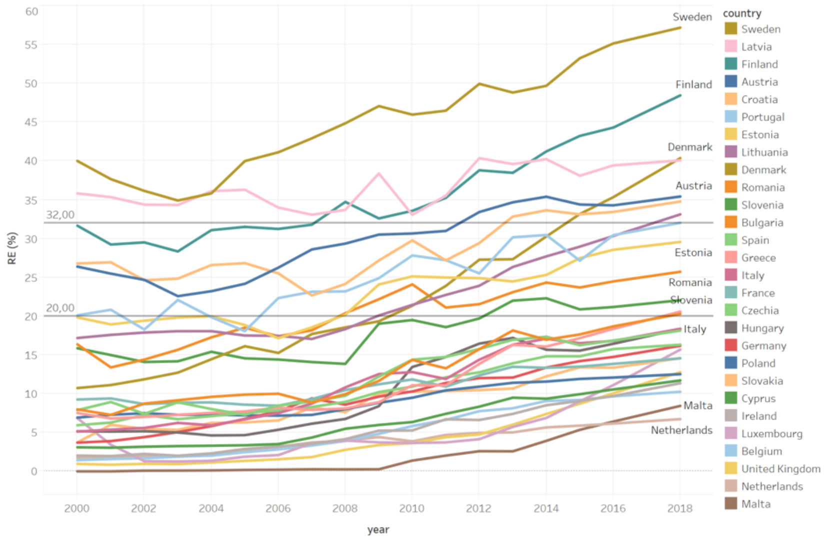



(b) fossil fuel consumption pc




(c) renewable energy consumption pc

**Figure 11:** Renewable energy targets 2020 and 2030: 20% final energy consumption from renewable sources by 2020 and at least 32% by 2030.




## 3. Discussion and Conclusions

We followed a visual approach to understand the dynamics of energy consumption and the effect on CO2 emissions and economic growth in EU 28 territory for the period from 2000 to 2018.

In the geographical clustering proposed by the UN, no similarities or uniformity per geographical region is observed. Thus, we grouped countries in clusters according to the level of their reported renewable and nonrenewable energy use, to observe patterns and policies exempt from country-level legislations, taxation, environmental motives, competitors, etc.

Exploratory data analysis indicated as outlier countries (i.e., nations with very high levels of energy consumption) Luxembourg and Finland concerning energy use pc, Luxembourg and The Netherlands concerning fossil fuel consumption pc, Finland, Sweden, Austria, and Estonia concerning renewable energy pc.

One main finding is the existence of strong correlations of energy variables with CO2 emissions, repeated consistently in all energy variables in all classifications. We consider carbon dioxide emissions an environmental degradation indicator. Correlation analysis showed that the higher the level of nonrenewable energy use pc, the more intense the CO2 emissions pc. On the contrary, CO2 emissions pc demonstrate an inverse relationship with renewable energy consumption pc. It is surprising to notice that in many clusters there is a contrary relation between GDP pc and energy consumption pc. This makes the evidence that rational use of energy is a key factor to socio-economic prosperity and sustainability.

The illustration of the dynamic evolution of energy consumption in national level through 2000-2018, revealed that in 2005 an era of change starts for top energy consuming countries. However, many countries are way behind from meeting their 2020 or 2030 renewable energy obligations.

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# Interventions in Existing Buildings and their Environment. Case Study: Environmental - Bioclimatic Upgrade of a School Building

**Vasileia Maragkaki[1] & Agisilaos Economou[1,2]**
[1]*School of Science and Technology, Hellenic Open University, 26335, Patras, Greece*
[2]*School of Applied Mathematical and Physical Sciences, National Technical University of Athens, 15780, Athens, Greece*
vamaragaki@gmail.com, aghs@mail.ntua.gr

**Abstract**
The high energy consumption of conventional school units and at the same time the important role of bioclimatic design of school buildings in upgrading the educational process makes the need for interventions in the school space in order to upgrade it environmentally and bioclimatically.
The present research refers to the possibilities of upgrading the school units taking into account the Building Energy Efficiency Regulation and the bioclimatic design. Then, the survey focuses on a conventional school unit (Leontio Lyceum in the Patissia area). Research in situ and a method of personal interviews with the teachers of the school unit took place in order to identify the problems of the school unit.
In the end, we propose interventions in the school unit, in order to environmentally and bioclimatically upgrade it, preserve its architecture and improve the conditions of thermal and visual comfort of the students. During the intervention plan, we take into account the characteristics of two bioclimatic school units of the German School in Marousi (Athens). In order to evaluate the interventions in the school unit we use the energy consumption calculation program "Easykenak", the design program "Autocad", as well as the 3D design and photorealism programs "Archicad" and "Lumion" to highlight the interventions.

**Keywords:** Bioclimatic design, sustainability, environment, school building upgrade.

**JEL Codes:** Q42, Q43, Q56, Q58.

## 1. Introduction

The main issues that existing buildings are facing today refer to energy losses, lack of thermal insulation, humidity, thermal bridges due to poor construction techniques, high energy consumption, pollutant emissions, increased thermal capacity of building materials, alterations to the microclimate (heat island effect, reduction of wind speed, reduction of solar radiation in the soil), and dense construction – an increased surface area of construction compared to the natural landscape capacity. These problems also apply to school units, the majority of which are old buildings with no prior energy efficient planning, lack of green space in the courtyard area and often classrooms with poor orientation and lack of shading.

However, today in Greece new school buildings are designed according to the bioclimatic design principles and a national code referred to as the Energy Efficiency Building Regulation (E.E.B.R) (OSB, 2008).

Bioclimatic design provides optimal conditions of thermal and visual comfort within the building's interior, aiming at the minimum non-renewable & conventional energy consumption by promoting the use of renewable energy sources. (http://buildinggreen.gr)

At the same time, the E.E.B.R aims to improve the energy efficiency of buildings through the selection of appropriate technical and technological characteristics. It offers the possibility of calculating the building's energy efficiency, thus setting minimum energy requirements and a classification of these buildings into the according energy consumption grades.

The European Union has adopted a number of energy conservation measures, such as the Energy Efficiency Directives as well as Green and White Papers. (https://eur-lex.europa.eu). Nowadays there are several recommendations for the design and construction of environmentally conscious buildings which have included methods for energy conservation, with the main categories being 'Green buildings' and 'Smart buildings'. (https://ec.europa.eu), (www.rcrwireless.com), (Groote et al, 2017).

This research focuses on the possibilities of an energy efficiency upgrading of a school unit in accordance with the principles of bioclimatic design and the E.E.B.R. The upgrading of the High school of Leontio in Athens's neighborhood Patissia has been selected as a case study for its conventional yet significant architectural character. (https://docathens.org)

## 2. Methods and Data

Initially, field research was conducted through interviews with teachers and students of the High school of Leontio. Moreover, two buildings following principles of bioclimatic design (a Kindergarten and a Primary school) of the German School located in the area of Marousi were analysed, to assess their specific conditions of thermal and visual comfort. The comparison of these three school units was imperative to identify the disadvantages in the conventional design of the case study. Subsequently, bioclimatic upgrading interventions were proposed paying respect to the building's architectural character. During the process of evaluating the energy efficiency upgrading (a) the Easykenak energy consumption calculation programme (b) the Autocad design programme for additional design interventions (c) the thermal-permeability factor and (d) a sun-shading diagram was used.

The thermal-permeability factor is given by:

$$Uw = [(Af*Uf) + (Ag*Ug) + (lg*\Psi g)] / (Af+Ag) \quad (1)$$

Ug the thermal-permeability factor of the window glass pane
Uf the thermal-permeability factor of the window frame
Af the surface area of the window frame
Ag the surface area of the window glass pane
Lg the perimeter of the glazing
Ψg the linear thermal-permeability factor of the window pane

### *2.1 Data*

**Table 1:** Exterior wall elements (TCG, 2017)

| External wall | | | |
|---|---|---|---|
| **Layers of building material** | **Thickness (d)** | **l for material** | **R=d/l** |
| | m | W/mK | |
| Coating (plaster) | 0.02 | 0.870 | 0.023 |
| Brick | 0.19 | 0.450 | 0.422 |
| Coating (plaster) | 0.02 | 0.870 | 0.023 |
| Thermal insulation (proposed) | 0.05 | 0.035 | 1.429 |
| Coating (plaster) | 0.02 | 0.870 | 0.023 |
| Total | 0.28 | R | 0.47 (before) / 1.92 (after) |
| U = 1/Ri+R+Ra | | | |
| Thermal transition resistance on the inner surface, Ri | | | 0.13 |
| Resistance of heat dissipation of building materials R | | | 1.92 |
| Thermal transition resistance on the external surface, Ra | | | 0.04 |
| R total ($m^2K/W$) | | | 2.09 |
| U ($W/m^2K$) | | | 1.57 (before)/ 0.48 (after) |

## 3. Case study

### *3.1 Leontio Lyceum of Patissia*

Leontio is located within the Municipality of Athens, in the area of Patissia. The educational facility includes an elementary, middle and high school, as well as sports facilities and mechanical facilities. This research focuses only on the high school unit. An initial on-site investigation identified its main characteristics:

The school complex spans a total area of 15007.69 $m^2$ and includes the high school building (5409.12 $m^2$), the middle school building (4030.88 $m^2$), the sports facilities (3149.77 $m^2$) and the mechanical facilities (486.40 $m^2$).

The school building has a "Γ" shape; therefore, the classrooms' orientation is east, west and south facing, (overall the school has a "Π" shape including the middle school wing) with an entrance to the court area via a pilotis (figure 1, 2).

Rectangular-shaped openings are positioned linearly along the facade.

The school is heated through natural gas.

**Figure 1:** The school complex of Leontio Lyceum of Patissia (https://www.google.gr/maps/)


**Figure 2:** Existing condition of the yard of the High school (https://www.google.com/search)

*3.2 Results of the questionnaires and teachers' interviews of the Leontio Lyceum of Patissia*

Students were given a questionnaire and several teachers were interviewed, in order to further investigate the bioclimatic behavior of its thermal and visual comfort conditions. Questionnaire results are presented below (117 students were asked)

**Figure 3:** Are the students annoyed by the dazzling sunlight?

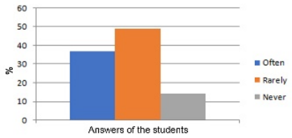



**Figure 4:** Do the students feel cold in the classrooms during the winter?

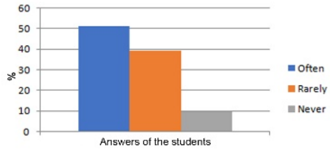



**Figure 5:** How often do you turn on the heating during the winter?

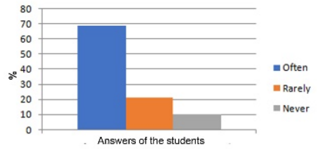



**Figure 6:** Do the students feel hot in the classrooms during the summer?

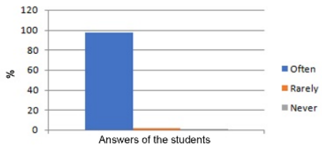



**Figure 7:** How do you usually achieve coolness in summer?

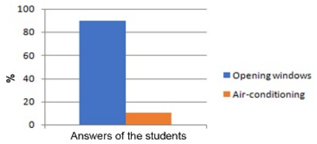



**Figure 8:** How often do you turn on the lights during the winter?

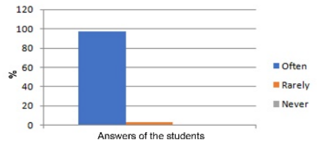



**Figure 9:** Is there any moisture in the classrooms during the winter?

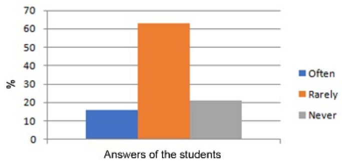



**Figure 10:** Do the students smell unpleasant odors in the classrooms?

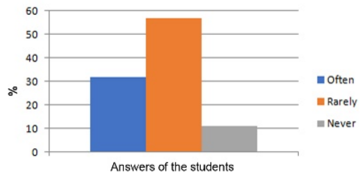



**Figure 11:** Are you annoyed by the traffic noise during the lesson?

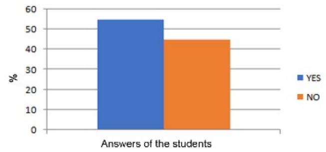



**Figure 12:** Are you annoyed by the noise coming from the yard?

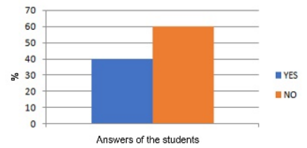



**Figure 13:** Which point of the yard do the students prefer during the winter?

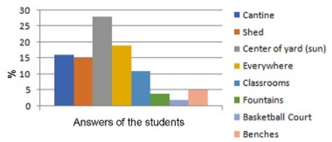
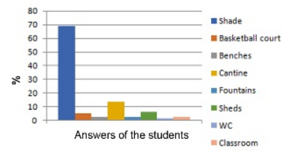



**Figure 14:** Which point of the yard do the students prefer during the summer?




Results from the preliminary research that took place showcased that thermal and visual comfort levels were far from ideal. Students reported feeling cold during winter, therefore the use of artificial lighting and heaters is frequent (figure 4,5,8). During the summer season, the students feel hot and result to opening all windows for cooling, while they say that direct sunlight is visually obstructive (figure 3,6,7). Noise pollution from traffic is noticeable, while noise in the courtyard is limited due to appropriate scheduling of yard activities between and while class is in session (figure 11,12) During the winter, students prefer to be in the courtyard especially around places that receive the most sunlight, while in the summer they prefer shaded areas (figure 13,14). The results of the questionnaires were also confirmed during the teachers' interviews.

*3.3 Results of research in the bioclimatic units of the German School*

On-site research on the bioclimatic units of the German School resulted that:

**Figure 15:** Kindergarten of the German School (https://www.ktirio.gr)

**Figure 16:** Ground floor plan of Kindergarten (https://www.ktirio.gr)

**Figure 17:** Primary School of German School (https://www.ktirio.gr)

**Figure 18:** Ground floor plan of primary school (https://www.ktirio.gr)

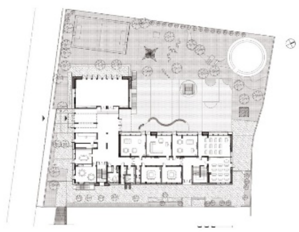


**Table 2:** Categorizing attributes

| Kindergarten of the German School | Primary School of German School |
|---|---|
| Classroom orientation: N, E, W | Classroom orientation: N, E, W, S |
| A zig zag built-in floor plan with alternating enclosed and outdoor spaces | “Γ”-shaped floor plan with a well ventilated and light passage from the entrance to the courtyard space on the ground floor |
| Openings: rectangular shapes arranged irregularly for maximum natural lighting and ventilation | Openings: rectangular shapes, grouped on the façade to form elongated openings |
| Energy aluminum frames | Energy aluminum frames |
| Sun protection elements: “Γ”-shaped and perforated | Sun protection elements: adjustable blinds |
| Ceiling fans used for cooling | Ceiling fans, VRF (Variable Refrigerant Flow) system |
| Enhanced thermal insulation - thermal comfort conditions | Heat recovery systems - thermal comfort conditions |
| Natural gas for heating and hot water | Natural gas for heating and hot water |
| Courtyard space with densely planted bushes, orchards available for the students, alternating materials | Courtyard including green space with plants and a grass lawn around the building |
| | Photovoltaic panels on the roof |

*3.4 Problem identification for the High school of Leontio in Patissia and proposals for an energy efficiency and bioclimatic upgrading*

Through the categorization of these three school units according to their characteristics and subsequent comparison, the disadvantages of conventional design and lack of optimal thermal and visual comfort conditions have been identified and bioclimatic upgrading interventions are proposed below (Table 3), taking financial feasibility into consideration.

**Table 3:** Disadvantages of conventional design of the High school of Leontio in Patissia and bioclimatic upgrade proposals

| Disadvantages | Bioclimatic upgrade proposals |
| --- | --- |
| Energy inefficient window frames | Changing of window frames |
| Lack of thermal insulation | Installation of interior thermal insulation |
| Lack of sun protective of elements | Installation of interior shading blinds |
| Inadequate and energy-consuming air conditioning | Installation of ceiling fans in classrooms |
| | Installation of VRF system in amphitheaters and office spaces |
| Inadequate ventilation | Creation of cross ventilating openings on the walls of classrooms facing the inner corridors |
| A courtyard covered with asphalt, a non-environmentally friendly material that hinders optimal thermal comfort conditions and lack of green space, which results in poor air quality and a heat island effect. | Redesigning the courtyard space |
| | Additional intervention: Addition of photovoltaics on the roof |

The redesign of the courtyard aims at its aesthetic and environmentally friendly upgrading, the programming of its users' activities and the creation of zones for circulation and pause. The programming of the spatial functions was defined by the orientation of the existing building volumes, the boundaries set by roads surrounding the school complex, the existing infrastructure of the courtyard area and the property boundaries. The activities taking place in the according spaces are of the following nature: sports (in the center of the courtyard including stadiums and bleachers), cultural activities (east facade) and recreational activities (canteen zone). The circulation zones extend throughout the paved part of the courtyard area as well as the rammed earth zone, while spaces for pause are located around designated areas with seats and shading in combination with green space (figure 19, 20,21).

The proposed materials are:

- Paving blocks for allowing the soil to breathe, avoiding overheating above ground and facilitating the drainage of rainwater. (https://pangea.gr)
- Rammed soil (the mixing of pozzolanic, natural aggregates and natural active substances, with an addition of a non-alkaline cement and water) as an environmentally conscious material in earth tones. (http://www.kourasanit.com)
- Grass to avoid overheating during the warm months, while in winter it helps draining the water runoff. (Figure 19)

Regarding green space planting, the following is proposed:

- Preservation of existing species of flora.
- New local species compatible with the regional climate.
- Aesthetically pleasing plants and flowers.
- Evergreen trees and shrubs around the area to filter noise pollution and airborne pollutants.

- East side: tall deciduous trees for providing shaded seating and protecting the east façade during the summer period (filtering of direct sunlight dazzle in the halls). In addition, deciduous trees shed their leaves during winter and thus do not prevent sunlight entering the halls (Figure 19).

**Figure 19:** Redesigning the courtyard space (personal processing)

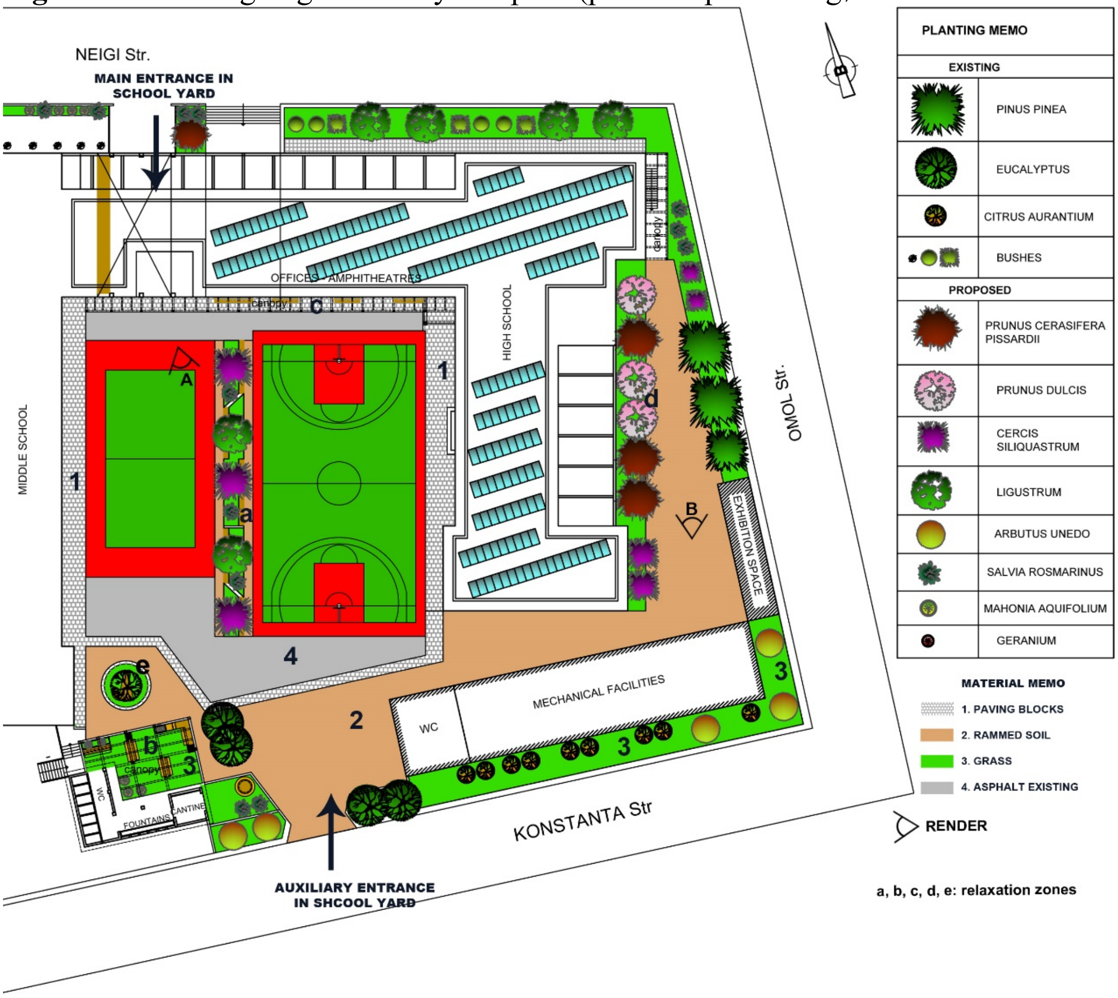



**Figure 20:** Relaxation and planting zone among the two courts (figure 19 render A) (personal processing)

**Figure 21:** Relaxation and planting zone at the eastern facade (figure 19 render B) (personal processing)

**4. Evaluation of interventions**

The potency of the interventions was evaluated and carried out through a sun-shading diagram, the Easykenak energy consumption calculation programme and the calculation of the thermal-permeability factor. More specifically:

*4.1 Sun-shading diagram*

Following the proposed interventions, spaces have become more functional since there are shaded areas (figure 22, 23).

Sun-shading diagrams before and after the proposed interventions are presented below (Jonos, 1985).

**Figure 22:** Sun-shading diagram:
21 May, 12:00 am, before interventions
(personal processing)

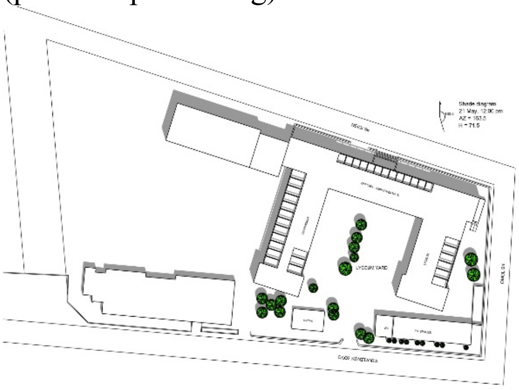


**Figure 23:** Sun-shading diagram:
21 May, 12:00 am, after interventions
(personal processing)


*4.2. Energy consumption calculation programme (Easykenak)*

Two energy efficient scenarios were applied through the Easykenak programme, to calculate energy consumption.

Before the interventions, the initial energy grade of the High school of Patissia was a D grade and the initial energy consumption was 110.70 KWh/m$^2$.

Scenario 1 includes interventions related to the E.E.B.R (changing of window frames, installation of internal thermal insulation, installation of a central heat pump for cooling – similar to a VRF system). Following interventions, the new energy grade of the High school of Patissia is a B+ grade and the new energy consumption is 51.40 KWh/m$^2$. Therefore, the building becomes energy efficient by 54%. (Table 4: Scenario 1)

Scenario 2 includes the addition of photovoltaic panels on the roof and upgrades the building a B energy grade and the new energy consumption is 61.30 KWh/m$^2$. Therefore, the building becomes energy efficient by 45%. (Table 4: Scenario 2)

The combination of scenarios 1 and 2 (changing of window frames, installation of internal thermal insulation, installation of a central heat pump for cooling, addition of photovoltaics) classifies the building into an upgraded energy grade A, with a new energy consumption of 29 KWh/m$^2$. Therefore, the building becomes energy efficient by 74% (Table 4: Scenario 1 & 2)

**Table 4:** Energy consumption table per use (kWh/m$^2$)

| Final use | Reference Building ($R_R$) | Existing Building (EP) | Scenario 1 | Scenario 2 | Scenario 1 & 2 |
|---|---|---|---|---|---|
| Heating | 18.8 | 56.8 | 14.5 | 56.8 | 20.7 |
| Cooling | 11.5 | 24.7 | 7.7 | 24.7 | 28.5 |
| Hot water | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lighting | 46.3 | 29.2 | 29.2 | 29.2 | 29.2 |
| Contribution of Renewable Sources and Cogeneration of Electricity and Heat | 0.0 | 0.0 | 0.0 | 49.4 | 49.4 |
| Total (kWh/m$^2$) | 76.6 | 110.7 | 51.4 | 61.30 | 29.0 |
| Energy Category | - | D | B+ | B | A |
| T = EP/$R_R$ | | 1.44 | 0.67 | 0.80 | 0.38 |

*4.3 Calculation of the thermal-permeability factor*

U wall before = 1.57 W/m$^2$K, U wall after = 0.48 W/m$^2$K (addition of thermal insulation, table 1)

Calculation of U frames (Uw) (depends on the type of frame)

- A/V = 0.20 where A is the surrounding surface of the building and V the volume of the building
- U total before = (U wall + U frames) /Area total = 2.80 W/m$^2$K
- U total after = (U wall + U frames) /Area total = 1.06 W/m$^2$K
  (Due to the addition of thermal insulation and the change of window frames)

The building of the Leontio Lyceum of Patissia belongs to the climate zone B, and A/V = 0.20.

According to E.E.B.R, the maximum value of an average thermal-permeability factor allowed is Um = 1.14 W/m$^2$K.

Following the interventions (addition of thermal insulation and changing of window frames) the energy behavior of the building is improved and thermal losses are reduced (by 62%) as demonstrated by the calculation of the thermal-permeability factor for a typical external wall. (U total after = 1.06 W/m$^2$K < 1.14 W/m$^2$K, table 1).

## 5. Conclusions

Research has shown that every school building has the potential to be upgraded in a bioclimatic way while maintaining its architectural character.

The use of the principles of bioclimatic design and E.E.B.R for an upgrade of the school building, although not identical, can be applied collaboratively in order to make for spaces, both interior and exterior, that are more environmentally and energy efficient. The interventions proposed for the High school of Leontio will improve the thermal and visual comfort conditions of its students and reduce its high energy consumption. Overall, the school will have an energy efficiency upgrade by 70-75%.

In view of the above, the European Union's guidelines for reducing energy consumption in buildings and upgrading the design of conventional school units is necessary. Upgrading interventions should also keep with the building's architectural character as well as take financial feasibility into consideration.

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# Factors determining the intention of citizens to participate and invest in local energy initiatives

**Spyridon Karytsas & Eleni Theodoropoulou**
*Department of Economics and Sustainable Development, School of Environment, Geography and Applied Economics, Harokopio University, 17671 Kallithea, Greece*
skaryts@hua.gr, etheodo@hua.gr

**Abstract**
Collective action is necessary to achieve the restructuring of societies into sustainable production and consumption models. Local energy initiatives can assist the achievement of this goal; however, their success requires citizens' acceptance, support, and participation.
The present paper is part of research that examines the institution of Energy Communities in Greece. Specifically, the research examines the level of information of the citizens and their intention to participate and invest in the Energy Communities, while at the same time examining issues such as the relevant structures, benefits, barriers, and motives. The present paper demonstrates the results of the literature review and the assessment of the aforementioned issues.
The findings of the present work will be further utilized for the definition and examination - through quantitative and qualitative analyses - of research questions targeting the Greek Energy Communities.

**Keywords:** Energy community, participation, investment, barriers, motives.

**JEL Codes**: P18, Q42, Q48.

## 1. Introduction

Energy Communities (EnComs) convert energy systems from centrally organized fossil-driven into decentralized low carbon systems (Beermann and Tews, 2017) while making citizens and local communities the core of the energy system (Koirala et al., 2016). Citizens are vital for effectively managing these ongoing energy transitions through their acceptance, support, and participation (Kalkbrenner and Roosen, 2016). Regardless of the efforts made, these topics have not been extensively explored so far. There are only a limited number of studies that provide empirical evidence on the determinants of willingness to get involved and invest in these initiatives (e.g. (Bauwens, 2016; Kalkbrenner and Roosen, 2016; Becker et al., 2017; Bauwens, 2019).

This paper comes as a part of a research project aiming to examine the institution of EnComs in Greece, focusing on individuals' attitudes on awareness, involvement and investment, and considering related topics that have not previously been addressed, such as benefits, barriers, and motives. In this sense, the present work sets out a review of the literature on the determinants of participation and investment in EnComs, along with related motives, barriers, and support measures.

Against this background, Section 2 presents the literature review's findings, including benefits (Section 2.1), barriers (Section 2.2), policies (Section 2.3), and motives and other determining factors (Section 2.4), while the main conclusions are presented in Section 3.

## 2. Literature review

The first step of the literature review involved a search on Scopus and Google Scholar platforms (conducted in February 2020) in identifying the material (mainly scientific papers) containing a combination of the phrases "Energy Community/Cooperative" and the terms "awareness, participation, investment, benefits, motives, barriers, policy, participants". After screening this material, around 60 items were identified as more applicable and were used to analyze the themes under examination and determine the knowledge gaps existing in the specific field.

*2.1 Benefits*

EnComs' benefits can be generally categorized as economic, environmental, and social. Economic benefits - being those most frequently mentioned in the relevant literature (Brummer, 2018) - are primarily locally-oriented, referring to profits reinvestment within the community and higher revenues for the local/regional authorities (Li et al., 2013). Moreover, they may lead to energy price reductions (Huybrechts and Mertens de Wilmars, 2011) and mitigation of energy poverty (Walker et al., 2012) while creating local jobs (Community Power, 2016) and enhancing the local circular economy (Creupelandt and Vansintjan, 2014).

Referring to environmental benefits, EnComs can promote climate, environmental, and energy goals by utilizing RES (Renewable Energy Sources) and improving energy savings, which can be accomplished through improved awareness and interpersonal trust, and the establishment of social norms (Coenen et al., 2017).

Social benefits involve improved RES local acceptance and diffusion (Romero-Rubio and de Andrés Díaz, 2015; Bauwens and Devine-Wright, 2018), development of energy self-sufficiency and security, strengthening of community principles, and promotion of self-governance and democratic procedures (Walker, 2008; Ortiz et al., 2012; Roberts et al., 2014; Koirala et al., 2016) while supporting community building (Brummer, 2018) and social cohesion (Walker et al., 2012).

*2.2 Barriers*

In general, EnComs' barriers can be grouped into economic, technical, social, and institutional. The most common economic challenges are high investment costs (Watson et al., 2006), long/uncertain payback periods (Boon and Dieperink, 2014), and lack of profitability (Herbes et al., 2017), while technical challenges involve lack of equipment, know-how, and expertise (Walker, 2008; Mignon and Rüdinger, 2016).

Social barriers involve low community involvement (Walker et al., 2012) in the sense of low participation/investment or unwillingness to cover managerial positions (Brummer, 2018). Local opposition may occur based on a lack of procedural and distributional justice (Walker et al., 2012) and collaboration between the stakeholders (Koirala et al., 2018), limited awareness, and previous negative experiences with cooperative structures (Bauwens et al., 2016).

The centrally-coordinated management and regulation of existing energy markets are the main barriers hindering the establishment and promotion of EnComs when referring to institutional challenges, with issues such as ineffective regulatory interventions, bureaucratic restrictions, and inconsistent short-term policies being worth mentioned (Boon and Dieperink, 2014; Heras-Saizarbitoria et al., 2018).

*2.3 Policies*

Different policies can be applied to establish and develop EnComs (Moroni et al., 2019), taking the form of financial tools, legislative and regulatory frameworks, and awareness activities. Nevertheless, it is not an easy task to create and launch policies that can simultaneously support all different types (in the context of applied technologies, members, organizational structures, funding, etc.) of EnComs, meaning that particular policies may be a better fit for specific types of EnComs compared to others (Moroni et al., 2019).

Against this background, financial incentives are an essential part of the different policy options since EnComs are organizations that depend on limited financial resources, including members' investments and external funds. The most common financial stimulants include subsidies and grants, income tax deductions, long-term low-interest loans, and loan guarantees (Sørensen et al., 2000; Li et al., 2013; Bauwens et al., 2016; Moroni et al., 2019).

### *2.4 Motives and other determinants*

Numerous factors have been identified to affect individuals' participation in EnComs, either through volunteering, investment, or being part of the organization's management. Both selfish and moral motives have been recognized as determinants of participation, and particularly involvement through investment. Selfish motives are manifested mainly via the Return on Investment (ROI) (Holstenkamp and Kahla, 2016; Bauwens, 2019), which is further determined by elements like financial support (e.g., subsidies and tax incentives) and operational costs (Bolinger, 2005 Breukers and Wolsink, 2007; Sardianou and Genoudi, 2013).

Likewise, individuals' decisions are influenced by moral motives, classified as social recognition, interpersonal trust, and environmental concerns (Kalkbrenner and Roosen, 2016). Social recognition has to do with people's need to be included in a group and being recognized by their community (Dóci and Vasileiadou, 2015; Holstenkamp and Kahla, 2016). Interpersonal trust has to do with the trust that must be developed between all EnComs' members (Walker et al., 2010; Dóci and Vasileiadou, 2015; Van Der Schoor and Scholtens, 2015; Koirala et al., 2018). Environmental concerns, positively affecting participation in EnComs', may appear in the form of residential RES-system ownership, desire to reduce $CO_2$ emissions, increased environmental awareness or behavior (Bamberg et al., 2015; Kalkbrenner and Roosen, 2016; Boon and Dieperink, 2014; Bauwens, 2019). It is worth mentioning that the presented selfish and moral motives may be influenced, in their turn, by different elements such as the current institutional conditions (Kalkbrenner and Roosen, 2016; Bauwens, 2016; Bauwens, 2019), spatial characteristics (e.g., communities of place vs. communities of interest) (Heiskanen et al., 2010), and inclination towards the adoption of innovations (Franceschinis et al., 2017).

Further on, various energy-related elements have been associated with people's participation in EnComs, such as involvement in the energy transition, impact on local energy policies, energy self-sufficiency, and acceptance of RES infrastructure (Boon and Dieperink, 2014; Yildiz et al., 2015; Holstenkamp and Kahla, 2016; Broughel and Hampl, 2018; Koirala et al., 2018). Additionally, demographic/ socioeconomic attributes have been reported as determinants, including age, gender, marital status, education (level and type), occupation, income, homeownership, and area of residence (Sardianou and Genoudi, 2013; Bamberg et al., 2015; Fraune, 2015; Höfer and Rommel, 2015; Kalkbrenner and Roosen, 2016; Broughel and Hampl, 2018; Karytsas et al., 2019).

Still, a limited number of studies have been performed so far on the determinants of individuals' participation in EnComs. Most studies rely on small-sample qualitative-based surveys (Bomberg and McEwen, 2012; Schreuer, 2012; Dóci and Vasileiadou, 2015; Yildiz et al., 2015; Goedkoop and Devine-Wright, 2016; Broughel and Hampl, 2018), while the few quantitative surveys examine either the motives of willingness to participate (Rogers et al., 2008; Bamberg et al., 2015; Kalkbrenner and Roosen, 2016; Koirala et al., 2018) or actual members' decision to participate or invest (Radtke, 2014; Bauwens, 2016; Holstenkamp and Kahla; 2016; Fleiß et al., 2017; Bauwens; 2019). It is worth noting that all studies mentioned above have been performed in a limited geographical setting, focusing exclusively on northern and central European countries (Germany, Austria, United Kingdom, Netherlands, Belgium, and Switzerland) (Karytsas and Theodoropoulou, 2021).

## 3. Conclusions

The present work aims to present the literature review results on the determinants of participation and investment in EnComs, along with related motives, barriers, and supporting policies.

In general, EnComs' benefits can be categorized as economic, environmental, and social, while barriers as economic, technical, social, and institutional. Various policies can support the establishment and development of EnComs, including financial tools, legislative and regulatory frameworks, and awareness activities. In any case, different benefits, barriers, and supporting policies apply to different types of EnComs regarding diverse technologies, members, organizational structures, funding, etc.

Either way, willingness to participate and invest is a requirement for the effective development of EnComs. Determinants of citizens' participation and investment include selfish motives (financial repayment), moral motives (social recognition, interpersonal trust, and environmental concerns), institutional and spatial settings, adoption of innovations, energy-related elements, and demographic/ socioeconomic attributes.

The findings of the present work will be further utilized for the definition and examination - through quantitative and qualitative analyses - of research questions targeting the Greek EnComs. Answering these questions could help policymakers employ effective support policies adapted to particular settings and developers work out strategies aligned with project-specific goals and advantages.

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# The MOF4AIR European project: Examining the determinants of social acceptance of carbon capture, transport and storage (CCS)

**Spyridon Karytsas, Olympia Polyzou, Theoni I. Oikonomou & Constantine Karytsas**
*Geothermal Energy Department, Division of Renewable Energy Sources, Centre for Renewable Energy Sources and Saving (CRES), 19009 Pikermi, Greece*
spkary@cres.gr, pololi@cres.gr, thoikonomou@cres.gr, kkari@cres.gr

**Abstract**
Carbon Capture and Storage (CCS) is the method of capturing $CO_2$ generated by power plants or heavy industry processes and transferring it to long-term geological storage systems. However, it is a divisive technology that often experiences public opposition when it comes to accepting individual projects. Thus, it should not be ignored that social acceptance of CCS is a requirement for its further development. In this sense, the MOF4AIR European project, which aims to illustrate the efficiency of $CO_2$ capture technologies focused on MOFs (Metal Organic Frameworks), involves relevant activities examining social issues related to CCS.
The findings of the initial stages of these activities are presented in this work. The determinants of social acceptance of CCS, as well as the relationships between them, were defined based on a literature review. Several factors have been identified to affect social acceptance, with perceived costs and benefits, trust in stakeholders, and knowledge of relevant subjects being the most frequently reported. Following the literature review, and based on the identification of relevant research gaps, a questionnaire has been developed for a quantitative social survey that will be performed in seven European countries.
The findings of the social survey, along with the results from interviews with targeted stakeholders, will be used to create public engagement scenarios.

**Keywords:** Carbon dioxide, carbon capture and storage, CCS, social acceptance.

**JEL Codes**: P18, Q49.

## 1. Introduction

The installation and operation of infrastructures for carbon capture, transport, and storage, to reduce CO2 emissions from power plants and carbon-intensive industries, is of major importance to fulfill the targets for the mitigation of greenhouse gas emissions (d'Amore et al., 2020). Actually, CCS (Carbon Capture and Storage) and CCUS (Carbon Capture Utilization and Storage) are the only technologies considered to be able to directly decarbonize industrial facilities such as cement, petrochemical and steel industries, without requiring a complete rethinking of the industrial sectors (IPCC, 2018).

A low carbon economy requires the development, testing and implementation of cost-effective carbon capture solutions. A variety of technologies of different maturity levels and performances are available for CO2 capture (e.g. oxy-fuel combustion, chilled ammonia technology, adsorptive processes, calcium looping, etc.). The most mature technology, post-combustion CO2 capture by amine scrubbing, does not offer sufficient performances. Adsorption processes are promising alternatives to CO2 capture from power plants and other energy-intensive industries.

In this respect, Metal Organic Frameworks (MOFs) are a well-studied class of porous adsorbents that offer enormous potential, due to their high CO2 adsorption capacity and high CO2 affinity. However, the performance of MOF-based carbon capture technologies has not been thoroughly evaluated (MOF4AIR European project, 2019).

*1.1 MOF4AIR European project*

Almost all climate action plans integrate CCS into the energy balance, but research and innovation are still essential to making these plans sustainable. In this context, the main objective of the MOF4AIR (Metal Organic Frameworks for Carbon Dioxide Adsorption in Power Production and Energy Intensive Industries) European project is to increase performances of MOF-based CO2 capture technologies in power plants and energy-intensive industries. To that purpose, MOF4AIR will demonstrate optimized MOF-based adsorbents with fine-tuned CO2 adsorption processes through a multidisciplinary approach. MOF4AIR is a Horizon 2020 project, with a budget of over € 11 million, started in July 2019, and is expected to be completed within 2023.

More specifically, the main objectives of the MOF4AIR project are:

1. Increase the cost-effectiveness of capture and geological storage of CO2 and decrease its energy penalty.
2. Qualitative specification and validation of suitable MOF materials for adsorption-based carbon capture.
3. Fine-tune adsorption processes for high-performance MOFs.
4. Demonstration of the performance of MOFs based on carbon adsorption in real operation.
5. Replicability of the technology in other carbon-intensive industries, and ensure its sustainability.
6. Increase stakeholders' and public awareness concerning challenges, benefits and other issues related to capture, transport, use and storage of CO2.

The MOF4AIR project, to ensure its success, brings together 14 partners from eight European countries and Asia and an Industrial Cluster Board (ICB). MONS University from Belgium coordinates the project, as a research center with broad experience in the MOFs, as well as the various carbon capture processes.

The project involves six research centers in total, which have the necessary experience to implement the project, three small and medium enterprises (SMEs) specialized in the production of MOFs and their configuration on an industrial scale, a cement production association, and an SME specialized in communication and dissemination. Specifically, the project partners are the following:

1. University of MONS (Coordinator of the project) / Research Center / Belgium
2. SINTEF AS / Research Center / Norway
3. Centre National De La Recherche Scientifique / Research center / France
4. Politecnico di Milano (POLIMI) / Research Center / Italy
5. Centre for Renewable Energy Sources and Saving / Research Center / Greece
6. SiKEMIA / Small Medium Enterprise / France
7. MOF Technologies Limited / Small Medium Enterprise / United Kingdom
8. Korea Research Institute of Chemical Technology / Research Center / S. Korea
9. ENGTECH CO LTD / Research Center / S. Korea
10. Technology Centre Mongstad / End-User / Norway
11. Solamat Merex / End User / France
12. Türkiye Petrol Rafinerileri A.Ş. / End-User / Turkey
13. Euroquality / Small Medium Enterprise / France
14. Türkiye Çimento Müstahsilleri Birliği / Cement Association / Turkey

The MOF4AIR partners want to create highly repeatable results to maximize the project's effectiveness. The MOF4AIR Replicability Study will be carried out in cooperation with the MOF4AIR Industrial Cluster Board (ICB). This Board will work in synergy with MOF4AIR, targeting more than ten different sectors (cement, limestone, energy, chemistry and petrochemistry, waste incinerator, etc.). ICB members will closely attend project outcomes, in particular the cost of carbon capture solutions, and will examine with MOF4AIR partners the possible implementation of the solutions in their industries.

*1.2 MOF4AIR project activities*

MOF4AIR is comprised of 11 Work Packages (WPs). Once the best MOFs in WP1 have been identified and validated through tests (e.g. in terms of stability and selectivity), in WP2, the most promising MOFs will be produced at a larger scale and will be scaled up in WP3. In WP4, simulations will be carried out to study the behavior of MOFs in two adsorption processes: VPSA (Vacuum Pressure Swing Adsorption) and MBTSA (Moving Bed Temperature Swing Adsorption) and their optimization will be performed. Both solutions will be tested at the laboratory in WP5. In WP6, three demonstration sites in Europe (France, Turkey and Norway) will demonstrate the cost-effectiveness and reliability of MOF-based carbon capture in CO2 in carbon intensity sectors: power plants, refineries and waste incineration plants. To ensure the wide dissemination of the solutions developed, WP7 will focus on legislative / regulatory issues, techno-economic and life cycle analysis, while WP8 will focus on social acceptance and replicability in other sectors. In WP9 all communication, dissemination and exploitation activities will be organized and in WP10 the smooth progress of the activities during the project will be ensured through the appropriate management. Finally, WP11 will focus on ethical issues related to the project activities.

**2. Social acceptance of carbon capture, transport and storage**

Carbon capture, transport and storage can contribute to global efforts to combat climate change. However, it remains a controversial technology that often faces public resistance to accepting specific projects. Thus, it should not be overlooked, that social acceptance of CCS is a prerequisite for the further development and dissemination of this technology.

*2.1 Examining social issues related to CO2 capture, transport and storage*

In this light, the MOF4AIR project explores this issue within WP8, which includes Task 8.1 "Study of social issues related to CO2 capture, transport and storage". This task includes a quantitative social survey targeting local communities, to study the factors that can affect the social acceptance of CO2 capture, transport and storage facilities. The research will be carried out in all European countries, being represented in the project consortium. In addition, a qualitative study (through interviews) will be conducted targeting government officials and project developers, to capture their different interpretations and views on CCS technologies. The qualitative study will include the assessment of costs, technical requirements and the impact of operation and safety on the relevant CCS infrastructure, as part of their integration into an infrastructure system.

The social research will define a stakeholder engagement strategy for the planned activities, taking into account various factors, such as positive and negative externalities, job creation and environmental sustainability. This strategy will be used to develop public engagement scenarios. Specific practices will be proposed for the developers and operators, as well as for the public authorities, to contribute to projects' social acceptance.

*2.2 Literature review*

The first step in conducting the quantitative social survey was to perform a literature review to identify factors that have been found to influence the social acceptance of CCS infrastructure. The initial step of the literature review was to identify articles, proceedings, reports, etc., which include a combination of two groups of words. The first group included the terms "CCS, CCUS, carbon capture and storage, carbon capture, use and storage". The second group included the following terms: social / societal acceptance, public acceptance, public engagement, public awareness, public knowledge, acceptability, willingness to pay, public support/ opposition / resistance, perception, communication, social license, stakeholder, attitude, opinion, local community, benefit-sharing mechanisms.

The search was conducted through the Scopus and Google Scholar online platforms; initially, around 350 articles, proceedings and reports were identified, including a combination of words coming from the two aforementioned groups. After an initial review of the material, approximately 50 articles (and other documents) were identified to be more relevant to the examination of CCS social acceptance through the application of quantitative social studies.

These articles were utilized to identify the factors that affect social acceptance of CCS, but also to identify relevant research gaps (i.e. issues that previously have not been adequately investigated) in the relevant literature. In addition, these articles will be used to create a framework for semi-structured interviews, which will be used within the qualitative research phase targeting government representatives and project developers / operators, as well as for the mapping of the relevant stakeholders.

### *2.3 Factors affecting social acceptance of carbon capture, transport and storage*

Figure 1 presents the factors identified to affect social acceptance -either on a general or on a local level- of CO2 capture, transport and storage. Perceived risks and benefits are the factors most often associated with CCS social acceptance (Kraeusel and Möst, 2012; Selma et al., 2014). Perceived risks and benefits are influenced in turn by a variety of factors, including awareness level, trust, the country's energy mix, and concerns about the sustainability of CCS infrastructure (Seigo et al., 2014; Selma et al., 2014). In addition, an association has been identified between the level of perceived risks and perceived benefits (Seigo et al., 2014). It should also be noted that according to the research of Arning et al. (2019), the perceived benefits and risks of each different stage of CCS (capture, transfer and storage) may have a different effect on the overall social acceptance.

Another key factor influencing acceptance, which has been thoroughly examined in previous studies, is trust in the various stakeholders (NGOs, industries, research organizations, government). Trust can affect acceptance either directly, or through perceived risks and benefits (Terwel et.al, 2011), while it has also been reported that it influences perceived benefits and risks through the positive and negative emotions that can be generated (Huijts et al., 2007; Midden and Huijts, 2009). It should also be noted that emotions can also directly affect acceptance, and not just through perceived risks and benefits (Midden and Huijts, 2009). In turn, trust can be influenced by the perceived motivations and competencies of each stakeholder (Terwel et al., 2009). In addition, perceived similarities between each individual and the stakeholder can affect trust either directly or through perceived motivations and competencies (Huijts et al., 2007).

Other factors that have been taken into account in several cases, in terms of either direct or indirect (e.g. through perceived risks and benefits) impact on social acceptance are knowledge about CO2, CCS and climate change (Duan, 2010; Kraeusel and Möst, 2012; Karimi and Toikka, 2014; Karimi and Toikka, 2018), climate change concerns (Duan, 2010; Kraeusel and Möst, 2012; Boyd et al., 2017; Whitmarsh et al., 2019) and environmental behavior / beliefs (Palmgren et al., 2004; Tokushige et al., 2007; Whitmarsh et al., 2019). In addition, the influence of certain factors on social acceptance has been studied to a smaller extent, such as general attitudes towards technology (Whitmarsh et al., 2019), life-guiding values (e.g. selfish motives, altruistic motives) (Carley et al., 2012; Braun et al., 2018) and place attachment (Xuan and Wang, 2012; Boyd et al., 2017; Whitmarsh et al., 2019). Previous experience in relevant issues (e.g. through work, or proximity to relevant infrastructure) is another factor that has been found to influence social acceptance, either directly or indirectly through the impact it can have on knowledge levels or perceived risks and benefits (Carley et al., 2012; Selma et al., 2014; Whitmarsh et al., 2019).

According to the results of research on the acceptance of energy / environmental projects in general, fairness (in terms of procedural and distributional justice) and public engagement actions are two additional factors that can affect social acceptance either directly, or indirectly (e.g. through trust, and perceived risks and benefits) (Besley, 2010; Huijts et al., 2012; Selma et al., 2014; Walker and

Baxter, 2017; Mueller and Keil, 2020). However, their role has not been adequately studied in terms of CCS acceptance. Thus, they are included in the model shown in Figure 1, but as their effect is not confirmed (within CCS) their relations to other factors are presented in dashed lines.

Socioeconomic factors and demographic characteristics (e.g. educational level, age, gender) can influence the perceived benefits and risks associated with CCS (Karimi and Toikka, 2014) as well as CCS acceptance (Duan, 2010; Braun et al., 2018; Whitmarsh et al., 2019). In this context, it should also be noted that cross-cultural characteristics that differ between countries may also affect the perceived benefits and risks associated with CCS. Karimi and Toikka (2014; 2018) have studied how these characteristics can differentiate the views of citizens in different countries, using Hofstede's Cross-Cultural Dimensions.

Finally, it should be noted that in addition to the examination of social acceptance, either on a general or on a local level, the factors that may affect the initiation of protests by residents have been examined to a limited extent. These factors include trust, perceived benefits and perceived risks (Terwel and Daamen, 2012; Wallquist et al., 2012).

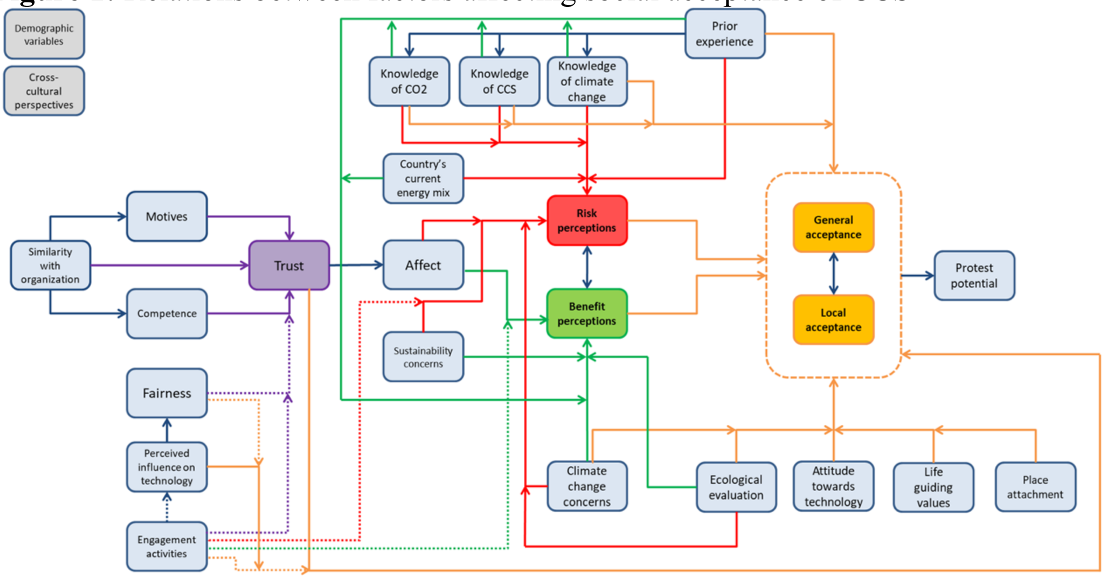
### *2.4 Innovative aspects of the present quantitative social research*

Having carried out the literature review, and having identified the factors that affect the social acceptance of CCS infrastructure, it was possible to detect the research gaps in relation to the specific issues, thus setting the specific research questions of the present study. In this context, the innovative elements that this research aims to provide - in relation to the corresponding existing research - are the following:

1. Carrying out a transnational comparison, by examining the social acceptance of the CCS in seven different countries. It should be noted that in the case of CCS, minimal research has been carried out in more than one country [see Whitmarsh et al. (2019)], usually aiming at the study of perceived risks and benefits, rather than social acceptance (Karimi and Toikka, 2014; Toma et al., 2014; Karimi et al., 2016; Karimi and Toikka, 2018), or in the examination of issues relevant to awareness or general views (Pietzner et al., 2011; Toma et al., 2014).
2. Comparison of the factors affecting the different stages of CCS, i.e. separate analysis and comparison of the CO2 capture, transport and storage phases. It should be noted that in the past such an analysis has been carried out in very few cases, and in no case on the basis of comparing different countries. Arning et al. (2019) examine separately the perceived risks in the different steps of CCS (capture, transport, storage) in Germany. Dütschke al. (2016) and Schumann al. (2014) in two surveys performed on a common basis, examine how citizens evaluate different CO2 storage and transport options in Germany. Also, Guo et al. (2019) examine separately the acceptance of facilities for capture, transport and storage, but without an in-depth study of the factors influencing the differences between the three stages.
3. Comparison between general acceptance and local acceptance. Existing studies examine either acceptance at a general socio-political level or local acceptance [see Wüstenhagen et al. (2007), for the definition of different dimensions of social acceptance]. The only identified study taking into account both general and local acceptance is that of Arning et al. (2019), where although no comparison is made between the two levels of acceptance, local acceptance of the project siting is considered a determinant of general acceptance. Thus, the present study aims to examine comparatively the factors that affect the two dimensions of social acceptance.
4. As mentioned in subsection 2.3, some factors that have been found to influence, either directly or indirectly, the acceptance of energy / environmental projects in general, have not been adequately studied in relation to the social acceptance of the CCS. The present study aims to fill this gap by examining the effects of fairness (in terms of procedural and distributional justice) and public engagement actions.

5. Confirmation of the theoretical model developed presenting all the relations between the relevant factors (see Figure 1), through the extraction of new empirical data.

**Figure 1:** Relations between factors affecting social acceptance of CCS




*2.5 Questionnaire development and next steps*

Taking into account all the above, a questionnaire was created including the following topics: CCS knowledge; climate change, and CO2 knowledge; prior experience; risk perception; benefit perception; trust of relevant stakeholders; perceived environmental behavior; engagement activities; fairness (procedural / distributional); place attachment; general / local acceptance; demographic characteristics.

It should be noted that between the first (CCS knowledge) and the second (knowledge of climate change and CO2) set of questions, an explanatory text presenting basic information about CCS will be provided. This information is as objective as possible, is provided to make it easier for respondents to answer the questions that follow, and is given at that point in the questionnaire so that the answers about the CCS knowledge will not be affected. The information text is provided, as it has been observed that the general population's level of knowledge is quite low regarding this technology (de Best-Waldhober and Daamen, 2011).

The next steps of the research, which have not yet been implemented, concern, first of all, the distribution of the questionnaire, which will be carried out through an online platform to citizens of seven European countries (all countries participating in the MOF4AIR project, except for South Korea). The statistical analysis of the data will follow, which in combination with the results from the qualitative research (interviews) will be used for the development of the engagement strategy and the targeted public engagement scenarios.

## 3. Conclusion

CCS technology, although being able to contribute to global efforts to tackle climate change, often deals with social acceptance issues of specific projects. Social acceptance should therefore be considered as a prerequisite for the further development and dissemination of this technology. In this context, the European MOF4AIR project, which aims to highlight the performance of MOF-based CO2 capture technologies in power plants and high-energy industries, includes specific activities related to the study of CCS-related social issues.

The present work presents the results that have emerged during the first steps of these activities. Specifically, based on the literature review, the factors that affect the social acceptance of CCS, as well as the relationships between them, were identified. In summary, the main factors influencing social acceptance are perceived risks and benefits, trust in stakeholders, and knowledge of relevant issues. Of course, several other factors have been found to influence acceptance, either directly or indirectly. Based on the results of the literature review, the gaps that exist in the literature were identified, to set the research questions of the present research. Based on the literature review and the determination of the existing research gaps, a questionnaire was created to implement quantitative social research. The next step of the research is the distribution of the questionnaire in seven European countries.

The results of this research, combined with the results of interviews with targeted stakeholders will be used to create an engagement strategy, which will lead to the development of public engagement scenarios.

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This output reflects only the author's view and the European Union cannot be held responsible for any use that may be made of the information contained therein.

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# Optimal sustainability solutions for the location of a floating wind energy farm in the Aegean Sea with the incorporation of wave energy hybrid systems.

**Leonidas Tsipouras, George Spiliotopoulos & Vanessa Katsardi**
*Department of Civil Engineering, University of Thessaly, Volos*
ltsipouras@uth.gr, gspiliotop@uth.gr, vkatsardi@civ.uth.gr

**Abstract**
Wind power is an excellent alternative source of energy by being inexhaustible and with zero emissions but until today no wind power is produced offshore in the Mediterranean. However, offshore energy benefits from increased wind energy potential and therefore constitutes the backbone of the Blue Energy and Blue Economy Sector. Featured in this paper is a methodology for calculating the total life-cycle cost of a floating offshore wind farm. A floating solution is more viable in the deep waters of the Aegean Sea avoiding significant social backlash that is observed against land installations. In addition, using the software "RETScreen Expert", several economic indices are calculated, based on which the economic viability of a floating offshore wind farm is assessed. In parallel, a hybrid solution combining the use of wave power is also examined. Three potential areas for installation are investigated (offshore Lemnos, Mykonos and Crete), coming to the conclusion that the most cost-effective solution is presented in the area of Eastern Crete. The proposed methodology can be used for the calculation of the economic indices of a floating offshore wind farm in any location.

**Keywords:** Blue Economy, Blue Energy, Floating Offshore Wind Farms, Hybrid Systems, Aegean Sea.

**JEL Codes**: Q01, Q20, Q25, Q28, Q42, Q47, Q48, Q51, Q55.

## 1. Introduction

Due to climate change and the exhaustion of conventional sources of energy, it is of utmost importance that we expand the ways in which we can harvest renewable energy. No wind power is produced offshore in the Mediterranean, but offshore energy benefits from increased wind energy potential, making the Aegean a prime candidate for the installation of offshore wind farms. Wave energy can also be harvested in offshore installations and wind-wave hybrid systems can utilize this potential. Also, the deep waters of the Aegean Sea push towards floating offshore wind platforms which can be additionally expanded into hybrid systems, combining Wave Energy Converters (WECs).

## 2. On Offshore Wind Energy

Offshore Wind Energy farms benefit from increased wind energy potential compared to onshore ones (Esteban et al., 2011). In addition, there is more space for installation and there are no limits in turbine size (Enevoldsen and Valentine, 2016). Also, offshore wind farms benefit from larger social acceptance that usually presents itself against onshore wind power installations, as there is no need for expropriation of private property and no significant danger to wildlife such as migratory birds (Bilgili et al., 2011). On the other hand, installation is much more expensive compared to onshore, and turbines must be more durable to adverse weather conditions and more resistant to corrosion due to the salinity of the marine environment (Esteban et al., 2011). The application of offshore wind is still in its infancy, as the first installation was completed only in 2009 (Kaldellis and Kapsali, 2013), although rapidly growing ever since. As a result, only a fraction of the total wind power in the world today is produced offshore, but the trend is that the proportion of offshore in the total new installations is steadily increasing annually (GWEC, 2021).

Especially for the deep waters of the Aegean Sea, floating offshore wind structures present an excellent solution as they are not limited by the depth requirement such as more conventional foundations such as monopiles and jacket platforms (IRENA, 2016); simultaneously benefitting from even larger wind energy potential. Another advantage, is that they can be moved quite easily, making installation an easier task (Uzunoglu et al., 2016). All these prior factors make floating solutions earn the title of being “the future” for offshore wind (IRENA, 2016). The downside of floating structures is their lack of rigidness due the incident wave and wind forces compared to fixed platforms or monopiles.

The Aegean Sea is a privileged area in terms of wind energy potential, notably in the central and southeast parts of it. These areas have an annual energy density of 900W/m$^2$ while any area with over 260W/m$^2$ is considered suitable for an offshore wind installation. The estimated available offshore area in Greece is over 30,000 km$^2$ and taking all the above into account the EU’s goal for offshore wind in Greece is 100,000 MW by 2030 (Soukissian et al., 2020).

**3. Hybrid Wind-Wave systems**

The combined wind and wave energy potential that exists in the sea are the largest part of the energy commonly referred to as Blue Energy. Harvesting wave energy is still in its infancy (Perez-Collazo, 2015), but it is set to become more important in the Blue Energy and Blue Economy sectors. Investment into wave power through WECs has been slow and minimal compared to other renewables. A possible push towards investment could be the integration of WECs into other renewable energy installations, in order to spark innovation and further optimization and streamlining of their manufacturing and operating processes.

Offshore wind platforms seem the most prime for integration, as offshore energy benefits from mutual increased wind and wave power potential. A hybrid system combines a wind turbine and a WEC in the same structure therefore reducing the environmental footprint as no additional space is required. (Perez-Collazo, 2014). The total efficiency of the structure is increased by the combination of the two energy sources, but a compromise must be reached between wind and wave energy potential for the location of the installation, as extreme conditions on either end could result in either structural failure or rendering one type of the energy converters useless.

*3.1 Oscillating Water Columns (OWCs)*

The OWC could be considered the most mature technology for harvesting wave energy. OWCs have been tested for both nearshore and offshore structures and need minimal maintenance after installation as they have no moving parts apart from the turbine, offering great reliability. OWCs consist of a semi-submerged chamber containing a trapped air bubble over a column of water. Waves make the water column work as a piston causing air to move through a unidirectional turbine that works as a generator (Perez-Collazo, 2015).

*3.2 Comparing cost and efficiency with offshore wind energy*

As per usual, cost is divided between capital and operational cost (Castro-Santos et al., 2016a) and a main benefit for WECs is that they add minimal operational costs as most additional expenses are toward their construction and not their operation (Perez-Collazo, 2014). Efficiency is separate between the two different energy converters as the wind and wave energy potential varies by location, though the two are very often naturally correlated. Power must be properly transmitted to the grid, but difficulties arise because WECS should be placed in great distances from the shore in order to increase their efficiency (Vasileiou et al., 2017). Energy from a WEC depends on the working hours, wave height and period and the operational width of the structure as is expressed in the following function (Castro-Santos et al., 2016a).

$$E_{WEC} = NHAT\frac{\rho g^2}{64\pi}T_e H_s^2 D_{WEC} \quad (3.1)$$

## 4. Feasibility study for a floating offshore wind farm

The proposed methodology is based on various parameters that allow the calculation of indices that point to the viability of the installation (Castro-Santos and Diaz-Casas, 2014). The five indices that were considered are as follows (Castro-Santos et al., 2016b):

- Net Present Value: $NPV = -G_0 + \sum_{t=1}^{n}\frac{CF_t}{(1+r)^t}$ (4.1)
- Internal Rate of Return: $-G_0 + \sum_{t=1}^{n}\frac{CF_t}{(1+IRR)^t} = 0$ (4.2)
- Discounted Pay-Back Period: $\sum_{t=1}^{n}\frac{CF_t}{(1+r)^t} \geq G_0$ (4.3)
- Levelized Cost of Energy: $LCOE = \frac{\sum_{t=0}^{N_{farm}}\frac{LCS_{FOWF_t}}{(1+r)^t}}{\sum_{t=0}^{N_{farm}}\frac{E_t}{(1+r)^t}}$ (4.4)
- Cost of Power Ratio: $C_{power} = \frac{LCS_{FOWF}}{NWT \cdot PWT}$ (4.5)

### *4.1 Total life cycle cost*

For the calculation of the total life cycle cost of each installation, cost was divided in the following categories (Castro-Santos et al., 2016b; Carroll et al., 2015):

- Concept and definition cost,
- Design and development cost,
- Manufacturing cost,
- Installation cost,
- Exploitation cost,
- Dismantling cost.

All the above have been examined in full detail during the investigation of each location as an example will be provided in Table 4 in the appendix.

### *4.2 Place in the Energy Market*

The Cost of Energy (COE) is very important as demand for renewable energy increases and investors may avoid investing in renewables if the COE is too high (Bruck et al., 2018). Therefore, optimization of LCOE is very significant for attracting investors (Miller et al., 2017). To help towards a steady market in the energy sector, Power Purchase Agreements (PPA) are signed which are contracts based on performance. PPAs use the LCOE to set a fair price for energy (Bruck et al., 2018) and the duration for a typical PPA for wind energy is ranging from 15 to 25 years, 20 being the typical standard (Miller et al., 2017).

## 5. Investigation for three locations in the Aegean Sea

The criteria used for placement of an offshore wind farm in the Aegean are:

- Suitable water depth that can ensure the technical suitability for installation of floating wind turbines,
- Less than 6 nautical miles distance from the coast,
- Avoiding locations with significant adverse environmental ramifications,
- Significant wind energy potential (Wind energy density > 260W/m2 on 80m above the sea-level).

*5.1 Placement and arrangement for the floating wind farm*

As previously mentioned, in the Aegean Sea shallow depths are limited to very close distances from the coast, making floating platforms more viable. Despite 18 km from the coast being ideal for offshore wind farms (Ladenburg and Dubgaard, 2007), Greek waters extend only 6 nautical miles (≈11 km) from the coast making 8 km for the nearest turbine an acceptable compromise.

Three areas in the Aegean, Lemnos, Mykonos and Eastern Crete, (Fig.1) stand out for their excellent wind energy potential (Soukissian et al., 2020), so they were selected to be studied further to evaluate the potential installation of a floating wind. The feasibility analysis is based on the NPV, IRR, DPBP, LCOE, Cpower indices. For the investment to be economically viable, the minimum electricity price of 0.16509 €/kWh is considered while income comes from emission reductions with a rate of 50 €/tn $CO_2$ as per the European Commission.

Climate data for each location is determined using the "RETScreen Expert" (Natural Resources Canada) software, calculating the annual energy output, the installation cost, reduction in emissions and payback time for the investment. The wind mean speed was sourced from the Global Wind Atlas and the water depth from the "Navionics+" (Navionics s.r.l.) web page.

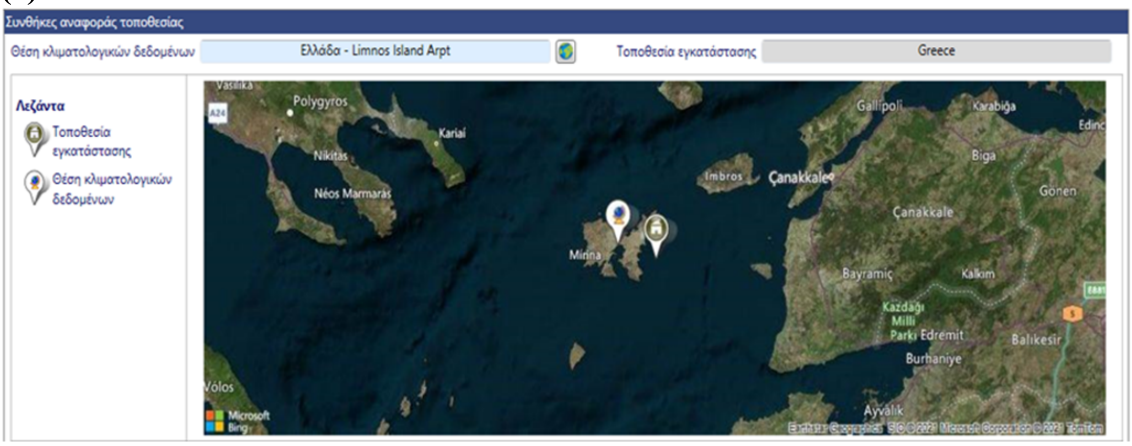
*5.2 Design parameters and arrangement*

The same installation was examined for each location, the only differentiating factor being climate characteristics and cabling concerns due to varying depth. The basic configuration of the farm consists of:

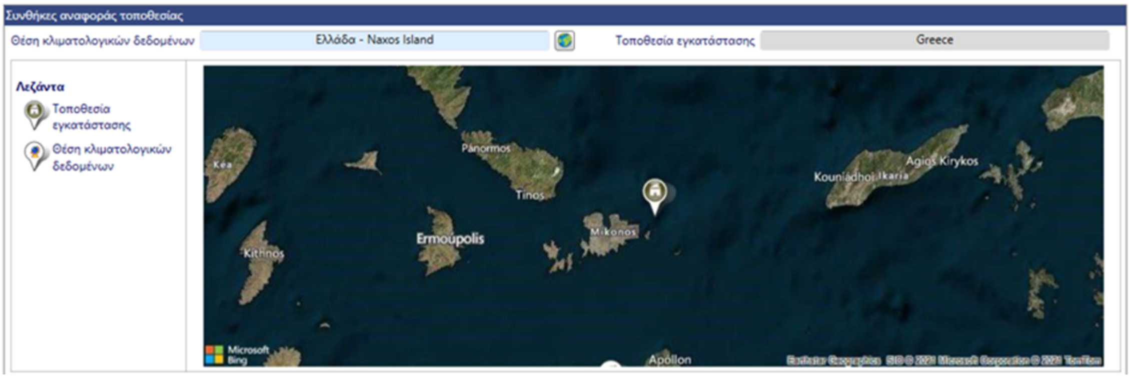
- 20 RE Power 5 M (5MW) turbines are considered with founding platforms being semi-submersible triangular floating structures (WindFloat concept) (Johannes, G., 2014).
- Rotor diameter is 126 m and total height reaches 95 m.
- Arrangement consists of 4 rows with 5 turbines each.

**Figure 1:** Location of the proposed wind farm in (a) Lemnos, (b) Mykonos and (c) Eastern Crete (Source: RETScreen Expert)

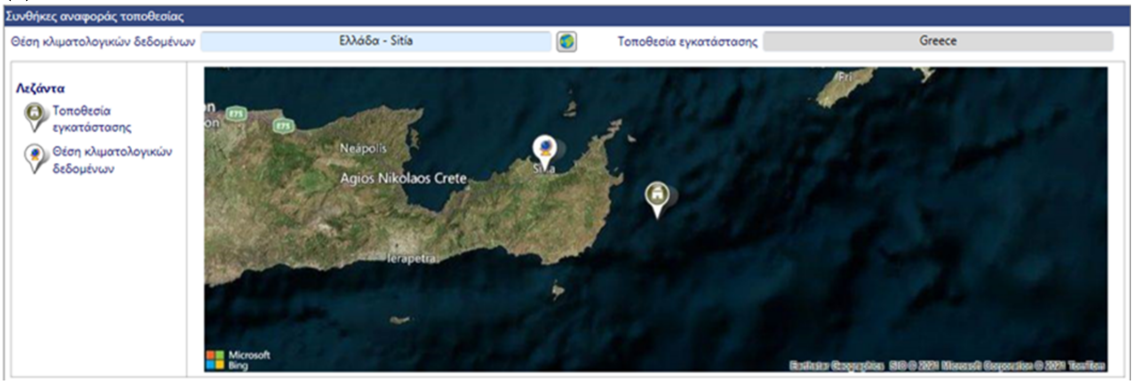
**(a)**



(b)




(c)




- The cut-out wind speed of the turbines is 25m/s (Jonkman et al., 2009), well above the average of 10m/s of wind speed that exists in the study areas.
- Ideal distance between turbines is determined at 882 m (Konstantinidis et al., 2014) making total area occupied by the installation 9.33 km$^2$.
- In addition, an offshore substation is placed 6 km from the shore on a similar foundation to the turbines.

*5.3 Comparison of the study areas*

It is important to mention that all results that were calculated were based on the considered electricity price. In the current study, a minimum electricity price was considered for the installation to be economically viable (0.16509 €/kWh). For that reason, these results could be very different if the current minimum electricity price for non-connected systems in Greece was considered (0.09945 €/kWh; law 3851, 4/06/2010).

Taking into account the Net Present Value (NPV) the optimal value presents for the study area of Crete (125,092,176 €), with the area of Mykonos following with a good value of 40,845,980 €, while in Lemnos the NPV is close to zero. Regarding the IRR, the optimal value still is for Crete (15.6%), followed by Mykonos (12.5%) and then Lemnos (7.3%). The soonest payback time is also for the area of Crete (10.5 years), followed again by Mykonos with 14.4 years and lastly Lemnos with 16.9 years.

The LCOE is smallest in the area of Crete (0.18 €/kWh) and largest in Lemnos (0.218 €/kWh) with Mykonos being in the middle with 0.204 €/kWh. Finally, considering the cost of power the results are reversed, with the smallest value in Lemnos (7,391,548.332 €/MW), followed by Mykonos (7,404,048.395 €/MW), and the largest value in Eastern Crete (7,444,987.2 €/MW). The above calculated variables are presented in detail in Table 1.

Taking all these results into account the most economically viable location in the Aegean for the installation of a floating offshore wind farm with a total power of 100 MW is the 3$^{rd}$ study area in Eastern

Crete, with a mean depth of 500m. On the other hand, the least favorable location is the 1st study area with a mean depth of 100m. All the three study areas are economically viable, and they can provide the electrical grid with an excellent amount of clean wind power.

The proposed wind farm in Crete for example covers 0.27% of the total energy consumption of Greece, equivalent to the needs of close to 30,000 residents. This means that 3 typical islands like Mykonos can become energy independent regarding the regular population, and the need for extra power in times of great tourist influx in the summer can be significantly reduced, paving the way towards an environmentally conscious way of producing energy in the Aegean.

**Table 1:** Location features and results of the feasibility analysis in each location

| Variable/Location | Lemnos | Mykonos | Eastern Crete |
|---|---|---|---|
| Water Depth (m) | 100 | 200 | 500 |
| Mean Wind Speed (m/s) | 8.92 | 9.39 | 10.52 |
| Power Factor | 40.2% | 43% | 49% |
| Annual power output (kWh) | 20,305,514 | 21,716,350 | 24,748,518 |
| Manufacturing cost (€) | 318,936,000 | 319,201,000 | 320,131,000.3 |
| Installation cost (€) | 269,168,890.9 | 270,154,412.3 | 273,323,258.3 |
| Exploitation cost (€) | 130,864,588.9 | 130,877,094.1 | 130,918,082.6 |
| Dismantling cost (€) | 15,865,353.41 | 15,852,333.11 | 15,806,379.11 |
| Total life cycle cost (€) | 739,154,833.2 | 740,404,839.5 | 744,498,720 |
| NPV (€) | 0 | 40,845,980 | 125,092,176 |
| IRR (%) | 7.3 | 12.5 | 15.6 |
| DPBP (years) | 16.9 | 14.4 | 10.5 |
| LCOE (€/kWh) | 0.218 | 0.204 | 0.18 |
| Cpower (€/MW) | 7,391,548.33 | 7,404,048.40 | 7,444,987.20 |

## 6. Examining the hybrid solution

The WindWaveFloat solution (Aubault et al., 2011) is proposed, using a base WindFloat platform and placing two OWCs, one on each column without a turbine. This solution is proposed for the current study. The OWC is constructed using 240 degrees around the column, avoiding the truss tubular (Aubault et al., 2011). These OWCs are part of a low maintenance solution that can be easily deployed and used in a floating platform compared to other WECs, using a unidirectional Wells turbine to generate electricity.

### *6.1 WEC Characteristics*

Overall, 40 floating OWCs are placed, two in each semisubmersible platform. Every OWC has a nominal power output of 400 kW with an operational width of 10 m. Therefore, the total additional power reaches 16 MW. A comprehensive techno-economical study for the considered platform has not yet been conducted, hence a precise determination of the OWCs' cost and power output contribution to the whole project cannot be accomplished. Nevertheless, because the WECs are part of the same structure it is not expected that they will add more than 20% to the construction cost as a rough estimate for additional steel needed for construction of the OWCs is not more than 300t; 12% of the total for a base WindFloat platform (2500t). Also close to 10% is expected to be added to the exploitation cost, based on a similar analysis by O' Sullivan (2014) which regards an array of multiple OWCs so in the present case should be even lower. For that reason, a compromising hypothesis is made for the current study that they add 15% to the total construction cost and 7.5% to the total operational cost. A more comprehensive analysis for the total added cost could yield even more favorable results for the combined platform as the technical know-how matures.

The displacement factor for these devices ranges from 25% to 40%; depending on the wave conditions. Additionally, from the operation of other similar OWCs it was deduced that they are operational for 60% of a year, or 5256 hours (Aubault et al., 2011). The wave conditions for each location were sourced from HCMR's "Poseidon" system.

*6.2 Analysis for each of the three study areas*

Between the three locations, as with the conventional wind farm, Eastern Crete is calculated to be the best value, in economic and energy terms. As can be seen in Tables 2 and 3, using OWCs to create a hybrid system adds additional output for little cost in every location while increasing marginally the LCOE. In the case of Eastern Crete though, the increase is minimal and through further optimization and streamlining of the manufacturing and operating processes as WEC technology matures, wind-wave hybrid systems can become of greater value in the foreseeable future.

## 7. Conclusions and Discussion

Floating wind farms are proven a realistic and viable step towards the emission reduction targets in Greece not least because they overcome the limitations arising from the deep waters in the Aegean Sea. Taking all the necessary factors and limitations into account, floating wind or hybrid farms are fully capable of exploiting the increased wind energy potential of the Aegean with a promising payback period of 10-17 years.

According to the above analysis, Eastern Crete is the optimal location in the Aegean for a floating wind farm installation, while also providing the best wave power potential of the three. All three locations provide for feasible investments that can help replace the current status quo of using hydrocarbon fuels for electric power in Greek islands and help reduce emissions while pushing these islands towards energy independence. Indeed, such an installation covers the annual energy needs of a typical island with a ~30,000 population representing the 0.3% of the energy needs of Greece.

**Table 2:** Wave data and contribution of WECs in each location

| | Significant wave height (m) | Wave period (s) | Device width (m) | Working hours (hrs) | E (kWh) | Total additional power output (kWh) |
|---|---|---|---|---|---|---|
| **Lemnos** | 0.7 | 4 | 10 | 5256 | 50,615.93 | 2,024,637.016 |
| **Mykonos** | 0.8 | 4.4 | 10 | 5256 | 72,721.66 | 2,908,866.244 |
| **Eastern Crete** | 0.9 | 4.8 | 10 | 5256 | 100,405.47 | 4,016,218.734 |

**Table 3:** Total cost and power output in each study areas

| | Total hybrid farm cost (€) | Annual hybrid farm output (kWh) | Cost increas e (%) | Annual output increase (%) | Wind farm LCOE (€/kWh) | Hybrid farm LCOE (€/kWh) |
|---|---|---|---|---|---|---|
| **Lemnos** | 796,810,077 | 22,330,151 | 7.24 | 9.07 | 0.22 | 0.24 |
| **Mykonos** | 798,100,772 | 24,625,216 | 7.23 | 11.81 | 0.20 | 0.22 |
| **Eastern Crete** | 802,337,226 | 28,764,736 | 7.21 | 13.96 | 0.18 | 0.19 |

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## Appendix

In Table 4 the life cycle for the 3rd study area in Eastern Crete is presented, in order to highlight the detailed approach of the methodology used. The tables from the other two areas are not presented for brevity purposes.

**Table 4:** The life cycle cost analysis for the 3rd study area (Eastern Crete)

| Costs | | Symbols | Value (€) | Cost | Value (€) |
|---|---|---|---|---|---|
| Concept and Definition | Market study | C11 | 100000 | **C1** | 4080000 |
| | Coefficient of Taxes | C12 | 100000 | | |
| | Wind farm design | C13 | 3880000 | | |
| Design and Development | | C2 | 240000 | **C2** | 240000 |
| Manufacturing | Turbines | C31 | 90000000 | **C3** | 320131000 |
| | Platforms | C32 | 77175000 | | |
| | Turbine platform | C3211pgenerator | 3675000 | | |
| | Substation platform | C3221psub | 3675000 | | |
| | Mooring | C33 | 3528000 | | |
| | Turbine platform mooring | C331 | 3528000 | | |
| | Substation platform mooring | C332 | 0 | | |
| | Anchoring | C34 | 21600000 | | |
| | Turbine platform anchoring | C341 | 21600000 | | |
| | Substation platform anchoring | C342 | 0 | | |
| | Electrical system | C35 | 127828000 | | |
| | Electrical cabling | C351 | 127043000 | | |
| | Substation | C352 | 785000 | | |
| Installation | Turbines | C41 | 248685.1852 | **C4** | 273323258.3 |
| | Port expenses for turbines | C41pa | 128685.1852 | | |
| | Turbine transport | C41transport | 0 | | |
| | Turbine installation | C41installation | 120000 | | |
| | Platforms | C42 | 8808685.185 | | |
| | Port expenses for platforms | C42pa | 7628685.185 | | |
| | Platform transport | C42transport | 780000 | | |
| | Platform installation | C42installation | 400000 | | |
| | Mooring and anchoring | C43 | 60000 | | |
| | Electrical system | C44 | 263605887.9 | | |
| | Electrical cabling | C44cable | 263280887.9 | | |
| | Substation | C44sub | 325000 | | |
| | Startup | C45 | 600000 | | |
| Exploitation | Taxation | C51 | 1143840 | **C5** | 130918082.6 |
| | Insurance | C52 | 5977742.583 | | |
| | Operation and Management | C53 | 121650000 | | |
| | Operation and Maintenance | C54 | 2146500 | | |
| | Precautionary maintenance | C541 | 23700 | | |
| | Repairs | C542 | 62160 | | |
| Dismantling | Turbines | C61 | 248685.1852 | **C6** | 15806379.11 |
| | Platforms | C62 | 8808685.185 | | |
| | Mooring and anchoring | C63 | 60000 | | |
| | Electrical system | C64 | 30000000 | | |
| | Cleanup | C65 | 300000 | | |
| | Components reselling | C66 | 23610991.26 | | |

# The GEORISK European project: Establishing risk mitigation schemes for geothermal projects

**Spyridon Karytsas, Ioannis Choropanitis, Theoni I. Oikonomou & Constantine Karytsas**
*Geothermal Energy Department, Division of Renewable Energy Sources, Centre for Renewable Energy Sources and Saving (CRES), 19009 Pikermi, Greece*
spkary@cres.gr, jchoro@cres.gr, thoikonomou@cres.gr, kkari@cres.gr

**Abstract**
Developing geothermal projects contains numerous elements of risk, with the most significant one being the geological resource risk, affecting primarily deep geothermal projects. Beyond the exploration phase, the performance and profitability of a geothermal project are threatened by this risk, which includes: (a) the short-term risk of not finding an economically viable geothermal resource and (b) the long-term risk of natural depletion of the geothermal resource.
Up till the drilling of the first borehole, project developers cannot be definite of the exact parameters of the planned geothermal project. After the first drilling has been carried out, tests and measurements reduce the geological risk and make it possible to attract external capital.
Geological risk is a common issue around Europe, with relevant insurance funds existing in a handful of countries. The GEORISK European project works on the establishment of risk mitigation schemes throughout Europe, focusing on covering the exploration phase and the first drilling. Hence, it deals with activities to be financed before the involvement of financial institutions and energy producers, which participate in the financing of the boreholes and surface systems that follow. The scheme that will limit the potential financial risk must be designed according to the degree of maturity of the market in question.
This study focuses on the development of a new risk mitigation scheme for Greece.

**Keywords:** Geothermal energy, geological resource risk, risk mitigation schemes.

**JEL Codes**: G32, Q42.

## 1. Introduction

The development of geothermal projects involves several elements of risk, the most important being the geological risk (also called resource risk). This risk mainly concerns high-temperature geothermal projects but also occurs in shallow geothermal systems. The geological risk includes a) the short-term risk of not finding an economically viable geothermal resource after drilling and b) the long-term risk of natural depletion of the geothermal resource, making exploitation economically unprofitable. The efficiency and profitability of a geothermal project are determined by the geological risk, which is a common issue throughout Europe. Some European countries (France, Germany, Iceland, the Netherlands, Denmark, and Switzerland) have already established risk mitigation schemes (RMS) (e.g. geothermal guarantees, risk insurance funds, capital grants) that allow project developers to transfer some of the geological risks to public bodies. With the notable exception of these six countries, those responsible for the development of geothermal projects have very little ability to manage this financial risk (Dumas et al., 2019).

There are three types of risk mitigations schemes; Public Schemes, PPP (Private-Public Partnership) Schemes and Private schemes. A legal basis (an act, an ordinance, or a decree) is generally present for a public scheme. For PPP schemes, publicly held banks or insurance firms are typically compelled by government or energy agencies to offer low-interest loans or loan guarantees, sometimes in collaboration with commercial privately-owned companies. In this case, the legal framework includes both corporate laws and banking regulations, as well as public laws. The legal and regulatory framework for a private scheme is defined by the articles of the organization, which stipulate that the private firm may engage in providing insurance solutions (Boissavy, 2021).

The GEORISK European project, funded by the H2020 programme, aims at establishing such RMSs throughout Europe, as well as in some key target third countries, to cover mainly the exploitation phase and the first drilling. The project duration is 36 months, having started in October 2018, with 15 participating partners from 8 different countries (France, Germany, Greece, Hungary, Poland, Switzerland, and Turkey). The project is coordinated by EGEC (European Geothermal Energy Council).

It is worth noting that the following countries, participating in the GEORISK project, already have existing RMSs available for geothermal projects: France, Germany, Switzerland, and Turkey. The remaining countries - Greece, Hungary, and Poland – do not have yet such a scheme. In these three target countries, the project partners have made significant efforts and have taken the necessary steps to initiate RMSs' development and establishment during the project duration.

This study focuses on the efforts made for the development of a new risk mitigation scheme for Greece and on presenting the steps to this direction and the progress made so far.

## 2. Risk assessment of geothermal projects

A significant step towards the development of a RMS is the exact definition of the type of risks that should be addressed, as different financial and insurance tools can be applied to cover the different identified risks. In this context, a workshop [organized in June 2019, see Calgano and Le Guenan (2019) for more details] and a targeted questionnaire [see Karytsas et al. (2021) for more details] were utilized to identify the potential risks threatening the Greek geothermal projects.

Three groups of geothermal reservoirs are taken into consideration, namely a) the shallow geothermal resources of Macedonia and Thrace Region, b) the deep sedimentary reservoirs, and c) the Aegean volcanic arc. The first two are located in sedimentary formations, whereas the last in volcanic rocks. The identified risks have been classified into three groups; socioeconomic risks, operational and geological risks, and drilling risks.

The geothermal resources in Macedonia and Thrace Region range from shallow to medium depths (0-2,000 m). According to the risk assessment, projects targeting at such depths pose medium-level risks. In terms of socioeconomic risks, financial uncertainty is viewed as the primary barrier to future development. It should be emphasized that such projects are heavily reliant on energy costs and available financial resources, while the regulatory framework may also be viewed as a risk to geothermal development. On the other hand, it appears that geological risks do not create serious risks, except for chemical composition concerns (i.e., the existence of aggressive chemicals in the water should be considered), as well as factors linked to the reinjection processes. According to the evaluation, drilling risks were rated as the least important, implying that they would not pose a significant threat to the development of geothermal projects.

The assessment of deep sedimentary reservoirs (2,000 - 5,000 m depth) reveals that risks are perceived to be medium and in any case greater than those of shallow-medium depths (Macedonia and Thrace Region). Concerning socioeconomic risks, the most common is social acceptance and political attitude, followed by a lack of clients, a lack of know-how, and suboptimal design quality. Moving on to operational and geological risks, the evaluation determined that the most critical aspects are fluid chemistry (potentially resulting in accelerated corrosion), the risk of not finding the expected geothermal resources (short-term resource risk), and the risk of surface leakages. Damage to the well/reservoir while drilling or testing, trajectory issues, wellbore instability and well casing collapse, technical failure of the equipment, and toxic emissions due to gases and fluids are all evaluated as medium-level drilling-related risks.

The Aegean volcanic arc extends from Nisyros and nearby islands to Santorini and Milos islands, and it extends inland in the Methana peninsula, Soussaki volcano, and further north with older extinct volcanoes. Because of the volcanic activity, its geothermal potential is very high, allowing power production. However, because there are presently no geothermal plants in operation, the evaluation of responders is based on exploratory data. Respondents stated that the development of geothermal projects in the region is impossible due to strong public resistance, which significantly impedes the launching of any new projects. Aside from this risk, another significant socioeconomic risk are changes in the legal and policy framework. At the same time, even though there is great potential for power production, the local infrastructure is inadequate to manage and transmit electricity to the mainland. Because of these challenges, geothermal energy development in the region has proven to be exceedingly challenging and, at this stage, requires government assistance.

More details on the assessment of the potential risks of Greek geothermal projects can be found in GEORISK's Del. 2.2 "Report on Risk Assessment" (Seyidov, 2019).

## 3. Developing a Greek risk mitigation scheme

Once the risks of the geothermal projects in Greece were identified, the next step was to develop a strategy for ensuring the engagement of all Greek stakeholders and together with them to develop and establish a new RMS for geothermal energy projects in Greece.

To accomplish the above, three national workshops were organised, where the Greek GEORISK partners – CRES (Center for Renewable Energy Sources and Saving) and PPC-RES (Public Power Corporation - RES) – presented GEORISK results, examined, and discussed with the attendees the existing RMSs in Europe and worldwide. Moreover, they worked on developing the legal, financial, and technical models of the RMSs for geothermal energy projects. The emphasis of these workshops was given on engaging the key stakeholders to the project, on creating cooperation with them on the development of appropriate RMSs for Greece, and on revealing the needed procedures for the establishment of the suitable scheme.

This section provides an analysis and synthesis of the key points and findings of the Greek technical workshops (Oikonomou et al. 2021). The main information of each Greek workshop is given in Table 1. The first workshop was a face-to-face meeting. It focused on the collection of the perceptions of participants regarding specific aspects of a possible RMS in Greece. The second and the third workshops were held online due to the Covid-19 pandemic. The objectives of the second Greek workshop were to present and analyse the GEORISK results, the Greek regulatory framework and strategies on geothermal projects, and case studies of geothermal applications in Greece. In the third Greek workshop, participants from CRES and the Greek Ministry of "Environment and Energy" participated. The objective of the workshop was to present the GEORISK results to the members of the Ministry and to discuss the suitable RMS for geothermal projects in Greece, based on the experience of mitigation schemes applied in the EU and worldwide.

**Table 1**: GEORISK Greek Workshops

| **Event title** | **1st Greek Workshop** | **2nd Greek Workshop** | **3rd Greek Workshop** |
|---|---|---|---|
| **Date** | 27th February 2020 | 16th June 2020 | 30th December 2020 |
| **Event organisers** | CRES | CRES | CRES |
| **Place** | Athens, Greece | Online | Online |
| **Participants No.** | 26 | 42 | 10 |

The main outcomes drawn from the three national workshops in Greece are the following:

Market – Technical aspects
- In Greece, there are 43 proven low-temperature geothermal fields and two high-temperature ones.
- The availability of exploration data is a factor of utmost significance, concerning the determination of the RMSs.
- Compared to other countries - such as Turkey, Italy, and Iceland - Greece is ranked in a low position in the exploitation of geothermal energy.
- It is important to receive funding to conduct research on a geothermal field potential. For the case studies that were presented in the 2nd workshop, the projects have received funding from the NSRF-National Strategic Reference Framework.
- Since investments for geothermal projects are capital intensive, there are difficulties in moving on with the relevant tenders, considering the lack of financial support during the research phase.

Identified risks
- The geothermal risk in high enthalpy fields is very high.
- The main issue in the case of deep geothermal projects (i.e. high temperatures) is the investment risk (initial cost, lack of financing tools, geological risk).
- An important risk in Greece is the social acceptance risk, perhaps in some cases (e.g. Milos, Nisyros) even more significant than the various technical risks; however, it is difficult to cover this type of risk through an RMS.

Legislation / policies
- The legislation on geothermal energy is being redesigned. The new Geothermal Law includes the provision of incentives, in collaboration with the Ministry of Development and Investments.
- The main Greek regulatory framework related to geothermal energy was presented during the second Greek workshop with emphasis on the new Law 4602/2019. The main innovations of this new law compared to the former ones are:
  - It is addressing to geothermal energy as a renewable energy source.
  - It categorises the geothermal fields according to their temperatures.
  - It distinguishes the proven geothermal fields from the unexplored ones.
  - It establishes contractual terms for geothermal projects.
  - Priority for the research and the monitoring of Greek geothermal fields is given to the researches of EAGME (Hellenic Survey of Geology & Mineral Exploration).
  - Financial incentives should be provided to promote the enhancement of geothermal energy in Greece, Article 14, refers to the establishment of these incentives.
- A corresponding RMS could be included in the legislative framework to reduce investors' uncertainty.

Suggestions for developing a risk mitigation scheme
- The aim should be to incorporate a RMS in the framework of the forthcoming geothermal tender calls. The Greek RMS should be tailored to the Greek market and should focus on the strengthening of the initial investment.
- The correlation between standard and expected risk should be evaluated, to establish RMSs compatible with the European market (in terms of state aid).
- The feed-in tariff of geothermal power production should be modified, to take into account the possible risks.

- The financial tools for high-temperature and low-temperature geothermal fields should be different.
- While developing the RMSs, it is important to take into account the type of applications that will be addressed (i.e., power generation, direct thermal applications), since they correspond to different investment costs. Hence, the appropriate tool for each application should be examined.
- Depending on the field [depth, region, application (shallow/ deep) available data], different parameters should apply for each RMS, as there are different risks. In addition, it is important to clarify if the scheme will cover "subsurface" or "above-surface" risks.
- Emphasis should be given to the research phase. However, geothermal projects' funding should be considered as a whole, in accordance with the operational aid (e.g. implementation of initial research financing, which will be reduced from the amount of operational aid).
- Since there are only two proven high-temperature geothermal fields (PPC-RES), priority should be given to unexplored fields, where the risk is higher. In low enthalpy, the risk is addressed through the researches of EAGME, while in high enthalpy fields the risk is undertaken by the investor. Even in the case of the proven geothermal fields, the success rate is regarded to be 90%, while in unexplored fields, research must be performed before making any reliable conclusions.
- It was suggested that PPPs could cover only cases of proven geothermal fields; in the cases of unexplored fields which have high risks, the private sector would not be possible to participate in the RMS.

The final step for the establishment of a RMS in Greece is the preparation of a specific proposal. Currently, CRES is preparing, in collaboration with the Greek Ministry of "Environment and Energy", such a proposal for a RMS in Greece, taking into consideration the risk assessment, the findings of the three workshops in Greece and the overall GEORISK project results.

## 3. Conclusions

The objective of this paper was to present the steps for establishing a risk mitigation scheme in Greece. Taking into account the risk assessment and the outcomes of the three workshops in Greece, CRES is preparing in collaboration with the Greek Ministry of "Environment and Energy" a specific proposal for a risk mitigation scheme. The proposed new mitigation scheme for Greece is tailored to the specific needs of Greece, as well as the maturity of the Greek geothermal market. To conclude, the establishment of the RMS is expected to be a pillar for the promotion of the geothermal energy sector in Greece.

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# Tracing the effects of the plastic bag levy on consumer behaviour in the case of Greece

**Georgios Maroulis[1], Charalampos Mentis[1], Dionysis Latinopoulos[2] & Kostas Bithas[1]**
[1]*Panteion University of Social Political Sciences, School of Economy and Public Administration, Department of Economic and Regional Development*
[2]*Aristotle University of Thessaloniki, School of Spatial Planning and Development, Faculty of Engineering*
georgios_maroulis@eesd.gr, x.mentis@eesd.gr, dlatinop@plandevel.auth.gr, kbithas@eesd.gr

**Abstract**
Plastic bags are consumed at an alarming rate on a global level while they also currently pose a significant environmental threat, especially concerning marine and coastal ecosystems, characterized by adverse implications for human health. The purpose of this study is to examine the effects of the plastic bag levy, introduced on January 1st, 2018 and further increasing as of January 1st, 2019, in Greece on the consumer behaviour. In this regard, a web-based survey was conducted on a national level resulting in 834 useful questionnaires in total. Our analysis results suggest that plastic bag consumption has diminished since the environmental levy took effect, though this decrease is mainly attributed to a shift towards pro-environmental behaviour on behalf of Greek citizens and less due to the environmental levy increase. In addition, the majority of consumers replaced plastic bags with more sustainable alternatives, whilst plastic bag demand considerably decreased by comparison of before and after the environmental levy implementation. This suggests that the use of both economic and non-economic measures can prove to be effective in drastically reducing plastic bag consumption along with its deleterious effects on the marine environment.

**Keywords:** Plastic bags, Plastic reduction, Plastic bag charge, Consumer behaviour, Behavior change intervention.

**JEL Codes**: D10, D80, Q50, Q58

## 1. Introduction

Sustainable development and sustainability as concepts are currently subjected to several threats at a global scale that already have and will continue to negatively affect societies and human beings. Our modern lifestyle is strongly based on the notions of consumerism, characterized by a plethora of needs constantly emerging as a result of the throw-away society. Plastics, and plastic bags especially, are abundantly produced worldwide acting as a representative of this particular way of living, whilst at the same time constituting an important environmental issue of global proportions due to the associated marine plastic pollution.

Marine litter and debris composed of plastic have adverse effects on marine biodiversity along with several marine and coastal ecosystem services, while public safety may also be under threat on account of a series of infectious diseases discovered in both marine species and humans due to marine plastic contamination and the process of biomagnification (Gregory, 1996; Derraik, 2002; Thompson et al., 2004; Ng and Obbard, 2006; Barnes et al., 2009; Fendall and Sewell, 2009; Ryan et al., 2009; Lozano

and Mouat, 2009). A multitude of research is currently carried out on the exact origins, deterioration procedure, and deleterious effects of plastics for human beings and ecosystems alike. Toward this effort and combined with the various mitigation strategies on marine plastic pollution and plastic waste, a great deal of resources and money have been spent on a global level. In particular, the effective management of plastic waste is associated with numerous challenges, taking into account that during 2015 approximately 60-99 million Mt (metric tons) of plastic waste and debris were produced worldwide (Lebreton and Andrady, 2019; Crowley, 2020), while almost 11.1 billion plastic pieces are scattered across the Asia-Pacific region, therefore, augmenting coral reefs' vulnerability to various diseases (Lamb et al., 2018).
Plastics are manufactured on the basis of non-renewable natural resources and are strongly associated with environmental pollution and potential human health hazards, as they are predominantly distributed along the coasts and ocean gyres in massive quantities (Bhuyan et al., 2021). Plastic bags (single-use mainly) are among the most prominent plastic waste items, traditionally based on the linear economy model, while their production process generates significant energy demands as well as energy losses regarding raw materials, thus, denoting their unsustainable consumption pattern across the world (OECD, 2011). The adverse economic and environmental implications of plastic waste and especially plastic bags, taking into consideration contemporary scientific evidence and data worldwide and coupled with the potential negative impacts on marine species and human health, have attracted a great deal of global attention, resulting in certain measures and precautions taken to reduce plastic consumption.
These measures entail partial or complete bans to plastic bag use, gradually phasing them out, and taxation along with environmental levies and fees. On certain occasions, a mixture of measures is often applied (bans according to μm - micrometers) (Rivers et al., 2017), promoting environmental awareness (Latinopoulos et al., 2018), recycling and waste management solutions, etc. (UNEP, 2018). Bearing in mind that over 7.5 billion people around the world depend on oceans for their survival and well-being (food, raw materials, regulating services, leisure and recreational services, etc.), the protection and conservation of the marine environment via drastically reducing plastic bag consumption has become of utmost importance (Steffen et al., 2011; Chatterjee and Sharma, 2019; Egessa et al., 2020; Bhuyan et al., 2021).
Our study aims to investigate the effects of applying this type of measures, particularly a plastic bag levy in the case of Greece introduced on January 1st, 2018, and further increased as of January 1st, 2019, on consumer behaviour. This study explores how this practice has affected consumer behaviour in relation to plastic bag demand along with examining the environmental attitude of Greek citizens regarding alternatives that are more sustainable/eco-friendly compared to plastic bags. Within the context of our research, we also trace whether the demand for plastic bags has been influenced by other factors besides the environmental levy. For this purpose, a web-based survey was conducted on a national level that resulted in 834 useful questionnaires in total.
In section 2, a concise literature review on relevant to this issue policies is presented. Section 3 refers to the survey's methods and presents the empirical results of the analysis. Section 4 is dedicated to the conclusions and explores certain implications for the future.

## 2. Literature Review

There has been a steady increase in the research regarding the effects and impact of the various plastic bags policies and measures on consumer behaviour at a global scale. In this regard, it would be useful to assort these policies according to the particular type of measures applied, i.e., taxation, environmental fee/levy, bans, legislative measures, and awareness raising campaigns.
In this sense, Convery et al. (2007) in Ireland, Dunn et al. (2014) in Logan, Utah (USA) along with Dikgang et al. (2012) in South Africa, Martinho et al. (2017) in Portugal and Sandalci (2019) in Turkey examined the effects of the plastic bag tax for each of their countries, respectively. In essence, the

taxation on plastic bags generated a substantial decline in plastic bag demand and consumption, whereas once consumers get accustomed to the price the policy tends to lose its momentum and effectiveness. In the case of plastic bags fees, He (2012) in China, Muralidharan and Sheehan (2016) in the USA, and Senturk and Dumludag (2021) in Turkey explored its efficiency as a more traditional type of measure. Based on their results it would be accurate to denote that environmental fees may prove to be reasonably successful in decreasing the use of plastic bags, whilst also shifting consumer behaviour toward re-usable solutions in an effort to avoid the fee.
Jakovcevic et al (2014) in Argentina and Poortinga et al. (2013) in the U.K. investigated the impact of charging for plastic bags, thus, revealing that consumers tend to bring their own bags for shopping in order to avoid the charge, whilst on several occasions this particular measure did not encourage people to change their shopping habits (plastic bag use) for the better. In reference to placing a ban on the single-use plastic bags, Gupta (2011) in India, Sharp et al. (2010) in Southern Australia and Santos et al. (2013) in Brazil concluded that for the most part consumers will bring their own bags for shopping or choose more eco-friendly solutions, but the ban may sometimes prove ineffective on account of insufficient inspection.
Lastly, awareness raising campaigns and environmental educations programs are revealed as rather promising measures for reducing plastic bag use while at the same time promoting environmental conservation. Based on Zen et al. (2013) in Malaysia, De Groot et al. (2013) in England, Kaplan et al. (2018) in the USA, Ohtomo and Ohnuma (2014) in Japan and Ari and Yilmaz (2017) in Turkey, it has been shown that information campaigns increase environmental awareness, therefore, shifting consumer behaviour toward reusable (bring your own bag) or more eco-friendly solutions for shopping. From this perspective consumers with a slightly increased environmental awareness were characterized by a lower sensitivity toward rising prices compared to the ones with a low level of environmental awareness.

## 3. Assessment of plastic bag use in the context of the environmental levy in Greece

### 3.1 Methods and empirical results

The research was based on a structured questionnaire and was carried out as a web-based survey applied to Greek consumers during the period October 2020- December 2020. In aggregate 834 responses were collected.
The focus of the survey was threefold. More specifically, it aimed at addressing three key issues:

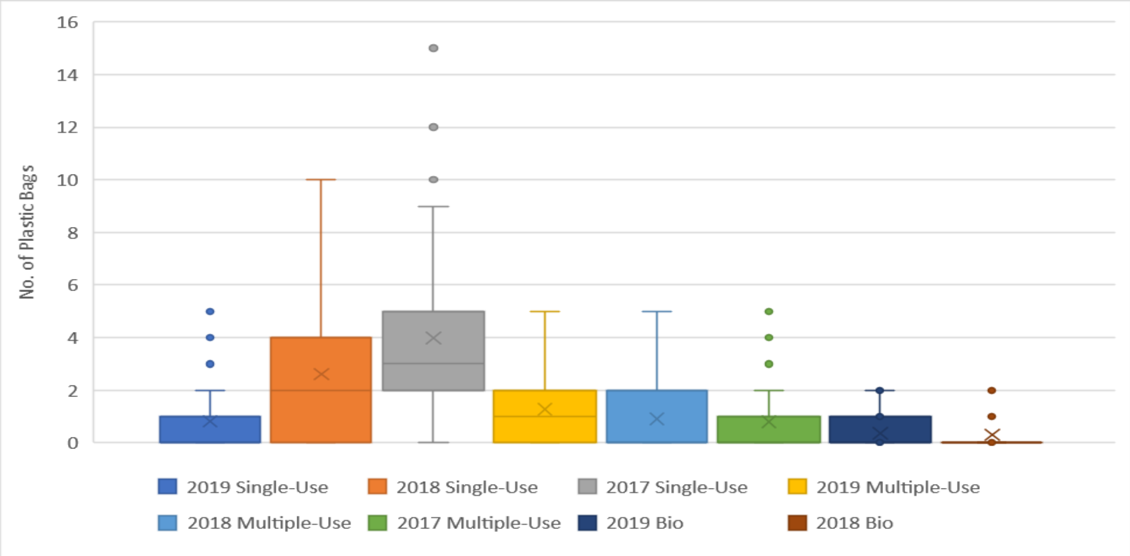
- to evaluate consumers' reaction regarding the policy of charging plastic bags (environmental levy) as of January 1st, 2018, that was further increased as of January 1st, 2019;
- the degree to which the policy affected consumers' habit of using plastic bags, degree of substituting single-use plastic bags with eco-friendly solutions and;
- Wtp for using (consuming) plastic bags (15-50μm, >50μm).

With regard to consumers' reaction regarding the policy of plastic bag levy, there was a uniform question concerning plastic bag use (15-50μm, >50μm and bio-degradable) in three distinct periods. The selection of these time periods was not arbitrary as it coincided with the imposition of levies on plastic bags. These were the following:

- After 01 January 2019, where an increased levy (0.09€) on plastic bags 15-50μm was imposed;
- After 01 January 2018, where a levy (0.04€) on plastic bags 15-50μm was introduced for the first time and;
- Prior to 2018.

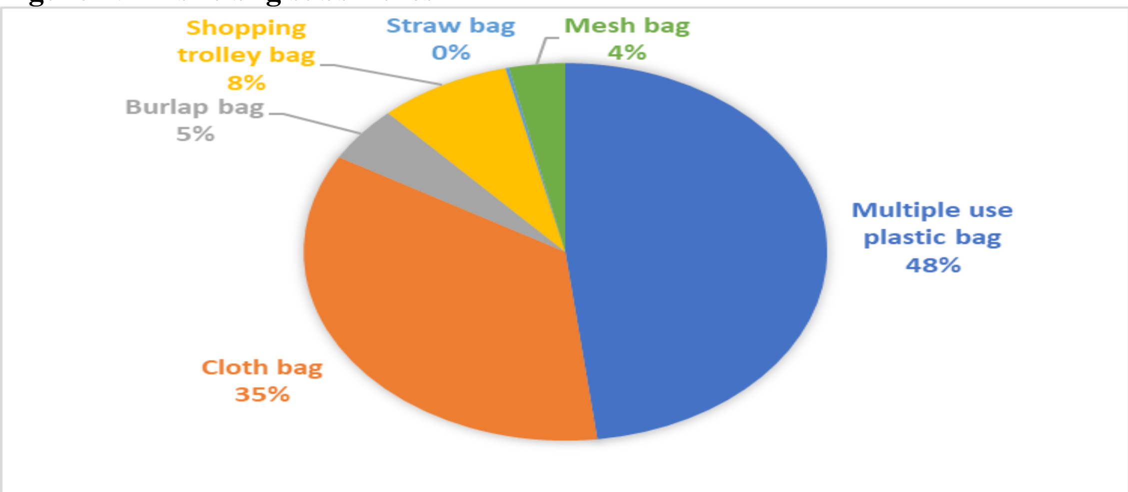
Regarding 2019 (Figure 1), plastic bag use has a downwards trend. Interestingly, a great proportion of the responders do not use any kind of plastic bag. More specifically, 461 responders do not use any lightweight plastic bags (15-50μm) (charged with a levy). There seems to be a preference towards multiple-use plastic bags (>50μm) as 326 responders do not use any of them. The maximum amount of all plastic bags does not exceed 6, as beyond that number, no significant use has been observed. Regarding 2018 (Figure 1), a similar trend can be observed. As of 2018, 216 responders have not used any lightweight plastic bags (15-50μm), almost half so many as in 2019. 425 responders have not used any multiple-use plastic bags (>50μm). This can be attributed to the fact that supermarkets have begun promoting these bags, as an alternative to lightweight plastic bags (15-50μm) from 2018 onwards, when the levy was first imposed. In 2018, the maximum amount of all plastic bags does not exceed 10. Figure 1 also depicts the situation prior to 2018. Lightweight plastic bags (15-50μm) were widely used (only 89 responders with zero use), while multiple-use plastic bags (>50μm) were not so preferred (485 responses with zero use).

**Figure 1: Plastic bag use (single-use, multiple-use, bio-degradable) for 2017-2019**




Concerning the single-use plastic bags substitutes, multiple use plastic bags and cloth bags were the main eco-friendly alternatives (Figure 2)

**Figure 2: Plastic bag substitutes**




In relation to Wtp for using plastic bags, Figure 3 and Figure 4 shows the responders' willingness for lightweight plastic bags (15-50μm) and multiple-use plastic bags (>50μm), respectively. It should be noted that in both cases the most frequent answer for plastic bags (350 for lightweight plastic bags 15-50μm and 279 responses for multiple-use plastic bags >50μm) was 0 € (I do not use any plastic bags).

**Figure 3: Willingness-to-pay (WTP) for a lightweight plastic bag (15-50μm)**

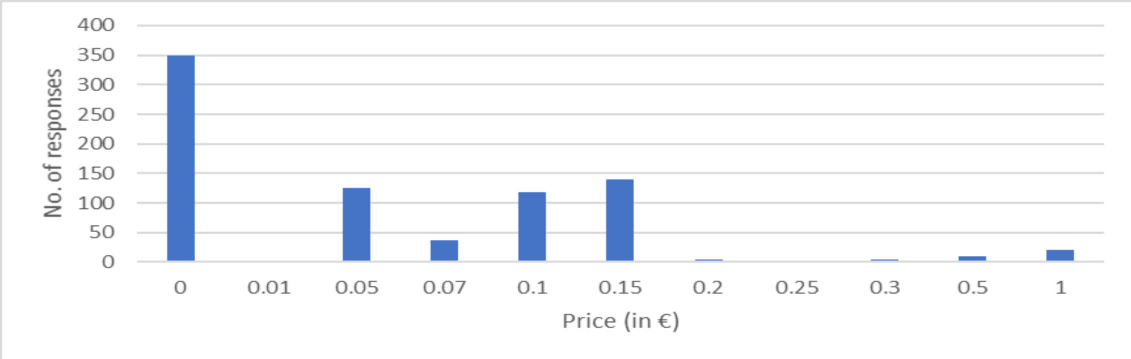
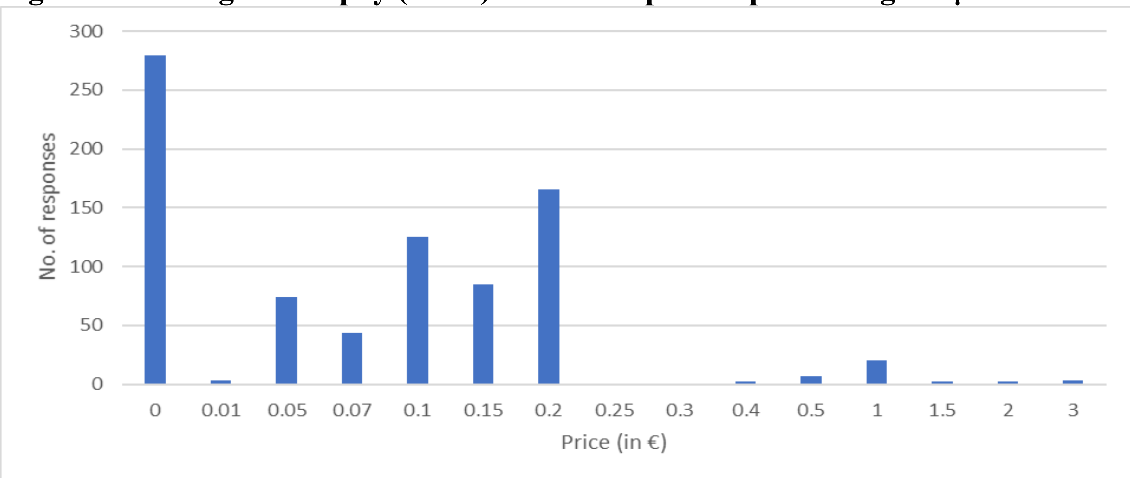
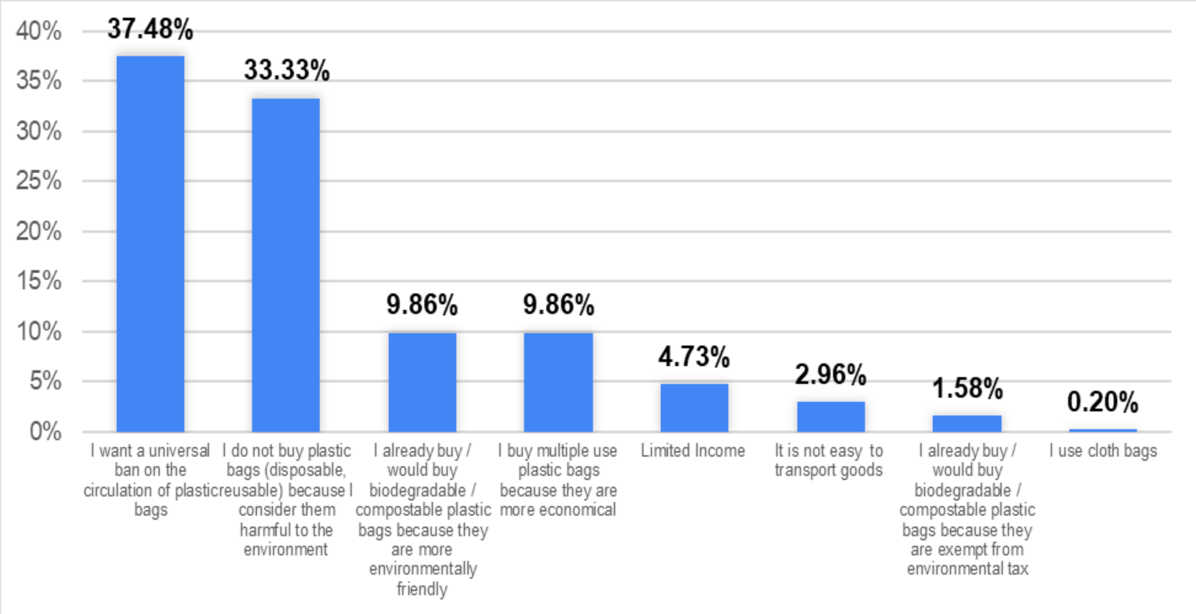



**Figure 4: Willingness-to-pay (WTP) for a multiple-use plastic bag >50μm**




The most frequent response for lightweight plastic bags (15-50μm) is 0.15€ (140 responses), above the existing levy of 0.09€, while for multiple-use plastic bags (>50μm) it is 0.2€ (166 responses).
As the number of responses "0 € (I do not use any plastic bags)" is very high, it is interesting to investigate, how the responders justified their option. The two most frequent responses are "I want a universal ban on the circulation of plastic bags" (190 responses) and "I do not buy plastic bags (disposable, reusable) because I consider them harmful to the environment" (169 responses). It is obvious that the main reason for not using any plastic bags are mainly environmental protection issues, rather than economic reason e.g., "limited income" received only 24 responses (Figure 5).

**Figure 5: Reasons for choosing 0€**




## 4. Conclusions and recommendations

The results of our analysis indicate substantial changes in consumers' behaviour regarding the use of plastic bags along with substitution of plastic bags with eco-friendlier solutions during their shopping. The environmental levy implemented since the 1st of January 2018 has been relatively successful, as plastic bag demand significantly decreased compared to the time period before its implementation. Nevertheless, this particular decrease in plastic bag use and demand may be also predominantly attributed to a shift on behalf of consumers toward pro-environmental behaviour. In this sense, this policy action may prove to be insufficient in further reducing plastic bag consumption as a stand-alone long-term measure.

The plastic waste problem is international, drastically deteriorating the marine environment on a global level. In this context, mitigations solutions should be based on combining economic and non-economic measures for maximum efficiency. Environmental policies with a main objective of reducing the use of plastic bags may be more effective when focusing on promoting and rewarding the "sustainable shopping" behaviour and lifestyle. In this respect, there is a strong need for measures that reinforce the feeling of responsibility through economic encouragements, though this type of incentives may also result in changes with regard to consumers' lifestyle which are ultimately temporary. For this purpose, pricing policies (economic measures) need to be supported with non-economic measures such as conducting awareness-raising campaigns, reinforcing public education, mechanical recycling, etc. (Latinopoulos et al., 2018; Lazarevic et al., 2010; Crowley, 2020).

**Acknowledgments**

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# Aspects of environmental policies in Athens in Classical times under an economics perspective

**George E. Halkos[1], Emmanouil M.L. Economou[2] & Nicholas C. Kyriazis[2]**
[1]*Operations Research Laboratory, Department of Economics, University of Thessaly*
[2]*Laboratory of Economic Policy and Strategic Planning (L.E.P.S.PLAN), Department of Economics, University of Thessaly*
halkos@uth.gr, emmoikon@uth.gr, nkyr@ergoman.net

**Abstract**
In this paper we present a series of environmental policies that were implemented in the city-state of Athens during the Classical times (508-323 BCE) under an economics perspective. We link these environmental policies to the provision of public goods and we argue that such goods proved to have been beneficial for the Athenian society as a whole. They basically included an efficient water management policy, the implementation of hygiene practices through a system of public baths in both a personal basis and as a collective opportunity for all the residents of the Athenian state, and furthermore, the implementation of a recycling process regarding animal manor and a waste management policy. Using a game theoretical approach we provide an economic assessment regarding the functioning of these institutions. Our results show that the success of these environmental institutions should be attributed to their effectiveness but also, and equally important, to the willingness of the people themselves to accept and adopt them through a spirit of a developing a consistent environmental awareness mentality.

**Keywords:** Environmental public goods, water management and hygiene, recycling and waste management policy, game theory, Classical Athens

**JEL Codes**: H41, I18, K32, N13, N53, Q53, Q58

## 1. Introduction

In this paper we present some aspects of a series of environmental policies that were implemented in the city-state of Athens during the Classical times (508-323 BCE) under an economics perspective. We link these environmental policies to the provision of public goods and we argue that such goods proved to have been beneficial for the Athenian society as a whole. They basically included: i) an efficient water management policy, ii) the implementation of hygiene practices through a system of public baths in both a personal basis and as a collective opportunity for allthe residents of the Athenian city-state iii) the implementation of a recycling process regarding animal manor iv) the implementation of an effective waste management policy.

Regarding the first issue, efficient water management policy, there is a vast bibliography in the field of *Environmental Economics* regarding the core issue of achieving a sustainable management of freshwater policies (see for example, van de Meene and Brown (2009) and Pahl-Wostl (2017)). This discussion is also related to the issues that are related to a destruction of a resource such as a lake or a river, what A.C. Pigou ([1920], 2002) in his seminal book, *The Economics of Welfare*, defined as a *negative externality*, a conceptual framework that was further expanded by other eminent authors such as Baumol (1972) at a later time. In fact *negative externalities* regarding the environment are an intertemporal problem that can be found in the core of the analysis of the modern *Environmental and Natural Resource Economics* (Halkos and Psarianos 2016).

Regarding the second issue, the implementation of hygiene practices that are related to satisfactory levels of health, this is also related to Environmental Economics: people cannot live well and economically thrive if the condition of the environment does not secure the basic precondition of leaving a healthy life, a least for the majority of a society's population. Pollution further is a deterrent to economic development (Halkos 2011).

The third issue that is analyzed in this paper is related to what we nowadays characterize as recycling processes. Effective recycling procedures are related to waste management, that is, the reduction of hazardous waste and environmental protection. Recycling procedures are further related to economic efficiency and growth (Shinkuma and Managi 2011). In sub-Section 4 we provide evidence for a profitable recycling procedure that the Athenians introduced and we link this finding with a game theoretical analysis which connects the Athenian environmental institutions to profitability prospects, that is, the collection and the recycling of garbage for making profit.

What we mainly describe in this paper is that the above environmental policies were implemented in Classical Athens, even if in a primitive way, and that their success should be attributed to the implementation of an efficient package of institutions that were specifically linked to environmental management policies. We further argue that the success of these institutions was further reinforced by the willingness of the people themselves to implement them. This issue is related to the development of an environmental conscience in a society.

Our paper is organized as follows: In Section 2 we describe the Athenian economy in brief. We think that this is necessary so that the reader can have a clearer picture regarding the Athenian economic institutions. This is important so as to better understand the logic through which the Athenians developed the sophisticated (for the era) set of environmental institutions that are described Section 3, in accordance to their economic implications. In Section 3 we primarily focus on the *koprologoi* and the *astynomoi* environmental institutions and the recycling policies and waste management procedures that were adopted by the Athenians. Section 4 concludes.

## 2. The Athenian economy in brief

During recent years, scholars have researched various aspects of the Athenian economy of the Classical period (508-323 BCE), showing its modern character and institutional set up in many areas. For example, Bresson (2016) among other authors, analyzed the structure of institutions and markets. Bresson (2016), Bitros et al. (2020) and Halkos et al. (2021) shed more light on the critical issue that, in actuality, the Athenian economy functioned as a primitive version of a market type of an economy where institutions such as the demand and supply mechanism, or public magistrates who protected the market against profiteering did truly exist. Bitros and Karayannis (2008) further analyzed the related issue of entrepreneurship in Athens under free market economy principles.

Furthermore, Economou and Kyriazis (2017) focused on the creation of an institutional set up in Classical Athens where property rights were protected and the validity of commercial contracts was backed up by law in case two traders ended up in court. Cohen (1992) in his seminal book the *Athenian Economy and Society: A Banking Perspective* futher analyzed exhaustively the sophisticated way banks functioned in Classical Athens. Acton (2014) among others, provided evidence regarding insurance services that were linked to the loans provided by the banks, for performing efficiently international commercial transactions. Acton further described the existence of a primitive version of joint stock companies. These companies were important for the promotion of the very extensive international commercial transactions between the city-state of Athens with other states and of course among Athens and her more than 300 allies in the Delian League during the Classical period (Bresson 2016; Harris and Lewis 2016; Woolmer 2016; Bitros et al. 2020; Halkos et al. 2021). This led its economy to achieve economic growth.

A very productive and extensive commercial network was established with Piraeus functioning as an international entrepot of her times. The Delian League functioned during the 478-404 BCE. Under it Athens had actually managed to integrate a large part of the East Mediterranean region into a unified area of economic cooperation. This was benefited and flourished by a network of parallel currencies being used of, where the famous Athenian drachma was the dominant one (Figueira 1998; Woolmer 2016; Bitros et al. 2020; Economou et al. 2021; Halkos et al. 2021).

Bitros et al. (2020) and Economou et al. (2021) further analyzed how decisions on public finance and public spending were taken by the two most important Athenian policymaking institutions, the Athenian Assembly of citizens (known as *Ecclesia*) and the *Council of the Five Hundred*[3] (known as *Boule*). Economou and Kyriazis (2019) argue that the process of transformation of the Athenian economy from an agrarian into a maritime economy during the Classical period lead also to "industrialization" in a variety of areas such as the development of primitive versions of small industries such as metalwork, the shipping industry silver mining, ceramics, carpentry, paints, fabrique, etc. and according to Halkos and Kyriazis (2010) all these procedures made Athens the first economy in history where "services" and "industrial" (handicrafts) sectors contributed more to (what we nowadays call) GDP than agriculture.

The above references consist only a small part of the international bibliography in the last 30 years that revisits the older, though influential, views of M. Finley (see e.g., Finley 1973, 1983) and his followers who argued that the Classical Athenian (and by extension ancient Greek) economy was characterized by primitive structures and organization and that it was "embedded" under the *substantivist* logic of Polanyi (1944) on social, political and religious aspects, meaning that it was not actually a market economy.

## 3. The provision of environmental public goods and services in Classical Athens

Bitros et al. (2020) provide interesting evidence regarding the issue of the partial provision of a series of public goods in Classical Athens, such as education, health, as well as to the full provision of public goods such as public buildings infrastructure and of course, defense. But due to space limitations we cannot reproduce this evidence here. Our purpose with this paper is to expand the findings of the above authors on four environmental goods and services that were provided as public goods in Classical Athens: water management, hygiene, fertilizing techniques as form of renewal energy resource and finally, waste management. To the best of our knowledge, this is the first time where this kind of research regarding Classical Athens is provided, from an *Environmental Economics* point of view.

### *3.1. Water management*

Water is an essential element of our lives, while modern medicine practices claim that the frequent use of clean water can improve our health, our physical condition, and even our appearance. The Athenians understood that water is of fundamental importance and central to the natural health and well-being of citizens.

For example, Plutarch (*Solon*, 23.5) informs us that the great law-giver Solon from the beginning of the 6th c. BCE had taken the following measure when water shortages appeared: since the area of Athens was adequately supplied with water, either by flowing rivers, lakes or rich springs, he instituted a law where there was a public well that everyone among the residents could use as a collective good. But if their homes were further away from the wells, they should have tried to obtain their own water by digging deep into the ground in their land properties and if they could not find water, they then had the right to use a jug of the size of almost 20 liters and twice a day to draw water from a local public spring.

[3] For the working of the two main political institutions in Classical Athens, the *Assembly* and the *Council of the Five Hundred*, see among others, the pivotal work of Hansen (1999).

According to our view, this information is important not only because it describes an established drinking primitive version of a water management procedure backed by law but also because it seems that Solon and the Athenians had in practice an idea, even if in a simplistic form, of how what we nowadays know as Hardin's (1968) *tragedy of commons* functioned in practice. And they had possibly understood the necessity of establishing an efficient system of water management exploitation which also determined their relationships with each other.

As it is very well-known, the *tragedy of the commons* is a situation in a shared-resource system where individual users, acting independently according to their own self-interest, behave contrary to the common good of all users by depleting or spoiling the shared resource through their collective action. If an effective cooperation and coordination mechanism is absent, this will lead to mis-exploitation or over-exploitation of a resource, e.g., a lake and this will finally lead to its exhaustion due to excessive consumption and misuse.

More recent studies such that of Ostrom's (1990) argue that Hardin's problem can be effectively solved providing that the many local communities that are related to the exploitation of a strategic resource, such a river or a lake, can cooperate under a commonly accepted set of rules which they all protect and respect. Another aspect of this is to establish efficient cooperation and coordination mechanisms so as to maximize and achieve an optimal level of exploitation of a source. This means that such mechanisms in order to flourish should be based on trust among those involved.

With a view to achieve an efficient system of water management the Athenians had further instituted the post of *epilemetes epi ton ydaton kai ton krunon*, a magistrate who required special knowledge with the duty to supervise the distribution of water and the cleanliness of the springs (Bitros et al. 2020).

We guess that it would have been almost impossible for him to supervise and ensure only by himself the fair distribution of water for all wells, fountains and springs throughout the polis. But from Aristotle (*Athenian Constitution*, 43.1) we learn that a number of guards were responsible for the proper daily use of the public springs and fountains. We guess that during the Classical times the post of *epilemetes epi ton ydaton kai ton krunon* was more related to ensure the technical perfection and functionality of the fountains. The guardians on their side were responsible for the fair distribution of the water among the citizens. In 333 BCE the Athenians awarded a gold wreath to Pytheus, an *epilemetes epi ton ydaton kai ton krunon* because he restored and maintained several fountains and aqueducts.

According to Koutsoyiannis and Mamassis (2015) who specified in the water supply system during (and even earlier than) Classical Athens, the Athenians developed a functional system of public water supply consisting of wells, fountains, and springs and there were also a number of private springs and wells. This infrastructure was built during the time of the tyrant Peisistratus and his sons and was further developed during the Classical Period.

What is also important to bear in mind is that the archaeological evidence has proved that the Athenian water supply system was further supported by a gutters system that reached a depth of up to 14 meters. Crouch (1994) and Koutsoyiannis, and Mamassis (2015) describe in detail the technical parameters of such a water supply system. The gutter system was constructed in sections, in various phases. This sounds logical as it was a very big project. It is enough to consider how much time and effort it takes when changes need to be made to the water pipes system in a modern town due to age, which means closing roads and entire urban complexes to traffic, etc. We consider the construction of a gutters system by the Athenians as a costly expenditure for providing a public good.

### 3.2. *Personal hygiene provided as a public good: The balaneia and the gymnasia*

Ensuring a high level of hygiene should be considered among the top priorities for societies that are characterized by strong economies. Especially now, with the current Covid-19 global pandemic, hygiene is of top priority in the agenda of politicians, policymakers, scientists and physicians specializing in epidemiology as a critical and successful precautionary measure to face the global pandemic. Of course hygiene is strongly related to having easy and regular access on bathroom infrastructure. Bathing, as a primary form of hygiene played a critical role in the lives of the Ancient Greeks as a whole, as attested by the archaeological findings regarding the construction of numerous bath buildings as well as frequent commentary on the baths by ancient authors from Homer onwards. This was true both at the level of personal hygiene and at the public level.

At the level of personal hygiene, the median house in Classical Athens had a bath. According to Gill (2008, 208-209) the earliest references to baths and bathing in Greece date to the 8th century BCE when Homer refers to the bathing of Homeric heroes in single tubs. Tubs have been found even in earlier periods, at Knossos, Mycenae, and Pylos during the Mycenaean Age period (1600-1100 BCE) which denotes that private bathing was an established social behaviour already existing at even much earlier times. References by Homer to hot baths appear in various passages in both the *Iliad* and the *Odyssey*.

In Athens as well as other Greek city-states during the Classical period, most of the houses had a bathroom with a small bathtub with a seat. But what is also very important is that the state also run public baths under a provision of a public good logic so as to secure the collective hygiene of citizens. In particular, those citizens and *metics* (alien residents, mostly Greeks from other city-states staying in Athens for work purposes) who did not enjoy a privilege of having a bath tub in their homes, from the 4th c. BCE could resort to public baths known as *balaneia*. Travlos (1971) who made a detailed study regarding the architectural constructions in Classical Athens and Gill (2008, 209-210) argues that by the mid–5th century BCE the *balaneion* (in singular), or Greek public bath, was well-established in Athens. Bresson (2007) adds that any citizen or a *metic* could take a comfortable bath with hot water for a small fee.

Thus, due to the very small price, the *balaneia* services should essentially be seen as a public good where, in reality, the Athenian state bore the substantial and the major part of the cost of operating these public infrastructures. The earliest of these urban baths dates to the mid-5th century BCE and is located outside the gate of Dipylon in the Kerameikos of Athens. In general, Greek baths can be found throughout the Mediterranean. They have been found at Olympia, Isthmia, Delphi, and Nemea, Corinth, Athens, Delos, Epidaurus, Messene and Olynthus and several other places in mainland Greece and elsewhere. They can also be found, among others, in Alexandria (Egypt) and Syracuse (South Italy).The *balaneia* were further expanded during the Hellenistic period (322-146 BCE) in Asia Minor and the Eastern societies due to the control of these areas by the Greeks under Alexander the Great.

Under the same logic with the public baths, the so-called *gymnasia* functioned. They were large athletic facilities which also provided baths, similar in philosophy to a modern fitness center. There were three public *gymnasia* (Academy, Lyceum, Cynosarges) where access was free to every free citizen or *metic* for taking a comfortable bath with hot water regardless of income and social class (Fisher 1998).

As a final comment, there is no doubt that the *balaneia* were also related to geothermal energy, which is a form of a renewable energy under modern standards This kind of energy was exploited by the Greeks as a mechanism for curing several body illnesses. Many thermal springs in the antiquity were exploited by the Greeks, and they are still being exploited nowadays for curative purposes, such as in Edipsos, in Methana, Pozar

### *3.3. Collective hygiene as a public good: The koprologoi and the astynomoi*

Regarding collective hygiene the Athenians had introduced laws that punished citizens who fouled the streets with any waste and sewage that was produced in their homes. In particular, in every of the Athenian neighborhoods any waste from cesspits and latrines, produced in each household had to be stored in a particular pit which also functioned as a statutory dump, placed just outside each household (Owens 1983: 44, 47).

The pits would then had to be emptied periodically and it was the owners' responsibility to ensure that this task was done, presumably by summoning the *koprologoi* a service being responsible for the collection and removal of sewage and the cleaning of the streets. Furthermore, defecating in the streets and in the Agora (the main Athenian marketplace) was severely punished with a fine imposed to them by the *astynomoi* (see below) (Owens 1983: 46). Essentially, the *koprologoi* were cesspool/sewage pickers who were responsible to empty the cesspools in each of the 139 municipalities of Athens (Lindenlauf 2004: 94).

There is no doubt that the Athenians imposed fines to the citizens or *metics* who polluted the streets because they had understood that non-compliance to hygiene measures, if becoming intense, could harm the collective hygiene not only in the microcosm of each separate neighborhood or a *deme* (municipality) but also in the society as a whole.[4] In a modern interpretation, the Athenians wanted to neutralize any kind of improper behaviour of citizens that could cause *negative externalities* (in environmental terms) in the society as a whole (under a Pigouvian logic).

The supervision of the cleanliness of the streets and the hygiene (environmental) behavior of citizens as a whole was assigned to a public service known as the *Ten Astynomoi*, each one originating from the ten Athenian tribes. They were elected by the Assembly of citizens for an annual year service. Half of them served in the city of Athens and the rest in the port of Piraeus. They had various duties regarding the cleanliness and maintain order on the streets. They among others, oversaw road maintenance and that the rubbish and dung collectors, that is, the *koprologoi*, did not drop their dung within ten *stadia* (approximately 1,85 kilometers) of the city wall (Cox 2007: 770). This means that the garbage was collected in a specific waste collection area which served as a place for collecting the total garbage of the city. Thus, in all probability, the Athenians were the first or one of the first societies ever where a waste management policy was implemented.

By both the ancient sources and their modern interpretations it is not absolutely clear if the *koprologoi* were either Athenian citizens who worked as private scavengers or public slaves instead, who acted as public sweepers under the direct supervision of the *astynomoi* (Cox 2007). However Owens (1983), Lindenlauf (2004) and Ault (2007, 263) persuasively argue that the *koprologoi* were in fact private scavengers. In other words, this shows a public-private partnership (*3P*) where the state outsources the private scavengers the cleanliness of the city essentially in the form of an agreement, which in the present era we could characterize as a public works contract with a private individual. *3P* practices are very well-known nowadays. This *3P* environmental cooperation procedure of the Athenians was not something unusual since the Athenians implemented similar kind of agreements in other cases too, such as tax collection through tax-farming, exploitation of the silver mines, the ship-building of warships known as *trierarchy* etc. Bitros et al. (2020) among others, provide extensive evidence on this.

As a final comment, Bresson (2007), an eminent historian on the economic organization regarding the Greek antiquity praises the system of personal hygiene of the Greeks to the point of arguing that the ordinary citizen of an ordinary Greek city would be able to give hygiene and cleanliness lessons to King Louis XIV of France and his court (17th AD). Bresson's view contradicts directly with Garland (1998) who describes hygiene conditions in Classical Athens almost as awful by wrongly arguing, for example, that due to the non-existence of an authority for cleaning the streets, garbage piled up on the streets in huge quantities, creating a terrible stench and posing a serious health hazard, especially during the summer months. But Garland does not provide any further evidence as to why he reached to such an unjustified view.

### *3.4. Fertilizer as a primitive form of a renewable energy resource*

Another important aspect regarding the institution of *koprologoi* is that it can be linked to what we nowadays characterize as recycling and renewable energy resources practices. Nowadays the following categories are considered as renewable resources: solar energy, wind energy, hydro energy, tidal energy,

[4] The city-state of Athens was organized into 139 separate *demes* where free citizens, *metics*, slaves and their families were living in out of a population of 250-300,000 inhabitants for the 5th century and 270,000 to 300,000 inhabitants for the 4th century (Hansen 1999).

geothermal energy and biomass energy. What we will describe here, we think that it is more closely related to the biomass.

In particular, from literary sources we know that the *koprologoi* were able to reach profit by recycling and selling waste materials, mainly the dung of the animals (known as *kopros* or *kopron(es)*) that was collected by them in the streets of Athens, then recycled and then sold as a fertilizer. In fact, this was a very profitable activity for them (Ault 2007, 263). This was a practice that was taking place not only in Athens but also in many other city-states of the time such as Larissa, Olynthus and the island of Thasos among others.

This is related to one of the first (or perhaps the first) recycling processes in recorded history and to one of the first (or perhaps the first) waste management policies. Waste was collected under a *3P* method of cooperation as described above instead of the collection procedure to be a matter of personal responsibility of each Athenian house separately.

## 4. Concluding remarks

This paper is an attempt to link some of the economic aspects of the environmental issues through their historical diastasis. With this paper we described, in a connective way five environmental issues: i) water management policy ii) hygiene measures both as a personal and a collective behavioural procedure iii) hygiene environmental auditing institutions, such as (mainly) the *koprologoi* and the *astynomoi* iv) we also raised the issue of geothermal energy regarding the bathing techniques as introduced in Ancient Greece v) a fertilizing technique and recycling practices as a form of renewable energy practice vi) waste management policy.

Furthermore, we argued that efficient environmental policy measures, in order to flourish require, not only robust, functional and enforceable environmental institutions introduced by the state authorities, but also environmental awareness by the majority of the member of a society as well.

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# Recycling of "Waste of Electrical and Electronic Equipment": an Exploratory Data Analysis

**Christos Liotiris & Zacharoula Andreopoulou**
*Forest Informatics Laboratory of the Department of Forestry and Natural Environment, Aristotle University of Thessaloniki*
liotiris@for.auth.gr, randreop@for.auth.gr

**Abstract**
Given the pace and scale of Waste of Electrical and Electronic Equipment (WEEE) generation globally, countries are called upon to tackle their management as drastically as possible in order to maintain the viability of ecosystems. Proper implementation, application and enforcement of EU waste legislation are among the key priorities of EU environmental legislation and policy. In their support, the European Commission has carried out, compliance promotion initiatives to assist Member States with the implementation of EU waste legislation. The complexity of dismantling and recycling, as well as the various hazardous substances in WEEE, constitute a frightful threat to the environment and human health. Subsequently, the EU revised its WEEE legislation to address these challenges more adequately. As a result, Directive 2012/19/EU (WEEE2 Directive) repealed the first WEEE Directive and entered into force in 2012. This paper deals with the screening of WEEE management operations in EU, in terms of technical content and ability to reach the targets of the WEEE2. In addition, a more detailed report on recycling indicators published by the Eurostat, will be based on an Exploratory Data Analysis. Finally, the overall aim of this study is to gain maximum insight into the data and understanding its underlying structure through graphical representation.

**Keywords:** Waste of Electrical and Electronic Equipment, Recycling, European Union (EU), Eurostat, Exploratory Data Analysis.

**JEL Codes**: Q00, Q53.

## 1. Introduction

The European Union, in 2003 published the Directive 2002/96/EC enforcing all European countries to meet some targets concerning the recycling and recovery of WEEE. The purpose of this Directive is, as a first priority, the prevention of waste electrical and electronic equipment (WEEE). In addition, the reuse, recycling and other forms of recovery of such wastes, so as to reduce the disposal of waste. It also seeks to improve the environmental performance of all operators involved in the life cycle of electrical and electronic equipment, e.g. producers, distributors and consumers, and in particular those operators directly involved in the treatment of WEEE (European Parliament, 2003). In accordance with this Directive, among other terminologies and concepts, it is defined as:

***'electrical and electronic equipment'** or **'EEE'** means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current;*

***'waste electrical and electronic equipment'** or **'WEEE'** means electrical or electronic equipment which is waste within the meaning of Article 1(a) of Directive 75/442/EEC, including all components, subassemblies and consumables which are part of the product at the time of discarding'.*

Moreover, in this Directive are defined the **EEE categories** set out in Annex IA and they are:

1. **Large household appliances** 2. **Small household appliances** 3. **IT and telecommunications equipment** 4. **Consumer equipment** 5. **Lighting equipment** 6. **Electrical and electronic tools (with the exception of large-scale stationary industrial tools)** 7**. Toys, leisure and sports equipment** 8.

**Medical devices (with the exception of all implanted and infected products)** 9**. Monitoring and control instruments** 10**. Automatic dispensers**

In 2012, the European Union published the Directive 2012/19/EU which is a recast and evolution of Directive 2002/96/EC. This Directive lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste from electrical and electronic equipment (European Parliament, 2012). According to this Directive, from 15 August 2018, the EEE falling within the categories set out in Annex I of Directive 2002/96/EC, have been classified within the categories listed in Annex III of Directive 2012/19/EU and they are:
1. **Temperature exchange equipment,** 2. **Screens, monitors, and equipment containing screens having a surface greater than 100 cm$^2$**, 3**. Lamps,** 4**. Large equipment** (any external dimension more than 50 cm) including, but not limited to: Household appliances; IT and telecommunication equipment; consumer equipment; luminaires; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure and sports equipment; medical devices; monitoring and control instruments; automatic dispensers; equipment for the generation of electric currents. This category does not include equipment included in categories 1 to 3, 5. **Small equipment** (no external dimension more than 50 cm) including, but not limited to: Household appliances; consumer equipment; luminaires; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure and sports equipment; medical devices; monitoring and control instruments; automatic dispensers; equipment for the generation of electric currents. This category does not include equipment included in categories 1 to 3 and 6, 6. **Small IT and telecommunication equipment** (no external dimension more than 50 cm).

Last but not least, Solving the E-waste Problem (StEP) Initiative is a network of e-waste experts and a multi-stakeholder platform for designing strategies that address all dimensions of electronics in an increasingly digitized world. The independent Initiative applies an integrated and science-rooted approach to create salient solutions to global e-waste challenges throughout the entire lifecycle of electronics (United Nations, 2014). According to StEP Initiative:
"*E-waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use"*
It is important to point out that the definition includes all types of EEE, as there is no room for regional variance or preference in a global definition.

## 2. Literature Review

WEEE belongs to the fastest growing waste stream in the world, with an increase from 33.8 Mt in 2010 to 53.6 Mt in 2019 and an expected amount of about 75 Mt by 2030. The growing amount of e-waste is mainly fueled by higher consumption rates of EEE, short life cycles, and few repair options (Forti et al., 2020). Notwithstanding the fact that during the use, collection, treatment and disposal of such waste, products may release hazardous substances such as lead, mercury and cadmium, which can cause major environmental and health problems (European Parliament, 2011). On the other hand, e-waste has been found to entail a number of valuable materials such as iron, copper and aluminium, and precious metals including silver, gold, platinum and palladium (UNEP, 2011; Baldé et al., 2015).

Over the past decade, only a small portion of the global scientific community has diligently devoted itself to the analysis of recycling data. With the aim of scanning for aberrations in the WEEE recycling indicators, Wang et al. (2013), proposed an advanced multivariate Input-Output Analysis which is able to prepare better datasets for modelling. According to Kumar et al. (2017), a linear relation was found between the Gross Domestic Product (GDP) of the countries and the amount of e-waste generated, while Arbulú et al. (2015) analyzed the relationship between Municipal Solid Waste generation, per capita income and tourism using the framework of the Environmental Kuznets Curve (EKC) hypothesis. Therefore, it is obvious that has not been placed particular emphasis to the exploration of WEEE recycling indicators. So as, this paper aims to fill this gap by conducting an

Exploratory Data Analysis (EDA) of the waste category "Total waste", using state-of-the-art technologies of Machine Learning, in order to build better datasets for further modelling and understanding their underlying structures.

## 3. Methods and Data

In order to analyze the WEEE recycling indicators of the present work have been used the fundamental techniques of Exploratory Data Analysis, while data have been retrieved from Eurostat (Eurostat, 2021). The programming language used is Python and the code development was implemented using the Jupyter Notebook. Below is a brief description of both.

**Exploratory Data Analysis (EDA)**

In 1977 EDA was promoted by John Tuckey to encourage statisticians to explore the data by identifying glaring errors, detecting outliers, discovering the relations between the variables and understanding the patterns within the data (Tukey, 1977). Also, he mentions in his book that:

*"Exploratory data analysis is detective work--numerical detective work--or counting detective work--or graphical detective work".*

EDA brings to light hidden motifs about the content without making any underlying assumptions. This is why data scientists use this process to understand what type of modeling and hypotheses can be formulated. Crucial components of exploratory data analysis include summarizing data, statistical analysis, and visualization of data (Mukhiya & Ahmed, 2020).

**Jupyter Notebook**

It is an open-source web application that allows data scientists to create and share codes, documents or even comprehensive reports. In summary, it is a powerful and versatile online notebook wherein code can be developed, data can be visualized, and the results-outputs can be analyzed without leaving the environment (Jupyter, 2021). Also, Jupyter system supports over 100 programming languages (called "kernels" in the Jupyter ecosystem) including Python, Java, R, Julia, Matlab, Octave, Scheme, Processing, Scala, and many more. For the project of this paper was used the IPython kernel (Python 3.8).

## 4. Empirical Results

Graphics are so central to EDA because the rich information they provide, is unrivaled in its ability to detect data patterns. Visual examination is the best way to discover the 'wholly unanticipated' (Tukey, 1980). So, let's jump to the EDA process.

Initially, the libraries must be imported that will be needed to conduct EDA. These libraries are: **Pandas** is a widely-used data analysis library providing numerous functions and methods to work on tabular data, **NumPy** is a fundamental package for scientific computing with Python, **Matplotlib** is a plotting library which produces quality figures in a variety of hardcopy formats and **Seaborn** is also a plotting library that is built on top of matplotlib and allows to create attractive and informative statistical graphics. Also, **warnings** library is used to ignore all the warnings during the interpretation and **%matplotlib inline** makes plot outputs appear and stored within the Notebook.

**Figure1:** Dataframe's structure of *'Waste collected.csv'*

| | Countries | Country code | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | European Union - 27 countries (from 2020) | EU-28 | NaN | NaN | 6.91 | 6.90 | 6.74 | 6.86 | 6.68 | 7.26 | 8.00 | 8.43 | 8.90 |
| 1 | European Union - 28 countries (2013-2020) | EU-27 | NaN | NaN | 7.00 | 7.06 | 6.88 | 6.96 | 6.86 | 7.63 | 8.87 | 9.04 | 9.34 |
| 2 | Belgium | BE | 8.32 | 9.54 | 9.69 | 10.42 | 10.49 | 10.79 | 10.38 | 10.51 | 11.27 | 10.90 | 12.10 |
| 3 | Bulgaria | BG | 5.39 | 4.49 | 6.09 | 5.50 | 5.26 | 4.84 | 5.86 | 8.64 | 8.63 | 7.70 | 7.49 |
| 4 | Czechia | CZ | 4.36 | 5.57 | 5.06 | 5.28 | 5.11 | 5.16 | 5.57 | 7.04 | 10.13 | 10.07 | 8.76 |

After this, data will be loaded and read from four different csv files into 4 dataframes. In the output (Figure 1) the first two columns refer to the countries of the European Union. The first one, which has the full names, can be dropped and the second one, which consists of the abbreviations of the countries, will be kept. The remaining columns refer to the years from 2008 to 2018 and contain numbers, mostly decimal. Furthermore, there are empty cells, entries with NaN values, which is a common issue in data analysis. Before any action or change is made to the datasets, copies of the dataframes will be made, so as, the initial datasets will be kept intact and secure.

**Figure 2:** Missing values of **'**Waste collected.csv' and **'**Recycling rate.csv'

Missing values of: **Waste Collected**

| | Missing Values | Percentage |
|---|---|---|
| 2018 | 4 | 12.121212 |
| 2008 | 4 | 12.121212 |
| 2009 | 3 | 9.090909 |
| 2017 | 1 | 3.030303 |
| 2016 | 1 | 3.030303 |
| 2010 | 1 | 3.030303 |
| 2015 | 0 | 0.000000 |
| 2014 | 0 | 0.000000 |
| 2013 | 0 | 0.000000 |
| 2012 | 0 | 0.000000 |
| 2011 | 0 | 0.000000 |

Missing values of: **Recycling rate**

| | Missing Values | Percentage |
|---|---|---|
| 2008 | 21 | 63.636364 |
| 2009 | 11 | 33.333333 |
| 2018 | 5 | 15.151515 |
| 2011 | 3 | 9.090909 |
| 2010 | 3 | 9.090909 |
| 2017 | 2 | 6.060606 |
| 2013 | 2 | 6.060606 |
| 2012 | 2 | 6.060606 |
| 2016 | 1 | 3.030303 |
| 2015 | 0 | 0.000000 |
| 2014 | 0 | 0.000000 |

Before analyzing the percentage and the number of missing values, it must be mentioned that Eurostat characterizes them as "unavailable values". The real-world data often has a lot of missing values. The cause of missing values can be data corruption or failure to record data. The handling of missing data is very important during the preprocessing of the dataset, as many Machine Learning algorithms do not support missing values. Therefore, missing values can be handled by deleting the rows and the columns having null values or can be replaced with the mean, median, or mode of the remaining values in the column (only for numeric continuous values). In this case, given that the datasets are too small and deletion will lead to the loss of a lot of meaningful information, missing values will be replaced and not deleted.

The fact that the entries of some countries are empty, indicates that they either did not have any recycling activity at that time or simply they did not notify Eurostat about their recycling data. Taking into consideration the fact that i.e. a country did not recycle for two years and these two entries were fulfilled by the mean value of the columns (recycling mean value of the year), then this dataset contains incorrect data which might lead to wrong estimations when the prediction algorithms of Machine Learning will be applied on. In any case, these NaN values will be replaced with zeros and the index of the dataframes will be set using the Country code column.

In both datasets, as is shown in Figure 2, there are 12% and 15% of missing values respectively in the year 2018, which is quite a high percentage, given that European legislation is particularly strict in terms of data collection, especially in the last 5 years. The highest percentage of missing values is 63% and it is presented in the Recycling rate dataset. This large number of null values can be explained taking account of the fact that the European directive on the management of WEEE, has been transposed into national legislation of the countries from 2010 onwards.

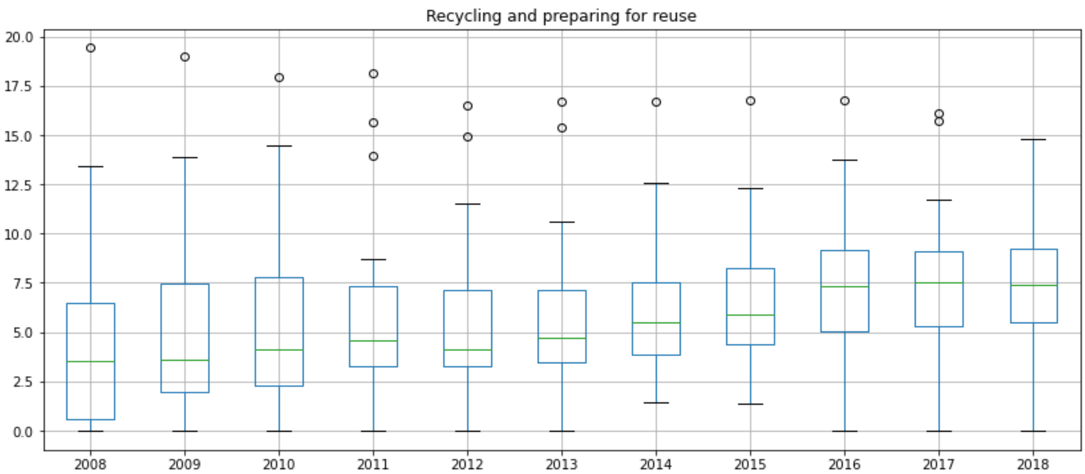
**Figure 3:** Descriptive statistics of *'Recycling and preparing for reuse.csv'*

Descriptive statistics of: **Recycling and preparing for reuse**

| | count | mean | std | min | 25% | 50% | 75% | max |
|---|---|---|---|---|---|---|---|---|
| 2008 | 33.0 | 4.449394 | 4.463209 | 0.00 | 0.58 | 3.52 | 6.49 | 19.42 |
| 2009 | 33.0 | 4.930909 | 4.237543 | 0.00 | 1.94 | 3.60 | 7.44 | 18.96 |
| 2010 | 33.0 | 5.230909 | 4.019918 | 0.00 | 2.29 | 4.10 | 7.77 | 17.97 |
| 2011 | 33.0 | 5.582121 | 4.075489 | 0.00 | 3.26 | 4.59 | 7.33 | 18.12 |
| 2012 | 33.0 | 5.406970 | 3.613417 | 0.00 | 3.28 | 4.12 | 7.17 | 16.48 |
| 2013 | 33.0 | 5.563636 | 3.610716 | 0.00 | 3.44 | 4.70 | 7.16 | 16.68 |
| 2014 | 33.0 | 6.019697 | 3.200159 | 1.41 | 3.84 | 5.47 | 7.52 | 16.71 |
| 2015 | 33.0 | 6.529394 | 3.239352 | 1.36 | 4.40 | 5.87 | 8.24 | 16.77 |
| 2016 | 33.0 | 7.220303 | 3.526346 | 0.00 | 5.01 | 7.34 | 9.19 | 16.74 |
| 2017 | 33.0 | 7.560303 | 3.373536 | 0.00 | 5.32 | 7.55 | 9.09 | 16.14 |
| 2018 | 33.0 | 7.079091 | 3.605360 | 0.00 | 5.48 | 7.42 | 9.26 | 14.78 |

At this point, after the changes were made, each dataset consists of 33 rows and 11 columns (shape of the datasets), while the data type is float64. In addition, descriptive statistics (Figure 3) provides useful information such as min, max, etc. Also, there are observations that appear to be far away and diverge from an overall pattern in the dataset (Figure 4). These observations are called outliers. Outlier is a common terminology by data scientists and need close attention otherwise it can result in wildly wrong estimations. Furthermore, the ideal way to tackle them is to find out the reason of having these outliers. The method to deal with them would then depend on the reason of their occurrence. Causes of outliers can be classified in two broad categories: 1. Artificial (Error)/Non-natural and 2. Natural. Since our datasets contain real-world data, the outliers are categorized as Natural. In more specific terms, the outliers of this project represent particularly high values for waste management operations and recycling, which means that some European countries recycle much more than others and even more properly. Due to the aforementioned factors, none of the outliers will be removed, as they constitute valuable information for the present research.

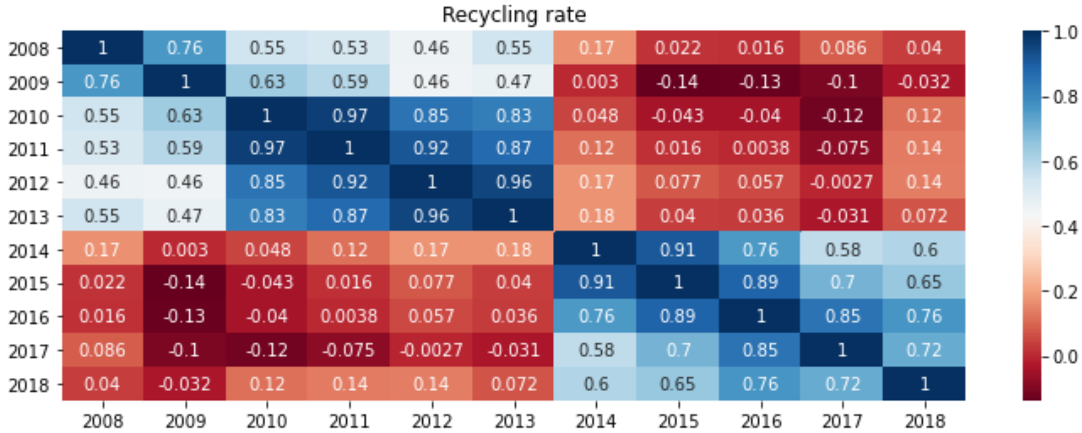
**Figure 4:** Detecting outliers (Boxplot)




The rate of recycling is particularly interesting in this area and has been a decisive factor for the implementation of this analysis, because it presents exactly how recycling is evolving in the European Union. Therefore, using the Correlation heatmap which represents the correlations between different variables, beneficial insights of the correlations between the years will be gained. In Figure 5, the heatmap is divided into 4 almost identical squares. This means that the years from 2008 to 2013 are strongly correlated as well as the same with the years from 2014 to 2018. As the recycling rate has started to increase since 2014, reaching its maximum value in 2015, it is crystal clear that the European

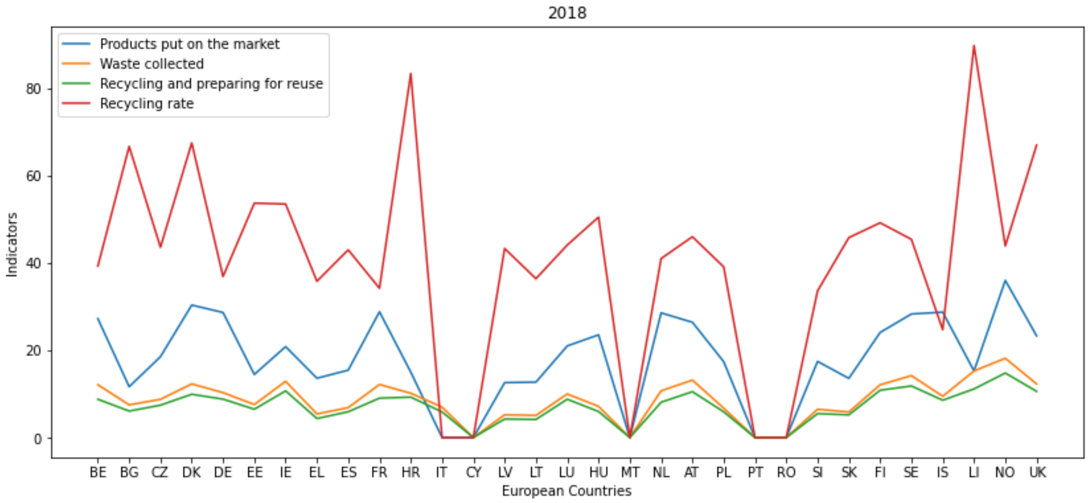
Member States are faithfully following the European Union guidelines for the management and recycling of WEEE.

**Figure 5:** Correlation Heatmap




Last but not least, in the line-plot of Figure 6, are represented the waste management operations of the European countries for the year 2018: 'Products put on the market', 'Waste collected' and 'Recycling and preparing for reuse', as well as the 'Recycling rate'. In 'Products put on the market' the mean value is 17,96 and the maximum is 36,01. In 'Waste collected' and 'Recycling and preparing for reuse' the mean values are 8,57 and 7,07 while the maximum values are 18,16 and 14,78 respectively. According to the above-mentioned values, 78% of waste was recycled or processed to be reused from the total number of e-waste collected in the year 2018, which is particularly promising for the future of recycling and consequently for humans and the environment. Furthermore, in the EU, the WEEE collected in year 2018 was estimated at 8.9 kg per inhabitant, while the average EEE put on the market over the period 2015-2017 was estimated at 19.1 kg per inhabitant. The variation in the collected amounts reflects differences in EEE consumption level between countries, as well as differences in the performance of their respective waste collection schemes. The ipython kernel of this Exploratory Data Analysis is available to GitHub (GitHub Repository, 2021).

**Figure 6:** Waste management operations in 2018



## 5. Conclusions

Throughout this paper, two main themes have been discussed. One of the most prominent has been the need to analyze the European recycling data of WEEE, in order to explicitly comprehend the background concept (European legislation framework) and definitions of such a substantial environmental issue. The other theme within the paper has been the presentation of EDA's necessity and its techniques, due to obtain as much information as possible and to understand the underlying structure of the data.

Finally, performing the EDA, data have been explored and understood in detail. Missing data have been replaced, outliers have been detected, useful information from the plots and graphs has been collected and the most important part of this process, is that the datasets have been unequivocally prepared for applying Machine Learning algorithms.

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# Mega Infrastructure Projects and their contribution to Sustainable Development The case of the Athens Metro

**Roido Mitoula & Angelos Papavasileiou**
*Department of Economics and Sustainable Development,*
*School of Environment, Geography and Applied Economics*
*Harokopio University of Athens*
mitoula@hua.gr, apapavasileiou@hua.gr

**Abstract**
The present paper investigates the critical role of significant infrastructure projects in sustainable urban and suburban development by presenting a Sustainable Infrastructure serum analysis supported by primary field research. In the case study of the Athens Metro, we examined the influence of the project on sustainable development through the users' opinions of the project. Thus, the Athens Metro provides a case study to improve our understanding of the concept of Sustainable Infrastructure as a framework for Green Growth. For the needs of the paper, a survey was conducted with questionnaires from October to December 2020. The sample consisted of 266 citizens of the Attica Region. Given the restrictions on movement due to the COVID-19 pandemic, questionnaires were sent and collected online. The organisation and processing of the research results was done through the open free program Microsoft forms. The Stata statistical program was used to process the results. From the data analysis, conclusions emerged, which are summarised at the end of the paper. The research results highlighted the acceptance and necessity of the project by directly correlating the results with sustainable development, the Economy, Society, and the Environment.

**Keywords**: Mega Infrastructure Projects, Sustainable Development, Sustainable Infrastructure, Public Transport, Athens Metro, Greece.

**JEL Codes**: Q01, Q50, Q56, R11, R40, R42.

## 1. Introduction

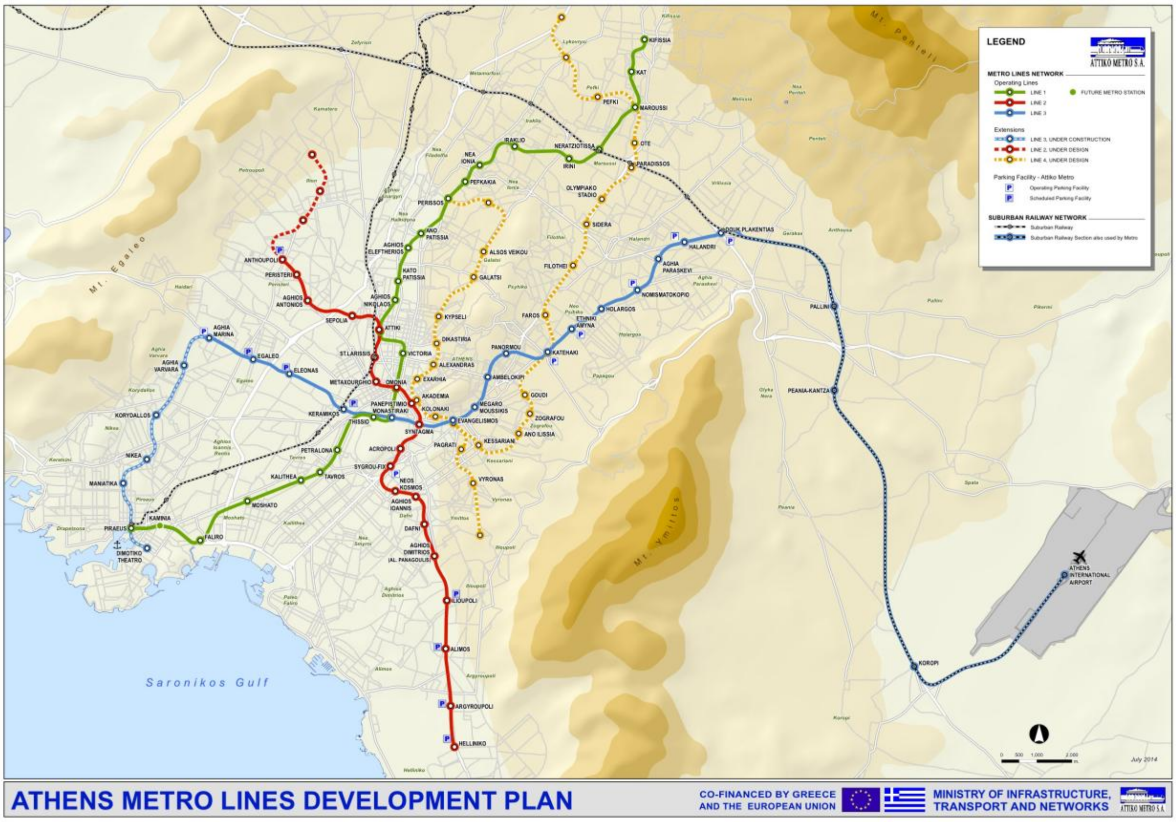
Transport is a critical infrastructure project and necessary in modern urban environments. The aim is to meet the daily needs for population and product movements (Mitoula et al. l, 2008). Today, citizens' quality of life depends on the existence of an efficient and accessible transport system. However, at the same time, transport can be detrimental to the environment and contribute to climate change.
Studies have shown that in the EU, the transport sector consumes one-third of the total final energy, which comes mainly from oil, and that transport contributes to a quarter of the total greenhouse gas emissions (Mitoula, Economou, 2008). While most of the other economic sectors, such as electricity generation and industry, have reduced their emissions since 1990, transport emissions have increased. Cars, vans, trucks and buses produce more than 70% of greenhouse gas emissions from transportation. It is noted that the remaining emissions come mainly from shipping and air transport (New Climate Economy, 2016). In addition to the above issues concerning the effects of transport on climate, there are other adverse effects: transport infrastructure occupies large areas of land, supports urban sprawl, and divide natural areas into smaller sections, with severe consequences for animals and plants.
As for urban rail networks and the Metro, these have developed rapidly worldwide and play an important role even in a city's growth. Their importance derives from the multitude of advantages they represent. These advantages, combined with the rapid growth of urban centres and the overcrowding of the population in cities, have made urban railway networks and the Metro the essential structural and functional elements of a modern city (Mitoula et al. l, 2003).

The present work refers to the Athens Metro, a major infrastructure project in the field of transport. The influence of the project on sustainable development is investigated through the opinion of its users. Thus, the Athens Metro provides a case study to improve our understanding of the concept of Sustainable Infrastructure as a framework for Green Growth. The purpose of the research is to gather the results for the work of the Athens Metro and its coupling with the sustainable development of the city and the country, in order to present its multidimensional influence on the residents and tourists of the city of Athens, but also in the broader economy and market. The findings from the collection of the questionnaire contain sufficient and valuable information about the operation and use, the pros and cons of the Athens Metro, as well as its reputation among the citizens who use it and benefit from it in various ways.
Finally, the research implications can contribute to the design of future studies for the Athens Metro, aiming to evaluate the contribution of large construction projects to sustainable development.

## 2. Athens Metro

The Athens Metro consists of 3 lines: 1) Line 1, which is the pre-existing electric railway that has been operating since 1869 (initially as a steam train), 2) line 2, which extends from Elliniko to Anthoupolis and 3) line 3, extending from Nikea to Doukissa Plakentias (see Map 1).
The Basic Project of the Athens Metro began construction in November 1992 with a planned 20km network with 21 stations on 2 Lines. The first 13 km with 14 stations in Line 3 and Line 2 were put into operation in January 2000, while 5 additional km with 5 stations were in operation in November 2000. Given the existence of important antiquities in the area of Athens, the construction company ATTIKO METRO SA funded archaeological excavations of 69,000 square meters, which are the largest ever made in the area. In addition, to minimise the chances of encountering archaeological finds, the Metro tunnels were drilled, on average, to a depth of more than 15 meters, a level lower than where archaeological finds are usually found.
In April 2003, the Syntagma - Monastiraki section was opened to the general public. In June 2004, the section Dafni - Agios Dimitrios, 1.2 km, was put into operation, followed by, in July 2004, the sections Ethniki Amyna-Chalandri, D. Plakentias, with a total length of 5.9 km. In August of the same year, the extension Sepolia - Agios Antonios began operation with a total distance of 1.4 km. In 2013, another 7 stations with a total length of 8.5 km were delivered to the general public.
On July 6, 2020, the first 3 stations to Piraeus were opened to passengers for use: Agia Varvara, Korydallos and Nikaia. It is noted that Attiko Metro SA. has designed the stations that were put into operation with an emphasis on bioclimatic characteristics and the safe movement of passengers in the Metro network. With the operation of the first three stations of the extension to Piraeus, the additional passengers total on the network is estimated at 63,000 per day. At the same time, the residents of the Municipalities of Agia Varvara, Korydallos and Nikaia have at their disposal a modern Metro line. The operation of the first three stations two years earlier than the completion of the full extension of Line 3 of the Metro has significant benefits, socio-economic and others, such as positive effects in tackling climate change: reducing car traffic vehicles by 11,000 per day and carbon dioxide emissions by 60 tonnes per day. The entire Line 3 Expansion is expected to be completed in the summer of 2022.

**Map 1. Athens Metro Lines Development Plan**




Source: https://www.athensguide.com/metromap.html

It is important to emphasise that with the completion of the project, a significant Transport Center is planned to be created at Piraeus Station, operationally joining two Metro lines (Lines 1 and 3), the Port, the Suburban Railway, and the Tram Extension to Piraeus (5,4 km single line and 12 stations), thus facilitating transfers between all modes of transport. In addition, the connection that will emerge between the Port of Piraeus and the Airport "Eleftherios Venizelos" through Metro Line 3 will provide unique development benefits to the greater area of Athens and Piraeus well as to the national economy in general. The Metro is the most important means of transportation in Athens and extends to 59.7 km, and 938,000 passengers are served daily by 43 modern stations. (Attiko Metro S.A., The Main Project, 2021)

**Attiko Metro Lines-Lengths-Stations -Daily Ridership 2021**

| **Metro Lines in Operation** | **Length (kilometres)** | **Stations** | **Daily Ridership** |
|---|---|---|---|
| Line 1 (ISAP) | 25,6 | 24 | 460.000 passengers |
| Line 2 & 3 (Metro) | 59,7 | 43 | 938.000 passengers |
| **Total** | **85,3** | **67** | **1.398.000 passengers** |

*Data: Attiko Metro S.A*

The operation of the Metro is carried out electrically. For most of its route, it is underground with an exclusive corridor in conventional or fixed structures. (Patargias et al., 2004). Regarding the environmental impact of the Metro in the city, its contribution is considered significant. The improvement of public transport has led to the reduction of the use of private vehicles in the centre of Athens, which leads to the improvement of the quality of the environment and the living standard of the citizens of Athens (Attiko Metro SA, 2020). According to a recent study for the future extension of line

4A, the results showed that in the year 2030, the amount of $CO_2$ would be reduced by 38% compared to the current situation. (Giakoumis et al., 2018)
In addition, Attiko Metro SA states that with the expansion of Metro line 3 to Piraeus, there will be significant benefits, socio-economic and others, such as positive effects in tackling climate change: reduction of car traffic vehicles by 11,000 per day and carbon dioxide emissions by 60 tonnes per day. Furthermore, with the completion of the project and the operation of the stations Maniatika, Piraeus and Municipal Theater, it is foreseen to increase the total passenger traffic in the Metro network by 132,000 citizens per day, thus reducing the traffic of private vehicles by 23,000 per day and carbon dioxide emissions by 120 tonnes per day. (Attiko Metro SA, Piraeus, 2021)
One of the main motivations that led to the construction of the Metro in Athens is the reduction of the traffic problem in the city centre and the consequent improvement of the environmental conditions. (Batsos & Tzouvadakis, 2007). The main feature of the Athenian urban structure is the radiocentric development, which has created several problems, especially in densely populated areas. A significant issue is traffic on the roads, especially during peak hours where the travel time to a location by car can be tripled compared to the rest of the day. Therefore, in addition to the contribution of the Metro to the reduction of environmental problems, another reason for its creation was the reduction of traffic on the roads. We can understand this from the ever-increasing number of people who use the Metro daily.
Specifically, the traffic on the streets of Athens is reduced daily by approximately 938,000 cars if this part of the population chooses to travel by Metro (Attiko Metro SA, The main project, 2021). Reducing this significant problem makes the Metro project one of the most critical projects in Athens. It should also be mentioned that it allows people who do not have the financial means to acquire a private vehicle to travel.

## 3. Research methodology

For the needs of the work, a survey was conducted with questionnaires from October to December 2020. The sample consisted of 266 citizens of the Attica Region. Given the restriction of movement due to the COVID-19 pandemic, questionnaires were sent and collected online. The research results were organised and processed through the open free program Microsoft forms. The Stata statistical program was used to process the results.
The questionnaire includes questions regarding the impact of the Metro on the environment, the economy and social life. The method used to conduct the research is to send and complete questionnaires of 27 questions using social media due to COVID-19. The main means of communication that were used were Facebook and Email.
The research was addressed to users or not of the Athens Metro. The research prioritised permanent residents of Attica's urban and suburban areas because they have sufficient experience of using and influencing the project in the respective areas where they work and live. As a result, they were more likely to observe the impact of this mega infrastructure project on their living environment. Individuals of any occupation or professional status were considered eligible to participate in the survey, provided that they were permanent residents of the respective areas covered by the project.
**The four (4) main research questions** related to sustainable development that were selected to be analysed and correlated with the demographic characteristics of the respondents with statistical analysis are the following:
- **Sustainability**: Did the surrounding Prefectures/Municipalities/Areas develop or generally benefit from the operation and construction of the project? The question will guide data collection on the benefits of infrastructure for authorities within the project site. The question seeks to understand the benefits of major infrastructure projects, including Sustainable Development. (InterAmerican Development Bank, 2018)
- **Society**: In your opinion, has the quality of life of residents in the area surrounding the project improved? The question assesses the impact of infrastructure on the overall quality of life. The main

aspects include job creation, promoting social opportunities and providing services to people. (Fischer and Amekudzi, 2011)

- **Economy**: In your opinion, was there an increase in trade in the wider project area? The increase in trade determines the importance and influence of the project in the region's economic development with direct results in society. Thus, enhancing business through the presence of an infrastructure project establishes economic and social prosperity and contributes to the people's overall well-being. This answer will therefore help to determine the value of infrastructure in relation to economic development. (Calderon Cesar, Serven Luis, 2004)
- **Environment**: Did the project contribute positively to the environmental impact of the surrounding areas? The statement will serve as a determining factor in the impact that infrastructure has had on the environment. The expected responses to the statement included yes or no, which will help determine the value of the project in terms of promoting environmental sustainability. (OECD, 2019)

## 4. Statistical Analysis

To identify and approach sustainable development theory through statistical analysis of project users' responses, we examined correlations and created types of regression analysis that explore the statistical significance and statistical prediction to conclude. Based on the following regression type:

**Formula**

$$Y_i = f(X_i, \beta) + e_i$$

We defined as dependent variables (Yi) the fundamental pillars of sustainable development (Figure 1) that we researched through specific questionnaire questions referred to in paragraph 3. We placed in the equation as independent variables (Xi) the demographics and the pillars of sustainable development (gender groups, level of education, work background and other principles of sustainable development other than the one we consider each time as a dependent variable).

Finally, **4 types of regression analysis** with **14 independent variables** emerged.

- **Environment**

Environment=β_0+β_1 Commerce+β_2 Quality of life+Demogr.β+ε_1 **(1)**

- **Economy**

Commerce=γ_0+γ_1 Environment+γ_2 Quality of life+Demogr.γ+η_1 **(2)**

- **Society**

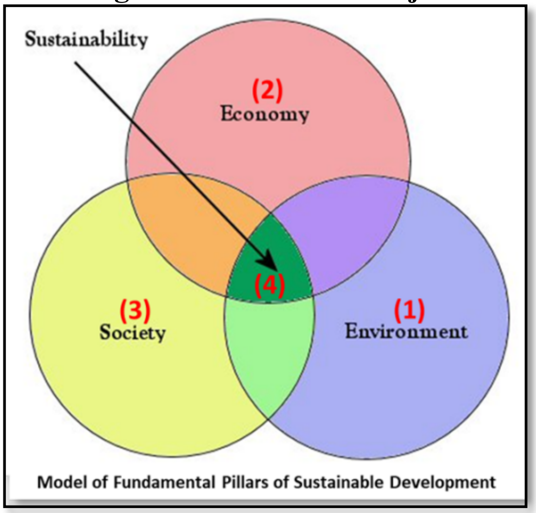
Quality of life=δ_0+δ_1 Environment+δ_2 Commerce+Demogr.δ+φ_1 **(3)**

***The relationship between the three fundamental pillars and Sustainable Development:***

- **Sustainability**

Growth=λ_0+λ_1 Environment+λ_2 Commerce+λ_3 Quality of life+Demogr.λ+θ_1 **(4)**

**Figure 1. The interaction between the three fundamental pillars of Sustainable Development in Mega Infrastructure Projects**




To investigate how the three fundamental pillars are connected, we start with simple correlations in pairs (Table 3). Next, to further evaluate these patterns, we performed a multivariate regression analysis (Table 4). The regression model is estimated using OLS (Ordinary Least Squares) with heteroskedasticity robust standard errors. Finally, since the above model depends on variables in all four models we estimate are binary (0/1), we estimate a Linear Probability model, where the estimated parameters/coefficients refer to changes in the probability that people make such statements. Indeed, the regression analysis in Table 4, controlling for various demographic characteristics of the respondents, confirms the correlations observed in Table 3.

## 5. Statistical Model Analysis Results

**Table 1: Definitions**

| *Variable name* | *Definition* |
|---|---|
| **Area_Growth** | *Did the surrounding Prefectures/Municipalities Areas develop or generally benefit from the operation and construction of the project?* |
| **Commerce** | *In your opinion, was there an increase in trade in the wider project area?* |
| **Qual_life** | *In your opinion, has the quality of life of residents in the area surrounding the project improved?* |
| **Environment** | *Did the project contribute positively to the environmental impact of the surrounding areas?* |

**Table 2: Descriptive Statistics**

| *Variable* | *Mean* | *Std. Dev.* | *Min* | *Max* |
|---|---|---|---|---|
| **area_growth** | **0.929** | **0.258** | 0 | 1 |
| **environment** | **0.759** | **0.428** | 0 | 1 |
| **qual_life** | **0.902** | **0.298** | 0 | 1 |
| **commerce** | **0.936** | **0.245** | 0 | 1 |
| female | 0.711 | 0.454 | 0 | 1 |
| age18_28 | 0.575 | 0.495 | 0 | 1 |
| age29_39 | 0.120 | 0.326 | 0 | 1 |
| age40_50 | 0.162 | 0.369 | 0 | 1 |
| educ_postsecond | 0.135 | 0.343 | 0 | 1 |
| educ_Uni | 0.316 | 0.466 | 0 | 1 |
| educ_postgrad | 0.049 | 0.216 | 0 | 1 |

| | | | | |
|---|---|---|---|---|
| single | 0.662 | 0.474 | 0 | 1 |
| unempl | 0.098 | 0.298 | 0 | 1 |
| selfempl | 0.045 | 0.208 | 0 | 1 |
| emplpub | 0.158 | 0.365 | 0 | 1 |
| emplpri | 0.211 | 0.408 | 0 | 1 |

**Table 3: Correlations**

| | *area_growth* | *commerce* | *qual_life* | *environment* |
|---|---|---|---|---|
| ***area_growth*** | | | | |
| ***commerce*** | 0.0469 | | | |
| ***qual_life*** | 0.2528* | 0.2245* | | |
| ***environment*** | 0.0829 | 0.1046 | 0.2590* | |

Note: Asterisk (*) denotes statistical significance at 5%

**Table 4: Regression analysis**

| | (1) *qual_life* | (2) *environment* | (3) *commerce* | (4) *area_growth* |
|---|---|---|---|---|
| | b/se | b/se | b/se | b/se |
| **qual_life** | | 0.379*** | 0.179** | 0.221** |
| | | (0.108) | (0.086) | (0.089) |
| **environment** | 0.184*** | | 0.010 | 0.030 |
| | (0.058) | | (0.043) | (0.040) |
| **commerce** | 0.251** | 0.030 | | -0.018 |
| | (0.118) | (0.123) | | (0.075) |
| female | 0.055 | -0.103* | 0.030 | 0.012 |
| | (0.042) | (0.059) | (0.035) | (0.039) |
| age18_28 | 0.086 | -0.093 | 0.033 | -0.177** |
| | (0.087) | (0.104) | (0.106) | (0.071) |
| age29_39 | 0.162*** | -0.085 | -0.062 | -0.157* |
| | (0.062) | (0.103) | (0.094) | (0.082) |
| age40_50 | -0.039 | 0.174** | 0.001 | -0.134** |
| | (0.064) | (0.076) | (0.050) | (0.066) |
| educ_postsecond | -0.003 | 0.060 | 0.113*** | 0.036 |
| | (0.063) | (0.090) | (0.033) | (0.053) |
| educ_Uni | 0.013 | 0.129** | 0.087*** | -0.004 |
| | (0.049) | (0.062) | (0.031) | (0.045) |
| educ_postgrad | 0.091 | 0.119 | 0.109*** | -0.032 |
| | (0.058) | (0.090) | (0.039) | (0.097) |
| single | -0.066 | -0.001 | 0.020 | 0.159*** |
| | (0.071) | (0.085) | (0.072) | (0.061) |
| unempl | -0.079 | 0.000 | 0.080*** | 0.000 |
| | (0.062) | (0.094) | (0.028) | (0.051) |
| selfempl | -0.082 | -0.159 | -0.001 | 0.013 |
| | (0.107) | (0.144) | (0.079) | (0.098) |
| emplpub | -0.033 | -0.074 | 0.061 | 0.013 |
| | (0.054) | (0.076) | (0.054) | (0.059) |
| emplpri | -0.110** | 0.117* | 0.059 | -0.034 |
| | (0.051) | (0.067) | (0.041) | (0.050) |
| _cons | 0.501*** | 0.439*** | 0.643*** | 0.754*** |
| | (0.136) | (0.151) | (0.106) | (0.115) |
| N | 266 | 266 | 266 | 266 |
| R-sq | 0.1567 | 0.1612 | 0.1120 | 0.1139 |

Note: Asterisks *, ** and *** denote statistical significance at 10%, 5% and 1% respectively

## 6. Discussion

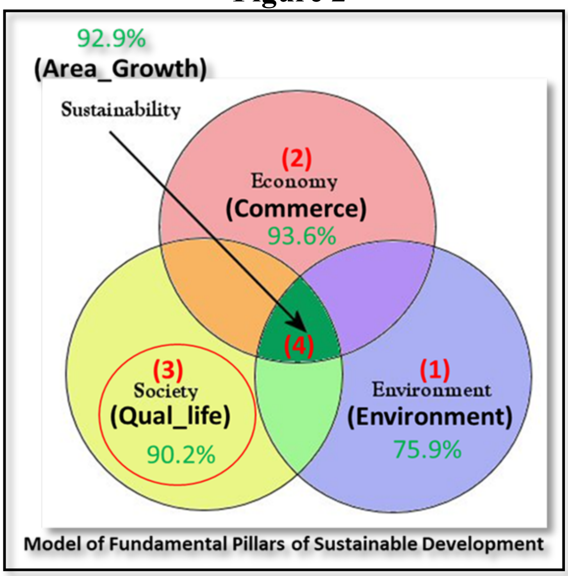
Through the statistical analysis model that we designed and analysed, the first obvious and crucial conclusion that we came to and confirmed through the correlation table 3 and the regression analysis table 4 is that:

Observing and examining the results of descriptive statistics, correlations and statistical regression analysis in detail, it becomes clear that the quality of life (Qual_life) that we have defined as the pillar of society in the theoretical model of sustainable development positively correlates with sustainable development. The results of the descriptive statistics (Table 2) give high acceptance rates to all the questions of the positive influence of the Athens Metro project that we set as fundamental pillars of the statistical model of sustainable development. The Quality of Life Improvement Question (Qual_life) recorded 90.2%, the Commerce Development Question 93.6%, the Environmental Impact Question 75.9% and the project positive contribution to the development of the project areas. (Area_Growth) 92.9% (Figure 2).

By trying to decipher trends and predictions of positive responses with the help of the statistical regression analysis of the model (Table 4) and the correlation control (Table 3), we observe here that the quality of life variable (Qual_life) that represents the pillar of society mutually reinforces all the other pillars that we set, namely the Environment (environment), Economy (commerce) and Sustainability (area_growth). In addition, we observe that the improvement of quality of life (Qual_life) interacts positively as an independent variable and as a dependent, which is a significant finding for the gravity of our research question. Furthermore, we see that the 29-39 age group is more likely to respond positively to the influence of the Athens Metro on improving the quality of life, where we can easily say that the age group is quite sensitive to issues of environment and quality of life. On the contrary, the regression analysis shows that respondents who work in the private sector (emplpri) are less likely to answer positively to the question of improving the quality of life, and this can be justified considering that they experience difficult working conditions and have identified them with everyday use of the Metro.

Regarding the statistical analysis of the Environment (environment) regression analysis, we observe that the age group 40-50 is likely to answer that the project contributes positively to the environment of the areas in which it runs. At the same time, the group of respondents with a university education level (educ_Uni) are pretty likely to respond positively to the positive impact of the project on the environment.

**Figure 2**



Finally, it is worth noting that the group of respondents working in the private sector (emplpri) has a high probability of responding positively to the positive effects of the Athens Metro on the environment. However, at the same time, the same group of respondents is less likely to answer that the project contributes to residents' quality of life in the areas it runs through. The experiential point of view can explain that they have formed this opinion through the daily use of the Athens Metro and influenced by the stressful rhythms of modern society that burden the daily lives of employees.
Proceeding with the decoding of the Economy pillar's statistical regression analysis results (commerce), we see that with a statistical significance of 1%, the groups of secondary school graduates (educ postsecond), university education (educ Uni), and the unemployed (unempl) are very likely to respond that the Athens Metro has contributed to the growth of trade and the economy in general in Athens.
Closing the discussion of the statistical regression analysis results of Sustainability (area_growth), the age groups 18-28, 29-39, 40-50 are less likely to answer that it contributed positively to its construction and operation to develop the areas where the Athens Metro runs, while the group of respondents without a relationship (singles) is very likely to answer positively to the same question. Here we see that the concept of the project's contribution to Sustainability and the general development of the areas under the Metro has a greater response to the ages over 50.

## 7. Conclusions

The above findings of the statistical research analysis contain enough valuable information about the contribution of Attiko Metro to the sustainable development of Athens and the areas it runs through, as well as its reputation to the passenger public and the citizens who use it and benefit from this in a variety of ways.
In the selected questions (Table 1) of the questionnaire used in the statistical analysis model, the research came to clear answers. First, the overwhelming majority believe that the areas covered by the project have been developed and have benefited in general due to the Metro's construction and existence, and hence respond positively to the sustainability pillar. Additionally, the research found that most respondents believed the Athens Metro contributed to the expansion of commerce in the surrounding districts by responding to the economy's pillar.
Simultaneously, respondents expressed strong views on whether the quality of life of residents of the surrounding areas, which serves as the research's pillar of the Society, has improved. The Metro's contribution is characterised as beneficial in terms of the surrounding areas' environmental impact, reflected by the pillar of Environment in the statistical model. Once again, the research indicated very high percentages of acceptance by respondents. Obviously, the presence of the Metro in the surrounding communities has alleviated many of the previously mentioned issues, and many of these locations have now become some of the most popular locations for installation. In addition, the Metro has improved people's living conditions, which is due to the increased flow of passengers that it transports daily, remodelling the surrounding areas.
In conclusion, we believe that the current research on the contribution of large infrastructure projects to sustainable development requires a great deal of analysis, and the aim is to continue with further investigation of the statistical model, enriching it with secondary statistics of statistical services and organisations, adding independent and dependent formulas of the fundamental pillars of Sustainable Development. The ultimate goal is to create a reliable statistical model for analysing the impact of large infrastructure projects on sustainable development.

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# Opinion of citizens about infrastructure privatization

**Emmanouil Vougioukalakis, Zoe Gareiou, Leonidas Vatikiotis & Efthimios Zervas**
*School of Science and Technology, Hellenic Open University, 26335, Patra, Greece*
zervas@eap.gr

**Abstract**
Nowadays, there is a huge demand on public infrastructure and services worldwide, while the government budget of any country is usually limited. In addition, the public sector often lacks the technologies and expertise required for efficient infrastructure development. As a result, many countries are turning to infrastructure privatization. This study investigates the opinion of the inhabitants of Athens, about infrastructure privatization, on the main sectors: transport, education, health, energy, water supply, telecommunications, public administration and municipal services.
The survey was conducted from January to March 2020 in Athens. The data were collected using a structured questionnaire and the responses were analyzed. For the statistical analysis of the data, simple descriptive statistics and chi-square test.
The results showed that the majority of respondents want public management in terms of transport, water supply, education, health, energy, public administration, telecommunications and municipal services. On the contrary, the majority of respondents are in favor of the private sector in terms of large industries, while maintaining a neutral stance in the case of media and banks.
Finally, the majority of respondents consider that the quality of infrastructure, which has already become private, has improved, while the cost has deteriorated.

**Keywords:** Privatization, Infrastructure, Opinion of citizens.

**JEL Codes**: Z0

## 1. Introduction

The presence of the private sector in all aspects of the daily life of citizens presents a constant intensity over the years, naturally affecting the construction sector and infrastructure. The need for economic recovery after 1970 and the trend of globalization created conditions for the search for detachment from the public sector and provide fertile ground for the private one. In the European Union in particular, both the legal framework and the motivation to promote the "free market" have made privatization and the reduction of state participation mandatory (Carrol and Steane, 2000).

Proponents of privatization focus on the fact that, due to the absence of financial resources from the states, the privatization of companies and industries can offer the maximum benefits (quality of services, infrastructure etc.). Therefore end-users (usually citizens) will benefit by increasing competition, the possibility of new innovative "players", without monopoly conditions and without harming the public interest and the relatively fair distribution of national income. On the other hand, their critics are sounding the alarm bell, arguing that it can be catastrophic for the economy of the state and the citizens, which requires very careful planning (Zou et al., 2008).

When categorizing infrastructures, there is a difference in terms of who pays for their construction and who gives the order for their construction. Public Infrastructures are defined as infrastructures, where their ownership status belongs to the Public Sector of the economy and as Private Infrastructures those that belong respectively to the Private Sector. The categories of infrastructure management can be divided according to their management bodies into: Fully Public Enterprises, Fully Private Enterprises and Mixed Enterprises (Hillebrandt, 2000).

In recent years, Public-Private Partnerships (PPPs) have been increasingly adopted with the availability payment method, attracting large construction groups. It is characteristic that 70% of the road infrastructure in Europe, but also projects with a total budget of 1,700,000,000€ are implemented, or will be implemented in the current period, in Greece with this PPP method (Special Secretariat for PPPs, 2019). The implementation of PPPs through the European Strategic Investment Fund seems to attract more private capital. Turning to these models and evaluating their contribution, in the coming years will be the "bet" of increasing economic growth through achieving greater productivity and consequently competitiveness (European Court of Auditors, 2018).

In this study we investigate the opinion of the residents of Athens, regarding the privatization of infrastructure, in the main sectors: transport (ports, airports and highways), education, health, energy, water supply, telecommunications, public administration and municipal services (e.g. waste management).

## 2. Methods and Data

In the present study the quantitative research was followed. For this study, 400 questionnaires were collected from January to March 2020, in the wider area of Attica. The stratified random sampling method was used (Robson, 2010).

The questionnaire consists of four sections. The questions of the first part help the participants to understand the purpose of the research, as they introduce them to the topics of the questionnaire. The second part consists of questions about the privatization of infrastructure, citizens' preferences regarding how they are financed, as well as the degree of influence of their quality and cost from privatization. The questions refer to structures that have already been privatized and the possible privatizations. The third part of the questions reflects the degree of public confidence in the previous and current governments regarding the privatization of infrastructure, as well as the degree to which they should be involved in privatization decisions. The fourth part consists of questions about the socio-demographic data of the citizens that are the sample of the research.

Statistical Package for Social Sciences (SPSS) was used for the data analysis. In a first step, descriptive statistics (mean values, standard deviation and frequency distribution) was applied to all questions. Next, a chi-square ($\chi 2$) test is used to reveal statistical significant correlations between the answers and the socio-demographic characteristics of the respondents. A statistical significant correlation is considered if $p<0.05$.

## 3. Results

### *3.1 Sample description*

From the results of our sample, the 52% of the respondents were female and the 48% male. The average age of both genders are 42.9 years. With regard to marital status, 49% of the respondents were married, while 39% are unmarried. Furthermore, the 48% of respondents do not have children, while 24% have 2 children. The 28% of respondents have completed primary education, 36% secondary education, while 23% higher education. In addition, the 39% of the respondents are private employees, 21% are public employees and 21% are self-employed. The annual total family income corresponds to 5.001-10.000€ for the 18% of the respondents, 10.001-15.000€ for the 18% of the respondents and 15.001-20.000€, also for the 18% of the respondents. Finally, regarding political beliefs, the 28% of the respondents belongs to center, 28% of the respondents declare center-left political belief, 16% left political belief, 14% right political belief, while 12% of the respondents declare center-right political belief.

The representativeness of the sample was tested according to the procedure proposed by Parke (2013). According to this test, our sample represented the adult Greek population in every level: gender, age distribution, marital status, number of children, education and occupation.

*3.2 Investigation of general interest regarding privatizations*

The interest of the respondents for the financial problems of Greece gathers high percentages. Specifically, the majority of the population is interested in the Greek economy (87%). Regarding infrastructure financing, the Figure 1 shows the respondents' preference for it.

**Figure 1:** Infrastructure Financing

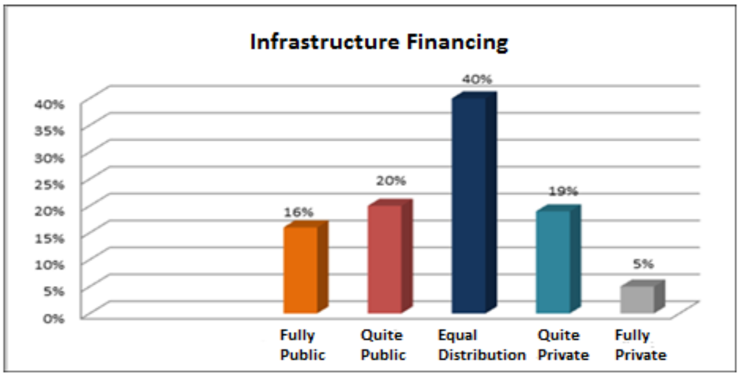



Figure 1 shows that the total percentage of citizens preferring public funding for infrastructure (36%) is much higher than the total percentage of funding from the private sector (24%). Public funding of infrastructure is more preferred by citizens with secondary education and with a left political belief.

Regarding infrastructure management, the Figure 2 shows the respondents' preference for it.

**Figure 2:** Infrastructure Management

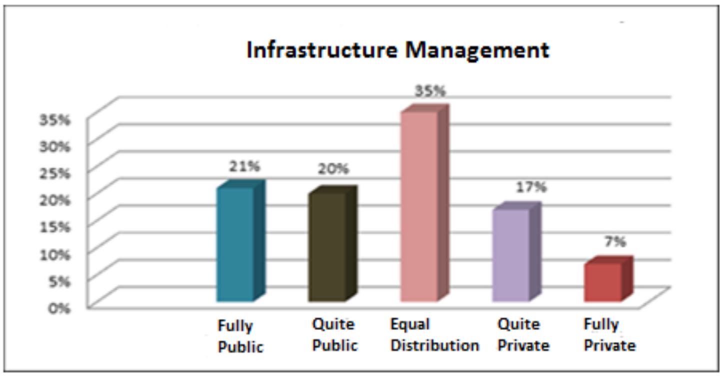



Figure 2 shows that the 41% of citizens prefer infrastructure management to be public, 24% of citizens prefer private management, while 35% of citizens prefer infrastructure management to be equally distributed. The public management of the infrastructures is preferred by citizens with secondary education, unemployed, with an income of up to €20,000 and with a left political belief.

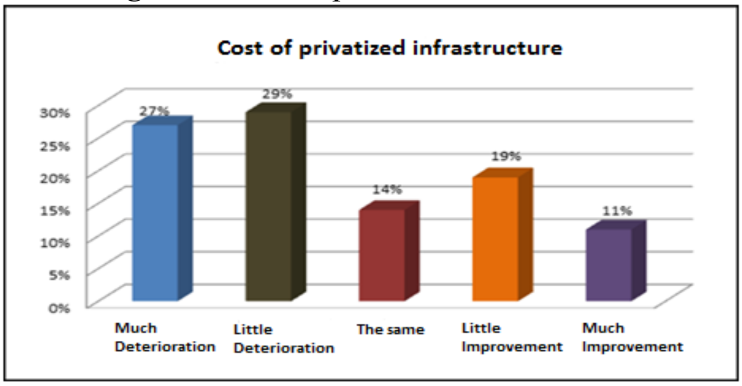
*3.3 Investigation of degree of preference of public or private infrastructure*

The elaboration of the second part of the questionnaire examines the degree to which citizens want the most important public or private infrastructure sectors.

Citizens prefer public management in terms of: transport (roads, airports, ports) (47%), water companies (71%), education (primary, secondary, universities) (68%), health (70%), energy (54%), public administration (65%), telecommunications (42%) and municipal services (e.g. electricity, waste management) (56%). Citizens prefer private and/or equal management in terms of: media (TV, radio and newspapers) (private: 37%, equal distribution: 37%), large industries (private: 48%, equal distribution: 30%) and banks (private: 35%, equal distribution: 35%).

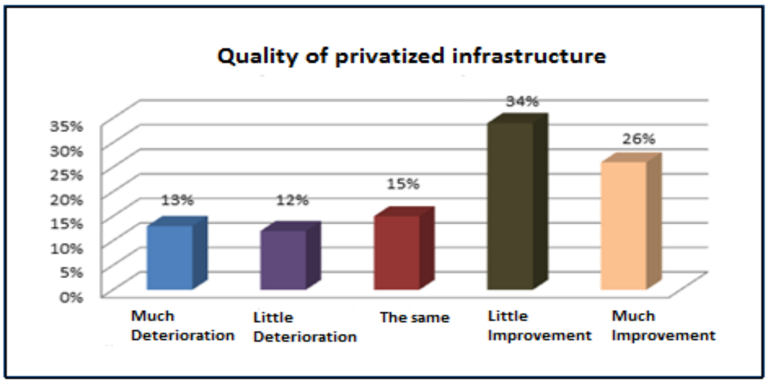
Furthermore, the survey showed citizens' opinions on the quality and cost of infrastructure that has already become private. Most respondents believe that the cost of infrastructure that has already become private has deteriorated (56%) (Figure 3). This opinion is more shared by citizens under the age of 40 and women.

**Figure 3:** Cost of privatized infrastructure




Regarding the quality of the infrastructure that has already been privatized, the largest percentage of the sample considers that it has improved (60%) (Figure 4). This opinion is more shared by men, citizens under the age of 40, citizens with a right political belief and citizens with secondary education.

**Figure 4:** Quality of privatized infrastructure




Citizens' forecasts regarding the quality and cost of infrastructure, in case the infrastructures are privatized, were also stated (Table 1).

**Table 1:** Quality and cost in case the infrastructures are privatized

| Infrastructure | Quality (%) | | | Cost (%) | | |
|---|---|---|---|---|---|---|
| | Deterioration | Same | Improvement | Deterioration | Same | Improvement |
| **Transportation** | 22 | 16 | **62** | **64** | 15 | 21 |
| **Water Supply** | 29 | **38** | 33 | 29 | **38** | 33 |
| **Education** | 30 | 22 | **48** | 30 | 22 | **48** |
| **Health** | 26 | 18 | **56** | **76** | 11 | 13 |
| **Energy** | 24 | 31 | **45** | **55** | 18 | 27 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Telecommunication** | 21 | 27 | **52** | **45** | 23 | 32 |
| **Public Administration** | 25 | 23 | **52** | **55** | 20 | 25 |
| **Municipal Services** | 24 | 20 | **56** | **57** | 19 | 24 |

Figure 5 shows that, apart from the water supply where the respondents believe that the quality of infrastructure will remain the same, in all other sectors the respondents believe that the quality will improve. Regarding cost, the respondents believe that the cost of education will improve in case of privatization, the cost of water supply will remain the same, while the cost of the other infrastructures will deteriorate.

In addition, the respondents stated the extent to which they want the privatization of important infrastructure and the majority of the citizens stated that they are against the privatization of the port of Piraeus, the highways, the regional airports, the regional ports, the coastal front of Attica, electricity, water supply and the services of the Municipalities (Table 2).

**Table 2:** In favor of Privatization

| **Infrastructure** | **In favor of Privatization (%)** | | |
|---|---|---|---|
| | **No** | **Moderate** | **Yes** |
| **Port of Piraeus** | **52** | 25 | 23 |
| **Highways** | **55** | 23 | 22 |
| **Regional Airports** | **51** | 21 | 28 |
| **Regional Ports** | **53** | 24 | 23 |
| **Attica Coastal Front** | **56** | 19 | 25 |
| **Electricity** | **55** | 16 | 29 |
| **Water Supply** | **68** | 14 | 18 |
| **Municipal Services** | **49** | 21 | 30 |

Citizens with higher education, citizens under 40 years old, unmarried, citizens with an income of up to €20,000 and with a left political belief, are against the privatization of them.

Furthermore, the majority of the respondents believe that tolls on Attiki Odos have high costs as well as tolls on highways and electricity. On the other hand, the cost of water from the respondents is not considered high (Table 3).

**Table 3:** High cost of infrastructure

| Infrastructure | High Cost (%) | | |
|---|---|---|---|
| | Not at all / A little | Moderate | Much / Very much |
| **Attiki Odos Tolls** | 12 | 18 | **70** |
| **Highways tolls** | 8 | 14 | **78** |
| **Electricity** | 10 | 20 | **70** |
| **Water Supply** | **48** | 26 | 26 |

Men and citizens over the age of 40 consider the cost of tolls on highways high, while citizens with secondary education, citizens over 40 years old, citizens with an income of up to €20,000 and women consider the cost of water high.

*3.4 Privatizations in the shadow of governments*

The 46% of citizens believe that they should be involved in privatization decisions (e.g. by referendum). Men who are in a permanent employment status, citizens with a right political belief and citizens who have an income of more than €20,000 do not agree with this opinion.

In addition, the 52% of respondents do not trust the government for privatization decisions, 28% has moderate confidence, while 20% of respondents trust the government for privatization decisions.

Finally, the 59% of citizens are in favor of PPPs. Citizens with a right political belief and those with an income of more than €20,000 are more in favor of PPPs, while citizens want more PPP projects in the case of highways (39%), waste management (53%), airports (39%) and energy infrastructure (45%), and do not want in the case of water management (55%) and port infrastructure (39%).

## 4. Conclusions

In conclusion, the survey showed that citizens have a different opinion of each infrastructure project in terms of its management and prefer either public or private management, depending on the type of infrastructure.

Citizens may also think that the quality of privatized infrastructure is improving somewhat, but they believe that their costs are deteriorating. The majority of citizens did not seem to have confidence in the previous governments on the issue of privatization, however, they are in favor of public-private partnerships in the implementation of projects and the current government wants to implement more projects with the participation of privates.

Summarizing all the above, we conclude that the citizens trust and prefer the public body, despite the negative features that characterize public infrastructure and despite the benefits that may result from the privatization of infrastructure, while the citizens are positive in the case of PPPs.

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# Comparative assessment of environmental effects of railways with regard to other transport modes

**Vassilios Profillidis & George Botzoris**
*Laboratory of Transportation and Spatial Planning, Department of Civil Engineering, Democritus University of Thrace, Kimmeria Campus, 67100 Xanthi, Greece*
vprofill@civil.duth.gr, gbotzori@civil.duth.gr

**Abstract**
In the present paper it is examined haw can railways contribute to reduce $CO_2$ emissions so as to keep increase of global temperature of the earth below 1.5°C. First, contribution of the transport sector in $CO_2$ emissions is examined. A causal correlation between GDP and individual consumption for transport is attempted. Specific $CO_2$ emissions from railways and other transport modes are assessed, and other (than $CO_2$) air pollutants are examined. The energy efficiency of rail transport in comparison with other transport modes is also presented.

**Keywords:** Transportation, $CO_2$ emissions, growth, energy efficiency.

**JEL Codes**: O44, R41, Q53, Q56.

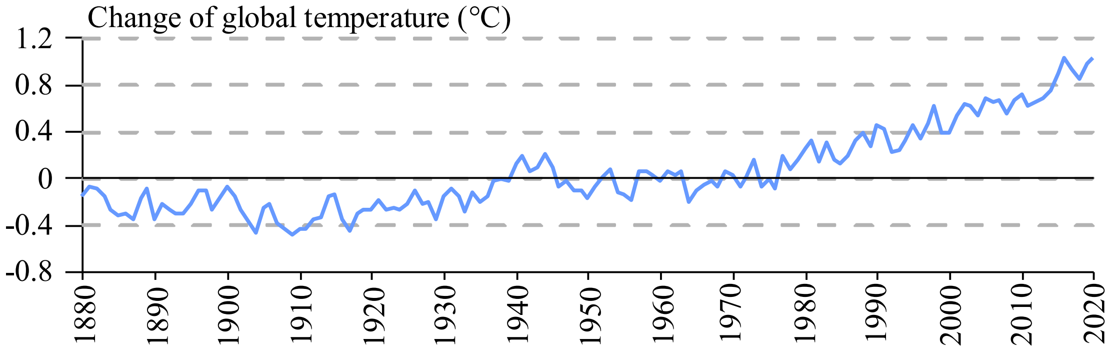
## 1. Climate change and sustainable development – Introduction

Every human activity has a minor or major effect on the environment. Up to a certain level of industrial production, the environment may absorb the effects of human activities through a natural procedure. However, beyond this level, climate change may appear and can be described as a significant and lasting change in the statistical distribution of weather patterns over periods from some decades to centuries or even thousands of years. The origins of climate change can be traced to human activities but also to factors exogenous to human intervention, such as oceanic processes, solar radiation, plate tectonics, and volcanic activity. The question is whether at this point we have reached a level of human impact on the environment, beyond which climate change becomes irreversible.

The United Nations intergovernmental panel on climate change has concluded since the early 1990s that the balance of evidence suggests a discerned human influence on global climate. The analyses of authorities such as the NASA make clear that, (NASA, 2021a; NASA, 2021b):

- the average global temperature has risen between 1900 and 2000 by 0.7 ºC, between 2000 and 2010 by 0.20 ºC, and between 2010 and 2020 by 0.24 ºC. If no change occurs in the actual rates of global warming, average temperatures will rise by 2.6÷4.7 ºC in 2100. Figure 1 illustrates annual changes of global temperature over the last 140 years,
- the global sea level has risen between 1900 and 2000 by around 20 cm and between 2000 and 2010 by 3 cm, with a rate of increase of 3.5 mm/year for the decade 2010÷2020. If no change occurs, a further rise at the global sea level of more than 30 cm should be expected by 2100, due principally to the melting of polar ice caps, (NASA, 2020),
- among 600 living beings tested, more than 75% present evidence compatible with an effort of adjustment to an increase in external temperature,
- known oil reserves will be exhausted by 2060,
- urban population is expected to double in the coming 30 years, from 3 billion in 2020 to 6 billion by 2050.

**Figure 1:** Evolution of change in global temperature of the earth from 1880 to 2020, (NASA, 2021a)




Due to human activities, most of which are based on the consumption of fossil fuels, since 1960 and particularly since 1980 we are producing more $CO_2$ and other greenhouse gases than in all the previous centuries. Thus, the greenhouse layer of the earth becomes thicker, causing increase in the global temperature of the earth. It is noteworthy that the lifetime until greenhouse gases are absorbed by a physical process is 5÷20 years for $CO_2$, 12 years for $CH_4$, at least 45 years for halocarbons, and 114 years for $NO_x$. The origins of greenhouse gases produced on the earth are in the late 2010s as follows: production of electricity and heating of houses 25%, agriculture 24%, industry 21%, transport 14%, buildings 6%, other 10%. Principal emitters of $CO_2$ are in 2019 the following countries: China 30%, USA 15%, EU-28 9%, India 7%, Russia 5%, Japan 4%, other 30%, (IEA, 2020).

Figure 1 illustrates the evolution of world $CO_2$ emissions in various parts of the world during the last two centuries. The rates of growth of $CO_2$ emissions are correlated with the rates of growth of world GDP, as illustrated in Figure 2. It becomes clear that climate change is a global problem and thus calls for a collective action from all countries and citizens of the world.

The first coordinated and universally accepted effort to combat climate change was put forward in the United Nations convention on climate change, which was adopted in 1992 and set long-term objectives; it was extended by the Kyoto protocol, adopted in 1997 and entered in force in 2005; the principal objective of the Kyoto protocol was to reduce greenhouse gas concentrations in the atmosphere to a level that would prevent anthropogenic interference with climate. The Kyoto protocol ended in 2012 and was replaced by the Doha agreement of 2012, which in turn was replaced by the Paris agreement of 2015. In 2021, 190 countries ratified the Paris agreement, whose principal global target is to keep by 2050 the increase of global average temperature below 2°C (preferably 1.5°C) compared to pre-industrial levels. The Paris agreement allows each country to set its own emission reduction targets and adopt its own strategy for reducing them; it does not foresee any sanction to be imposed upon everyone who does not respect the undertaken commitments.

Awareness of the shortage of natural resources and of the effects of human activities on the environment has led world institutions and most governments to the adoption of the term 'sustainable development', which is understood as the kind of economic and social development in which resource use aims to meet human needs while preserving the environment, so that future generations can satisfy their needs and enjoy a level of prosperity not very different of that of generations between 1950 and 2020. Principal factors for the achievement of sustainable development are economic efficiency, environmental responsibility, and social equity, (Profillidis et al., 2014; Profillidis and Botzoris, 2018).

**Figure 2:** Annual growth of global GDP and $CO_2$ emissions, (IEA, 2020)

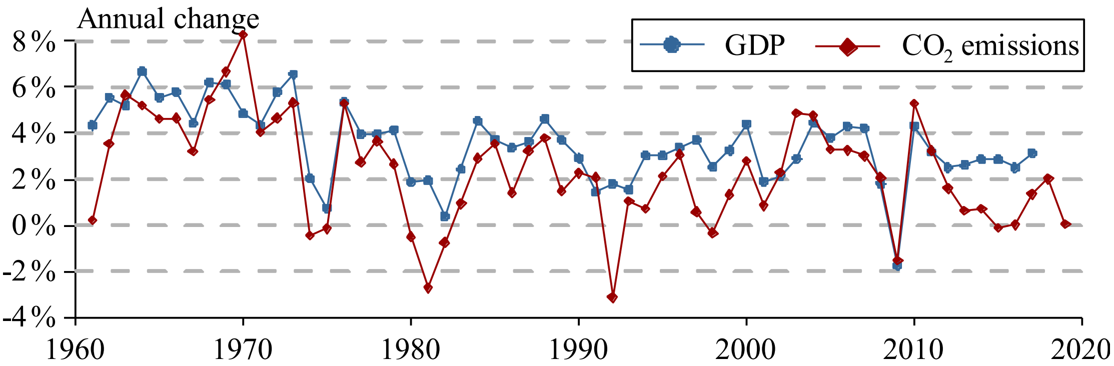
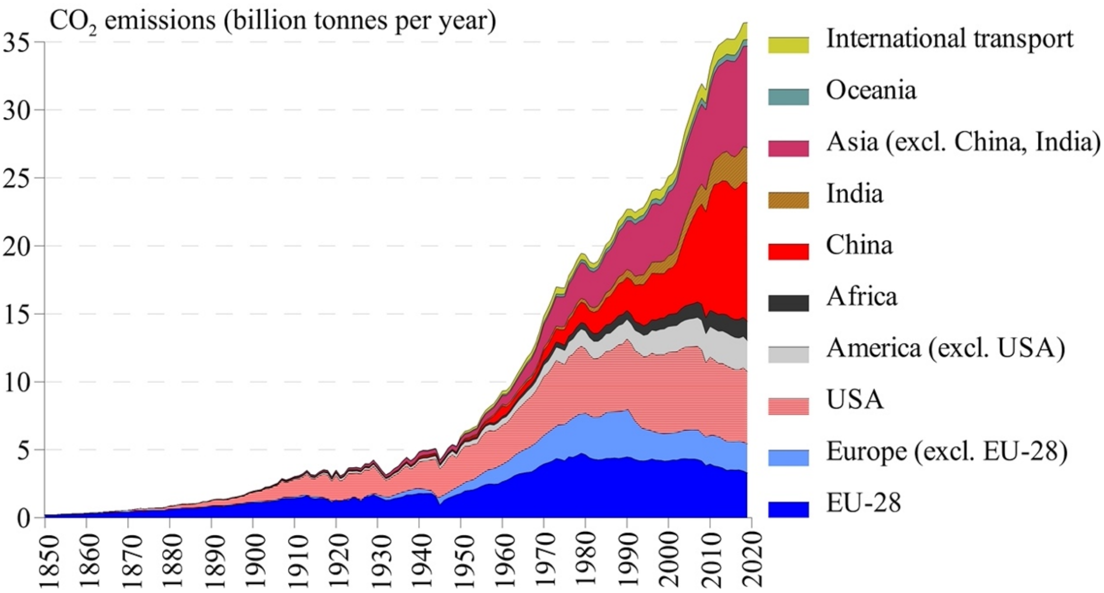



**Figure 3:** Evolution of world $CO_2$ emissions since 1850, (IEA, 2020)



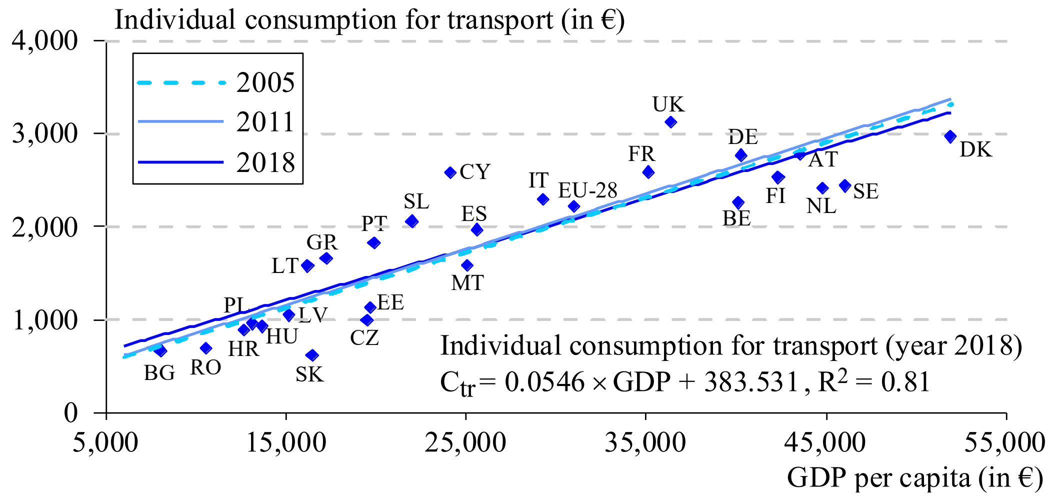

## 2. Transport and the environment

The transport sector has together with the industrial, tertiary, and household activities sectors a number of harmful effects on the environment, such as air and noise pollution, consumption of energy, accidents and safety, land occupancy, (Botzoris et al., 2015; Profillidis et al., 2018; Profillidis and Botzoris, 2018). Within the transport sector, however, railways are the least harmful to the environment mode of transport and this could prove a critical element for their development in the future.

The environmental effects of each transport mode (road, rail, air, sea) include passenger and freight traffic and may refer to i) construction and maintenance of infrastructure, ii) manufacture, maintenance, and disposal of rail and road vehicles, airplanes, ships, and iii) operation.

The consumption of transport by individuals is affected by their income and the GDP of the specific country. A causal relationship can be established between the individual consumption of transport $C_{tr}$ and the GDP for various countries, as illustrated in Figure 4. We can remark that from 2005 to 2018 the curve relating individual consumption for transport and GDP per capita has shifted by very little downwards, a fact testifying that individuals still continue to spend almost the same money for transport during the last two decades. Conclusive evidence suggests that for many decades and all over the world the amount of time that people are willing to spend on travel has remained remarkably constant at approximately 1.1 hours per day. This means that as people have an increased income, they make use of faster modes of transport, a fact leading to more harm to the environment.

**Figure 4:** A causal correlation between per capita GDP and individual consumption for transport




Legend: AT: Austria, BE: Belgium, BG: Bulgaria, CZ: Czech Republic, DK: Denmark, EE: Estonia, ES: Spain, FI: Finland, FR: France, DE: Germany, GR: Greece, HR: Croatia, HU: Hungary, IT: Italy, LT: Lithuania, LV: Latvia, PL: Poland, PT: Portugal, RO: Romania, SE: Sweden, SK: Slovakia, SL: Slovenia, MT: Malta, NL: The Netherlands, UK: United Kingdom, EU-28: European Union of 28 countries.

**3. Air pollution and railways**

*3.1 Air pollutants from railways and other transport modes*

Transport is an important air pollution emitter; though the problem is global, there is no consensus about the measures to be taken by the various countries around the world and the accurate measuring and recording of air pollution data. Thus, most analyses focus on specific parts of the world, e.g. the EU, USA, China, etc., (EEA, 2018). In the late 2010s, the transport sector was responsible in the EU countries for 20.98% of CO emissions, for 55.38% of nitrogen oxides ($NO_x$) emissions, for 12.08% of sulfur oxides ($SO_x$) emissions, and for 9.28% of non-methane volatile organic compounds, (EEA, 2018; EEA, 2021a) (Figure 5).

Figures 6 and 7 illustrate specific emissions (gr of pollutant (CO, $NO_x$, $SO_x$, NMVOC) per passenger-km or tonne-km) from railways and other transport modes.

**Figure 5:** Degree of participation (%) of the transport and the non-transport sectors and of the various transport modes in the emissions of CO, $NO_x$, $SO_x$, NMVOC for the EU-28 countries, (EEA, 2018; EEA, 2021a)

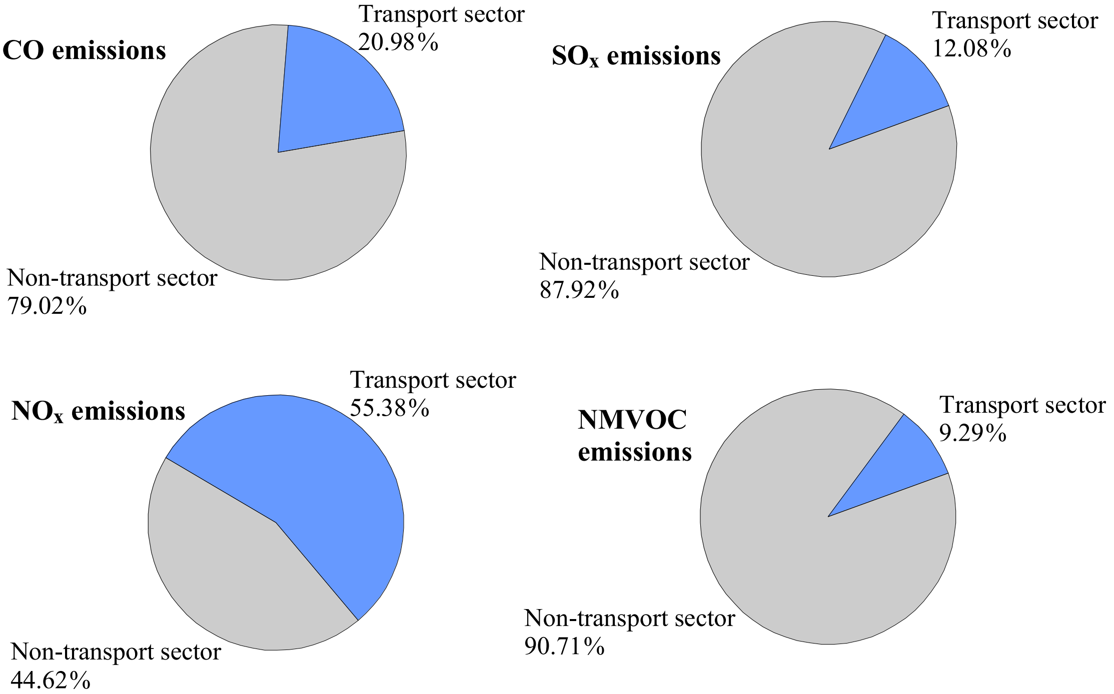
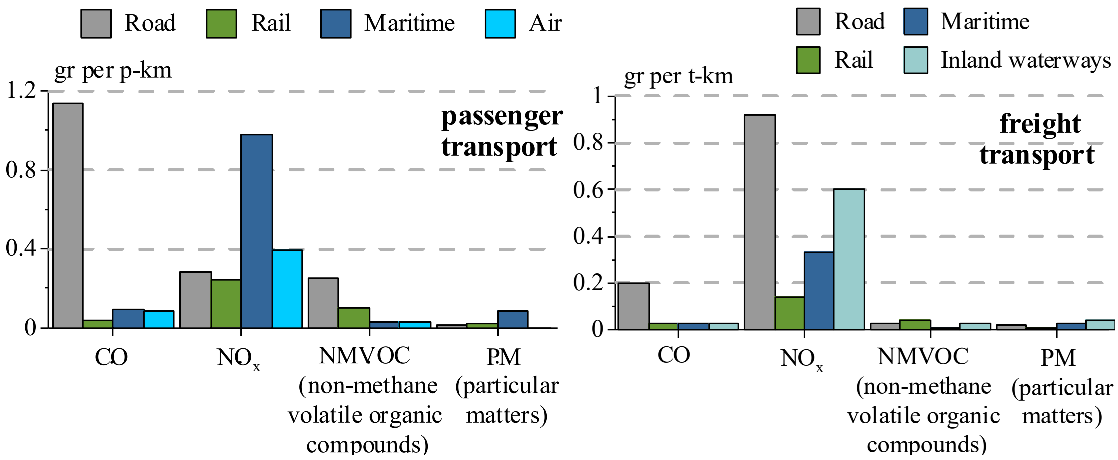



**Figure 6:** Specific emissions of air pollutants from passenger and freight transport for railways and other transport modes in the EU-28 countries, (EEA, 2021a)




*3.2 The greenhouse effect and $CO_2$ emissions from railways and other transport modes*

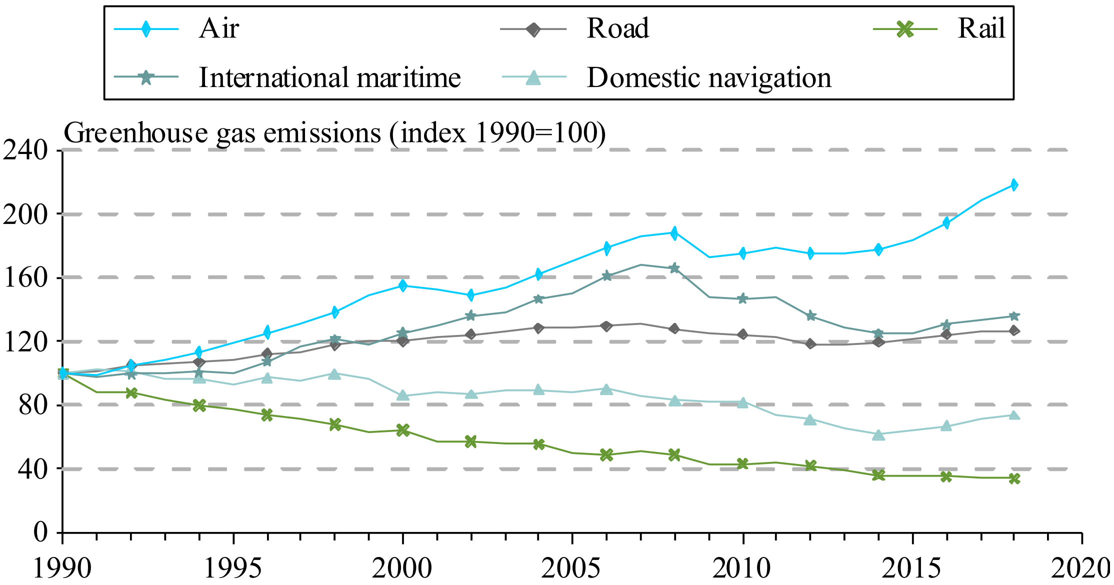
The greenhouse effect is at the origin of the existence of life on earth. However, human activities during the last 4÷5 decades, principally the burning of fossil fuels and deforestation, have led to the increase and accumulation of $CO_2$ concentrations around the earth, a fact that intensifies the natural greenhouse effect and causes additional global warming.

Though $CO_2$ is the principal gas contributing to the greenhouse effect (by 76% worldwide), other gases (such as methane (by 16%), nitrous oxides (by 6%), halocarbons (by 2%)) also play a contributing role. The contribution of the transport sector to the emissions of greenhouse gases is 15.9% worldwide, of which 3.7% from the USA, 1.8% from China, 1.7% from EU-28, 0.6% from India, and 0.5% from Russia.

Within the transport sector, the contribution of the various transport modes in greenhouse gases emissions was for the EU-28 countries for the year 2018 as follows: roads 71.0%, aviation 14.4%, navigation 13.6%, railways 0.5%, other 0.5%. However, the situation varies at world level, where most railways are not electrified. Thus, greenhouse gases emissions from the various transport modes at world level for the year 2018 are as follows: private cars 44.4%, trucks 29.6%, aviation 11.3%, navigation 11.1%, railways 1.2%, and other 2.4%, (EEA, 2021b).

In spite of measures taken to control and reduce greenhouse gases emissions in the EU-28 countries for the past three decades (since 1990), Figure 7 illustrates that railways succeeded to reduce drastically their greenhouse gases emissions, domestic navigation to a lesser degree, whereas in the case of road transport these emissions increased and in the case of air transport greenhouse gases emissions saw a great increase, (EEA, 2021b).

**Figure 7:** Evolution of greenhouse gas emissions from various trans-port modes in the EU-28 countries between 1990 and 2019, (EEA, 2021b)




*3.3 Specific $CO_2$ emissions from railways and other transport modes*

Specific $CO_2$ emissions from transport differ from one area of the world to the other, depending on the degree of electrification of railways, the load factor of the specific transport mode, the use of old or new technology to impart motion, etc.

Figure 8 illustrates average values of $CO_2$ emissions of railways and other transport modes for the EU-28 countries, whereas Figure 9 illustrates the specific $CO_2$ emissions of high-speed trains, maglev trains (a system of train transportation that uses two sets of magnets: one set to repel and push the train up off the track, and another set to move the elevated train ahead, taking advantage of the lack of friction), and aircrafts. Specific emissions do not vary for railways in relation to the distance travelled, whereas they vary greatly for aircrafts, (Janic, 2020).

It is noteworthy that specific emissions of gr $CO_2$/passenger-km were, on average for railways in Europe, 52 in 1990, 38 in 2010, and are expected to fall to 26 in 2030. Specific emissions for rail freight transport in Europe were (in gr $CO_2$/tonne-km) 31 in 1990, 18 in 2010, and are expected to fall to 15 in 2030, (UIC and CER, 2015).

**Figure 8:** Comparative $CO_2$ emissions of railways and other trans-port modes for the EU countries, (Profillidis, 2016)

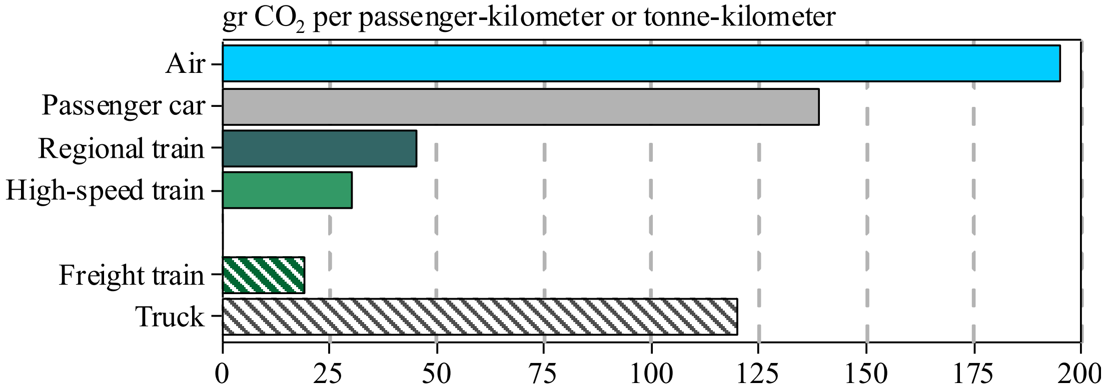
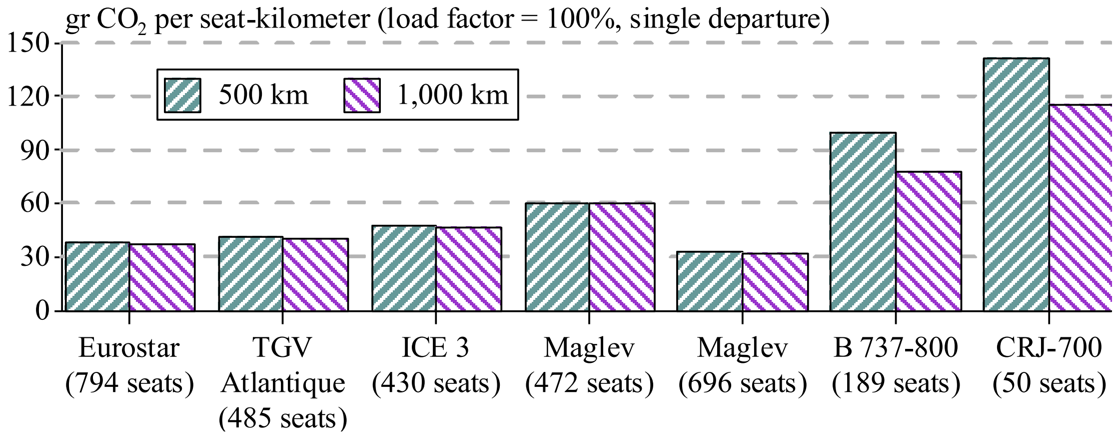



**Figure 9:** Specific emissions of $CO_2$ per seat-km for high-speed trains, maglev trains, and aircrafts, (Janic, 2020)




*3.3 Internalization of costs of $CO_2$ emissions*

Internalization of external costs in the real cost of transport, paid by the user, can become an efficient tool for tracking environmental problems. As a way to confront the greenhouse effect and $CO_2$ emissions, a carbon tax per tonne of carbon emitted has been suggested, with a value of 40÷50 US$ / tonne of $CO_2$ in spring 2021 on the European market. If this internalization proceeds, something that is not very likely, a shift of traffic to the railways can be expected. Assessment of this shift of traffic may be approached as follows, (Profillidis, 2016; Profillidis and Botzoris, 2018).

First, a decision should be made about whether:

- internalization shall include only $CO_2$ emissions or all external costs,
- internalization shall be based on medium external cost or on marginal social cost.

A study on the internalization of all external costs for the EU countries was based on the increase of operation costs that would result and on cross-elasticities between rail and other transport modes. If internalization is conducted according to the average external costs, expected shift of traffic to the railways would be on the order of 12÷15% for passenger traffic and up to 24% for freight traffic. If, however, internalization is conducted according to the marginal social cost, the expected shift of traffic for passenger and freight would be on the order of only 6%, (Profillidis, 2016).

## 4. Energy consumption and railways

*4.1 Energy consumption and the transport sector*

With regard to the EU-28 countries in the year 2018, the transport sector consumed 33.9% of total energy, households 24.7%, industry 25.3%, services 13.4%, agriculture 2.4%, other activities 0.3%. Percentages of the consumption of energy at the world level for the year 2018 were as follows: transport 32.6%, industry 31.8%, households 19.1%, services 8.8%, other (agriculture, mining, etc.) activities 7.7%, (European Commission, 2020).

*4.2 Energy consumption within the transport sector*

Within the transport sector for the EU countries in the year 2018, railways consumed 1.7% of total energy for transport activities, road transport 80.4%, domestic navigation 1.4%, air transport 0.7%, and other 0.7%, (European Commission, 2020).

Figure 10 illustrates specific energy consumption of some railway services in comparison with aircrafts. The energy efficiency of rail transport in comparison with other transport modes is illustrated in Figure 11 for passenger transport and in Figure 12 for freight transport.

**Figure 10:** Specific energy consumption for various high-speed railway services in comparison with aircrafts and maglev, (Janic, 2020)

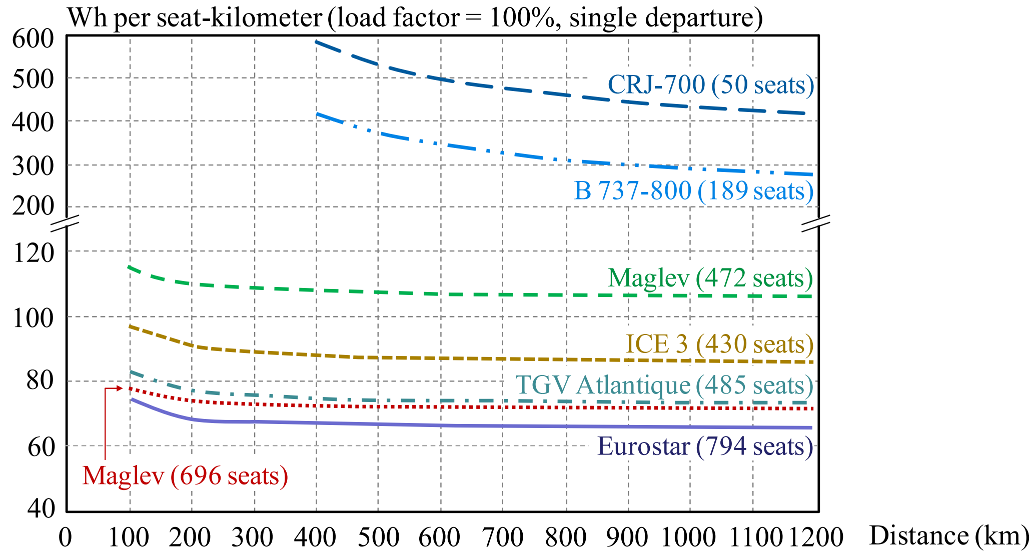



**Figure 11:** Number of passenger-km transported when consuming 1 kWh of energy for railways and other transport modes, (UNECE, 2018)

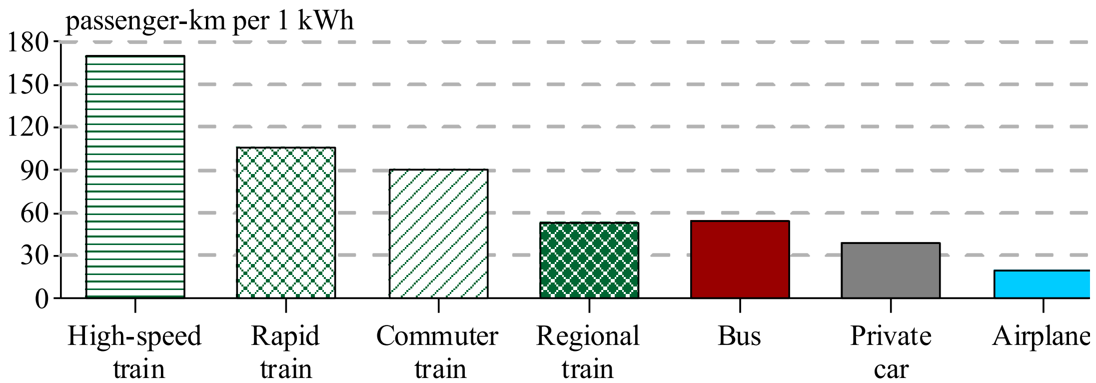
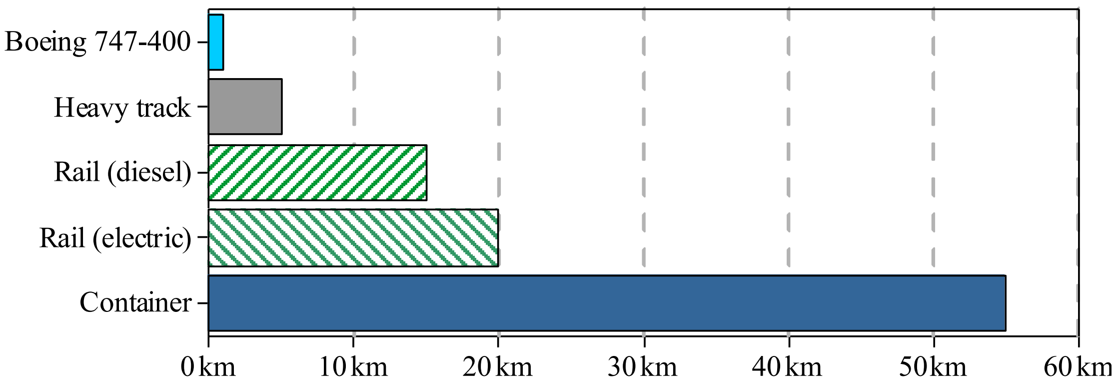


**Figure 12:** Distance traveled by various transport modes for 1 tonne of freight when using 1 kWh of energy, (IEA and UIC, 2017)




## 5. Conclusions

In the present paper we tried to clarify and suggest specific measures related to the transport sector, so as to keep increase of global temperature of the earth below 1.5°C. We presented an overview of the evolution of the global temperature of the earth during the last two decades and we emphasized on the dangerously increasing temperature during the last three decades. We studied in detail the correlation between $CO_2$ emissions and annual growth of GDP during the last six decades. We investigated the various pollutants emitted by the transport and the non-transport sector. We established a causal correlation between individual consumption for transport and per capita GDP, which testifies only a slight reduction in the consumption for transport of individuals during the last two decades. The paper focuses also on how the various transport modes changed (increased or decreased) their emissions during the last three decades. Specific $CO_2$ emissions are analyzed as well as effects of an eventual internalization of $CO_2$ costs. Specific consumption of energy by each transport mode is also assessed.

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# The road to sustainability through the education of professionals in the field of construction

**Sofia Giannarou[1], Efthimios Zervas[1] & Michael Tsatiris[2]**
[1] *Hellenic Open University, School of Science and Technology, Laboratory of Technology and Policy of Energy and Environment, Parodos Aristotelous 18, 26335 Patras, Greece*
[2] *Democritus University of Thrace, School of Agricultural and Forest Sciences, Department of Forestry and Management of the Environment & Natural Resources, 193 Pantazidou Street, 68 200, Orestiada, Greece*
giannarou.sofia@ac.eap.gr, zervas@eap.gr, tsatiris@fmenr.duth.gr

**Abstract**
The bioclimatic design of buildings is an urgent need that begins with the acceptance of the facts of the reckless use of energy resources, the destruction of the environment and the deterioration of the quality of life of animals and humans and continues with the realization that this is a socio-political rather than a technical issue which requires mainly a change of mentality and a redefinition of the social priorities and goals of humanity. Therefore, today's society demands the environmental awareness of all citizens and the bioclimatic architectural training of the engineers of the future. To date, ignorance of the goals and benefits of climate-based construction, academic inaction, and rigid curricula in educational institutions, combined with limited expertise, non-social compliance, and a lack of inspiring standards have led to unsustainable ways life and a future doubtful for humanity. The purpose of this research using structured questionnaires is to investigate the knowledge of professionals in the field of building construction in Greece on bioclimatic design and the causes of the lack of environmental awareness of Greek citizens until recently, which led to a building stock with small number of bioclimatic buildings.

**Keywords:** Bioclimatic design, sustainability, engineering education, environmental education.

**JEL Codes**: O44, O33, Q43, Q52.

## 1. Introduction

Globally, the reckless consumption of conventional energy in all areas of human activity, including the building, has led to significant problems such as climate change and at the same time pollution and environmental destruction. Extreme weather events such as heavy rainfall, deadly hurricanes, extreme temperatures, heat waves, glaciers, droughts and floods have been observed in recent years.

All of the above have led humanity around the world to realize that growth and progress today must not undermine the future growth and progress of humanity.

Andre Gorz aptly predicted in 1980 that the world was in danger of extinction if humanity continue as before, the oceans and rivers will dry up, the earth will become barren, the air in the cities polluted and life will be the prerogative of a new race chemically prepared and genetically programmed so that it can survive in the new ecological reality (Gorz translated by Vigderman & Cloud, 1980).

Efthymopoulos in 2017, in his book "The dilemma of the butterfly", refers to the risk of extinction of butterflies due to poor conditions during their migratory journey, at the end of the book he states that the risk of extinction does not only concern butterflies but also humans. However, human society, unlike butterflies, can be active and prevent the worst case scenario of environmental disaster with the consequent extinction of species (Efthymiopoulos, 2017).

The concept of sustainable development was introduced by Brundtland in 1987 on behalf of the World Committee on Environment and Development, which aims to meet the needs of current generations in a way that does not endanger the needs of future generations (Members of the Commission, Bruntland Report, 1987). The extension of the above definition to the construction sector leads to the concept of sustainable or bioclimatic design of buildings. These are buildings that can and do meet the needs of current users, but without making it difficult for future generations to meet their own needs (Maroulas, 2011).

The bioclimatic design of buildings is an ancient design technique. However, the technological development of recent years has led to the excessive use of mechanical heating and cooling systems in buildings, so the importance of climate and sustainability in architectural design has been overshadowed, resulting in excessive consumption and depletion of conventional energy sources, harmful environment and carbon emissions, climate change everywhere and undermining the health of living organisms on the planet and especially humans.

Therefore, the current season requires the design of new and the renovation of existing buildings, according to the particular microclimatic conditions prevailing in each area, the use of renewable energy sources such as sun and air and the minimization of conventional energy consumption for heating and cooling for providing thermal comfort to building users (Olgyay V. & Olgyay A., 1963; Athienitis et al., 2002; Nguyen et al., 2014; Manzano-Agugliaro et al., 2015).

## 2. National action framework for reduction of energy consumption of the structured environment

The successful implementation of the goals of sustainable development in the construction sector is based on the adoption of policies, actions and the implementation of programs both nationally and internationally. Governments have the primary responsibility for monitoring the progress of the implementation of the Sustainable Development Goals, nationally, regionally and globally.

However, Greek legislation has significantly delayed the implementation of energy efficiency measures for buildings. Specifically, in Greece the first regulation for the construction of bioclimatic buildings was the Thermal Insulation Regulation of Buildings introduced in 1980. Its substantial revision was made in 2010 with the Energy Efficiency Regulation of Buildings and its amendment in 2017.

So, the buildings, according to the report on the long-term strategy for mobilizing investments for the renovation and conversion of the national building stock, consisting of residential and commercial buildings, public and private, in high energy efficiency buildings, without carbon emissions by 2050, are classified in the following age categories (Ministry of Environment and Energy, 2021; European Commission, 2021; BPIE, 2021):

- Buildings without measures for their thermal protection, which were constructed before the Thermal Insulation Regulation of Buildings, before 1980, which constitute more than half for the houses: 55.7% and for the tertiary sector: 38.7%.
- Buildings, which have been constructed before the entry into force of the Energy Efficiency Regulation of Buildings, before 2010, with the implementation of minimum thermal insulation measures, which constitute a percentage for residences: 42.7% and for the tertiary sector: 59.0%.
- Buildings, which have been constructed after the entry into force of the Energy Efficiency Regulation of Buildings, after 2010, which constitute a percentage for residential: 1.6% and for the tertiary sector: 2.3% in the last five years.

It is characteristic that the houses are not demolished for many years after their construction. Therefore, taking into account the large number of old buildings and the small number of newly built buildings, it's derived that most of the building stock of Greece is old and with high energy consumption, which is due to the unjustified delay of Greek legislation on the energy efficiency of buildings.

Therefore, in Greece, regarding the new buildings, the transition of the real estate sector to the so-called "green" buildings becomes necessary and at the same time becomes more and more obvious. Bioclimatic buildings with a range of certifications, which have a very low energy and environmental footprint, seem to be gradually gaining more and more penetration in the real estate market. The transition to green buildings and sustainable development is a given today. Another goal is the energy upgrade of 12-15% of the buildings by 2030, through targeted policy measures. While by 2050 the buildings should have almost zero energy balance and almost the entire stock of buildings in the country should be upgraded in terms of energy consumption (Ministry of Environment and Energy, 2021).

It is very easy to understand that professionals in the construction sector play a fundamental role in achieving the above goals, as they build green buildings and upgrade existing ones.

## 3. Methods and Data

### *3.1 Methodology and Data*

This article explores the views of construction professionals in Greece through the distribution of questionnaires in 2018-2019 using Google forms and at the same time suggests actions through which the state will be able to teach them sustainability and at the same time instill in them an environmental lifestyle. The questionnaires collected were 138 and the statistical analysis was performed using SPSS.

### *3.2 Results and Discussion*

This section of the paper includes some of the results of the descriptive analysis performed and the chi-square independence test.

Regarding the knowledge and application of the principles of bioclimatic buildings, most of the respondents answered that the application of bioclimatic strategies in the design and construction of a building is known and also the legislation on the energy efficiency of buildings. But most of them did not learn about the bioclimatic construction of buildings through their teaching in their studies, but from other sources of knowledge as shown in Figure 1. This result was expected, as bioclimatic architecture began to interest Greeks during the last decade, with the result that its systematic integration into university curricula has taken place in recent years. Most of the respondents (two in three) also answered that they are certified energy inspectors and participated in projects and the construction of autonomous energy buildings (Figure 2). They also claim to know most and perhaps the most well-known principles of bioclimatic architecture (Figure 3). Besides, the strict regulations imposed by the Greek state from 2010 onwards led in this direction. In addition, the majority of the sample answered that they do not believe that the bioclimatic design of buildings is a practice adopted by the general public of Greece, due to the indifference of the Greek state to instill sustainability in their lives (Figure 4). Finally, the respondents answered that the solution to achieve the goals of sustainability in the building sector can be achieved through the training of engineers and all citizens. All the answers argued that sustainability should be taught in universities and especially in the prospective engineers who shape the built environment and also the majority of the sample believes that the state should take action to shape environmental awareness among Greeks (Figure 5).

The correlations between the variables with the chi-square test of independence show that: Most professionals in the construction sector, regardless of employment, have studied the legislation ($p < 0.05$). Certified energy inspectors are engineers involved in the design and construction of buildings and not engineers involved in research or training. Finally, people who graduated before 2010 did not attend many bioclimatic design courses, unlike those who graduated in the last decade, due to the late adoption of sustainability in universities.

**Figure 1:** Knowledge and application of the principles of bioclimatic buildings

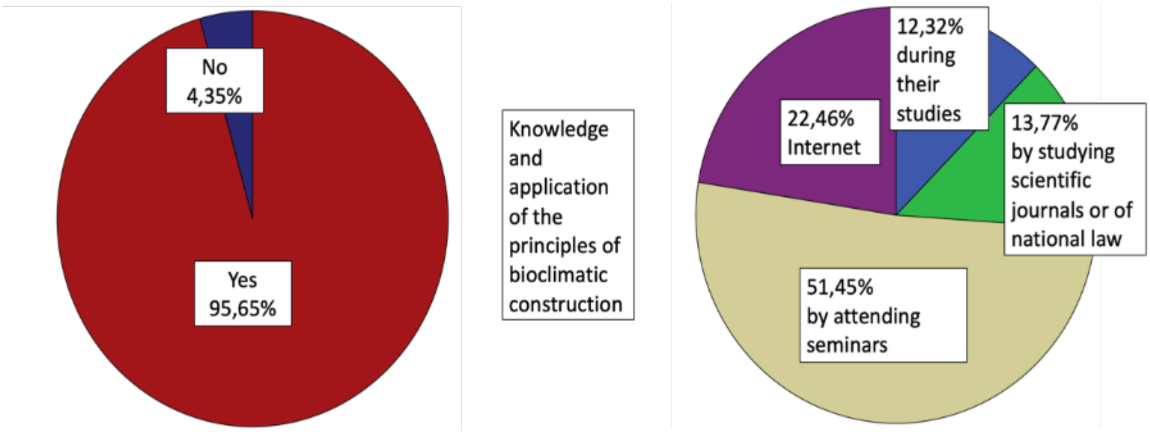



**Figure 2:** Percentage of certified energy inspectors and number of energy upgrade projects and construction of autonomous energy buildings.

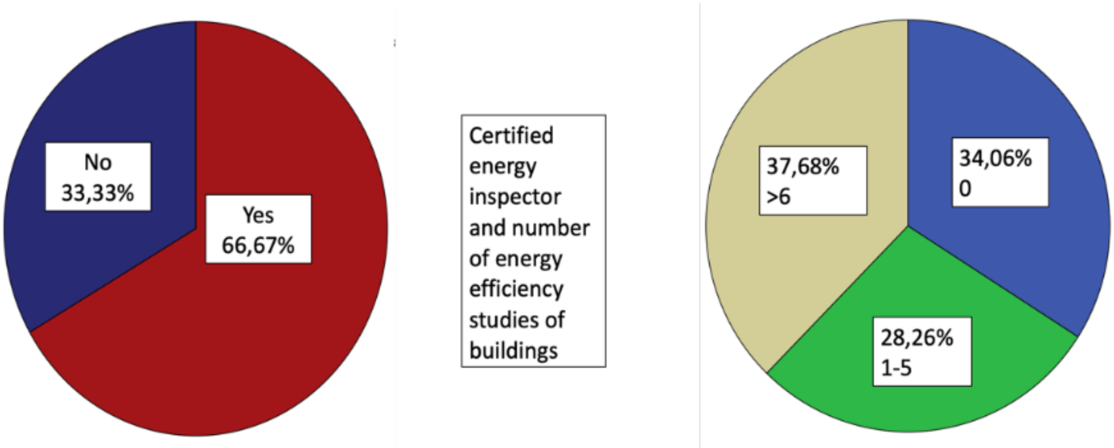



**Figure 3:** Knowledge of principles of bioclimatic architecture.

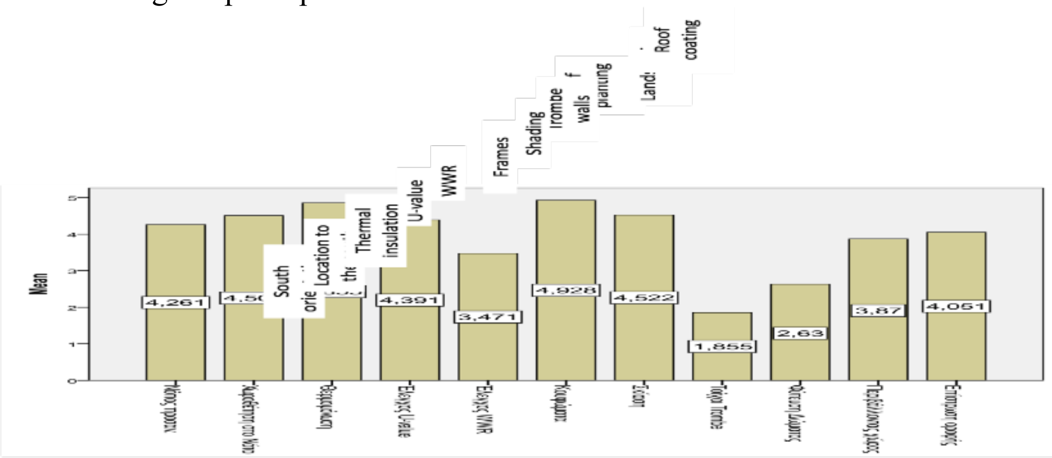


**Figure 4:** The bioclimatic design of buildings is a practice adopted by the general public of Greece.

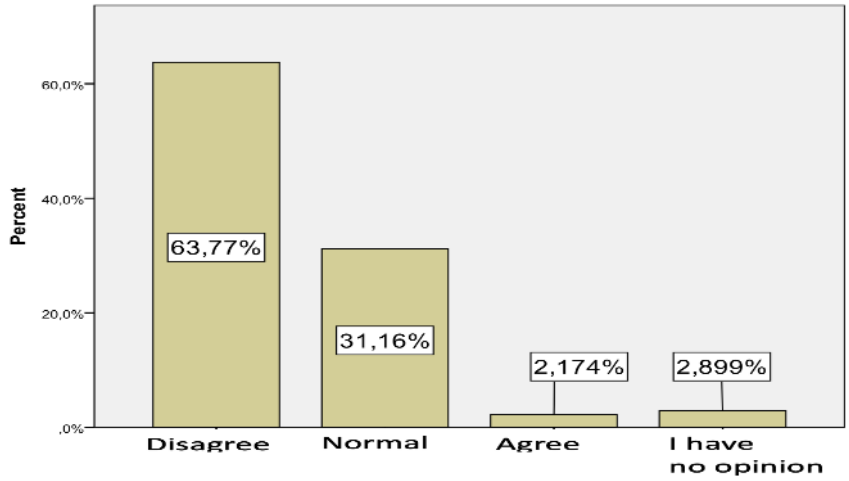
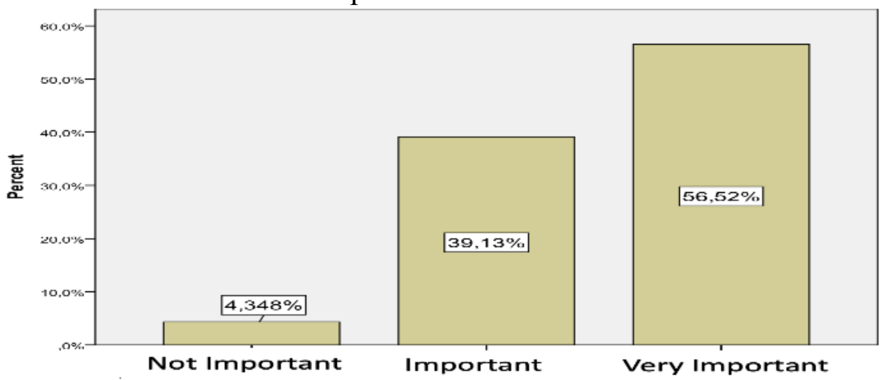



**Figure 5:** The state should take action to shape environmental awareness in Greeks.




## 5. Conclusions

Engineers are primarily responsible for shaping a sustainable built environment as they make decisions during the design and construction phase. That is why in the present study structured questionnaires were distributed to engineers, about bioclimatic architecture and sustainability in Greece.

The findings of this research show that the state, although significantly delayed, has now enacted stricter legislation on the energy efficiency of buildings. Also, schools, higher education institutions, and especially engineering schools, students and researchers, have already started processes of change and integration of sustainability in teaching and research programs, also with the environmental management of school and university complexes and in collaboration with society. The responsibility of engineering schools is greater as by training future professionals, they can contribute to shaping a promising sustainable future.

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# Kriging Analysis for Atmosphere Pollutants and House Prices: The case of Athens

**Polixeni Iliopoulou & Christos Kitsos**
*University of West Attica, School of Engineering*
piliop@uniwa.gr, xkitsos@uniwa.gr

**Abstract**
In this paper the effect of air pollutants on housing prices in the Greater Athens region is examined employing kriging analysis. Data concerning air pollution in Attica are provided for a network of stations in a time series. Several methods of spatial interpolation can be used in order to create an air pollution surface for the study region, such as polynomials and splines.
These methods are not considered when the measurement depends on time in the sense that $y_i = y(t_i)$, as the Atmosphere Pollution indexes, the prices in any market etc. In such stochastic oriented data, not only Explanatory Data Analysis (EDA) is needed, but a structural model is required, providing the best estimates, by kriging, as well as the variance of the estimated error.
In this paper the air pollutant surfaces resulting from kriging analysis are used in order to assign air pollution values to houses for sale, employing GIS techniques. The effect of selected air pollutants on housing prices is examined and the results indicate that although structural characteristics of houses, i.e. size, are more important, the effect of air pollutants is not negligible.

**Keywords:** Kriging, interpolation, EDA, Inverse Distance Weighting, air-pollution

**JEL Codes**: C21, R32, C31, C52

## 1. Introduction

The problem of interpolation is essential for a given polynomial. We are restricted to polynomial interpolation, mainly due to a Weierstrass Theorem: For a given smooth real function $f(x)$, defined on a subset of R, say I, there is a polynomial $p(x)$, such that $|f(x)-p(x)|<\varepsilon$, $\varepsilon>0$, for x in I. Polynomial interpolation provides an estimation of the response for a given input value, within the domain I, and is mainly a Numerical Analysis method, see Froberg (1985), among others.

It can be proved that for given n+1 points ($x_i$ , $y_i$ , $i = 0, 1,2,\dots n$ there exists a polynomial of n degree, $p_n(x)$ that interpolates the data, in the sense that $p_n(x_i) = y_i$, i=0,1,2..n, provided that $x_i$ are distinct. When the fitted polynomial is of degree m<n, i.e. $p_m(x)$, which occurs when the $x_i$'s are not distinct, the Ordinary Least Square method (OLS) can be applied, also known as Regression method in Statistics. Moreover, in both cases either bounds, through Numerical techniques or estimates of the variance of the involved errors can be evaluated. When the domain I can be partitioned in a number of sub-intervals, say Ij, $j = 1,2,\dots k$, where a cubic polynomial fits the data at each Ij, then the Cubic Splines can also be adopted, under certain assumptions, to reduce the error comparing to OLS, see the pioneering work of Schoenberg (1947, 1973). Certain type of Splines is related to Lattice theory (Entezari et. al. 2008). When a surface is studied, in considerable experimental region, the Response Surface Method (RSM), see Mead and Pike (1975) among others, can be applied, while for larger experimental areas, as the airplane surface, the Surface Splines are adopted (Li et. al. 2018). Moreover in application one can adopt either the RSM or the Cubic Splines (Gülüma et. al., 2019), while to cover a "surface" the B-splines are always a useful tool, as it has been discussed in the early work of de Boor (1962, 1972).

These methods suffer that cannot be considered, when the measurement depends on time, in the sense that $y_i = y\ (t_i)$, as the Atmosphere Pollution indexes, the prices in any market etc. In such stochastic oriented data, not only Explanatory Data Analysis (EDA) is needed, but a structural model is required, providing the best estimates, by kriging, as well as the variance of the estimated error. Thus, we can say that there are two groups, of not so different techniques, related to the subject:

(i) The deterministic interpolation and

(ii) The stochastic interpolation

That is why Spatial interpolation methods (Isaaks and Srivastava, 1989), in principle, differ in the line of thought essentially from the referred traditional modeling approaches, in the way that they need to incorporate more information in a grand scale of geographical research focused primarily on the geographic position of the sample points, at the certain time, acting as a "functional" depending data analysis (Ramsey and Silverman, 2006). This is the case that one works on a large-scale surface, not to a "response surface" method (RSM) and still needs more information to incorporate on the interpolation he plans: Spatial interpolation methods offer a means of characterizing a variety of different input variables or responses over different spatial scales, recalling that collecting and analyzing Spatial Data needs to focus on the fact that time is continuous, the data is discrete and the techniques are based on properties proved for continuous functions.

Such a method is adopted in this paper, to investigate the Atmosphere Pollutants influence on the house prices, in the polluted areas: the method of Kriging, which is briefly described below. The researcher needs to clarify the deterministic methods, before pass to stochastic ones. This is attempted in section 2, while in section 3 the kriging method is closely described and reviewed in a compact line of thought.

## 2. Background

To explore the response surface of an experiment is essential, as might provide the information of where the extreme points take place. The RSM attempts to comprise a set of statistical techniques appropriate for design and data analysis, based on model building and model exploration that enhance the exploration of a region of the design variable involved in the measurable of one (or more) response.

In principle, the input (or explanatory) variables, say, are quantitative and assumed to be without error. They are also considered fixed by the experimenter, and usually transformed so that to be within [-1,1]. The experimental region is usually defined as a "squared" or "cyclical" while the observed response, y say, differs from the true one, η say, by the error e, i.e.

$$y = \eta + e. \tag{2.1}$$

The assumptions imposed for the errors are that are independent identically distributed (iid) with $E(e)=0$, $V(e)=\sigma^2$. Notice that in matrix notation y can be considered as:

$$y = y(x) = \hat{a}_0 + x'\hat{a} + x'\hat{A}\, x + e \tag{2.2}$$

Where:

$x', \beta' \in R^k, \beta_o \in R$, $B = \left(\beta_{ij}\right) \in R^{kxk}$, with all the off-diagonal elements of the matrix B divided by 2. The input variables are supposed to be standardized, while the stationary point $x_o$ equals to:

$$x_0 = -\tfrac{1}{2}\hat{B}^{-1}\hat{\beta} \tag{2.3}$$

See Kitsos (1995) for details. The gain is RSM is that a "local" smooth function is obtained, through (2.2). "Local", in the sense that the described with model (2.2) surface, is considered in the neighborhood of the stationary point. That is the method is adapted to experimental design theory. For larger requested areas, as the surface in a boat (Jung, 2010), or other fields (Li et. al., 2018), while for an airplane surface the RSM was applied also, satisfactory.

A cubic spline function comprises polynomial pieces on subintervals joined together with certain continuity conditions, at the end points, to link the piece-wise polynomials, known as knots. Briefly: for given n+1 data points, considered as a partition of the interval in R, say I = [K, L] such that K= $x_0 < x_1$

$< \cdots < x_n = L$, which are the knots, a cubic spline function, $C_s$ , of degree k, with knots $x_0, x_1, \ldots, x_n$ is a function Cs such that the following conditions hold:

(i) In each interval $I_i = [x_{i-1}, x_i]$, $C_s$ is a polynomial of degree $\leq k$;

(ii) Polynomial $C_s$ has a continuous $(k - 1)$st derivative on $[K, L] = [x_0, x_n]$.

Considering a cubic spline, as it has been mentioned, the target is to derive a third-order polynomial, de Boor (1962, 1972) for each interval between the defined knots of the form:

$$C_{s\,i}(x) = a_i + b_i (x - x_i) + c_i (x - x_i)^2 + di (x - x_i)^3 \qquad (2.4)$$

The generalization and the application to the industry came in 1962 by the French engineer Pierre Bézier (1910-1999) who used them to design automobile bodies. Briefly Bézier surfaces are a species of splines used in computer graphics, computer-aided design (CAD, originated by him) plus other mathematical techniques (Bohm, 1977).

The above described methods are deterministic. Stochastic methods try to obtain the Best Linear Unbiased Estimators (BLUE) and so does the stochastic kriging method, based on the multivariable Gaussian distribution. The stochastic feature of the kriging, provides evidence that prediction of uncertainty is possible. In section 2 the main deterministic methods were briefly discussed, so that in section 3 the kriging method can be better approached and clarified, in the sense that eventually, the data analysis in section 4 to be faced under a solid background, as it is based on a complicated functional analysis line of thought (Ramsey and Silverman, 2006).

*2.1 Spatial interpolation*

The principle of underlying spatial interpolation is the First Law of Geography. Formulated by Waldo Tobler, Tobler (1970), this law states that everything is related to everything else, but near things are more related than distant things.

Spatial interpolation is the process of using points with known values to estimate values at other unknown points. Elevation data, precipitation, snow accumulation, water table, air pollution data and population density are types of data that can be computed using interpolation.

Deterministic methods such as Inverse Distance Weighting (IDW) can be used as well as kriging methods, see section 3.

Inverse distance weighted (IDW) interpolation explicitly implements the assumption that things that are close to one another, in the same “neighbourhood” (either with the Geographical meaning or the Mathematical one) are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location. In principle the measured values closest to the prediction location have more influence on the predicted value, than those farther away. From Statistical point of view, the value at time t+1 heavily depends on the current value at time t and so is formed the idea of a martingale in the theory of Stochastic Processes. IDW assumes that each measured point has a local influence that diminishes with distance. It gives greater weights to points closest to the prediction location, and the weights diminish as a function of distance. IDW does not provide prediction standard errors.

On the other hand, Kriging assumes that at least some of the spatial variation observed, in natural phenomena, can be modelled by random processes with spatial autocorrelation, and requires that the spatial autocorrelation be explicitly modelled. Kriging techniques can be used to describe and model spatial patterns, predict values at unmeasured locations, and assess the uncertainty associated with a predicted value at the unmeasured locations.

The choice of a correct type of interpolation method depends on many factors. There is no general method that is suitable for all problems: it depends on the nature of the variables involved and on the time-scale on which the variables are represented. The “quality” of sample point set can affect the choice of interpolation method as well. If the sample points are poorly distributed or there are few of them, the surface might not represent the actual terrain very well. If we have too few sample points it is possible to add more sample points in areas where the terrain changes abruptly or frequently and then try using Kriging.

In the case of measurements at a precise point location, the most used and promising techniques are universal kriging and linear regression models, in combination with Kriging (residual Kriging) or IDW. In this paper a combination of IDW and kriging is presented in order to create surfaces of air pollutants in the study region.

## 3. Interpolation with kriging

For the response variable y, let a set of measurements ($y_1$ , $y_2$ ,….$y_n$ ) at n sampled data points ($x_1$ , $x_2$ ,…$x_n$) of the explanatory variable x are observed. Consider the variable z to be modeled, while the set of values $\{z(x),\ x\in A\}$, with A the area under consideration, describing a multi-Gaussian stochastic process, for a theoretical approach to Gaussian systems see Karlin and Taylor (1975). The variable z is linked with the stochastic errors $e_i$ and the response y as:

$$y_i = z_i + e_i \quad i=1, 2,\dots, n$$

In order to be $z^*(x_o)$ the (simple) kriging estimate of the response z at the given point $x_o$ the following has to be satisfied:

$$\begin{aligned}
&\text{(i)} && z^*(x_o) = \sum_{i=1}^{n} w_i\, y(x_i) \\
&\text{(ii)} && E[z^*(x_o)] = z(x_o) \qquad\qquad (3.1)\\
&\text{(iii)} && z^*(x_o) = \arg\min \{z^L(x_o): Var[z^L(x_o) - z(x_o)]\}
\end{aligned}$$

where in (i) $w_i$ is the weight given at observation $y(x_i)$ and the summation is over the values 1(1)n, (ii) declares that the estimator $z^*(x_o)$ is an unbiased estimator of the response point, in (iii) $z^L(x_o)$ presents any linear estimator of $z(x_o)$, while Var (T) is the variance of the random variable T, as usual. The underlying stochastic process gives rise to two kinds of kriging:

(i) the one where the stochastic process is a stationary of order 2, then the kriging is referred as “ordinary kriging”, and

(ii) when there is a trend, the data do not form a stochastic process as above, the kriging is referred as “universal kriging”.

Notice that in case (i) the expected value remains invariant within the area A under consideration and the covariance between two measurements in different locations depends only on the deviation vector of the considered locations. Its estimation of the variance is:

$$\sigma^2 = \mathrm{E}\{[z(x) - z(x_o)]^2\} \qquad (3.2)$$

For the ordinary kriging, due to multi Gaussian character of the stochastic process, and the related discussion it holds that:

$$E[z(x)] = \mu \quad \text{and} \quad Cov\,(z(x_i) - z(x_j)) = \Gamma(x_i - x_j) \qquad (3.3)$$

Eventually the kriging estimator can be expressed as a linear combination of the values ($\Gamma(x_i - x_o)$, i =1,2,…n) in the sense that :

$$z^*(x_o) = \sum_{i=1}^{n} \gamma_\iota\, \Gamma(x_i - x_o), \qquad (3.4)$$

with the coefficients $\gamma_\iota$ , i=1,2,…,n being the solution of the simultaneous equations:

$$\Sigma \gamma_i = 0 \quad , \; z^*(x_k) + \sigma^2(x_k)\gamma_\kappa = y(x_k), \quad k = 1,2,\ldots, n \qquad (3.5)$$

As far as the universal kriging concerns it is distinguished from ordinary (or simple) kriging, as above, by the fact that a set of functions was introduced (Cressie, 1993), to represent the drift of a non-stationary random process, as a linear combination of them. The elements of the non-stationary process are representable as in (3.1), while (3.3) is still valid. The BLUE of the predictor $z^{**}(x_o)$, the corresponding to the one in (3.4) is obtained as a linear combination of the optimum values λ*, of any vector λ defined as bellow in (3.7):

$$z^{**}(x_o) = \Sigma\lambda^*_\iota\, z(x_i) \;\; i=1(1)n \qquad (3.6)$$

with the optimal value $\lambda^* = (\lambda^*_{1,\ldots,}\lambda^*_n)$ to be obtained as:

$$\lambda^* := \operatorname{argmin} \{\mathrm{Var}[z(x_{o,\lambda}) - z(x_o)],\ \lambda=(\lambda_1,\ldots,\lambda_n)\in R^n,\ z(x_{o,\lambda}) = \sum_{i=1}^{n}\lambda_\iota z(x_i),$$

$$\text{with } E[z(x_{o,\lambda})] = \text{drift of the process}\ \} \qquad (3.7)$$

Notice that (3.7) is a generalization of (3.1) (iii), while the computational effort is faced with the appropriate software, see section 4.

*3.1 Variogram, Validation, weights*

The theoretical frame work for kriging is based to offer a Statistical hand to Geographical problems. Typical example is that kriging assumes that variation is continuous. If there are discontinuities at soil boundaries, then even the hypothesis that the theoretical framework is based on quasi-stationarity does not hold.

In practice the weights are chosen so that of the nearest (few) data to $x_o$ are much larger than those further away. Thus, the quantity $h_i = ||x_i - x_o||$ is used as a parameter to weights, to provide emphasis that kriging is in any case local, and therefore it is necessary to assume only a local stationary or quasi-stationarity. That helps to compute a (single) global variogram, accurate over only short distances.

In principle in Geostatistics the second order spatial dependence it is not based on the covariance function but on the variogram, noticed as 2γ, see below. Notice that the function $\gamma = \gamma(h)$, depends on h, the distance of the considered points from the area A were the stochastic process is considered, i.e $h=||x_i - x_j||$. The following definitions are widely used in practical problems, and are mainly adopted in many fields of applications (Kitsos 2015), among others.

The global covariance function of the process is the function:

$$C = C(x_i; x_j) = \mathrm{Cov}(x_i ;\_x_j) := E[(x_i - E(x_i))(x_j - E(x_j))] \qquad (3.8)$$

The matrix C is considered positive definite throughout the kriging framework. The global variance Var(z) of the underlying assumed stochastic process ruling the considered kriging (either simple or universal) is defined as:

$$\sigma^2(x) = \mathrm{Var}(z(x)) = E[\|z-E(z)\|^2], \quad x\in A \qquad (3.9)$$

The global semi variogram of the process is the function:

$$\gamma : D\times D \rightarrow [0,+\infty] : (x_i, x_j) \rightarrow \gamma(x_i, x_j) = 1/2\ \mathrm{Var}[z(x_i) - z(x_j)] \qquad (3.10)$$

which is conditionally negative definite function. When the value 2γ is considered we are referred to the global variogram of the process.

The idea of variogram goes back to histogram, which is the typical starting point for a smoothed estimator, of an unknown probability density function (pdf) f with a cumulative distribution function (cdf) F. Then the idea was adapted also to splines: As the interval I = [K, L] can be partitioned to (K-L)/k intervals, see section 2, then the histospline estimator can be obtained (Schoenberg 1972; Boneva et. al. 1971). Eventually Schoenberg's splinegram s(x) is defined as the quadratic spline, of second order having as its graph the union of appropriately defined "arcs".

Then, the next extension of the histogram, is the variogram: theoretical variogram, as it has been defined through (3.10), is a function describing the degree of spatial dependence of a spatial stochastic process. In applied Geostatistics and especially in kriging methods, the empirical variograms are approximated by model function ensuring validity. Some important models are, according to Cressie (1993): The exponential, the spherical and the Gaussian variogram model. When a stationary process (Karlin and Taylor,1975) is assumed, the variogram and semivariogram can be represented as a function $\gamma_s(x_i, x_j) = \gamma(0, h)$, of the Euclidean distance of the points $h = \|x_j - x_i\|$ between locations only, as:

$$\gamma(x_i, x_j) = \gamma_s(x_i - x_j) \qquad (3.11)$$

For the isotropic process the variogram and semivariogram can be represented as a function of the distance of the two points, h as above, Cressie (1993). Moreover, it holds :

$$\gamma(h) = E[\{z(x) - z(x + h)\}^2] \qquad (3.12)$$

To give an example to clarify how important is the choice of the points and their distance consider a lignite mining. A variogram provides the appropriate measure, to qualify, of how much two samples taken from the mining area will vary in lignite percentage depending on the distance between those samples. It is very clear that samples taken far apart, big enough h, will vary more than samples taken close to each other, small enough h.

Based on the notation (3.10) the variance as in (3.2) can be expressed as:

$$\sigma^2 = 2\sum_{i=1}^{n} w_i \gamma(x_i, x_o) - \sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \gamma(x_i, x_j) \qquad (3.13)$$

In practice, needless to say, there are involving errors, either due the underlying assumptions, which is hard to hold as the Mathematical background is rather strict, or the variances are not known, with a desired accuracy, or both. So, the interpolation or prediction it is not an easy procedure, recall cubic splines or even more complicated cases as the surface splines thus the methods must be validated in any rigorous comparison.

In geostatistical practice the typical method of validation accepted in this paper is the cross-validation. It retains the same variogram, and to be considered as a true cross-validation, the variogram should be recomputed and fitted. This needs calculations, time, and it is a very cumbersome procedure. These can be avoided by using a separate independent set of data for validation, as we recommend. Values are estimated at the sites in the second well known set, and the predicted and measured values are compared. The Mean Square Error (MSE) can always be a useful statistic in such calculations, especially the Mean Square Deviation Ratio (MSDR) $R = MSE/\sigma^2$

Eventually prediction can be more "safe", adopting the appropriate statistics, although always there is an uncertainty.

## 4. Analysis of air pollutants in the Greater Athens region

Air pollution is considered to affect house prices in a negative way (Carriazo-Osorio, 2001; Harisson and Rubinfeld, 1978; Liu et al, 2021). Hedonic pricing models are often used to measure the effect of environmental conditions on housing prices (Chasco and Gallo, 2012; Freeman, 1979). Hedonic models estimate house prices through a variety of regression techniques with the house prices being the measurement. Independent variables usually include the structural characteristics of the houses, i.e. size, age, parking, fire place etc., locational characteristics, such as proximity to parks, transportation and a variety of services as well as neighborhood characteristics (Iliopoulou and Stratakis, 2018). The structural characteristics, especially the size of the property, are proved to influence house prices the most, together with the location of the property, which may refer to the quality of the neighborhood from several aspects, including socioeconomic status. Although there are numerous applications of hedonic modeling worldwide, environmental variables are not included very often in the analysis. Actually, the hedonic models might not be able to capture the effect of air pollution on house prices, since the negative effect on living condition and house prices are more evident in short distances from the pollution source and depend on microclimate conditions, such as the direction of winds (Sullivan 2016).

In this study regression modeling is going to be employed to evaluate the effect of air pollution on house prices in the study region.

### *4.1. Study region and Data*

The study region comprises 59 municipalities in the Greater Athens region (map 1). The study area is defined according to the density of houses for sale, since the purpose of this paper is to relate air pollution with house prices.

In this study three air pollutants were examined, i.e. nitrogen dioxide ($NO_2$), ozone ($O_3$) and carbon monoxide (CO). These are among the most important air pollutants in the Greater Athens Region and there are measurement records for several decades (Ministry of Environment and Energy, 2019). The main source of nitrogen dioxide ($NO_2$) is combustion engines and it is related to transportation and industry. Ozone ($O_3$) is considered to be a suburban air pollutant since it is composed in the atmosphere as a result of chemical reactions of primary air pollutants, such as nitrogen oxides, and solar radiation. Carbon monoxide (CO) is the result of thermal combustion. Air pollutants are measured in the Attica region at 14 monitoring stations. In this study data from only 12 monitoring stations are analyzed which correspond to the Greater Athens Region (the stations of Elefsina and Koropi were excluded). The measurements of the three air pollutants in this study are the annual average of the decade 2009-2019, since the last available measurements are for the year 2019 (Ministry of Environment and Energy, 2019). However, measurements are not available for all monitoring stations for all air pollutants. Considering the three air pollutants in this study, data are available for all 12 monitoring stations for $NO_2$ and $O_3$, while for CO data are available for only seven monitoring stations.

Data on house prices comprise a sample of 700 houses for sale in 2020. Data were derived from real estate webpages and are a part of a much larger sample. Several characteristics of the houses are available, such as price, size, age, floor, price per square meter, parking space etc. In addition, spatial data on tax zones were available, all data being produced at the Geography Laboratory, Department of Surveying and Geoinformatics Engineering, University of West Attica.

### *4.2 Interpolation*

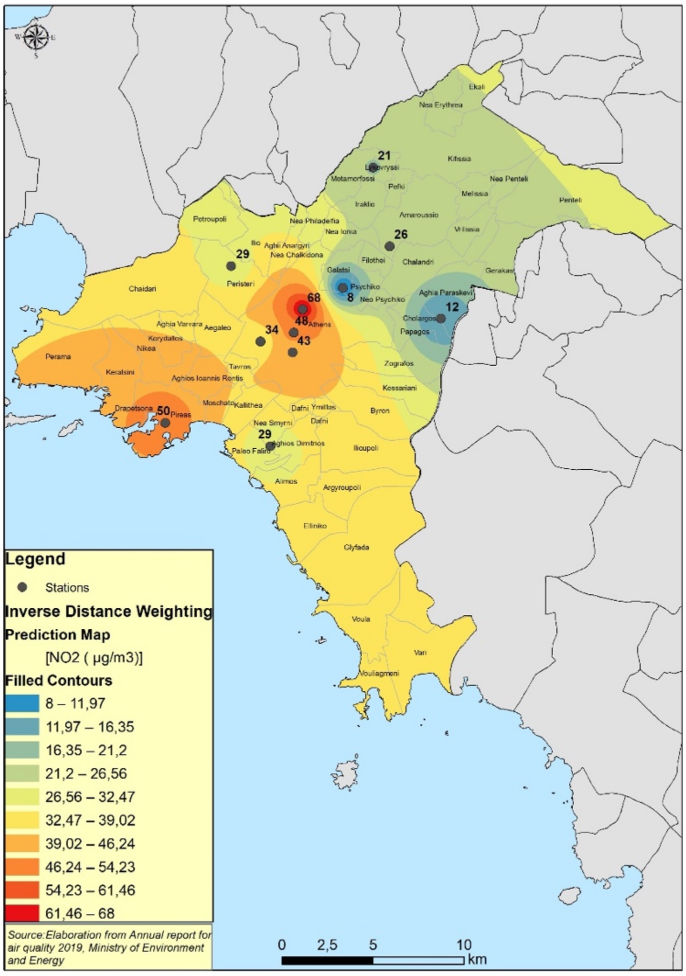
Kriging interpolation was initially employed to create surfaces of the three pollutants in the study region. However, because of the limited number of points (monitoring stations), either the method could not be applied (in the case of CO) or the spatial autocorrelation in the data was not captured. Therefore, an IDW interpolation was initially employed in order to produce more points. This action is justified by the fact that air pollution is a classic example of spatial autocorrelation, i.e. neighboring locations are expected to have similar levels of air pollutions. That is why for this particular purpose the IDW method was considered appropriate, since it is based on the distance h between points and no smoothing of the surface is applied. Employing IDW (Maps 1-3) values for the three air pollutants were produced for each municipality in the study region. Based on this practical line of thought it is recommended that in such cases a two-stage interpolation can be applied:

(i) Augment appropriately the “auxiliary information”, in this case the monitoring stations, and then

(ii) Perform the kriging interpolation, so that the variogram to be, eventually, essentially improved

The IDW interpolation was carried out employing the available measurements for each pollutant. The calculations were performed through the Geostatistical Analyst Tool in ArcMap 10.x. The resulting surfaces are presented in maps 1-3. In terms of $NO_2$ there is a clear pattern of concentration around the center of Athens and around Piraeus, while smaller levels of pollution are observed at the northern suburbs (Map 1). The spatial pattern of ozone follows rather the dual one, with the highest concentration at the north-eastern municipalities of the study region and the lower values in the center of Athens and the region of Piraeus (Map 2).

**NO2: IDW INTERPOLATION**

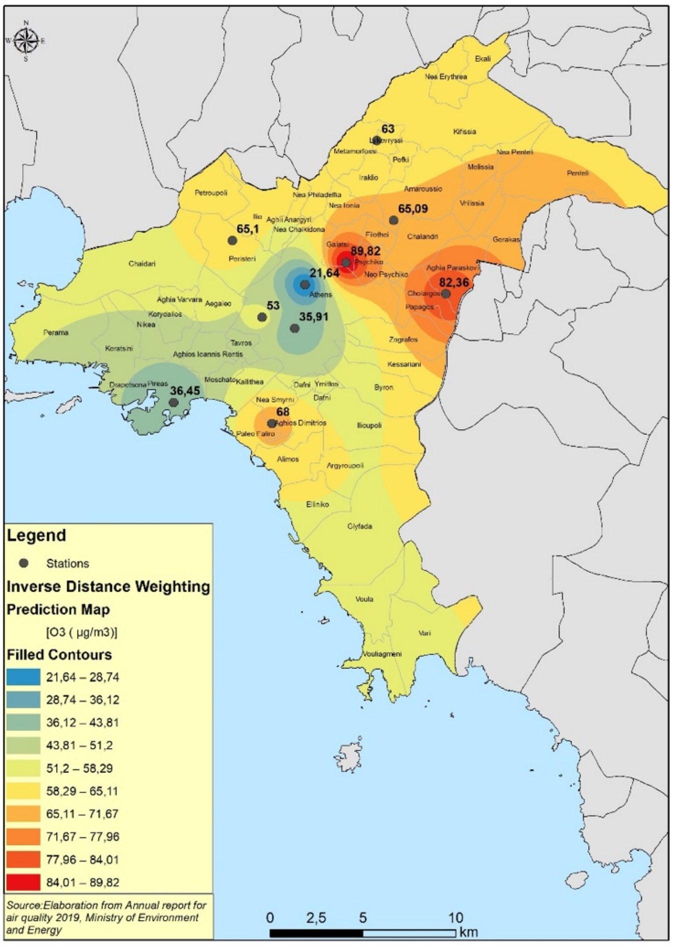



**Map 1:** Nitrogen dioxide ($NO_2$): Measurements and Inverse Distance Weighting Interpolation (IDW)

Concerning carbon monoxide, the highest concentration is observed at the city center, while the lowest ones are observed in the municipalities of Peristeri, Amarousio and Paleo Faliro.

The next step of the procedure is to produce the mean values of air pollutants for each one of the 59 municipalities of the study region. This procedure was performed through the zonal statistics tool in ArcGIS 10.x, where the statistic selected was the mean value for each polygon (municipality). Therefore, a total of 59 points, corresponding to the centroid of each polygon, were produced for the three pollutants. These points were subsequently employed, in order to produce statistical surfaces of the pollutants, through kriging analysis.

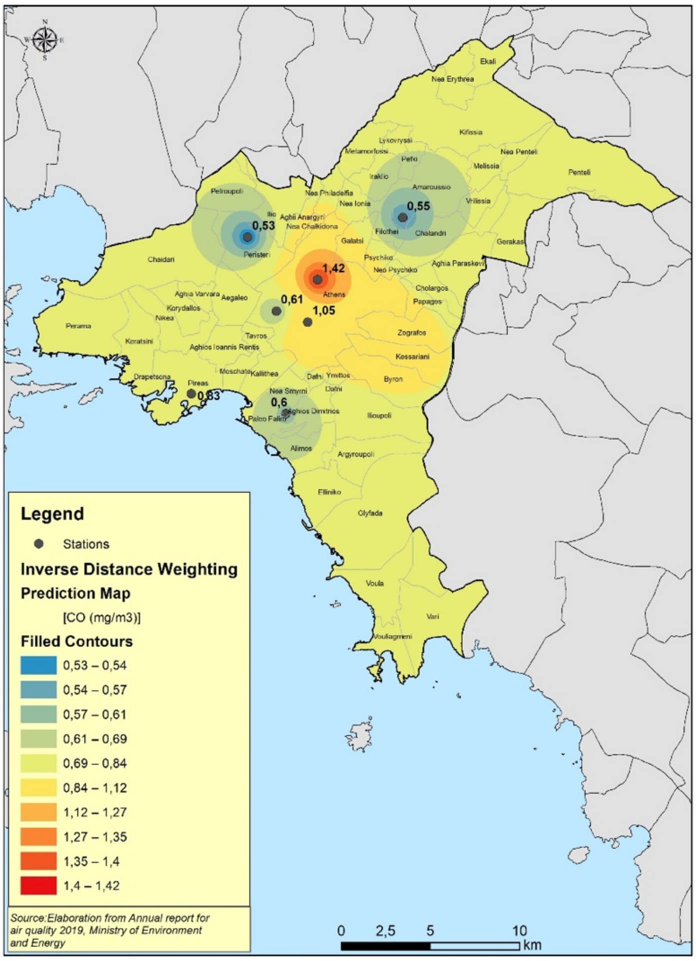
**O3: IDW INTERPOLATION**




**Map 2:** Ozone ($O_3$): Measurements and Inverse Distance Weighting Interpolation (IDW)

Kriging analysis was carried out in the Geostatistical Analyst Environment of ArcGIS 10.x. The results for universal kriging are presented in Figures 1-3. In these figures the surfaces are presented and they share similarities with the surfaces created by the IDW procedure, in terms of the spatial patterns. The estimated variograms are also shown in Figures 1-3 and the presence of spatial autocorrelation can be observed. In addition, the diagnostics and the resulting errors are presented. When the mean prediction error is close to zero, we may conclude that the predictions are unbiased. A root-mean-square (RMSE) as a standardized prediction error close to 1 indicates that the standard errors are accurate. If the predictions do not to deviate from the measured values, the root-mean square error and the average standard error will be small. In that respect, the results presented in Figures 1-3 satisfy these conditions, although the fit of the CO surface is not as good as for the other two pollutants.

**CO: IDW INTERPOLATION**




**Map 3:** Carbon monoxide (CO): Measurements and Inverse Distance Weighting Interpolation (IDW)

*4.3. House prices and air pollutants*

After creating the statistical surfaces for the three air pollutants, it is possible to assign pollution values for each house through the validation/prediction procedure of the Geostatistical Analyst (ArcGIS 10.x). These measurements were appended to the structural characteristics of the houses in the sample.

Data analysis includes:

(i) calculation of Pearson correlation coefficients,

(ii) regression analysis with price as the dependent variable and the three air pollutants as independent variables,

(iii) a hedonic pricing model with price as the dependent variable and independent variables structural and locational characteristics of the houses, together with the air pollutants.

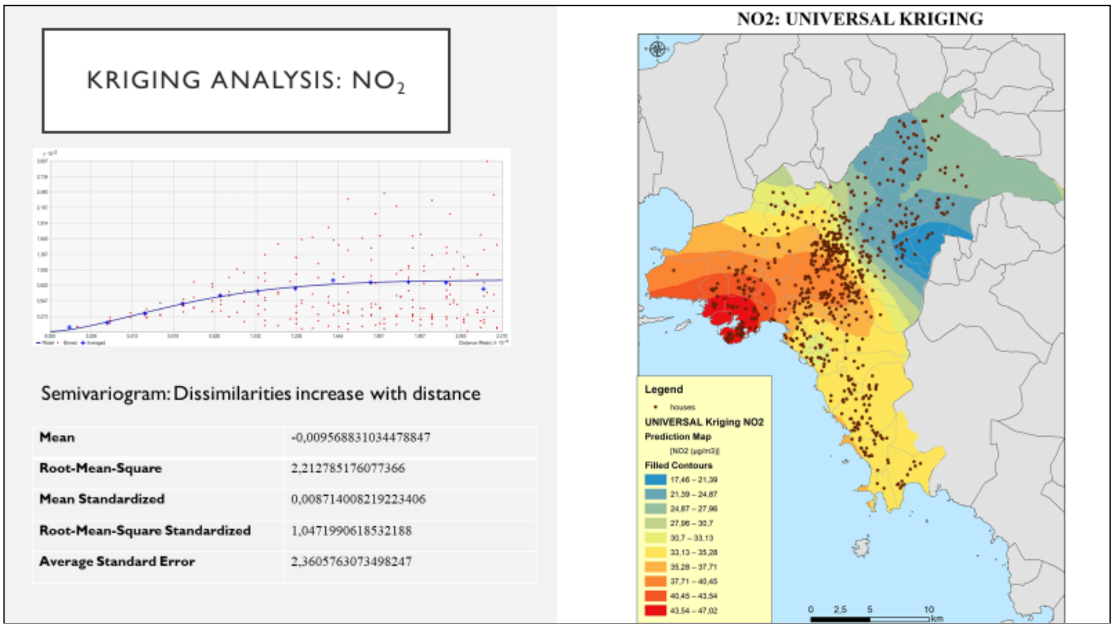



**Figure 1**: $NO_2$: Universal kriging

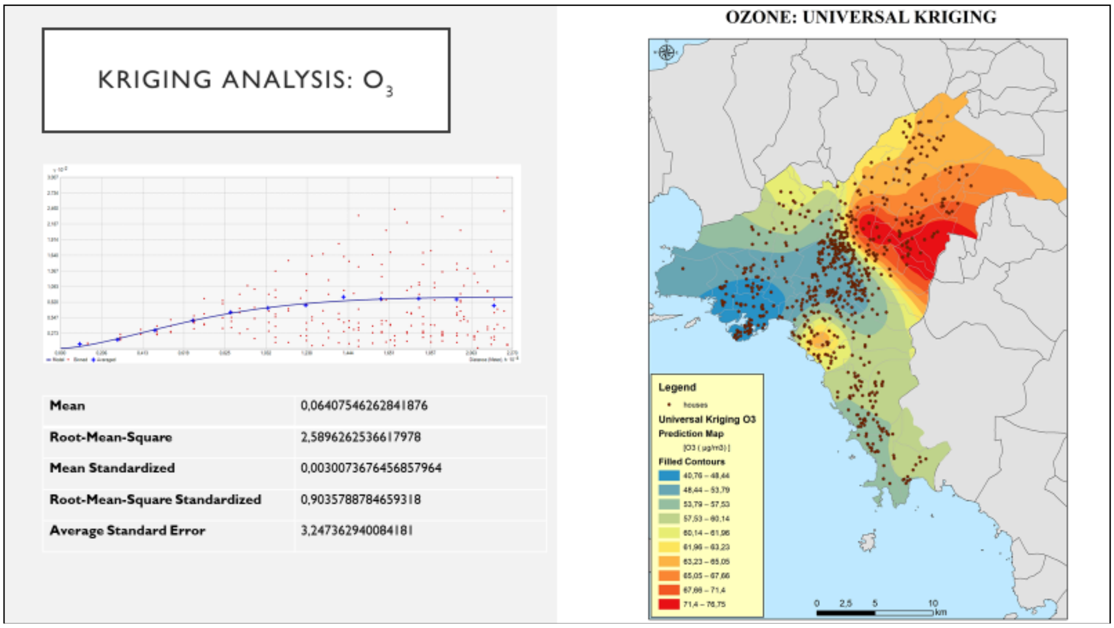



**Figure 2**: $O_3$: Universal kriging

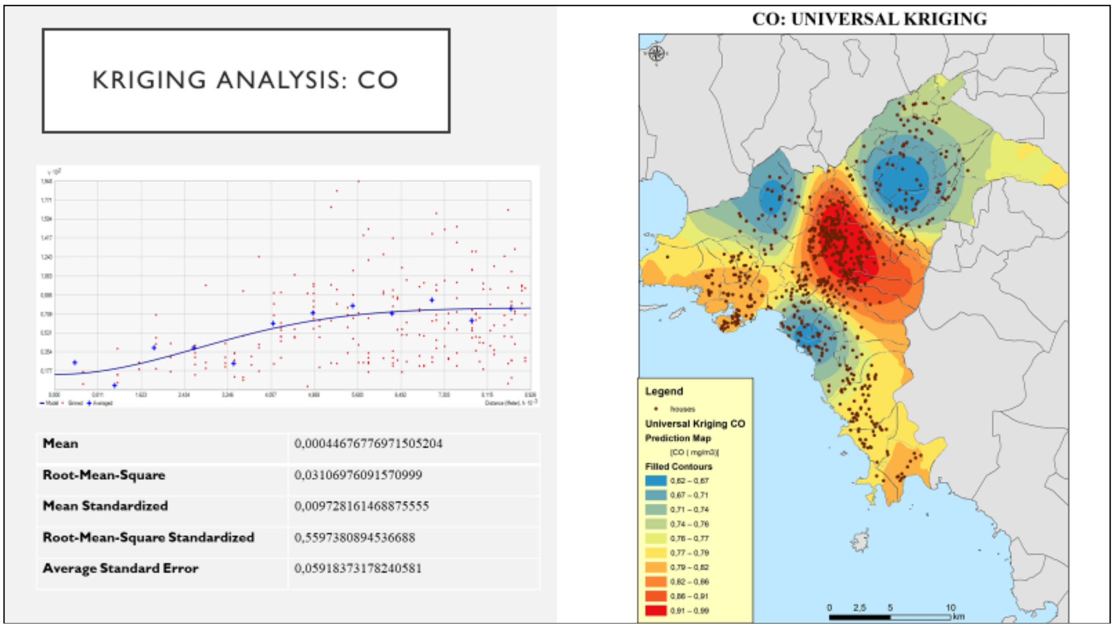



**Figure 3**: CO: Universal kriging

The variables which represent structural characteristics of the properties are size, age, bathrooms and availability of parking space, while the locational characteristics are approximated by the tax zone value at the location of each house. The values assigned to zones for taxation purposes are considered to represent the overall quality of the neighborhood. They are quite detailed, in the study region more than 500 zones have been delineated for tax purposes and through GIS operations it was possible to assign a tax value to each individual property. The values for $NO_2$, $O_3$ and CO are those produced by universal kriging analysis. Statistical analysis was carried out employing SPSS v. 26.

The results of correlation analysis (Pearson correlation coefficients) indicate that property price has a strong correlation with size (r=0.722), as expected, and a quite strong correlation with the number of bathrooms (r=0.687). However, these two variables are strongly correlated with each other (r=0.776). Concerning correlations of price with the three air pollutants, the coefficients are rather low. It is interesting that two of the pollutants ($NO_2$ and CO) have negative sign, indicating that their presence reduces house prices. On the contrary, $O_3$ has a positive correlation with prices. As it has been mentioned, $O_3$ is an air pollutant concentrated in suburban areas, away from the source of emission (see Map 2). Another interesting remark is the almost perfect negative correlation between $NO_2$ and $O_3$ (r=-0,955). This finding is consistent with the observation of the spatial patterns in maps 1 and 2 where it can be seen that low values for one of the pollutants correspond to high values for the other pollutant, especially at the northeastern and western municipalities of the study region.

In order to evaluate the impact of air pollution on house prices, a regression analysis was calculated with dependent variable property price and independent variables the three pollutants. In order to address multicollinearity, the backward method for multiple regression analysis was employed. The results are presented in Table 1.

According to the backward method for the selection of independent variables, $NO_2$ is excluded, due to its strong correlation with $O_3$. The adjusted coefficient of determination is 14,6% which indicates a significant contribution of $O_3$ and CO to house prices. The regression coefficients indicate a positive contribution for $O_3$ and a negative impact of CO. In addition, the standardized beta coefficients indicate a higher impact of CO compared to $O_3$.

The next step is to examine the impact of air pollution on the house prices in the context of a hedonic pricing model, including structural and locational characteristics together with the air pollution variables. The backward selection method was employed again with the probability of removal set at the 0.05 level. The results are presented in Table 6. The coefficient of determination is quite strong ($R^2$=73%) and CO is excluded from the analysis at the 0.05-significance level). The other two air pollution variables remain in the analysis; however, the sign of the regression coefficient for $NO_2$ has turned positive. If the standardized beta coefficients are compared, it appears that the contribution of $NO_2$ and $O_3$ to the house prices is similar to the rest of the independent variables, with the exception of property size.

| Variables | Coefficients and diagnostics | Standardized coefficients | Sig. |
|---|---|---|---|
| Dependent Variable: House price | | | |
| (Constant) | 387728,976 | | |
| $O_3$ | 4297,946 | 0,183 | 0,000 |
| CO | -501892,071 | -0,285 | 0,000 |
| $R^2$ Adj. | 0.146 | | |

**Table 1**: Regression analysis: air pollution

| Variables | Coefficients and diagnostics | Standardized coefficients | Sig. |
|---|---|---|---|
| Dependent Variable: House price | | | |
| (Constant) | -488629,533 | | |
| NO2 | 5714,007 | 0,208 | 0,001 |
| O3 | 4157,608 | 0,177 | 0,002 |
| size | 1143,143 | 0,437 | 0,009 |
| bathrooms | 34755,220 | 0,180 | 0,000 |
| age | -1286,211 | -0,149 | 0,000 |
| parking | 70073,430 | 0,208 | 0,000 |
| tax value | 88,028 | 0,283 | 0,000 |
| $R^2$ Adj. | 0,727 | | |

**Table 2**: Hedonic regression

**4. Discussion**

Kriging interpolation can create statistical surfaces for air pollutants with small errors. In this study a two stage approach was adopted due to the limited number of air pollution monitoring stations. First a deterministic interpolation (IDW) was carried out, for the initial data of the monitoring stations, for three air pollutants ($NO_2$, $O_3$, CO). It was therefore possible to augment the information and perform kriging analysis.

All three air pollutants present clear spatial patterns, while spatial patterns for $NO_2$ and $O_3$ are dual, with $O_3$ presenting concentration in the northern suburbs where relatively high house prices prevail.

Correlation analysis indicated weak correlation between house prices and the three air pollutants, with negative signs for $NO_2$ and CO and positive sign for $O_3$. On the other hand, house prices are strongly correlated with structural characteristics, especially the size of the property.

It is noticeable that $NO_2$ and $O_3$ present an almost perfect negative correlation. This can be partly explained by the fact that $O_3$ is the result of chemical reactions of nitrogen oxides and solar radiation. Actually, another pollutant, nitrogen monoxide (NO), was tested and correlation analysis indicated strong correlations from a spatial viewpoint, among $NO_2$, $O_3$ and NO.

Regression analysis with independent variables the three air pollutants indicated small but significant contribution of $O_3$ and CO to house prices (14,6%). In the context of a hedonic pricing model, the contribution of air pollutants to prices is small but comparable to the effect of several structural and locational characteristics of the houses.

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# A study for corporate environmental strategy. The interaction between environmental legislation, innovation and intellectual capital

**Nikolaos S. Trevlopoulos & Ioannis E. Nikolaou**
*Business Economics and Environmental Technology Lab, Department of Environmental Engineering, Democritus University of Thrace, Vas. Sofias, 12, Xanthi, Greece*
ntrevlop@env.duth.gr, inikol@env.duth.gr

**Abstract**
Today more than ever, industries are called to comply with domestic, community and international environmental legislation to ensure sustainable development. In order to achieve these objectives, firms follow a specific strategy that is sometimes accompanied by costs and sometimes by benefits such as new innovations and intellectual capital development. The purpose of this article is to study the interactions between environmental legislation, environmental innovation and green intellectual capital. To do this, a questionnaire-based survey is carried out in a sample of 62 chemical enterprises. The results show that environmental legislation positively affects environmental innovation and green intellectual capital, while green intellectual capital positively affects environmental innovation.

**Keywords:** Corporate environmental strategy, corporate environmental management, environmental innovation, green intellectual capital.

**JEL Codes**: K32, O31, O34, Q50.

## 1. Introduction

Today, corporate environmental management has gained a great momentum among scholars and practitioners due to their interest in changing corporate behavior to preserve essential natural resources which are necessary for future generations to meet their needs. Many studies have emphasized on examining the effects of environmental regulations on corporate environmental strategy (Berry and Rondinelli, 1998; López-Gamero *et al.*, 2010; Iraldo *et al.,* 2011). More specific, one significant research question of current literature is to determine the reasons which play a critical role in firms' decisions to adopt (or not) environmental management strategies. Some interesting reasons of firms are the increase of the corporate environmental performance, competitiveness and financial performance (López-Gamero *et al.,* 2010; Testa *et al.,* 2011).

In the influential paper of Porter and Van der Linde (1995), it is highlighted that under certain circumstances environmental regulations could offer significant opportunities for firms to create innovations. It is popular as the "win-win" term which implies simultaneous progress on corporate environmental performance and financial position (Karagozoglu and Lindell, 2000; Murty *et al.*, 2003). The former "win" shows that flexible and well-designed regulations offer opportunities for firms to address the goals of environmental policy (Kagan *et al.*, 2003; Wu *et al.*, 2020). The latter "win" defines the effects of environmental regulations on economic and financial positions of firms (López-Gamero *et al.*, 2010).

Two significant approaches are existed in relative literature regarding the corporate environmental behavior such as the reactive and proactive corporate behavior. The former approach explains corporate environmental practices as action of firms to align their operation with environmental regulatory requirements (Liston-Heyes and Brust, 2016). Literature has associated this approach mainly with financial loss (Hang *et al.*, 2018). The latter approach entails an ex post strategic position of firms to adapt their day-today operation with contemporary needs of stakeholders for "clean" production and products. The proactive behavior of firms is mainly associated with financial benefits through new innovation and competitiveness (Liu *et al.*, 2019).

The benefits from corporate environmental management could be arisen from the creation of GIC and EI (Trevlopoulos *et al.*, 2021a). This is a significant research area which aims at examining the way of which corporate environmental performance is positively related with GIC and EI (Trevlopoulos *et al.*, 2021b). However, very little work has been made in this area to examine the mechanisms of which environmental regulations trigger GIC, EI and environmental performance. To contribute to this debate, this article aims at developing a conceptual model to determine the reactive behavior of firms. Particularly, it seeks to identify the influence of environmental regulations on corporate environmental performance, EI and GIC. This model is tested in a sample of 62 chemical firms. The appropriate information is drawn by a questionnaire-based survey. The most important findings have shown that there is a positive relationship between environmental regulations, GIC and EI.

The rest of the article is consisted of four sections. The second section describes the background of corporate environmental literature, innovation and GIC. The third section includes the conceptual model suggested by developing research questions, sample selection and questionnaire development. The next section analyzes the results of this survey and the final section presents the conclusions, limitations and future research.

## 2. Theoretical background

### 2.1 A reactive approach of corporate environmental performance

A great part of relative literature examines the alignment of the behavior of firms with the requirement of environmental regulations. It examines mainly the reactive behavior of firms to comply with regulatory requirements and obviously with their avoidance to look for environmental and economic benefits (Liston-Heyes and Brust, 2016). Many results show that the reactive behavior of firms focuses only on avoiding non-compliance costs with environmental regulations (Silberman, 2000). Furthermore, three types of license are requested from firms in order to invest in environmental practices such as to gain legal, social and economic license (Rorie, 2015). The legal pressure is key factor for corporate environmental behavior since they attempt to avoid potential sanctions.

The size of firms is another significant factor which plays a critical role in the way of which they face environmental regulations. The small-sized firms seem to adopt mainly a reactive behavior, while the large-sized firms adopt a proactive behavior (Vormedal and Skjærseth, 2020). Furthermore, the small-sized firms align their operation with environmental regulations to avoid potential compliance costs, while the large-sized firms put efforts to address requirements of environmental regulations by gaining simultaneously competitive advantage. Obviously, the weaknesses of small-sized firms to seek for benefits from environmental regulations is justified through the lack of necessary capabilities and resources to make new innovations. Moreover, large-sized organizations have the capability to face easier the stringent environmental regulations since their lower compliance costs (Zhou *et al.,* 2017).

### 2.2 A Porter hypothesis on corporate environmental management

Another important drift of relative literature points out the positive effects of environmental regulations on corporate financial performance. This view was primarily made popular by Porter and van Der Linde (1995) who have pointed out that, under certain circumstances, flexible environmental regulations could have positive effects on corporate environmental and financial performance. Several normative models have been suggested to confirm Porter's hypothesis by determining positive effects on business productivity, innovations and competitive advantage (Ambec and Barla, 2002). Some studies have identified cases where environmental regulations have assisted firms in improving their productivity and environmental performance (Xepapadeas and de Zeeuw, 1999; Mohr, 2002).

There are many approaches regarding Porter's hypothesis such as narrow, weak, and strong (Rubashkina, *et al.* 2015). A narrow approach seeks to associate environmental regulations only with innovations. A weak version of Porter's hypothesis implies that certain environmental regulations are suitable for creating corporate environmental innovation and strong approach emphasizes on examining how environmental regulations increase corporate competitiveness and productivity (Yuan and Zhang, 2017).

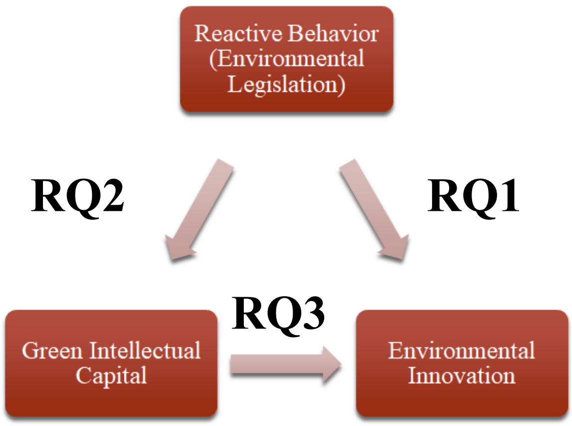
Based on the above analysis of corporate sustainability management literature and the drivers which shape the relevant firms' environmental behavior, three research questions arose that are addressed in this paper.

**RQ1:** *Which are the impacts of the reactive behavior of firms on the promotion of environmental innovations?*

**RQ2:** *Which are the impacts of the reactive behavior of firms on GIC?*

**RQ3:** *Does the GIC have an impact on the corporate environmental innovations?*

**Figure 1.** The graphical presentation of Research Questions (RQ)




## 3. Research methodology

### *3.1 Sample Selection*

To address the above RQs, a research was designed in a sample of Greek chemicals firms which is regarded as a heavy pollutant sector since their operations are linked with the use and production of chemical substances and hazardous materials. Also, a range of environmental regulations has been enacted the last decades to reduce chemical pollutants (e.g. REACH regulation) which have a strong effect on their operations and consequently on firms' attempts to respond to the requirements of the changing regulatory regime. Finally, this sector plays a critical role in the economic development either as sector itself or as a key part of various supply networks (Jenck et al., 2004).

A fully structured questionnaire was developed to gather the necessary data. The questionnaires were sent out via email to 88 chemical firms where their headquarters located in Greece or they are subsidiaries of foreign multinational enterprises. In total, 62 fully answered questionnaires were received (the respond rate was 70.45%) from chemical firms which produce a variety of products (such as paints, varnishes, inks, fertilizers and cleaner products.

*3.2 The structure of the questionnaire*

As for the questionnaire developed for the purpose of this research, it is divided into three sections where each of them includes a set of carefully selected questions. Actually, the primary goal of each section was to elicit the necessary information from firms in order to examine the RQs (Tables 1 and 2). In more details, the first section was focused on regulatory factors and explored the development of various environmental management systems proposed by European Directives such as the Directive EU 2018/852 for packaging waste (PACK), Directive EU 2000/53 for end of life vehicles (VEH), Presidential Decree No 109/2004 for used vehicle tires (USTIR), Directive EU 2008/98 for waste oils (OIL), Directive 2012/19 for electrical and electronic equipment wastes (ELECTR), Directive EU 2006/66 for batteries and accumulators (ACCUM) and also Directive 2010/75/EU for industrial emissions (IED) and REACH Regulation EC 1907/2006 (REACH). The second section included questions which explored the environmental innovations which promoted by the sampled firms and related to diverse aspects of corporate performance such as waste treatment and emission reductions. Based on the answers of firms on these two aspects, a variable was created which measures the actual number of implemented corporate innovations (INV).

**Table 1.** Variables (first and second section)

| **Variable** | **Description** | **Number of firms** |
|---|---|---|
| **PACK** | Implementation of a packaging waste management system according to the Directive EU 2018/852 | Yes: 55<br>No:7 |
| **VEH** | Implementation of an end-of-life vehicles management system according to Directive EU 2000/53 | Yes: 8<br>No:54 |
| **USTIR** | Implementation of a used vehicle tires management system according to the Presidential Decree No 109/2004 | Yes: 12<br>No: 50 |
| **OIL** | Implementation of a waste oil management system according to Directive EU 2008/98 | Yes: 24<br>No:38 |
| **ELEC** | Implementation of a waste electrical and electronic equipment management system according to Directive 2012/19 | Yes: 25<br>No:37 |
| **ACCUM** | Implementation of a waste batteries and accumulators management system according to Directive EU 2006/66 | Yes: 26<br>No: 36 |
| **IED** | Implementation of Best Available Techniques according to Directive 2010/75/EC to achieve the emission limits | Yes: 34<br>No: 28 |
| **REACH** | Implementation of REACH Regulation (EC 1907/2006) | Yes: 38<br>No: 24 |
| **INV** | Actual number of innovative technologies adopted or developed by firms. | From 0 to 15 |

The last section of the questionnaire included a group of questions for the evaluation of different aspects of GIC. In particular, the improvements in the level of the environmental education of employees (ENVEDU) and the effectiveness of recycling system at organization level (EFFREC) were selected as indicative GIC aspects which can be easily assessed by firms. Also, other two assessed GIC aspects were the establishment and operation of a specific corporate department for managing environmental issues (DEP) and if firms obtain a patent (PTNT).

**Table 2.** Variables (third section)

| Variable | Description | Number of firms |
|---|---|---|
| **ENVEDU** | Improvements in the level of the environmental education of employees | Not at all:1, Low: 6, Average: 20, High: 28, Very high: 7 |
| **EFFREC** | Improvements in the effectiveness of the recycling system | Certainly no: 6, Maybe no: 16, Maybe yes: 24, Certainly yes: 16 |
| **DEP** | Operation of a specific corporate environmental department | Yes: 41, No: 21 |
| **PTNT** | Acquirement of a patent | Yes: 4, No: 58 |

## 4. Results

Concerning the RQ1, regulatory factors were used to investigate their impacts on the promotion of the corporate environmental innovations. Table 3 indicates that the introduction of innovations is a result of the regulatory requirements. That is to say, the reactive behavior of firms towards environmental management systems has an influence on the innovations levels of firm. More specifically, the adoption of several management systems, as firms' responses to adjust their operations to the regulations, has positive impacts on the innovation levels of examined firms. So, the end of life vehicles ($z$=-2.725, $p$=0.006), the used vehicle tires ($z$=-3.205, $p$=0.001), the waste oils ($z$=-1.959, $p$=0.050), the waste electrical and electronic equipment ($z$=-3.323, $p$=0.001) and the batteries and accumulators waste ($z$=-2.671, $p$=0.008) have an influence on the introduction of environmental innovations.

**Table 3.** The effects of environmental legislations on the promotion of environmental innovations

| | | Mean Rank | Mann-Whitney U | Z | p |
|---|---|---|---|---|---|
| **VEH** | Yes | 46.88 | 93 | -2.725 | 0.006 |
| | No | 29.22 | | | |
| **USTIR** | Yes | 45.71 | 129.5 | -3.205 | 0.001 |
| | No | 28.09 | | | |
| **OIL** | Yes | 36.85 | 327.5 | -1.959 | 0.05 |
| | No | 28.12 | | | |
| **ELEC** | Yes | 40.28 | 243 | -3.323 | 0.001 |
| | No | 25.57 | | | |
| **ACCUM** | Yes | 35.33 | 290.5 | -2.671 | 0.008 |
| | No | 26.57 | | | |

The second RQ examines the effects of the reactive stance of firms towards environmental managements systems on different aspects of the GIC. To this end, Mann-Whitney test was used to identify the impact of regulatory factors on the level of the environmental education of employees and the effectiveness of recycling system at organization level. Table 4 indicates that Mann-Whitney test was statically significant for REACH Regulation ($z$=-2.747, $p$=0.006) where the implementation of this legislation has a positive impact on the educational level.

**Table 4.** The effects of environmental legislations on the level of environmental education

| | | Mean Rank | Mann-Whitney U | Z | p |
|---|---|---|---|---|---|
| **REACH** | Yes | 36.17 | 278.5 | -2.747 | 0.006 |
| | No | 24.10 | | | |

Moreover, the implementation of a management system associated with waste oils (OIL) and batteries has a positive effect on the overall operation of the recycling system (z=-2.140, $p$=0.032 and z=-2.202, $p$=0.028, respectively) (Table 5).

**Table 5.** The effects of environmental legislations on the effectiveness of a recycling system

| | | Mean Rank | Mann-Whitney U | Z | p |
|---|---|---|---|---|---|
| **OIL** | Yes | 37.38 | 315 | -2.140 | 0.032 |
| | No | 27.79 | | | |
| **ACCUM** | Yes | 37.15 | 321 | -2.202 | 0.028 |
| | No | 27.42 | | | |

Finally, in order to examine the influence of GIC to the promotion of environmental innovation, the existence of a specific corporate environmental department and if the firms hold a patent were used to examine the impacts on the corporate innovation level. According to Table 6, only the establishment of an environmental department has a positive effect on the promotion of environmental innovations (z=-3.060, $p$=0.002).

**Table 6.** The effects of the operation of corporate environmental department on the environmental innovation.

| | | Mean Rank | Mann-Whitney U | Z | p |
|---|---|---|---|---|---|
| **DEP** | Yes | 36.26 | 235.5 | -3.060 | 0.002 |
| | No | 22.21 | | | |

## 5. Conclusions

A methodological framework is developed to examine the influence of regulatory regime through reactive approach on the decisions of a sample of chemical companies to adopt environmental practices. According to this approach, firms adapt their operation to comply with environmental regulations to avoid potential penalties. However, this approach implies that firms see environmental regulations as opportunity to seize new benefits.

To this context, a significant contribution of this paper is to identify the reactive character of environmental strategy of the sampled firms. Today, many articles have shown the positive relationship between environmental regulations and economic performance of firms (Dechezleprêtre and Sato, 2017). A gap of previous literature is the limited examination of mediating factors which confirm the relationship between environmental strategies and economic performance.

To overcome this gap, this paper examines the relationship between environmental regulations and mediating factors such as innovation and intellectual capital. Regarding the former mediating factor, many innovations have been created by many of the sampled firms as result of legislations. This finding is confirmed from a great part of literature whish shows positive relationship between environmental regulations and environmental innovations (Kemp et al., 2000; Yuan and Xiang, 2018).

Another contribution is made on the effect of environmental regulations on green intellectual capital of firms. The current literature put very little emphasis on how environmental regulations affect corporate environmental management projects and green intellectual capital (Yusliza et al., 2020; Nikolaou, 2019). This paper shows that environmental regulations of chemical industry (e.g. REACH) have affected some of the GIC's components.

This paper examines also the impact of GIC on EI. The positive influence of some GIC aspects on EI means that this significant corporate asset, which is intellectual capital, could trigger competitiveness in firms. This is confirmed by organization theories, and especially the resource-based view of companies which support that firms achieve competitive advantage and superior performance through exploiting strategic assets (Liu, 2010).

One limitation of this paper is the small sample of examined firms. Although the sample includes 62 firms from 88 firms (70.45% total population), nevertheless the findings cannot be generalized. They provide interesting information for corporate environmental literature but more study needs to be conducted with greater sample. Another limitation is that all sampled firms are located in one country (Greece). This has some positive effects on the study since the sampled firms faced same cultural and institutional environment, but have also negative effects due to the low economic development and low innovation spirit of county's firms. More studies could be conducted in different countries to identify the effects of innovation and technological level on EI and GIC of chemical industries.

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# Enriching the “social” in circular economy: the commons perspective

**Dionysia Evgenia Paraschi[1] & Paschalis Arvanitidis[2]**
[1] *MSc Social and Solidarity Economy, Hellenic Open University, Greece*
[2] *Department of Economics, University of Thessaly, Greece*
deniaparaschi@hotmail.com, parvanit@uth.gr

**Abstract**
The mainstream approach to the issue of Circular Economy (CE) places particular emphasis on the environmental and the economic dimensions disregarding key aspects of social significance. Yet, these aspects constitute not only desired outcomes of adopting circular practices, but determinants of a truly sustainable circular society, that is a society that embraces in full all circularity dimensions and principles. The commons, which constitutes an alternative, community-based, model of governance and socioeconomic behavior, embraces in full this rich social spectrum of CE and therefore is a more appropriate theoretical and analytical concept to explore and assess circular economy initiatives and actions. The current research draws on commons in order to explore the social character of a specific sector of CE, that of the second-hand clothing. It finds that the commons model describes quite well all CE structures examined (a collectivity, a social enterprise, and a non-profit organization), though to a different degree depending on their particular characteristics. It is also found that all structures set up satisfying mechanisms of effective commons management, determined by the extend of collective, bottom-up representation, operational flexibility, and implementation of democratic decision-making processes, showing a degree of adaptability and continuity as well that enables them to thrive even during the testing times of COVID crisis.

**Keywords:** Circular economy, commons, second-hand clothing, sustainable development, solidarity economy.

**JEL Codes:** B52, B55, D02, L31, O17, O35, Q56

## 1. Introduction

It is common knowledge that the world consumes more natural resources than Earth can replenish. According to the United Nations (2021) at the current rate of growth and resource exploitation three planets will be needed by 2050 to provide the means necessary to maintain our current way of life. This necessitates humanity to adjust its consumption behavior and shift its focus towards more "socially inclusive and environmentally sustainable economic growth" for both current and future generations (Sachs, 2015, p.5).

An innovative approach towards this end is identified under the concept of Circular Economy (CE). In plain terms, CE concerns extending the life cycle of products and saving natural resources, also through the reduction, reuse, recycling and recovery of raw materials, energy and waste. In that way economic growth can be achieved through the use of fewer resources, giving credit to an economic model that allows greater environmental protection as compared to the current linear one. Yet, transitioning to a CE should not be seen simply as an attempt to mitigate the negative impacts of the linear economy. Rather, it indicates a structural shift in both production and consumption mentality aiming to forge a sustainable society, that is a society that deeply embraces environmental, economic, and especially societal concerns (Kirchherr et al., 2017).

Although the social dimension constitutes one of the cornerstones of sustainable development, and so an important element of CE, these concerns have only marginally incorporated into the mainstream CE literature (Geissdoerfer et al., 2017; Padilla-Rivera et al., 2020). Most scholars place emphasis on the economic opportunities and benefits that the transition to the circular model entails (at corporate, sectoral and macroeconomic levels), outlined as improved efficiency, increased competitiveness and employment growth. There is, therefore, a significant void in the literature regarding the social content of CE, that requires proper consideration, given the links between circularity and sustainability.

We argue that such a consideration needs to take into account the social frame, the social relations and social values, and consequently the economic behavior and consumption attitudes of the society, highlighting the importance of social capital, social engagement and participation, cooperation and collective action, and sharing and caring for the others and the environment (Schröder et al., 2019). The concept of commons seems to fit well within the abovementioned, since it promotes an alternative economic behavior and organizational model that goes beyond the duality of market and state, to prioritize social and environmental objectives. The idea of commons centers on communities of people, who put their forces together aiming to protect their common resources. A commons is, in a sense, a governance regime or an institution just like the state or the market, where citizens in a bottom-up fashion establish a set of arrangements, rules and processes to collectively manage their goods and resources in a sustainable way.

Interestingly, very few pieces of research (Patala et al., 2018; Micheaux and Aggeri, 2019) have highlighted the apparent links between CE and the commons, arguing that the later can provide a successful alternative model not only to align CE with sustainable development principles but also to build a truly sustainable society. Seeking to contribute inductively to this literature, the aim of the current paper is to analyze and evaluate specific CE initiatives from the perspective of commons. In doing so the research has drawn on local initiatives that specialize in the reuse of used clothing in Athens, Greece, to explore whether, and if so to what degree, they are embracing the values and principles of commons reflecting the latter's effectiveness and longevity. The selected cases are representative (if not unique) examples of the field and comprise: a collectivity, a social enterprise and a non-profit organization. The paper is organized as follows: section 2 highlights the lack of a strong social dimension in CE, section 3 outlines the commons perspective, section 4 presents our empirical research and section 5 concludes.

## 2. The Social Aspect Of Circular Economy

The CE model place emphasis on design compatible with disassembly, repair and recycling processes in order to achieve the reduction of natural resources and the maintenance of their value, through a multilevel approach and the involvement of different stakeholders (Ellen MacArthur Foundation, 2013). Thus, a positively enhanced growth cycle becomes possible, while the damage caused by the linear economy is reduced (Ellen MacArthur Foundation, 2015).

Although the CE model, by placing emphasis on redesign and recycling, provides a modern perspective to integrate economic development and environmental wellbeing in a sustainable way, there seems to be no explicit attention on the social pillar of sustainable development (Murray et al.,2017). The above constitutes a weakness of the CE approach since important moral and ethical issues, such as: inter- and intra-generational social equity, financial equality and equality of social opportunity, are not taken under proper consideration.

More specifically, Kirchhnerr et al. (2017) make clear that the missing link between CE and sustainable development is due to the CE's main emphasis on economic prosperity, given that environmental quality is attained. However, there is a close relationship between circularity and sustainability, since CE is perceived as a means towards the achievement of sustainable development goals (Suárez-Eiroa et al, 2019). In a similar view, Prieto-Sandoval et al. (2018) see CE as a field in which the way society innovates, in terms of legislation, production and consumption, in order to create wealth along the lines of sustainable development.

Overall, sustainable development concerns setting goals in order to solve problems, whereas CE can be seen as a tool to address some of the causes of these problems (Suárez-Eiroa et al., 2019).

However, the majority of CE literature place emphasis on the economic and ecological concerns, to the detriment of social ones, placing CE in areas 1 and 2 of Figure 1. By enhancing the social parameters and consequently infusing a more humanistic flavor into CE (area 2 of Figure 1), the CE model can be properly aligned to the idea of sustainability to provide a more balanced approach towards sustainable development (Kirchhnerr et al., 2017; Murray et al., 2017). This alignment and the full embracement of the social aspect in CE requires to look at the real needs of people, their relations, the social values and socioeconomic practices, and ultimately on the role communities can play towards this end. The growing literature on social innovation, social and solidarity economy and the commons provides a solid base to think over these issues.

**Figure 1**: Circular economy within the pillars of sustainable development


Source: Suárez-Eiroa et al (2019, p.955)

**3. The Commons Perspective**

Certain resources available to people are non-excludable, meaning that it is too costly to exclude potential appropriators, and subtractable, meaning that appropriation by some reduces availability to others. These features induce economic-rational individuals to exploit the resource as they like without taking full responsibility for their actions, that is disregarding the social, long-term costs from overuse (Bromley, 1991). As a result, the resource is gradually depleted, and eventually led to degradation and destruction, a situation known as "the tragedy of the commons" (Hardin, 1968).

Possible way out of this situation would be to instill a stewardship ethic and to encourage moral behavior toward sustainability (Worrell and Appleby, 2000; Barclay, 2004), and/or, as Hardin (1968) and others (e.g. Demsetz, 1967) have highlighted, to attribute clearly defined property rights, either to individuals (privatization) or to the state (nationalization), giving the owner incentives and the authority to enforce resource sustainability.

However, this dichotomic solution (privatization - nationalization) have been criticized on the basis that they restrict the rights and actions of certain people, usually those most concerned, destroying the social relations and values (i.e. the social capital) that characterize local communities, to the detriment of both these communities and the sustainability of the resource. The most prominent exponent of this view is the 2009 Nobel laureate in economics, Elinor Ostrom. Drawing on a number of empirical studies across the world, Ostrom (1990, 1992, 2000) has demonstrated that communities can collectively self-manage their resources with great success, even in the absence of private property rights and a strong regulatory authority. This corroborates the argument that human behavior does not fall always into the abstract model of homo economicus, optimally pursuing individual interests. Instead, under certain circumstances people prioritize collective interest with emphasis on social and community benefits.

As a result, a third, more socially acceptable governance alternative emerges, the commons, where the users themselves overcome collective-action problems and create strong and stable structures for the sustainable management and appropriation of their resources. These structures entail specific social/informal arrangements (rules, norms, practices etc.) and formal regulations (laws, constitutions etc.) which define and allocate rights and obligations among the involved parties and provide the mechanisms for policing, enforcement and conflict resolution. A commons is in a sense a governance regime, an institution just like the state or the market, where a self-identified community of people in a bottom-up fashion establish a set of arrangements, rules and processes to collectively manage their goods and resources in a sustainable way.

Drawing on extensive empirical work globally, Ostrom (1990) identified eight design principles on how common resources can be governed sustainably among interested parties. They could be considered as a kind of a basic checklist, used to assess the success and longevity of a commons institution, whereas each principle can provide insights into areas for improvement in the existing governance structure or next steps (a roadmap) for those ongoing policy initiatives (Cox et al., 2010). Moreover, it is argued that they are applicable to other organizational structures where people act collectively to achieve joint goals, since they mitigate the opportunities for free riding (Wilson et al., 2013). These eight design principles highlight the need for:

1. Clearly defined boundaries.
2. Congruence between appropriation and provision rules and local conditions.
3. Collective-choice arrangements made through democratic participation.
4. Monitoring of rule compliance.
5. Graduated sanctions to violators.
6. Conflict resolution mechanisms.
7. Minimal recognition of rights by government/state.
8. In the case of larger resource systems: governance organization through multiple layers.

Overall, the socio-centric element is apparent in the commons perspective and in harmony with the values of social justice and equality, which constitute fundamental components of sustainable development at an intergenerational and intragenerational level. Furthermore, a successful commons requires the embracement of collective engagement, trust, cooperation and sharing with and caring for others, among the members of the community. The abovementioned values are critical not only for the achievement of collective benefits, but also for the transition to a different socio-economic model that promotes a less materialistic consumption culture and individualistic economic behavior.

## 4. Empirical Research

The aim of the empirical research is to approach socially-oriented CE initiatives through the lenses of commons and to evaluate their correspondence to the eight design principles of commons. Following Wilson et al. (2013) we argue that high such correspondence entails greater effectiveness, success and longevity of the initiatives.

The initiatives chosen to be examined are representative cases from the field of social and solidarity economy, that is: a collectivity, a social enterprise, and a non-profit organization. All operate in the reuse of used clothing in Greece. The choice of the particular sector, i.e. used clothing, was driven by the fact that the textile sector is largely responsible for the environmental degradation of the planet (European Parliament, 2020).

The resource in all cases is donated second-hand clothing. The members of the initiatives constitute the commons' community. These include those employees and the volunteers of the initiatives that run the initiative and manage the resource. From a broader perspective, however, every person who has a systematic or occasional active involvement as a donor (regardless of whether he or she can also be a beneficiary) and subsequently participates in the emerging grid of social relations is considered as a member of the community. Overall, we argue that organization along the values and principles of commons can not only contribute to the future reduction of raw materials in the textile industry and the improvement of the natural environment but has also the potential to forge an alternative consumer culture that defines a truly sustainable society.

Research was conducted employing the case study methodology. Data collected through both secondary and primary sources, that is, internet and printed material, and semi-structured interviews with the representatives of the initiatives.

*4.1 Collectivity - Skoros*

Skoros (https://el-gr.facebook.com/skoroscc) is a solidarity-economy initiative in Greece with no formal recognition, that is engaged in the reuse of used clothing. Seeking the emergence of a post-capitalist society, the members of the collectivity embrace the values and principles of ecology, degrowth and solidarity. As such they provide the resources to those in need without the mediation of money, aiming to educate society to change its capitalist economic behavior and consumption patterns endorsing the values of sharing and gift-giving.

Through solid praxis the collectivity questions the mantra "I consume therefore I am" and invites everyone independent of socio-economic status to be part of their reuse and recirculation project as an act of resistance towards the depletion of natural resources and the impoverishment of society.

As far as the way it operates, Skoros accepts mostly clothing donations and distributes them equally - on the basis of an agreed number of pieces per household - in order to have effective and equitable management of the donations. Items in general are given as "a gift" since money-based transactions are ideologically rejected.

Governance decisions are all taken by the General Assembly through consensus-based, democratic deliberation, stressing the importance of participating in assembly meetings and committing to common responsibilities.

Finally, the members of the initiative intend to achieve furthers collaborations with similar initiatives and to implement actions of social interest and publicity. As such the place constitutes a meeting point for socialization, communication, exchange of ideas and collective action, with resulting benefits that are spread to the residents of the area.

*4.2 Social Cooperative Enterprise – Second Hand Shop*

The Second Hand Shop (https://acoop.gr/second-hand-shop/) is a Social Cooperative Enterprise (SCE) [5] for persons with mental health problems. It aims to support work integration, socialization, and empowerment of such socially vulnerable people and on that basis, it promotes the CE idea of clothing-reuse through the market channel. The cooperative accepts donations of items by anyone with such ecological and social sensitivity. The items are being sold at relatively low prices with the main purpose being not to have profits but to support employment of the vulnerable people.

Part of the vision of the Second Hand Shop is the adoption of clothing-reuse practice by all citizens-consumers, leading to the development of wide network of people who share goods, care for each other, and all benefit due to the positive externality of their actions. As a result, the development of a vibrant network with other SCEs is deemed important by the Second Hand Shop, as well as the strengthening of their cooperation with the municipal services, which provide them with appropriate

[5] The SCE was introduced in Greece by Law 4019/2011 as a particular form of civil cooperative with an explicit social purpose.

recycling equipment. This dual ecological and social role and significance of the cooperative is acknowledged in the social media and by the several people who have been engaged with the initiative.

The governance institutions of the SCE are the General Assembly and the Executive Committee. The General Assembly is the supreme organ and has general authority on all matters of the SCE, where decisions are taken through unanimous voting by the members of the SCE. All members (apart from the socially vulnerable ones) have renounced their entitlement to the cooperatives' returns. After all, the Second Hand Shop is a special-purpose civil cooperative, a commons, aiming to the social care of the specific vulnerable population group. In these terms, its place is a point of reference where people with similar social and ecological sensitivities, meet, communicate and work together.

*4.3 Non-Profit-Organization – Fabric Republic*

Fabric Republic (http://www.fabricrepublic.gr/) is a non-profit organization (NPO) managed by a tripartite Board of Directors. It is an innovative and comprehensive used-clothing management initiative with a clear focus on sustainability and sustainable development. It's vision is the development of social and ecological consciousness of the population, aiming towards "zero waste" through the optimization of the cyclical management of excess clothing, which will ultimately contribute to the reduction of environmental inequalities as well. Furthermore, the NPO employs socially vulnerable people, incorporating also the social dimension of sustainable development.

Fabric Republic does not conduct money transactions. Thus, it accepts money and clothing donations either from companies or individuals, in order to distribute them to solidarity organizations for donations. Citizens can contribute by placing used clothing in one of the especially designed Fabric Republic bins that have been strategically placed in an ever-expanding network of cities. Items that cannot be used are transferred to companies for recycling.

The NPO has developed a strong network of partners and strategic partnerships with public and private organizations.  At the same time, it participates in environmental, artistic and informative events and organizes promotional actions to raise public awareness regarding environmental and social issues. Finally, volunteers are considered as key factor for the overall success of the project.

*4.4 Evaluation and discussion*

The research finds that the commons model describes quite well all CE initiatives examined, providing a sound basis to expand and enrich the concept and the approach of CE with due emphasis on the social dimension.  Also, all of them exhibit a degree of adaptability and continuity that enables them to thrive even during the testing times of COVID crisis.

In particular, we argue that the examined initiatives incorporate the three elements of commons: the common good/resource, the community, and the governance structure. Furthermore, all initiatives satisfy the Ostromian principles and set up satisfying mechanisms of effective self-management. Yet, the different initiatives exhibit different degree of efficiency and potential for success in the long run, due to inability to incorporate all the elements of a fully blossomed commons institution.

Specifically, the collectivity and the non-profit organization have a specific and exclusive focus on used-clothing recycling (that means, clear resource boundaries) in relation to the social enterprise which embrace CE in order to suport the social care of the specific vulnerable people under concern. On the other hand, both the social enterprise and the collectivity implement in a more successful way the Ostromian principles of collective choice arrangements and of low-cost conflict resolution mechanisms since their members can participate equally in providing the governance rules and mechanisms of the commons through the adoption of democratic decision-making processes. Furthermore, the market mentality of the social enterprise (since items are sold instead of given away) puts it a bit at adds with the commons rationale of sharing and caring.

Regardless of the ideological framework by which each initiative adopts in approaching the concept of "closing the loop of clothing", the social service element is very strong in all of them, since the clothing needs of population are met through gift (collectivity), purchase at low prices (SCE), or charity (NPO). Also in all cases, there is a strong and sincere effort on behalf of the members of each scheme to spread the idea of CE to the benefit of both the environment and the society. Of all three, the collectivity adopts democratic decision-making processes and stands critical to the market mechanism, constituting it more social accountable and closer to the alternative consumption mentality of a truly sustainable society.

## 5. Conclusions

Aiming to contribute towards enhancement of the social dimension of CE, the current work analyzed and evaluated specific CE initiatives specialized in the reuse of used clothing in Greece, employing the perspective of commons. A number of points that emerged are highlighted.

First the mainstream approach to the issue of CE places particular emphasis on the environmental and the economic dimensions disregarding key aspects of social significance, such as social service and equality. Yet, these aspects constitute not only desired outcomes of adopting circular practices, but determinants of a truly sustainable "circular society", that is a society that embraces in full all circularity dimensions and principles.

Furthermore, the integration of the social and egalitarian dimensions of sustainable development requires the adoption of a different lifestyle, consumption culture and of economic behavior in general. Key factor to the transition to a sustainable socioeconomic model is the institutional framework and the support it provides to new ideas, practices, and initiatives, that pay due respect to community collaboration, collective action, self-management and sharing. Such initiatives fall within the mentality of commons, since they develop social relationships founded upon trust, cooperation, solidarity among people and caring for others. Thus, it seems to constitute ideal schemes to spread the idea of a real cyclical society.

Obviously, all these issues raised in the current paper are quite new and unexplored in the literature. Therefore, there is a wide range of opportunities for future research in the linkage between CE and commons and the actual impacts of these two concepts towards the enrichment of the social aspect of sustainable development. From our point of view, the state should support further collective actions of civic engagement and community empowerment with clear social and environmental objectives. Policies are needed that provide proper incentives for participation, collaboration, and networking, along with a supportive legal framework that allows, consolidates and strengthens such initiatives.

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# Economic valuation of honeybee pollination services

**Simeon Marnasidis[1], Garyfallos Arabatzis[1], Chrisovalantis Malesios[2], Fani Hatjina[3], Apostolos Kantartzis[1] & Efstathia Verikouki[4]**

[1] *Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, 193 Pantazidou St., 68200 Orestiada, Greece*

[2] *Department of Agricultural Economics and Rural Development, Agricultural University of Athens, 75 Iera odos St., 11855 Athens, Greece*

[3] *Dep. of Apiculture, Institute of Animal Science— National Agricultural Organization DEMETER, 63200 Nea Moudania, Greece*

[4] *Faculty of Agriculture, Vocational School (EPAL) of Edessa, Melinas Merkouri 28, 58200 Edessa, Greece*

marnasidis@pella.gr, garamp@fmenr.duth.gr, malesios@aua.gr, fhatjina@instmelissocomias.gr, apkantar@fmenr.duth.gr, verikouki@sch.gr

**Abstract**

Honeybees are closely linked with natural and agricultural ecosystems, due to their ability to pollinate a large array of food crops and native plants worldwide, particularly in intensively cultivated areas. Greece is a country where pollination services are hardly developed. Using data from the Regional Unit of Pella, Northern Greece, as well as a number of measurable indicators, the current paper focuses, for the first time in this country, on the economic valuation of honeybee pollination services and investigates their adequacy. Our results demonstrate that for the 28 insect pollinated crops examined in the study, the commercial value of pollination services was estimated at €89.34 million by means of the net income method; in addition, the economic value of pollination services attributable to honeybees, based on the available number of hives, was found to be equal to €26.9 million in 2018. From our analysis it also emerged that apples and kiwifruit plants were the crops with the highest value of pollination services per hectare, which amounted to €10,350.24 and €9,059.23, respectively. Another important finding of the research is that the total hive stocks available are insufficient to cover even half of the demands of honeybee pollinated crops. Especially as far as cherry trees are concerned, which frequently fail to set fruit, the total hives available at a Regional Unit level were found to be sufficient to cover only 66.5% of pollination needs.

**Key words:** Apiculture, honeybees, pollination services, agricultural development.

**JEL Codes:** Q00, Q01, Q50, Q57, Q58.

## 1. Introduction

Ecosystem services (ES) refer to the numerous ways in which nature benefits people. However, ecosystems are faced with unprecedented pressures that could eventually lead to their degradation, thus affecting their supply of services to current and future generations (Buytaert et al., 2014). At the same time, there exists a steadily growing need to quantify the contribution of ecosystems to human well-being and the economy (Bateman et al., 2013; European Commission, 2014; Vallecillo et al., 2019). In this context, various methods for the valuation of ecosystem services have been developed that provide valuable insights into the role that ecosystems play in service provision and how they meet the demands of society (Mace, 2019). Pollination is considered as the most essential regulating, supporting, and cultural ecosystem service (Devkota et al., 2016; Lautenbach, 2019; Requier and Crewe, 2019).

Pollination services (PS) provide substantial benefits to human populations and, more specifically, to agriculture, since they contribute enormously to the production of primary agricultural products (Breeze et al., 2011). Honeybees (Apis Mellifera) offer pollination services to several crops along with other insect pollinators, which are, nevertheless, considered more effective in this process, according to recent studies (Garibaldi et al., 2018). However, honeybees (HB) have traditionally been the main pollinators of many crops in the USA (McGregor, 1976) to such an extent that certain crops (e.g., almonds) are almost exclusively dependent on them for pollination (Hatjina, 2006; Narjes and Lippert, 2019). The role that bees play as pollinators is also of crucial importance in natural habitats (Aslan et al., 2016; Hung et al., 2018). For market-traded products such as agricultural goods, pollination services can be considered as an input to production (Hatjina, 2006; A. J. Vanbergen et al., 2014). This input is often provided by bees to farmers at no cost so that it can be classified as "spillover" (free of charge) pollination (Morse and Calderone, 2000). Demand for pollinators is constantly growing. Pollination service demands in forty-one (41) European states increased 4.9 times as fast as available honeybee stocks between 2005 and 2010. Increased demand for pollinators may be attributed, inter alia, to the expansion in acreage of energy crops (Breeze et al., 2014). Pollination services can be measured using a variety of methods, depending on the type of research study and the measurement approaches adopted (Liss et al., 2013). The valuation of pollination services in agriculture is, for a number of reasons, a very complicated and multifaceted process, with numerous knowledge "gaps" and different perceptions among researchers (Breeze et al., 2016; FAO, 2008; IPBES, 2016; Melathopoulos et al., 2015). However, an empirical assessment of the commercial value of pollination services is considered to be absolutely vital if policy makers need evidence on the economic benefits in market conditions from the protection of pollinator populations and take into account the economic cost incurred from the decline in pollinator numbers (Vanbergen et al., 2014).

The present study aims to explore the economic valuation and adequacy of crop pollination services provided by honeybees in Greece, by using readily accessed data. It is expected to inform the public, stakeholders, and agricultural policy bodies about the value of honeybee pollination services so that decisions can be made with a view to promoting effective reinforcement and the protection of honeybee pollinators.

## 2. Materials and methods

### 2.1. Research area

The Regional Unit of Pella in Greece was chosen as the research area of the present study as beekeeping in this specific region is a rapidly growing activity. According to the relevant literature, twenty-eight (28) crops grown in this area are pollinator dependent. Twenty (20) of these crops depend on honeybees for their pollination (Table 1). Natural meadows (GA) comprise approximately 9,350 hectares with Christ's thorn (*Paliurus spina-Christi Miller*), a deciduous shrub, offering significant amounts of pollen and nectar depending on weather conditions (Hasilidis, 2011). Forest areas cover about 106,500 hectares (Grigoriadis, 2013).

### 2.2 Adequacy of Honeybee Pollination Services

The following measurements (Breeze et al., 2014) were used to assess the ability of existing hive stocks to provide adequate pollination services in the study area:

*Potential Crop Demand (PCD)*

The potential number of bee colonies (hives) required to provide adequate pollination services was estimated using the following equation:

$$\mathrm{PCD} = \mathrm{CA} \cdot \mathrm{RSR} \qquad (1)$$

- PCD = Potential crop demand.
- CA = Area (ha) of pollinated crops. Source: Greek Payment Authority of Common Agricultural Policy (C.A.P.) Aid Schemes (OPEKEPE).
- RSR = Recommended Stocking Rate = number of hives (hives per hectare) for a specific crop. International bibliographic data were used. The results are presented in Table 1 below:

**Table 1.** Recommended stocking rates

| Crop | Area (ha) | RSR (hives per ha) |
|---|---|---|
| Kiwifruit (*Actinidia deliciosa*) | 619.46 | 8 |
| Almonds (*Prunus amygdalus*) | 245.21 | 6 |
| Pears (*Pyrus communis*) | 332.79 | 4 |
| Apricots (*Prunus armeniaca*) | 1,915.88 | 2 |
| Plums (*Prunus domestica and P. spinosa*) | 1,143.07 | 3 |
| Rapeseed (*Brassica napus*) | 125.19 | 5 |
| Sunflower (*Helianthus annuus*) | 360.02 | 2 |
| Sweet chestnuts (*Castanea sativa*) | 745.62 | 1,5 |
| Sweet and sour cherries (*Prunus avium*; *Prunus cerasus*) | 10,509.63 | 5 |
| Cucumbers (*Cucumis sativus*) | 2.09 | ***Vegetables 5 |
| Eggplants (*Solanum melongena*) | 18.92 | |
| Melon seed (*Cucumis melo*) | 59.12 | |
| Pumpkin, squash, and gourds (*Cucurbita maxima, C. mixta, C. moschata, C. pepo*) | 32.4 | |
| Strawberries (*Fragaria spp.*) | 0.94 | |
| Watermelon (*Citrullus lanatus*) | 93.02 | |
| Apples (*Malus domestica*) | 1,033.72 | 4 |
| *Quinces (*Cydonia oblonga*) | 43.74 | 4 |
| Peaches and nectarines (*Prunus persica* and *Persica laevis*) | 17,388.54 | 2 |
| Soybeans (*Glycine max and G. soja*) | 10.13 | 4 |
| **Sesame (*Sesamum indicum*) | 4.1 | 1 |

* According to Benedek et al. (2001), honeybees are essential pollinators. There are no available data for recommended number of hives. ** According to Kamel et al. (2013) and Stein et al. (2017), honeybees are considered pollinators, although sesame is an auto-fertile species. There are no available data for recommended number of hives. *** Vegetable crop requirements differ. However, we used approximately the same RSR for all of them.

*Total Supply Density (TSD)*

$$\mathrm{TSD} = \frac{\mathrm{TAS}}{\mathrm{CA_t}} \qquad (2)$$

- TSD = Total supply density (number of hives available per hectare of pollinated crops).
- TAS = Total available stocks (total number of colonies owned by beekeepers in the Regional Unit).
- CAt = Total area of crops depending on honeybee pollination (hectares).

*Total Density of Demand (TDD)*

$$\text{TDD} = \frac{\sum_{i=1}^{n}(\text{CA}_i \cdot \text{RSR}_i)}{\text{CA}_t} \quad (3)$$

- TDD = Total density of demand. It refers to the number of beehives per hectare required to pollinate all crops in the study area.
- $\sum_{i=1}^{n}(\text{CA}_i \cdot \text{RSR}_i)$ = Total number of beehives necessary for adequate pollination services in the research area.
- $\text{CA}_t$ = Total area of crops benefiting from honeybee pollination (hectares).

### 2.3 Economic Valuation of Pollination Services

The economic value of the pollination services provided by all pollinators in the research area is estimated by means of the net income method (Winfree et al., 2011):

$$V\Delta_p \approx (P_i \times Y_i - VC_i) \times D_i \times \rho \quad (4)$$

- $V\Delta_p$ = Income hypothetically earned by local farmers from all insect pollination services or income lost due to the absence of pollinators (€). i = 1,2… 28 crops.
- $V\Delta_{HB}$ = Income hypothetically earned by local farmers from honeybee pollination services or income lost due to the absence of honeybee pollinators (€).
- $P_i$ = Product price (€ / TN).
- Yi = Average yield per hectare (TN / ha).
- $VC_i$ = Variable cultivation costs expressed in euro per ton (€ / TN).
- $D_i$ = Crop Dependence Ratio = $1-(fp_e/f_p)$, where $fp_e$ = fruit set under conditions of insect pollinator exclusion and $f_p$ = fruit set with insect pollinators present. The typical dependence means were used, as derived from the work of Klein et al. (2007) and are applied by the FAO (Food and Agriculture Organization of the United Nations 2020; Gallai and Vaissière, 2009). Following this approach, the following Dependence Ratio classes were formed: 1) essential, D = 0.95; 2) great, D = 0.65; 3) modest, D = 0.25, and 4) little, D = 0.05.
- ρ = Pollinator loss fraction receiving values from 0 to 1. When valuation of pollination services concerns all insect pollinators, its value is equal to 1. When valuation concerns only honeybees, $\rho_{hb}$ = total fraction of pollen grains deposited by honeybees on crop flowers.

As there are no available data on floral visits from honeybees, bumble bees and wild bees in Greece, calculations concerning the fraction of total pollen grains deposited by each of the above groups were not possible. Thus, the calculation of $\rho_{hb}$ was performed based on the available beehive stocks in relation to the required colonies (RSR) that could hypothetically replace all insect pollinators (equation 5). Allsopp et al. (2008) followed a similar approach, to calculate the proportion of pollinators (P) that are honeybees, for individual crops in the Western Cape deciduous fruit industry (South Africa).

$$\rho_{hb} = \frac{\text{TAS}}{\sum_{i=1}^{n}\text{PCD}_i} = \frac{\text{TAS}}{\sum_{i=1}^{n}(\text{CA}_i \cdot \text{RSR}_i)} \quad (5)$$

- $\rho_{hb}$ = Ratio of pollinating honeybees.
- TAS = Total available hive stocks in the research area.
- $\sum_{i=1}^{n} PCD_i$ = Overall beehive requirements of i=1,2, ...,20 crops also pollinated by honeybees or total (hypothetical) number of hives that could replace all insect pollinators.

Therefore, the economic value of pollination services attributable to honeybees for the twenty (20) crops benefiting from honeybees is calculated as follows:

$$V_{\Delta HB} \approx \sum_{1}^{i}[(P_i \text{ x } Y_i - VC_i) * D_i] \text{ x } \rho_{hb} \qquad (6)$$

- $V_{\Delta HB}$ = Income hypothetically earned by local farmers from HB pollination services or income lost due to the absence of HB pollinators (€). i = 1,2… 20 crops.

## 3. Results and discussion

### 3.1 Adequacy of Honeybee Pollination Services

The application of equation (3) revealed that the total demand ($\Sigma_t$PCD) in the research area amounted to 110,145 hives and the total demand density (TDD) was equal to 3.18 hives per hectare in 2018 (Figure 1). The total area covered by the 20 bee pollinated crops rose from 24,876.56 hectares in 2012 to 34,673.49 hectares (+ 39%) in 2018 (Figure 2), causing at the same time a significant increase in the demand for pollinators, a trend that is observed worldwide (Sáez et al., 2019).

Total available hive stocks (TAS) increased by 35% between 2012 and 2018, from 25,827 to 34,900 hives, which is regarded as a positive trend for the specific area. Total supply density (TSD) showed a variance throughout the reference period, with a value equal to 1.0 hives per hectare in 2018 (Figures 1 and 2). Sweet cherries, peaches and nectarines, apricots, plums, and kiwi fruits (5 perennial crops) occupied 31.566,48 ha (≈88% of crop area). At the same time, the potential demand ($\Sigma_5$PCD) was 99.491,38 colonies and the density of demand ($DD_5$) was 3.15 colonies per hectare. The aggregate colony supply (TAS) of local (regional) beekeepers was enough for almost one third of the demands ($\Sigma_5$PCD) of these 5 perennial crops. A similar situation was also recorded in the United Kingdom, where, according to estimates, the number of registered hives was adequate enough to cover only one third of the required pollination services resulting in this gap being bridged by natural pollinators (Smith et al., 2011).

**Figure 1.** Total Supply Density (TSD) and Total Density of Demand (TDD)

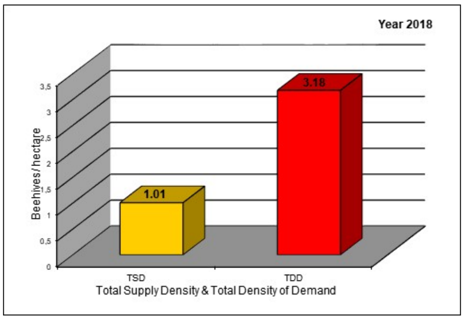
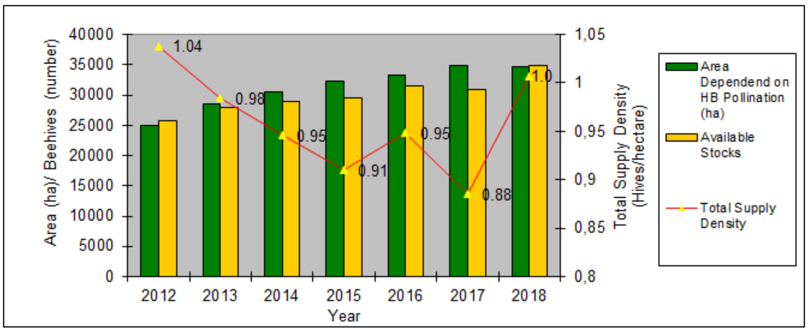



**Figure 2.** Total Crop Area Pollinated by Honeybees; Total Available Stocks (TAS) and Total Supply Density (TSD)



Sweet cherries were the most demanding of the 28 insect-pollinated (IP) crops, with a potential demand for 52,498 colonies, while total available stocks (TAS) amounted to only 34,900 colonies, a figure that corresponds to only 66.5% of the crop's pollination needs. According to local reports and press releases, the year 2018 was among the least productive ones for sweet cherries because of poor flower fertilization (official website of "Nea Paseges", 2018; official website of "Agronews", 2018). Technical studies show that high temperatures during blooming reduce the number of pollen tubes growing along the style and accelerate ovule degeneration (Hedhly et al., 2007; Radičević et al., 2016). Pollinators (bees) must be placed in the orchard from the beginning of the bloom (10%). The results of a recent study combining metrics for flower visitation rate, pollen deposition, and yield showed that sweet cherry yield is frequently limited by lack of pollinators in some American States (Reilly et all., 2020). Complaints about low production rates in several crops because of the small number of pollinators were also recorded in a European survey (Breeze et al., 2019).

Kiwi fruit, which is highly dependent on honeybees for pollination (eight colonies/ha), demanded 4,955.68 colonies, whereas peaches and nectarines occupying 17,388.54 ha of agricultural land demanded 34,777 colonies. Biofuel crop demands (sunflower and rapeseed) have also followed an increasing trend during the last 8 years; for instance, in 2018 these crops covered 485.21 ha and their pollination demands amounted to approximately 1,345.99 honeybee colonies. These numbers indicate that, although total available bee stocks (TAS) were not sufficient for the five main perennial crops which have similar flowering periods (early spring), they were adequate for crops flowering later in the same season, such as biofuel plants and vegetables. This is crucial when determining the total available stock. In fact, this stock should refer to each crop or group of crops that bloom almost simultaneously.

### 3.2 Economic Valuation of Honeybee Pollination Services

By applying the net income method (equation 4) for the year 2018, we calculated that the total PS value (VΔp) for the 28 crops was € 89,338,902.12 and the total PS value per hectare (VΔp/ha) was € 1,878.78. For cotton, decoupled direct payments per hectare of € 749 were taken into account in our calculations. PS values per crop were € 38,239,872 for peaches and nectarines; € 16,960,922 for sweet cherries; € 10,699,248 for apples; € 5,997,122 for apricots; € 5,611,833 for kiwi fruit; € 3,789,501 for cotton; € 3,306,295 for chestnuts; € 1,523,010 for plums and € 1,186,935 for almonds.

**Table 2.** PS economic values per D class

| Dependence Ratio (D) | Total (€) | Percentage |
|---|---|---|
| 0,05 | 464,188.29 | 0.52% |
| 0,25 | 7,300,037.09 | 8.17% |
| 0,65 | 75,497,512.95 | 84.51% |
| 0,95 | 6,077,163.79 | 6.8% |
| **Total (€)** | **89,338,902.12** | **100%** |

Among the 28 crops relatively dependent on IP, the greatest PS economic value was generated (Table 2) from class "great" or D = 0.65, with 84.51% (75,497,512.95 €), as well as from class "modest" or D = 0.25, with 8.17% (7,300,037.09 €). In class "great", the most representative crop was "peaches and nectarines" with € 38,239,871.70.

The values of pollination services per hectare (VΔp/ha) were calculated at: € 10,350,24 for apples, € 9,059,23 for kiwi, €4,840,48 for almonds, € 4,434,29 for chestnuts, € 3,827,07 € for pumpkin, squash, and gourds, € 3,130,22 for apricots, 2,629,72 € for sour cherries, € 2,422.11 for pears, € 2,395,62 for watermelons, € 2,199.14 for peaches and nectarines, € 2,004,28 for melons, € 1,615,40 for sweet cherries and between € 85 and € 1,600 for the rest of the crops.

By comparing our results pertaining to apple crops (10,350,24 € / ha) with the value means (17,000 US $/ha) calculated between 1996 and 2010 for various countries using the method of dependence factors (Breeze et al., 2016) as well as with the value (14,006 US $/ha) calculated for the year 2005 for the USA (Mburu et al., 2006), and having the euro - dollar exchange rate set at 1.4, we can see that our results are distinctly different as they depend to a great extent on the annual yield, the crop selling price, dependence indicators (Breeze et al., 2016), and the variable cost of production which is different among countries.

The pollination honeybee ratio $\boxed{\rho_{hb}}$ is calculated with the help of equation (5) as follows: (34,900 / 110,145) x 100% = 31.7%; the economic value of pollination services attributable to honeybees ($V\Delta_{HB}$) for the 20 bee pollinated crops is calculated with the application of equation (6) to be 84,935,738.44 x 31.7% = 26,912,286.28€. Although this particular method of calculation is quick and easy to implement, it has certain drawbacks including: (i) it is impossible for a certain honeybee population to replace all insect pollinators; (ii) little is known about the ideal number of honeybee hives in intensive crop pollination; (iii) it is unlikely that all beekeepers will place their hives in the crops, a fact that would result in deficient pollination services even if stocks were theoretically adequate (Underwood et al., 2017; Isaacs et al., 2017; Breeze et al., 2014); (iv) we considered that there will be no price effect because the region's yield was small relative to the global market supply and thus the change in the economic value produced is the result of the change in the producer surplus only (Hein, 2009); and (v) no approach to economic valuation can capture the true value of pollinators which is arguably infinite (Jordan et all., 2021).

## 4. Conclusions

The findings of the present study underscore evidence of poor honeybee pollination services in fruit trees and especially in sweet cherries. Therefore, pollination is highly dependent on wild pollinators' diversity and abundance. Poor flower fertilization in sweet cherries could be connected with inadequate pollination services. Future research should focus on honeybee pollination services and fruit yields in Greece.

Apples and kiwifruit were the crops with the highest value of pollination services per hectare. The values of insect pollination services are useful only for a certain year and a given area as they depend on the annual yield, the market prices, the dependence ratios (Breeze et al., 2016) as well as the variable costs. If the benefits derived from honeybee pollination services are compared with the other benefits of apiculture, it becomes clear that the former are substantially higher than the benefits from honey production (Mburu et al., 2006). In this study, the gross revenue from all beekeeping products is estimated as € 103.2/beehive X 34,900 beehives=€ 3.6 million. On the other hand, the PS value of all insect pollinators ($V\Delta p$) was found to be equal to € 89.3 million and the economic value that could be attributed to honeybees to € 26.9 million.

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# Applying Factor Analysis and Structural Equation Models for urban parks in Greece: The relationship between motives and perceived characteristics, satisfaction and future visit

**George Halkos[1], Aikaterini Leonti[2] & Eleni Sardianou[2]**
[1]*Laboratory of Operations Research, Department of Economics, University of Thessaly, 28hs Octovriou 78, 38333 Volos, Greece*
[2]*Department of Economics and Sustainable Development, School of Environment, Geography and Applied Economics, Harokopio University, El. Venizelou 70, 17671 Athens, Greece*
halkos@econ.uth.gr, aleonti@hua.gr, esardianou@hua.gr

**Abstract**
Understanding the motivations for moving to specific locations is a complex process. This article examines the possible relationships between the satisfaction of visitors to two urban parks in Greece and the motivation to visit, as well as their perceptions of the parks. The relationship between visitor satisfaction and future visit is also studied. The total sample consisted of 761 urban parks visitors in Attica. For the purposes of the research, *Exploratory Factor Analysis*, *Confirmatory Factor Analysis* and *Structural Equation Models* were applied. According to the results, three factors were extracted for the motivation to visit the urban parks and five factors for the perceived characteristics of the parks. Motives for the visit were found to affect visitor satisfaction, which statistically significantly affects the probability of revisiting urban parks. It is also interesting the fact that the perceived security provided in the urban parks that were studied as well as the improvements that could be made in the parks have a positive effect on the degree of visitor satisfaction. On the contrary, the perceived negative effects that come from the parks negatively affect the satisfaction.

**Keywords:** Motives, Perceived characteristics, Urban Parks, Factor analysis, SEM.

**JEL Codes**: Q01, Q51, Q58, Z30.

## 1. Introduction

Motives to visit a site could be a combination of push and pull factors (Mohamed and Othman, 2016). Push factors includes for example relaxation and contact with family and nature, while pull factors are related to the attractions of a site. Meng et al. (2008) claimed that a significant pull factor is the image of a destination. As the actual behavior of the consumer is influenced by perceptions, perceptions are more important than reality (Kotler and Keller, 2012).

In the present paper, we examine the relationship between motives and perceived characteristics, satisfaction and future visit. The following research questions have arisen: 1) What are the relationships between the motivation to visit urban parks, the satisfaction of visitors and their possible revisit? and 2) What are the relationships between perceived characteristics of urban parks and visitors satisfaction?.

The results based on the preferences of parks visitors will maximize their satisfaction and consequently improve the quality of life because, as has been shown, the well-being of individuals is positively affected by their involvement with green spaces (Ma et al., 2019). Policy makers will be able to configure the park infrastructure according to the preferences of visitors as researched here.

## 2. Methods and Data

For the purposes of our research, an appropriate questionnaire was distributed to visitors of two urban parks in Attica, Greece: The Stavros Niarchos Park and the Antonis Tritsis Park. The survey was conducted from July 2018 to March 2019. The total sample consisted of 1.000 visitors, of which 761 were the usable answers.

Descriptive statistics was used for the motivation and the perceived characteristics of urban parks, while then the analysis was performed in three stages: Firstly, we used *Exploratory Factor Analysis* to extract the factors for the reasons for visiting the parks and the perceived characteristics of the parks. Secondly, we applied *Confirmatory Factor Analysis* to confirm whether the models developed fit well. Finally, we developed *Structural Equation Models* to test the relationships between motivation and park characteristics, visitor satisfaction and future visit.

## 3. Empirical Results

### 3.1 Descriptive statistics for the motives of the visit and the perceived characteristics of urban parks

Most respondents answered that they visit urban parks “very” or “very much” to enjoy the view (63.1%), the cool environment (62.6%), the fresh air (Sreetheran, 2017), but also to reduce stress levels (60.3%) and engage in walk and physical exercise (60.2%) (Terkenli et al., 2017). However, the less important reasons to visit urban parks are cycling (16.3%), reading (14.4%), school trips (12.5%) and breaks (12.3%).

Regarding the perceived characteristics of urban parks, most respondents stated that they “agree” or “totally agree” with the following statements: Parks are green lung for the city (89.8%), they contribute to improved health (88.4%), they are necessary for citizens (87.4%) and they contribute to the aesthetic improvement of the city (87.3%). On the contrary, respondents do not seem to agree with the following statements: The parks contribute to increased crime, they contribute to increased congestion and to noise pollution.

### 3.2 Exploratory Factor Analysis

*3.2.1 Motives for visit urban parks*

*Principal Component Analysis* led to the extraction of three components, explaining 63.396% of the total variance. The Kaiser-Meyer-Olkin (KMO) coefficient is 89.8%. According to Kaiser (1974), this value is a commendable measure.

The first factor termed “Relaxation and contact with nature”, explains 39.154% of the total variance and the reliability analysis showed that Cronbach’ s a is equal to 0.917. As Norusis (2006) stated, the reliability analysis for this factor is probably very good because it exceeds 80%. This factor consists of eight activities during the visit.

The second factor is called “Educational activities” and consists of three variables. This factor explains the 12.475% of the total variance. According to the reliability analysis, Cronbach’s a is equal to 0.540.

The third factor that came out explains the 11.767% of the total variance. It was named “Activities for children” because it consists of “Activities for children, e.g. playground” and “Cycling”. Cronbach’ s a for the third factor is equal to 0.588.

*3.2.2 Perceived characteristics of urban parks*

*Principal Component Analysis* revealed the presence of five components explaining 68.430% of the total variance. The first factor termed “Environmental & social benefits” explains 28.093% of the total variance. The second factor termed “Improvements” explains 11.809% of the total variance. The third factor “Negative effects” explains 10.415% of the total variance. The fourth factor “Safety” explains 10.276% of the total variance. Finally, the fifth factor “Economic benefits” explains 7.837% of the total variance. Cronbach's a is equal to 0.923, 0.730, 0.705, 0.865 and 0.695 for the first, second, third, fourth and fifth factor, respectively.

**3.3 Confirmatory Factor Analysis**

*3.3.1 Motives for visit urban parks*

The results of the *Confirmatory Factor Analysis* showed that in all cases, p-value is less than 0.10. Average Variance Extracted (AVE) is 0.590665, 0.2961 and 0.499423 for the first, second and third factor, respectively. Maximum Shared Variance (MSV) values are less than AVE (0.12564827, 0.220120019 and 0.220120019). Composite reliability (CR) is 0.918532457, 0.549926298 and 0.647648211 for each of three latent variables.

The Robust SRMR index is equivalent to 0.045 and the Robust CFI equal to 0.9389. These prices are desirable so we can say that the model is well adapted (Hu and Bentler, 1999)

*3.3.2 Perceived characteristics of urban parks*

In case of the perceived characteristic of urban parks, *Confirmatory Factor Analysis* showed that in all cases, p-value equals to 0.000. CR is above 0.7 for all latent variables and MSV values are less than AVE. AVE values are above 0.5, except for the latent variables "Improvements" and "Negative effects". In these cases, AVE is equal to 0.430718 and 0.4913, respectively.

The indicators for model adaptation have the following values: Robust CFI = 0.9016, Robust SRMR = 0.067. Based on these values, the model developed seems to be well adapted.

**3.4 SEM**

*3.4.1 Motives, satisfaction and future revisit to urban parks*

*SEM* was applied to examine the relationships between the motives for the visit, visitor satisfaction and future visit to urban parks. The hypotheses formulated are the following:

Hypothesis1: The search for relaxation and contact with nature positively affects the degree of satisfaction from visiting urban parks.

Hypothesis2: The search for educational activities positively affects the degree of satisfaction from visiting urban parks.

Hypothesis3: The search for activities for children positively affects the degree of satisfaction from visiting urban parks.

Hypothesis4: The degree of visitor satisfaction positively affects the revisit to the urban parks.

The results of the analysis are presented in the Table 1a. First of all, for the Hypothesis1, p-value is equal to 0.000 and the estimated coefficient has a positive sign. Therefore, the Hypothesis1 is supported. Similar are the results for Hypothesis2. According to p-value (0.016) and the positive sign of the estimated coefficient, we accept Hypothesis2. In case of Hypothesis3, p-value is equal to 0.016 which is less than 5%. The estimated coefficient has a negative sign and as a result, Hypothesis3 is rejected. However, we can say that people looking for activities for their children when they visit urban parks are less satisfied with their visit. Regarding Hypothesis4, the positive sign of the estimated coefficient and p-value show that the more satisfied someone is with their visit to urban parks, the more likely they are to visit them again in the future.

The model adjustment indicators had the following results: Robust CFI equals to 0.9256 and Robust TLI is equal to 0.9082. Both of these values approach the unit. Furthermore, Robust SRMR is equal to 0.052 and Robust RMSEA is equal to 0.0775.

**Table 1a:** SEM for motives, satisfaction and future visit (Robust Maximum Likelihood)

| Hypothesis | Hypothesized Path | Coefficient | Std. Err. | P>\|z\| | Result |
|---|---|---|---|---|---|
| Hypothesis1 | relax_nature → satisfied | 0.1525919 | 0.0429096 | 0.000 | Accepted |
| Hypothesis2 | educ → satisfied | 0.1529495 | 0.0637658 | 0.016 | Accepted |
| Hypothesis3 | activities_children → satisfied | -0.1167683 | 0.0483788 | 0.016 | Rejected |
| Hypothesis4 | satisfied → future visit | 0.6962435 | 0.0224759 | 0.000 | Accepted |

(Robust CFI = 0.9256, Robust TLI = 0.9082, Robust RMSEA = 0.0775, Robust SRMR = 0.052)

*3.4.2 Perceived characteristics of urban parks and visitors' satisfaction*

*SEM* was also applied to investigate the possible relationships between perceived characteristics of urban parks and visitors' satisfaction. In this case, the hypotheses proposed are as follows:
Hypothesis5: The perceived environmental and social benefits of the parks positively affect the degree of visitor satisfaction.
Hypothesis6: The improvements of the parks have a positive effect on the degree of visitor satisfaction.
Hypothesis7: The perceived negative effects of the parks have a positive effect on the degree of visitor satisfaction.
Hypothesis8: The perceived safety in the parks positively affects the degree of visitor satisfaction.
Hypothesis9: The perceived economic benefits of the parks positively affect the degree of visitor satisfaction.

According to the results (Table 1b), Hypothesis5 and Hypothesis9 are rejected. This means that the degree of visitor satisfaction is not affected by the perceived environmental, social and economic benefits of the parks. In case of Hypothesis6 and Hypothesis8, p-value is less than 0.10 and the estimated coefficients have a positive sign. Therefore, these two hypotheses are accepted. On the other hand, Hypothesis7 shows a negative sign of the estimated coefficient, so it is rejected. However, the p-value is equal to 0.049 so we can claim that the perceived negative effects resulting from the parks negatively affect the degree of visitor satisfaction.
Robust SRMR was found to be equal to 0.066 and Robust RMSEA equal to 0.0787. Robust CFI equals to 0.9038 and Robust TLI is equal to 0.8829.

**Table 1b:** SEM for the perceived characteristics of urban parks and visitors satisfaction

| Hypothesis | Hypothesized Path | Coefficient | Std. Err. | P>\|z\| | Result |
|---|---|---|---|---|---|
| Hypothesis5 | environmental and social benefits → satisfaction | 0.0540006 | 0.0478381 | 0.259 | Rejected |
| Hypothesis6 | improvements → satisfaction | 0.109107 | 0.0422263 | 0.010 | Accepted |
| Hypothesis7 | negative effects → satisfaction | -0.0753219 | 0.0382954 | 0.049 | Rejected |
| Hypothesis8 | safety → satisfaction | 0.626133 | 0.0355098 | 0.000 | Accepted |
| Hypothesis9 | economic benefits → satisfaction | 0.0756321 | 0.0529212 | 0.153 | Rejected |

(Robust CFI = 0.9038, Robust TLI = 0.8829, Robust RMSEA = 0.0787, Robust SRMR = 0.066)

## 4. Conclusions and Discussion

Visitors to urban parks in Attica are looking for relaxation and contact with nature, but also a place that offers educational activities and activities for children. According to the results, relaxation and contact with the natural environment is the main factor of a visit. *SEM* showed that the motivation of the visit affects the degree of visitors' satisfaction (Khuong and Ha, 2014). In particular, those looking to relax, get in contact with nature and engage in educational activities are more satisfied with their visit to the urban parks. On the contrary, people who visit urban parks for activities for their children are less satisfied with their visit.

The perceived environmental and social benefits derived from urban parks are the most important, while guarding in park facilities is a major variable in the factor model built. The perceived security provided in urban parks has a positive effect on the degree of satisfaction (Hermawan et al., 2019) and improvements that could take place in urban parks would result in greater visitor satisfaction. Finally, this study proved that satisfaction positively affects the intention for a future visit (Prayogo, 2019; Lee et al., 2020).

It seems that the environmental benefits of the parks are of particular importance to visitors. Consequently, emphasis could be given to the preservation of the natural and manmade environment of the urban park. However, motives for the visit as well as visitors' perceptions of urban parks during and after Covid-19 pandemic could be a field for further research.

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# Modelling the transition dynamics of the socio-technical urban mobility system

**Vasiliki V. Georgatzi & Yeoryios Stamboulis**
*Department of Economics, University of Thessaly, Volos, Greece*
vageorgatzi@uth.gr, ystambou@uth.gr

**Abstract**
Urban Mobility (UM) is in a state of transition, in an era of digitalization and climate change. Several researchers have analyzed the transition of UM through qualitative and quantitative approaches, focusing mostly on technological change and, less on changes of the mode of mobility. Digitalization and business model disruption have attracted less attention. In this paper, we aim to view change in UM adopting the holistic multi-level perspective of socio-technical transition in combination with a triple helix analysis. More specifically, we present a model of the transition from the current state of the dominant regime based on internal combustion engine technology and private car to a new one where new modes of mobility (ride hailing, car sharing) challenge incumbent ones (private car, taxi, public transport), and new technologies arise as niche-innovations (electric vehicles, ICTs) in the UM system, so as to lead to sustainability. We present a system dynamics model of the transition, based on stock and flow diagrams, facilitating the exploration of different scenarios and policy mixes.

**Keywords:** System dynamics, transition, urban mobility, helices, sustainability.

**JEL Codes:** O33, Q56, R40

## 1. Introduction

The need for urban and suburban mobility is constantly rising, resulting in further increases in emissions, noise, congestion and infrastructure overload (Karlsson et al., 2019), this situation contributes to a high amount of emission production and calls for sustainability.

In this paper, we examine UM as a socio-technical system that fulfils citizens need for mobility and "consist[s] of artefacts, knowledge, capital, labour, cultural meaning, etc." (Geels, 2004, p. 900). External and internal external pressures occur and destabilize the socio-technical regime structure. Transition takes place as new modes of UM and new technologies emerge changing the way mobility needs are served. New modes compete against old ones, as well as amongst themselves, in an evolutionary process towards a new regime ensemble, involving the development of different assets - resources, technologies, infrastructures, etc. - and institutional arrangements.

We apply a systemic approach to the socio-technical transition of UM, wherein different helices (social, governmental, industry) coexist and interact. The key issues addressed are to examine the interactions of the different spheres within the urban mobility system, and determine the factors that are necessary to lead to a new more sustainable mix of modes of mobility (e.g., financial, user behaviour), both from the viewpoint of business models under which the different mobility modes operate, as well as by the technological viewpoint. Finally, we study the way that different elements of each helix influence the trajectory of each UM mode and of the system in general.

In the rest of the paper, we present a concise literature review in section 2, the methodological approach in section 3, the causal loop and the stock-flow diagrams of the system's model in section 4 and conclusions in section 5.

## 2. UM transition

The UM transition is based on three different important pillars. The first one is the concern for the environment and the “obligation” to change to become more sustainable. The second one is technology improvement, and the third one is business model innovation (Lüdeke-Freund, 2019).

A variety of factors operate as barriers as well as drivers, to these pillars, including existing socio-technical systems, regimes and infrastructures that impede change due to lock-ins and path dependencies (Klitkou et al., 2015).

In a previous study we have categorized factors affecting the environmental impact of UM in five categories, political, economic, behavioural, demographic, and environmental factors (Georgatzi and Stamboulis, 2021). Policies like fuel taxes and transport taxes may have a positive impact towards the climate change mitigations (Giblin and McNabola, 2009; Santos et al., 2010; Timilsina and Dulal, 2011). However, the fact that there is an established regime, for which a substantial investment has been made over time to provide a favorable environment and complementary infrastructures and from users on vehicles, creates lock-in that impedes change (Klitkou et al., 2015; Kotilainen et al., 2019).

Behavioural factors may operate as drivers to the climate change mitigation, for example environmental awareness (Egbue and Long, 2012), or as barriers, e.g. lack of knowledge about more sustainable modes of transport or technologies (Balint et al., 2016; Benvenutti et al., 2017; Cruz and Sarmento, 2020; Georgatzi and Stamboulis, 2021; Langbroek et al., 2016). Demographic factors like the population density and individual income level can influence the trajectory to climate change mitigation. Income level has negative influence as the greater it is the more individuals tend to commute more (Lei, Zhang and Li, 2012; Harvey, 2013; Ivanova *et al.*, 2018), while population density appears to have a negative impact on the private car choice (Timilsina and Dulal, 2011; Lei, Zhang and Li, 2012; Ivanova *et al.*, 2018). Finally, when access to public transport is high and network density is sufficient then its attractiveness is increasing (Timilsina and Dulal, 2011; Lei, Zhang and Li, 2012).

The choice of powertrain technology depends on fuel and energy prices and cost-of-use of vehicles. The fact that ICE vehicles have been produced – until now - at much higher volume that AFVs, benefits them with economies of scale in cost and public awareness (Köhler et al., 2018b, 2009; Struben and Sterman, 2008).

Improvement of AFV technology in terms of mileage range and battery life, over time (Struben and Sterman, 2008; Walther et al., 2010) and as variety of choice of AFVs is increasing, make them more attractive alternative to ICE. (Janssen *et al.*, 2006; Struben and Sterman, 2008). Public funding or subsidies and credits for the purchasing of AFVs may be also an important driver for the diffusion of the AFVs (Kwon, 2012; Santos et al., 2010; Struben and Sterman, 2008; Walther et al., 2010).

Availability of complementary assets, infrastructures (e.g., charging stations) and maintenance service facilities are also an important factor, whose absence may delay the diffusion of AFVs (Köhler et al., 2018a; Kwon, 2012; Struben and Sterman, 2008). Finally, increasing environmental awareness of the population has a positive impact on AFVs diffusion (Köhler et al., 2009; Struben and Sterman, 2008).

Alternative modes of mobility (vis-à-vis the private car) also contribute to the mitigation of climate change, as they lead commuters away the private car, along with propriate legislation and strong political will. Taxes on the use of private car (e.g., fuel taxes, transport taxes), discourage commuters from using their private cars (Bernardino et al., 2015; Smith et al., 2018). Economic incentives, like fare discounts also encourage the choice of other modes of transport (Smith, Sochor and Karlsson, 2018; Karlsson *et al.*, 2019).

Fleet size of alternative modes of mobility increases the quality of services, rendering them attractive (Kim, 2015). Income level tends to be a negative factor for the selection of alternative modes of mobility (Bernardino *et al.*, 2015; Kim, 2015). On the other hand, greater population density favors the choice of alternative mobility modes (Timilsina and Dulal, 2011; Bernardino *et al.*, 2015; Kim, 2015).

The higher the level of ICT usage play is, the more likely it is that commuters select a mode that is based on ICTs (Köhler *et al.*, 2009). Fnally, commuters opinion of different modes of mobility and their level of acceptance for each mode of mobility affect significantly their preferences (Bernardino et al., 2015). Emissions levels may render a mode unattractive, as environmental awareness is increasing (Bernardino et al., 2015; Pangbourne et al., 2020; Shen et al., 2008).

## 3. Methodological approach

The most common approaches to study climate change mitigation effect of urban mobility transition are multi-level perspective (MLP), transition management (TM), innovation systems (IS), strategic niche management (SNM), and agent-based modeling (ABM).

Studies that adopt the MLP tend to focus on the development and diffusion of new artefactual technologies (Sarasini and Linder, 2018). Approaches such as strategic niche management, transition management and innovation systems, also have a strong focus on technology. It seems that organizational or business model innovation have been overlooked by these approaches (Sarasini and Linder, 2018). SNM has been used mostly for *ex post* analysis (Lachman, 2013) in transition cases, ABM lacks a broader system view, missing the feedbacks and the synergies of the system (McDowall, 2014), and TM is usually biased towards the incumbent regimes and giving insufficient attention to niches (Lachman, 2013). The IS approach focuses on how systems affect the development, diffusion, and use of new innovations.

A few studies have dealt with the mobility using System Dynamics methodology. Most of them stay at the level of CLD diagrams and focus on effects of specific transport segments such as urban transport (Jifeng, Huapu and Hu, 2008; Pangbourne *et al.*, 2020), transport modes (Kim, 2015; Karlsson *et al.*, 2019), or road transport, individual policy measures e.g. mobility services, taxes or scrappage schemes (Karlsson et al., 2019), and particular technologies like biofuels or electric vehicles (Walther et al., 2010). Existing research does not provide a high level of detail and is not explanatory and informative enough on the interactions technological change and modal change in UM.

Regimes according to the transition theory, encompass different dimensions, such as technology, science, policy, user practices, markets, the cultural and symbolic meaning of technology, and industry networks (Geels, 2005). In our analysis we categorise the factors based on the framework of the N-duple Innovation Helix Model. As our level of analysis is the city, we consider the academia helix and technical change in general as external to the system. We combine the N-duple Innovation Helix Model (Leydesdorff, 2012) with MLP, using system dynamics, so as to depict the interactions within and amongst helices and their impact on the transition dynamics from old to new technologies and UM modes.

Along the lines of the MLP approach, we perceive modes of mobility as alternative regimes (Geels, 2018), while niche innovations are the technologies and the complementary assets needed for the alternative regimes to succeed, and landscape pressures come from environmental crisis, economic growth, etc.

Table 1: Levels of analysis

| Level | |
|---|---|
| **Landscape** | • The gap between global level of AMUM and the level that prevails in some countries creates business opportunities for AMUM companies to develop and help close this gap.<br>• The environmental crisis pushes the operators to use more sustainable vehicles.<br>• Digitalization helps the increase of AMUM penetration. |
| **Regime** | • Commuters have to choose the mode or the modes that they will use to cover their mobility needs every period.<br>• ITC usage penetration contributes in the increase of AMUM use, as well as at the collection of accurate data.<br>• Financial resources and data resources affect service quality. |
| **Niche** | • New technologies are available and tested to examine their reliability and efficiency. |

As Geels states, three different interactions take place, within the multi-regime system of urban mobility, amongst the different regimes/modes of mobility: competition, symbiosis or integration. Competition interactions are those that will drive a “modal shift” from private ownership vehicle use to alternative modes (e.g. car sharing, ride hailing). Symbiosis amongst the regimes means that the different co-existing regimes interact but they are relative independent. While integration means that the regimes closely interact to form a new future system. A combination of various modes of mobility can be integrated into inter-modal transport systems (e.g. MaaS) (Geels, 2018).

## 4. The system dynamics model

In this section, we present a model that captures the dynamics of change and the interactions taking place at different levels (landscape, regime, niche) and spheres (helices) and may lead to the establishment of alternative UM regimes.

Three reinforcing and three main balancing loops are salient in the CLD . The first reinforcing loop (R1) shows that quality of service (QoS) affects attractiveness of urban mobility modes; as attractiveness increases word of mouth increases as well, and more users are convinced to use a particular mode, increasing the cumulative experience which leads to better QoS (QoS; UMM attractiveness; Adoption from WoM; Users of UMM; UMM cumulative experience). The second reinforcing loop (R2) shows how advertising affects the adoption of urban mobility modes (UMM), additionally to R1 (QoS; UMM attractiveness; Adoption from Advertising; Users of UMM; UMM cumulative experience). The third reinforcing loop (R3) shows the effect of environmental awareness on the demand of UMMs. The less pollution a mode produces, the higher the attractiveness of the mode which consequently increases the adoption rate from WoM and advertising, leading to a higher demand (New less polluting vehicles purchase to cover demand; UMM attractiveness; Adoption from WoM/Adoption from advertising; Users of UMM; UMM demand).

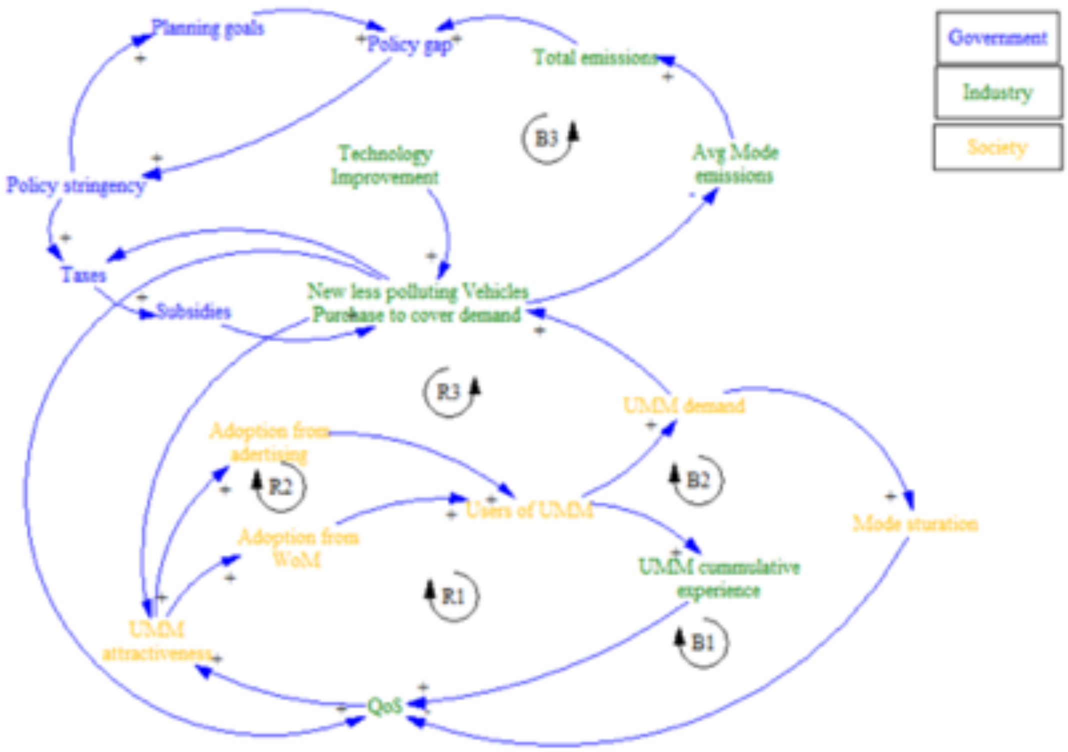


*Figure 1: CLD showing main feedback loops noticed in UMM diffusion. Source: own work using Vensim®.*

The first two balancing loops show how increase in demand leads to mode saturation, which erodes quality of service and consequently reduces attractiveness of the mode (B1) while advertising may accelerate this even further (B2); (Mode saturation; QoS; UMM attractiveness; Adoption from WoM/Adoption from advertising; Users of UMM; UMM demand). B3 shows the interaction between the industry helix and the government helix: as pollution levels are rising government policy becomes stricter (e.g. higher taxes) rendering the purchase or use of vehicles less attractive, leading to pollution reduction (Policy gap; Policy stringency; Taxes; Subsidies; New less polluting vehicles purchased to cover demand; Avg mode emissions; Total emissions).

In the stock-and-flow diagram, we model four different road modes of passenger mobility, three incumbent ones, private car, taxi, public transport (PT) dominated by the ICE vehicles, and two alternative modes of urban mobility (AMUM) car sharing and ride hailing. Transition is measured by the change is stock values (fleets of various mode-powertrain mixes, mode users, emission levels). Impact is measured as total emissions and fiscal impact.

The combined effect of factors from various helices (government: taxation, subsidies, promotion of new modes; society: digital literacy, environmental awareness, population density; and industry: technical change, investment in complementary assets etc.) is modelled along with their interaction. The current landscape already has some of the required conditions for new UM modes, as well as new powertrains (e.g., roads, parking spaces), but there is still need for new complementary assets (e.g., maintenance networks, charging infrastructures).

The Bass diffusion model (Sterman, 2000) is used so as to describe the mechanism through which users adopt a specific UM mode. The model reflects the competition between the four different modes of urban road passenger mobility (private car, taxi, PT, AMUM). We add mode attractiveness as a complementary factor affecting adoption; attractiveness is affected by a variety of industry, social and government factors (see Fig. A.1)

Potential adopters are the total population minus the users that have adopted each mode. This number is reducing by the adoption rate and increasing by the discard rate of users. Adoption rate is affected by advertising and word-of-mouth. The mode attractiveness is influenced by 1) the time that a travel needs to get accomplished; PT takes the more time, while AMUM and taxi seem to take the less, 2) the access to public transport and the sensitivity that it has in the mobility mode choice, 3) the COVID-19 impact that lately entered our lives and changed our habits, with the PT losing the higher part of its market share comparing with the other modes, 4) quality of service (QoS) also influence the attractiveness of each mode, with the mode attractiveness being higher as the QoS rises, 5) environmental awareness and the emissions that are produced by each vehicle used by the mode is also a factor that could change the attractiveness of the mode, 6) ICT usage can also change the attractiveness of a mode. This factor influences more the modes that are more digitalized and "oblige" the users to be digitally literal to use them, and finally 7) the existence of an integrated system of mobility, like mobility as a service (MaaS) can change the socio-technical system's synthesis and influence the market share of the different modes of mobility.

The average distance travelled per trip by each user is affected by the transport taxes, the price change of each mode of mobility the income changes and the urban density change, as well as the teleworking -immobility rate and the average mode emissions produced by each vehicle. The efficiency of the vehicles is a factor that can provoke more travelling as the cost of the travelling reduces and with the same or less cost and emissions commuters can travel more. We assume that the main factors that influence the choice between the two examining powertrains are sensitivity to vehicle price change, the sensitivity to environmental issues, the governments environmental policy stringency, the existence of complementary services (e.g., maintenance network, charging infrastructure. etc.).

Cumulative experience is a factor that aids to calculate the QoS for each of the modes of mobility; cumulative experience is based on the volume of use. As the number of users change the commuters in peak hours also change determining how many vehicles need to be purchased. The emissions each powertrain produces per km of use is calculated with an average rate of technology improvement, causing annual emissions improvement. Average mode emissions per vehicle is calculated by dividing the emissions produced by each mode by the total vehicles of each mode, in order to calculate total emissions. Finally, regarding the government helix, we aim to compare the total emissions produced by the passenger road mobility through time and examine the fiscal impact of each policy mix (taxes, subsidies etc).

## 5. Discussion and conclusions

Our literature review has revealed a gap in the study of the interaction between technological change and business model innovation, which takes the form on new modes of UM. Through our approach we aim to explore the drivers of system change, under technological and modal change. Combining MLP and N-tuple innovation helix model under the system dynamics methodology, we will be capable to determine the behaviour and interactions at the level of UM modalities (regimes) and helices (as quasi-actors) that are involved in the development of an emerging UM system. In addition, we will be able to highlight potential synergies, points of leverage for policy intervention and conflicts and trade-offs amongst alternative technical choices.

We use system dynamics modelling to simulate the interactions within and amongst various helices, involved in the transition process. Through this analysis, we should be able to understand system behavior and determine the dominant feedback loops. Understanding system behavior will facilitate policy design addressing citizens' and cities' needs by providing a participatory policy-making tool.

**Acknowledgments**
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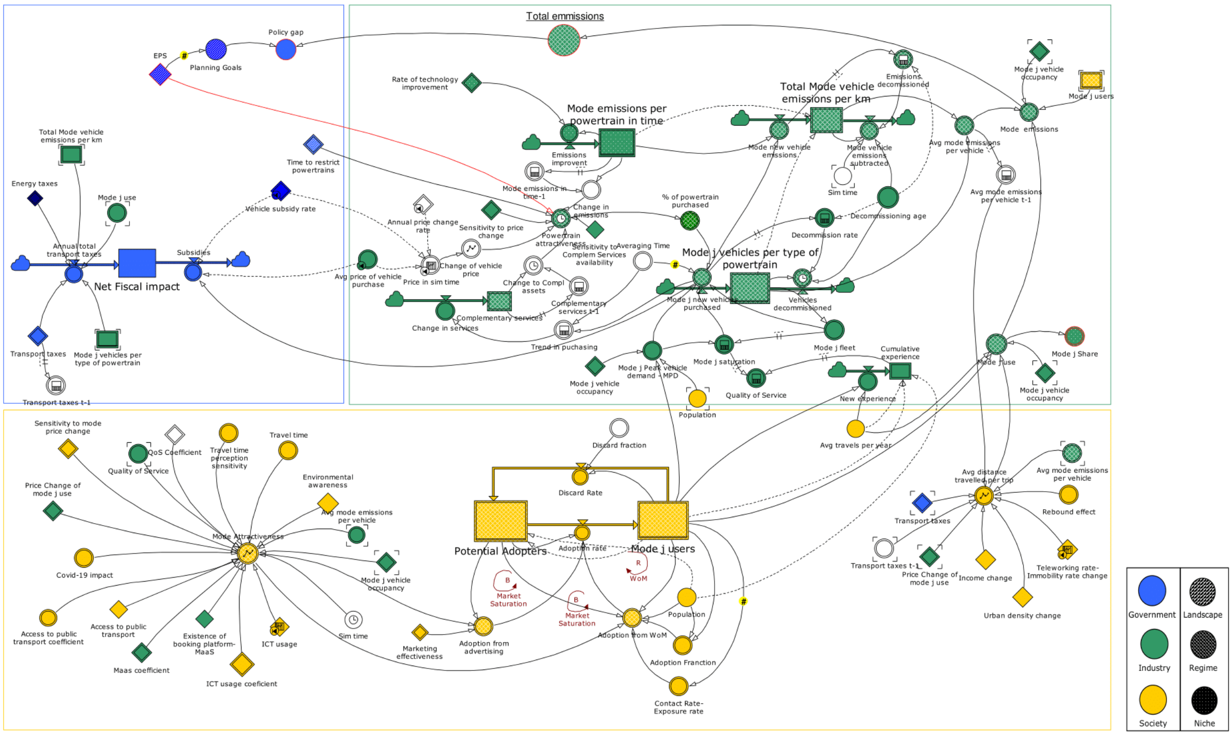
Figure A.1: The stock-flow diagram



# Methodology approach for the development of an online tourism app: The case of the Greece – Bulgaria Interreg project «Stage for Cross Border Culture – CULSTAGE»

**Zacharoula Andreopoulou[1], Konstantinos Ioannou[2], Christiana Koliouska[1], Evangelia Karasmanaki[3], Georgios Tsantopoulos[3] & Kleanthis Xenitidis[3]**

*[1] Laboratory of Forest Informatics, School of Forestry and Natural Environment, Aristotle University of Thessaloniki, Box 247, 54124, Greece*

*[2] National Agricultural Organization –"DEMETER", Forest Research Institute, Vasilika, Thessaloniki, 57006, Greece*

*[3] Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, Pantazidou 193, Orestiada, 68200, Greece*

kleodrama@gmail.com, randreop@for.auth.gr, ioannou.konstantinos@gmail.com, ckolious@for.auth.gr, evagkara2@fmenr.duth.gr, tsantopo@fmenr.duth.gr

**Abstract**

The project "Stage for Cross Border Culture – CULSTAGE" highlights the importance of alternative tourism development in the area of Paggaion Municipality, which is near the Cross Border (CB) area of Greece and Bulgaria. The area is mostly famous among tourists for its natural resources while it possesses a big potential to expand tourism into alternative forms. Many, century old monasteries are located in the region which have visitors on daily basis. The project introduces a well-structured and standardized methodology for promoting effective and sustainable usage of cultural and natural heritage and upgrading tourism in the area. This is achieved through an innovative approach which incorporates religious tourism development including the following activities: improvement of cultural infrastructure (by means of restoration works in monasteries both in Greece and Bulgaria), popularization of religious destinations and development of a Decision Support System (DSS) in the form of a Web application and a Smart Phone application which can help visitors in navigating throughout the region while at the same time it can help the local authorities to improve the offered regions' tourist product. For the investigation of both residents' and visitors' perceptions regarding local development, questionnaires were distributed to the population of the Paggaio municipality as well as the areas' visitors during the summer of 2020,. The web application includes detailed statistics regarding the data gathered from the questionnaires as well as real time data created by the application users. The project results include, among other, detailed information regarding tourist behavior, visitor priorities, identification of visitor preferences regarding locations as well as a comprehensive tourist management tool.

**Keywords:** CULSTAGE, alternative tourism, Decision Support System, web application, local development

**JEL Codes**: O3, Z32, O2.

## 1. Introduction

Alternative tourism produces new business opportunities for profitability and sustainable development through the provision of tourists services of highest level (Koliouska et al., 2021). Cultural tourism constitutes a significant income stream for the tourism industry (Lin et al., 2021) and at the same time, it promotes sustainability by tackling the destruction of ecosystems by mass tourism (Soutsas et al., 2006). Furthermore, the new media era supports the promotion of sustainable tourism and sustainable business (Andreopoulou et al., 2016). The potential of tourism in regional areas is enhanced by the capacity to motivate local people toward development process (Quaranta, Citro and Salvia, 2016). This project suggests an innovative approach to valorize the common assets of the territory by providing a "stage" for the frequently forgotten Christian values, alternative forms of culture exchange giving life of religious celebrations as a form of tourism, and fostering the religious and cultural tourism. In order to face this common challenge, the project follows the below stated integrated approach – involving partners from the private and public sector, together with Rozhen monastery – a significant religious monument of culture and a mighty Christian institution in the region, working in close cooperation with the common aim to valorise the natural and cultural heritage of the area by intensifying the alternative and religious tourism. For achieving of its goal, the project envisages the groups of measures:

- Improving of cultural infrastructure and providing stage for intensified and diversified cultural file, as an alternative form of tourism
- Popularization of religious sites, as a way of enhancing the religious tourism
- Giving life of religious celebrations as an innovative form of alternative tourism
- Development of web-management system for intensifying the alternative tourism
- The project will achieve an extensive added value by popularizing the frequently forgotten in our dynamic society Christian values, thus adding to the overall GOOD in the region

## 2. Methods and Data

In this research, we focused on residents and Bulgarian visitors in the Municipality of Paggaio, the study area. The quantitative data were derived from questionnaires. In order to investigate residents' and Bulgarian visitors' views on tourism development, two questionnaires were developed, one for each group.

- The questionnaires for the residents consists of the following sections:
  1. Resident demographics
  2. Residents' views on life quality in the study area as well as economic and social problems (Including resident satisfaction from local infrastructures and services).
  3. Perceptions and attitudes regarding the contribution of various sectors to local development ,as well as the effect of the areas' to local development.
  4. Suggestions of alternative destinations that can contribute to local tourism development, and personal attitudes regarding the effects of tourism on the area development.

The sampling method that was followed was the simple random sampling. The sample size was estimated based on the formulae of simple random sampling. Therefore, the sample size was calculated at 285 households. Personal interviews were conducted with a randomly selected household member of each chosen household in order to complete the questionnaires. The collected data were then coded in SPSS. At present, we are conducting various statistical analyses including descriptive statistics and the non-parametric Friedman test.

- The questionnaires for the visitors consists of the following sections:
  1. Demographic characteristics
  2. IT knowledge, access to mobile internet and interest regarding the usage of smartphone apps.

3. Data regarding their visit
4. Accommodation type, number of overnight stays, amount of money visitors spent during their stay and transportation means.
5. Data regarding visitors' intention to revisit the region in the next two year as well as their intention to recommend the destination to other potential visitors.
6. Visitors accommodation satisfaction and overall satisfaction from their experience in the area. Additional data were gathered regarding the level of expectation satisfaction (satisfaction created prior to their visit).

The collection of questionnaires addressed to Bulgarian visitors started in the beginning of June 2020 and ended in August 2020. The chosen sampling method was simple random sampling. The sample size was estimated using the formulas of simple random sampling and, according to these formulas, the sample size was estimated at 435 visitors. The collected data are currently analyzed using SPSS. In more detail, the researchers intend to perform descriptive statistics, factor analysis and cluster analysis using K-means.

The Information System (IS) is based on the combination of two separate components. The first component consists of a web application which is accessible only by  the municipality authorities. The second component is a Smartphone application (currently compatible with Android OS) which can be installed free of charge to smart devices

## 3. Results

### 3.1 Web Application

The Web Application includes detailed statistics regarding the data gathered from the questionnaires as well as real time statistics gathered from the application usage. Authorised users can access the application using a web browser and monitor a series of different statistics including current visitors preferences. From the provided statistics the authorities can understand the behavior of the visitors, and insert weight coefficients in order to promote destinations which are not selected from tourists.

- Monitor requests made by visitors
- Provide information regarding areas (text, images, videos)
- Identify problems and plan solutions

**Figure 1:** Web Application Homepage

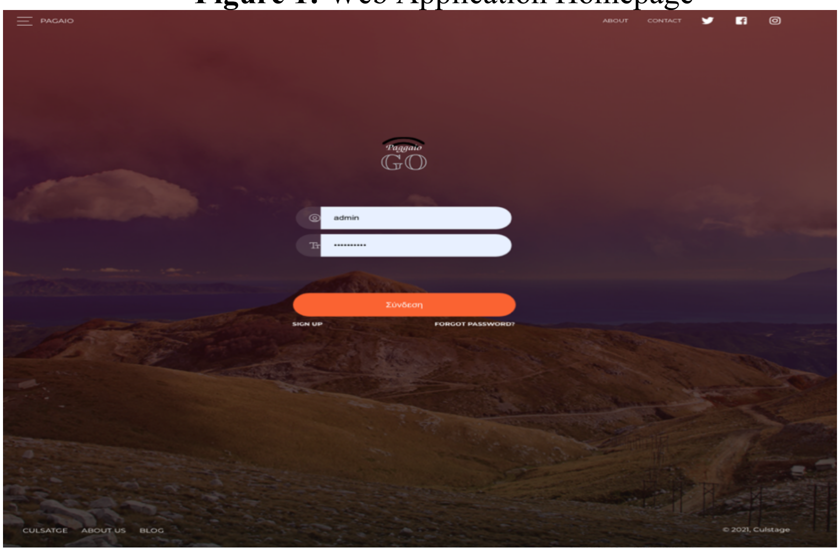
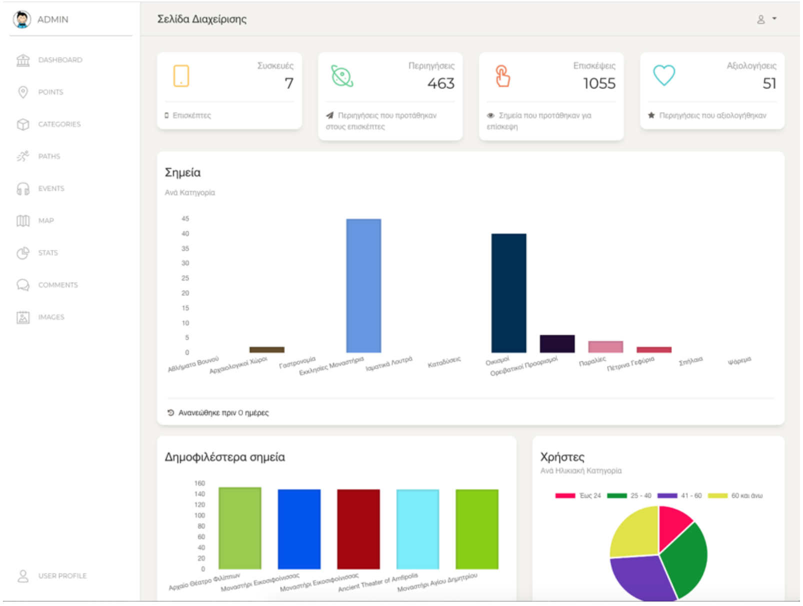


**Figure 2:** Administration page




Additionally, authorities can add new Categories as well as new Points Of Interest, Events etc. Every modification which is performed through the web application is automatically presented by the Android Application and the authorities have the ability to monitor the effect to the visitors behavior through the statistics section.

**Figure 3:** Points of Interest Section -1-

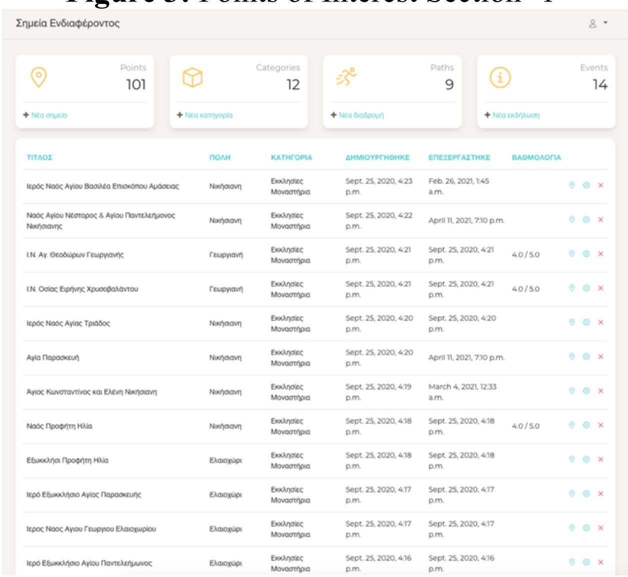


**Figure 4:** Points of Interest Section -2-

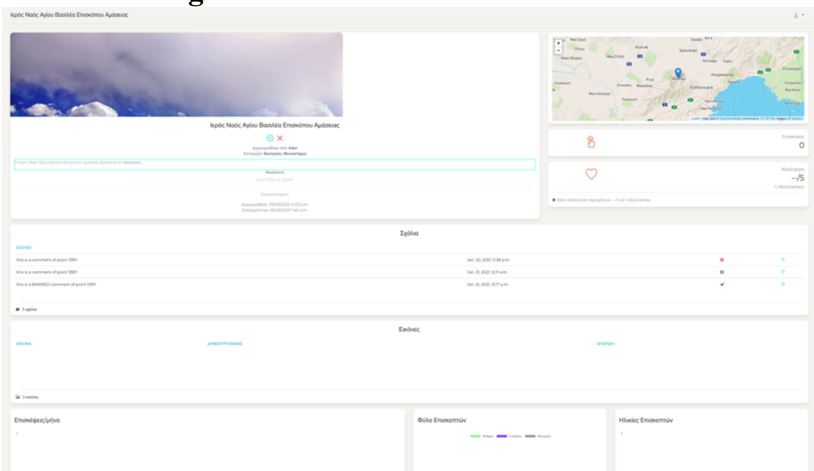


**Figure 5:** Categories Section -1-

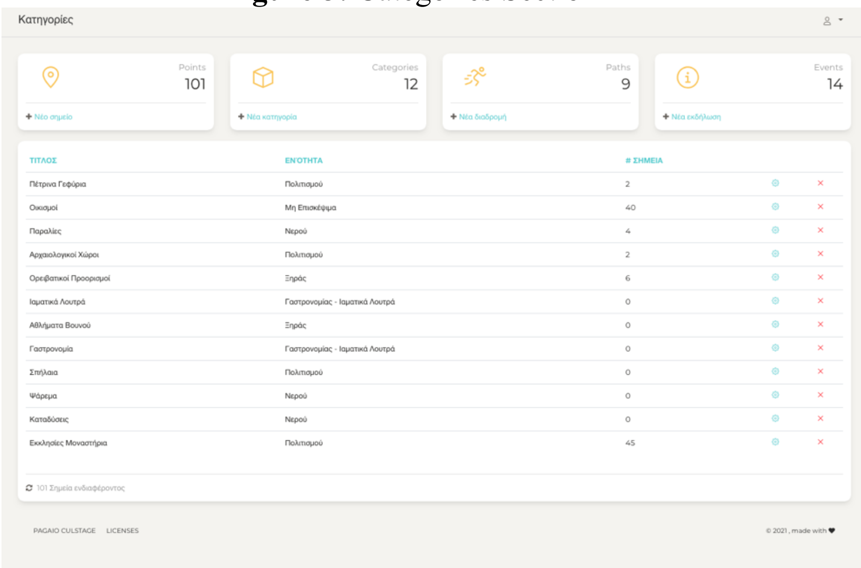



**Figure 6:** Categories Section -2-

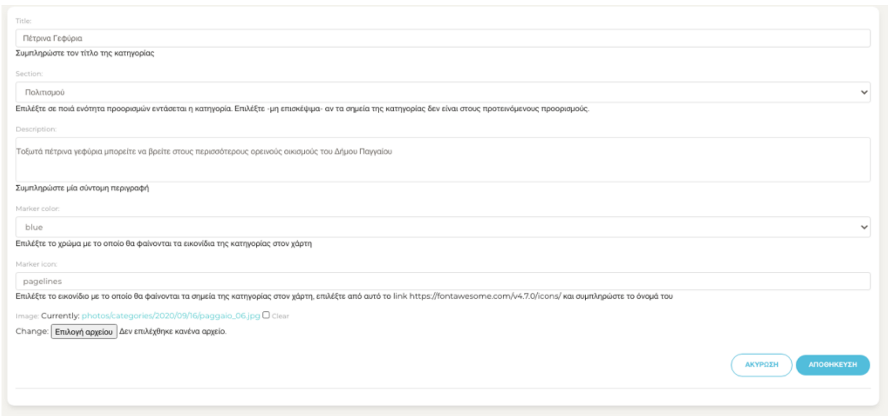


**Figure 7:** Trails Section -1-

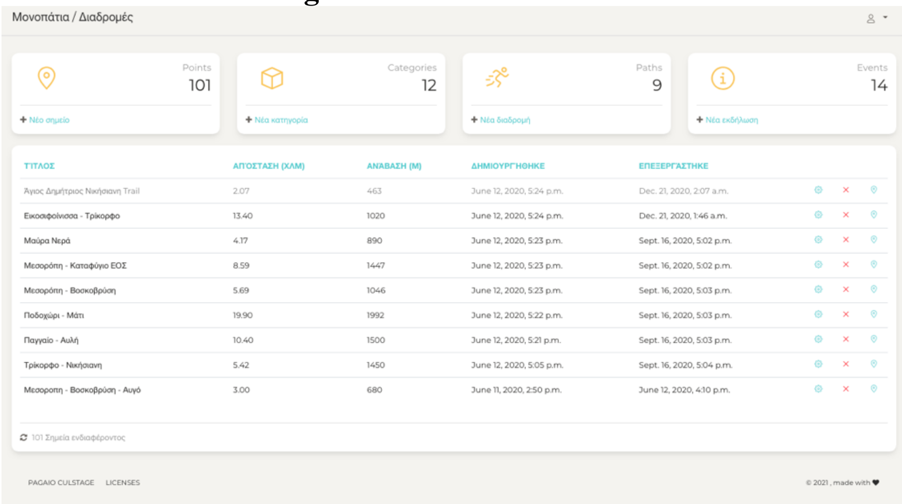



**Figure 8:** Trails Section -2-

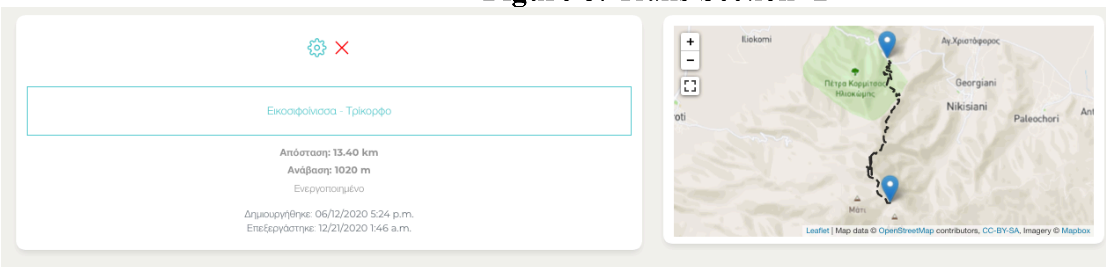



**Figure 9:** Events Section

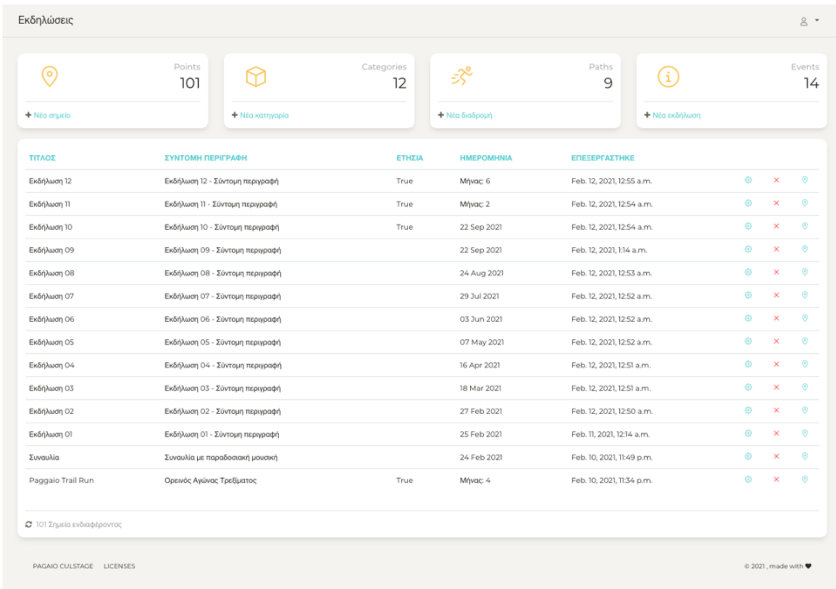
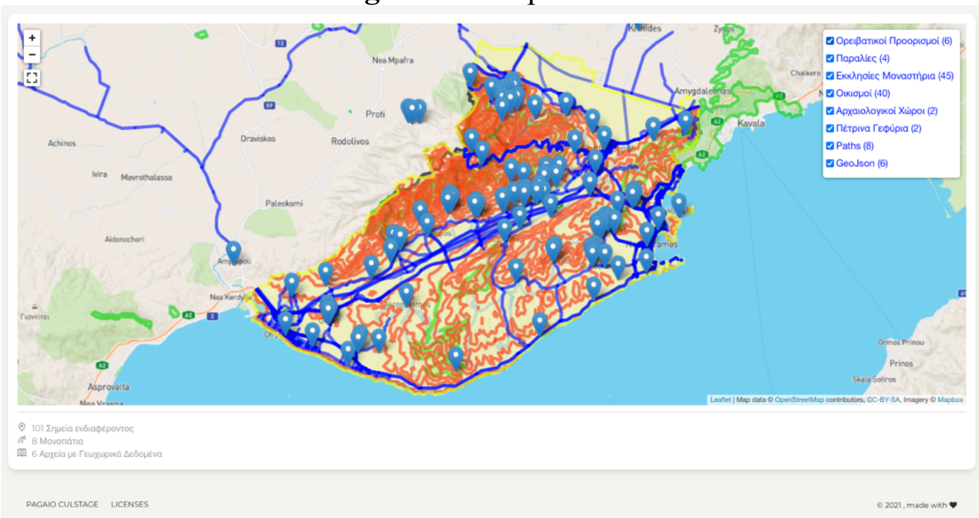


**Figure 10:** Map Section




3.2 Smart Phone Application

The Android application was developed having in mind two usages

- Helping visitors in their trip to Paggaion Municipality (act as a digital guide)
- Provide detailed statistics to the Municipality Authorities
- Act as a mean to record the visitors requests and needs

The app can function as a Tourist Guide, by presenting the user with

- Points Of Interest
- Categories of Interest (Museums, Monasteries etc)
- Events taking place
- Trails
- Information regarding destinations

Or act as an interactive Tourist Guide which allows tourists to create their personalized experience of the region, by selecting the “Go” Option.

**Figure 11:** Tourist Guide

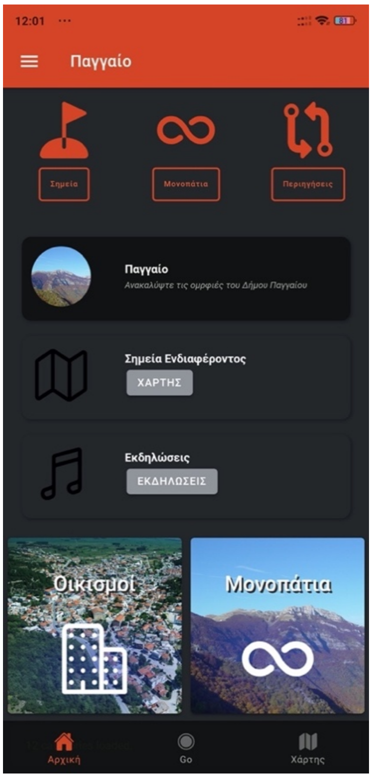



**Figure 12:** Interactive Tourist Guide

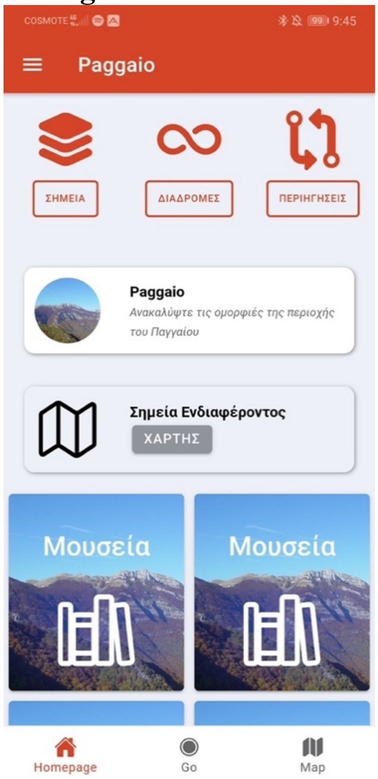



**Figure 13:** Web app – Age


**Figure 14:**Web app - Preferences

**Figure 15:** Web app – Route info

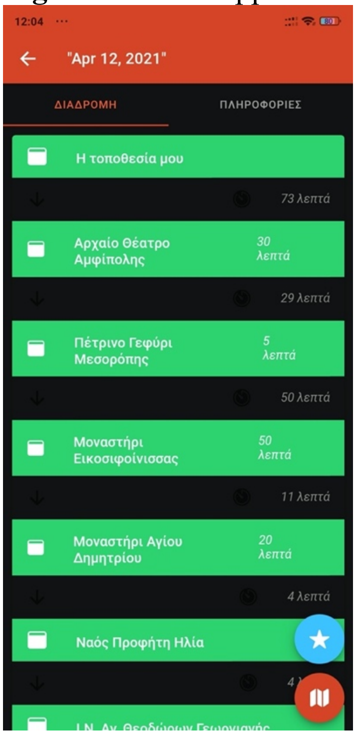
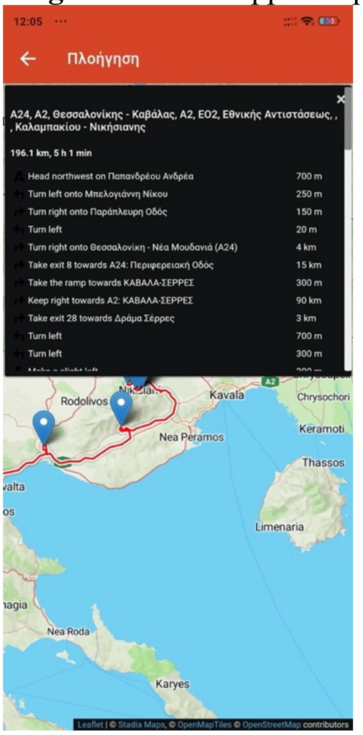


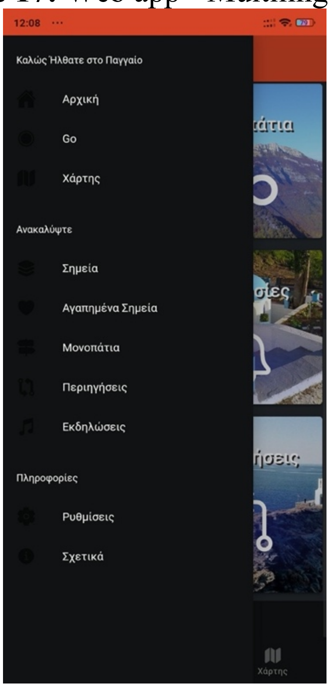

**Figure 16:** Web app - Map




"Go" initiates a procedure in which the user must respond to a series of questions regarding his/hers interest. Based on the answers to these questions in combination with the location of the user (acquired from the device's GPS) will allow the software to provide a series of visiting locations

The application is multilingual and also provides the users with the ability to save favorite trails, points, locations etc.

**Figure 17:** Web app - Multilingualism



## 4. Conclusions

The objective of the project is to promote the natural and cultural heritage of the area by intensifying the alternative and religious tourism. All project activities are designed in order to cause a broad area impact, spreading far beyond the territories of the project partners. One of the factors for the great significance of the project is inclusion of Rozhen Monastery as a partner, which is one of the most important cultural and religious centers of the Republic of Bulgaria (Stankova, 2020). It is both Christian Institution of significant importance and a tourist site provoking great interest. It is visited yearly by 60 000 tourists on regional, national, CB and international level. Rozhen Monastery is particularly engaged in the projects with the following measures: Rising of its attractiveness with activities for better tourist interpretation of its magnificence; Research on the religious sites and elaboration of routes for religious tourism; Cultural networking (linking the partners with other significant religious monuments in the CB area for support of culture exchange). All the above is a factor which will ensure the broad impact and the great significance in the project.

The added value of the project will be: 1) enhanced cooperation of cultural institutions from public and private sector, including religious institutions, through the created cultural network under the project; 2) included particular approach for disabled people 3) Popularized Christian values adding to the overall GOOD in the region.

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# Vulnerability Assessment to Desertification in Greece Using Composite Indicators.

**Demetrios E. Tsesmelis[1,2], Efthimios Zervas[1] & Christos A. Karavitis[2]**
[1] *Hellenic Open University, Laboratory of Technology and Policy of Energy and Environment, Parodos Aristotelous 18, 26335, Patra, Greece*
[2] *Agricultural University of Athens, Laboratory of agricultural hydraulics, Iera Odos 75, 11855 Athens*
tsesmelis@aua.gr, zervas@eap.gr, ckaravitis@aua.gr

**Abstract**
The Environmentally Sensitive Areas (ESA) Index estimates a region's vulnerability to desertification through the analysis of various parameters, such as soil, geology, vegetation, climate, and anthropogenic activities. Each of these parameters is categorized and every factor presents its own weightings for each category. ESAI index is divided into four different categories: soil quality, climate quality, vegetation quality and finally, the quality of the management applied. After calculating these four indicators for each quality, vulnerability to desertification is estimated. The Greek territory appears to be degraded, with several areas facing a significant risk. The examined period for this assessment implementation in Greece is from 1983 to 1996. This particular period, in which various changes have taken place, such as the increase of cultivated land in the rural distribution, was characterized as the driest period of the last 100 years (mainly between 1988 and 1993). In addition, there has been an increase in irrigation demand, due to crop growth and the intensification of agriculture.

**Keywords:** Desertification Vulnerability, Composite Indicators, Spatial Analysis, Natural Resources Management, Environmental Management

**JEL Codes**: O13, P28, P48, Q24, Q25.

## 1. Introduction

Due to its mountainous nature, Greece presents elevation differences, forming surfaces with steep slopes within a large part of the country. In particular, gradients exceeding 10% appear to cover 50% of the total area (Karavitis et al. 2014; Tsesmelis 2017; Tsesmelis et al. 2019). Strong gradients cause intense surface discharges of rainwater and severe erosion of soils wherever there is insufficient plant cover. These procedures constitute the leading causes of desertification in Greece (Kosmas and Danalatos 1994; Kosmas et al. 1997, 2000). As defined at the United Nations Conference on Environment and Development (1992), is the degradation of typically dry, semi-dry and sheltered areas, resulting from variousfactors including climate change and human activities (UNEP 1992). The term desertification should not be confused with the creation of a desert (dessication). Desertification is the process by which productive land degrades, and gradually becomes inhospitable to growing vegetation, thus creating spots of stripped areas with the appearance of the parent rock on the surface (Binns 1990; Kosmas and Danalatos 1994; D'Odorico et al. 2013; Briassoulis 2019). The degradation caused by desertification, refers to the reduction or loss of productivity of agricultural and forestry land (Geist 2005; Danfeng et al. 2006; Sivakumar 2007). The main process responsible for desertification is erosion, which poses the most significant risk of degradation of hilly areas. Man is primarily responsible for this process and who, through their interventions in the environment, often accelerates:

- rates of water, wind and mechanical soil erosion
- degradation of the physical, chemical and biological properties of natural resources
- loss of natural vegetation.

Today, desertification is seen as a major threat to the degradation of the Mediterranean countries. Although the Mediterranean basin is a complex mosaic of different ecosystems, different cultures and therefore a different history of human intervention in the environment, it has as its common denominator several factors contributing to the phenomenon of desertification (Kosmas and Danalatos 1994; Geeson et al. 2003; Hoffman 2009). These factors are the several climatic conditions that present high variation, thefrequent and high intensity rainfall, seasonal droughts, intense topographical terrain, and the – in general - limited plant coverage. Moreover, this long history of intervention in the environment, as well as the recent abandonment of rural areas while reducing rural potential, reinforce the spread of the phenomenon (UN Secretariat 1977; Binns 1990; Geeson et al. 2003; Kosmas et al. 2006). Greece appears to be severely degraded, having many of its areas facing a significant risk of desertification. Areas at high-risk of desertification are western Central Greece, most of the Peloponnese, the mountainous zone of the Ionian Islands, Crete, the Aegean islands, Evia and a number of parts of Epirus, Thessaly and Thrace. According to recent studies, 35% of Greece is at high risk of desertification, or has already been deserted, while 49% are considered to be at moderate vulnerability of desertification (Kosmas et al. 2000).

The Mediterranean climate is characterized by large seasonal and annual fluctuations in rainfall, high temperatures during the summer season and severe drought for a relatively long period. Due to rainfall, its high intensity and low frequency, combined with the intense topographical terrain (large gradients) often cause large surface discharges accompanied by loss of fertile soil, large fluctuations in rivers runoff and often catastrophic flooding. However, during the plants' growing season, water requirements are much more significant than rainfall can provide. Therefore, severe drought degrades the sparse vegetation of sensitive areas that become even more vulnerable, to the corrosive effect of rapid rainfall (Kosmas and Danalatos 1994; Kosmas et al. 1997; Yang and Zehnder 2002; Geeson et al. 2003; Hoffman 2009; Kalogeropoulos and Chalkias 2013; Depraetere et al. 2020).

## 2. Methods and Data

The first step of the current effort was the study of drought vulnerability for the time-period of 1971 to 2004 in Greece. The extensive press coverage on the problems created by drought over the years, has triggered further study and analysis of the results. Briefly, all steps followed were; a)the collection and entry of the data required for the calculation of the indicators and b) the calculation of the ESA index.
The Environmentally Sensitive Areas (ESA) index estimates a region's vulnerability to desertification through the analysis of various parameters, such as soil, geology, vegetation, climate, and anthropogenic activities. Each of these parameters is categorized and every factor presents its own weightings for each category. The composite indicator is divided into four categories: soil quality, climate quality, vegetation quality and, finally the quality of the management applied. After calculating the four indicators for each quality, each of which consists of 15 sub-indicators, ESA is produced. The index is graded into 8 different classes (Table 1) and grouped into 4 formulas (geometric mean). The methodology for calculating vulnerability to desertification was based on the MEDALUS research project, "Mediterranean Desertification and Land Use" (Kosmas et al. 1999).

Type A includes areas that are extremely degraded due to the application of bad practices, and are classified as critical, posing a threat to the environment and surrounding areas. For example, type A may include areas that have suffered significant erosion due to large runoff and soil loss (flooding). Type B ranks areas where a single change in the delicate balance of physical and human activities is likely to lead to desertification and are classified as sensitive. For example, the effects of a major drought can result in a large area of plant cover being lost, resulting in greater erosion and, finally, a change of type (i.e. transition from type B to type A). Changes in land use, such as the shift towards grain cultivation, can lead directly to an increase in runoff and erosion, even to a possible pollution downstream from pesticides and fertilizers. Type C concerns areas threatened by desertification under significant changes in many areas, such as incorrect use of pesticides and fertilizers and simultaneous changes in existing social and economic conditions. Furthermore, land abandonment and erroneous practices conducted by the implemented policies also affect these areas, which are ultimately classified as potentially sensitive. Unlike the above types, areas of type D do not show vulnerability to desertification.

For the calculation of the ESA index, data on soil, plant cover, climate and land management characteristics are needed (figure 1).

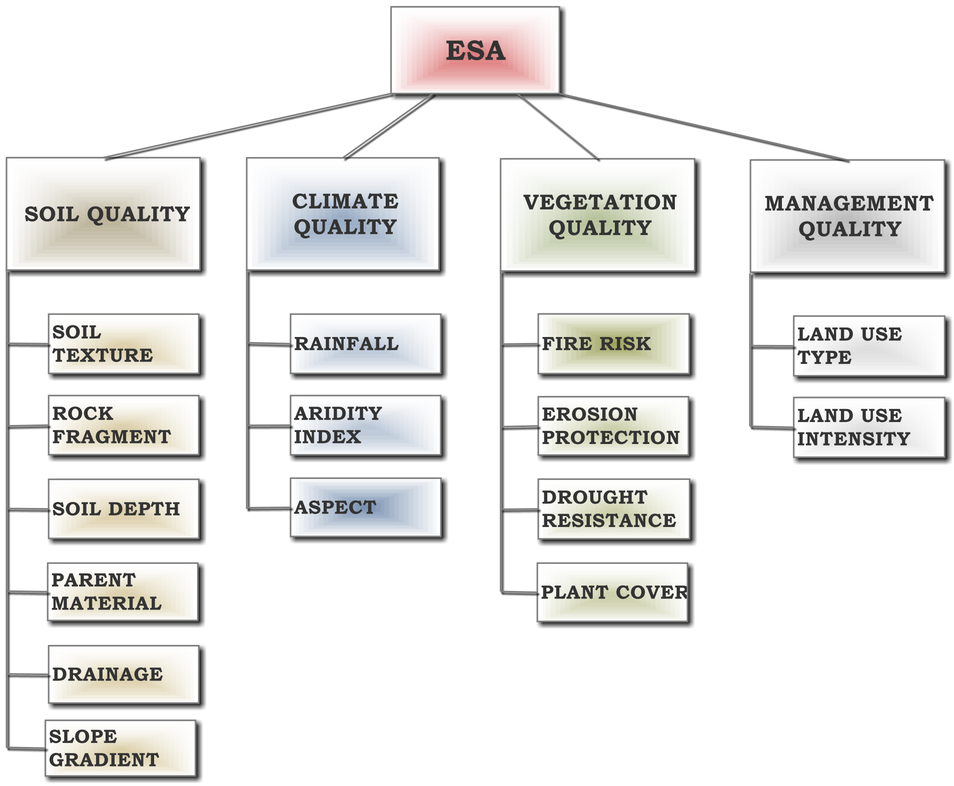


*Figure 1. The structure of ESA Index and the indicators* (Kosmas et al. 1999).

The final stage contains the matchup of the natural environment with soil quality, climate quality, vegetation quality and anthropogenic measures taken to reduce vulnerability to desertification (management quality). For the definition of the different types of areas which are vulnerable to desertification, Equation 1, which includes all four indicators, is applied.

$$ESA = \sqrt[4]{SQI * CQI * VQI * MQI} \qquad (1)$$

The categories in the ESA Index are eight and are shown in the following Table 1.

**Table 1:** *Types and categories of ESA Index.*

| Type | Category | ESAI Values |
|---|---|---|
| Critical | C3 | > 1.53 |
| « | C2 | 1.42 - 1.53 |
| « | C1 | 1.38 - 1.41 |
| Fragile | F3 | 1.33 - 1.37 |
| « | F2 | 1.27 - 1.32 |
| « | F1 | 1.23 - 1.26 |
| Potential | P | 1.17 - 1.22 |
| Non affected | N | < 1.17 |

## 3. Empirical Results

Soil is the dominant factor of terrestrial ecosystems in arid, semi-dry and dry areas mainly through its effect on biomass production. Soil Quality Indicators for mapping environmentally sensitive areas in desertification, may be related to water availability and corrosion resistance.

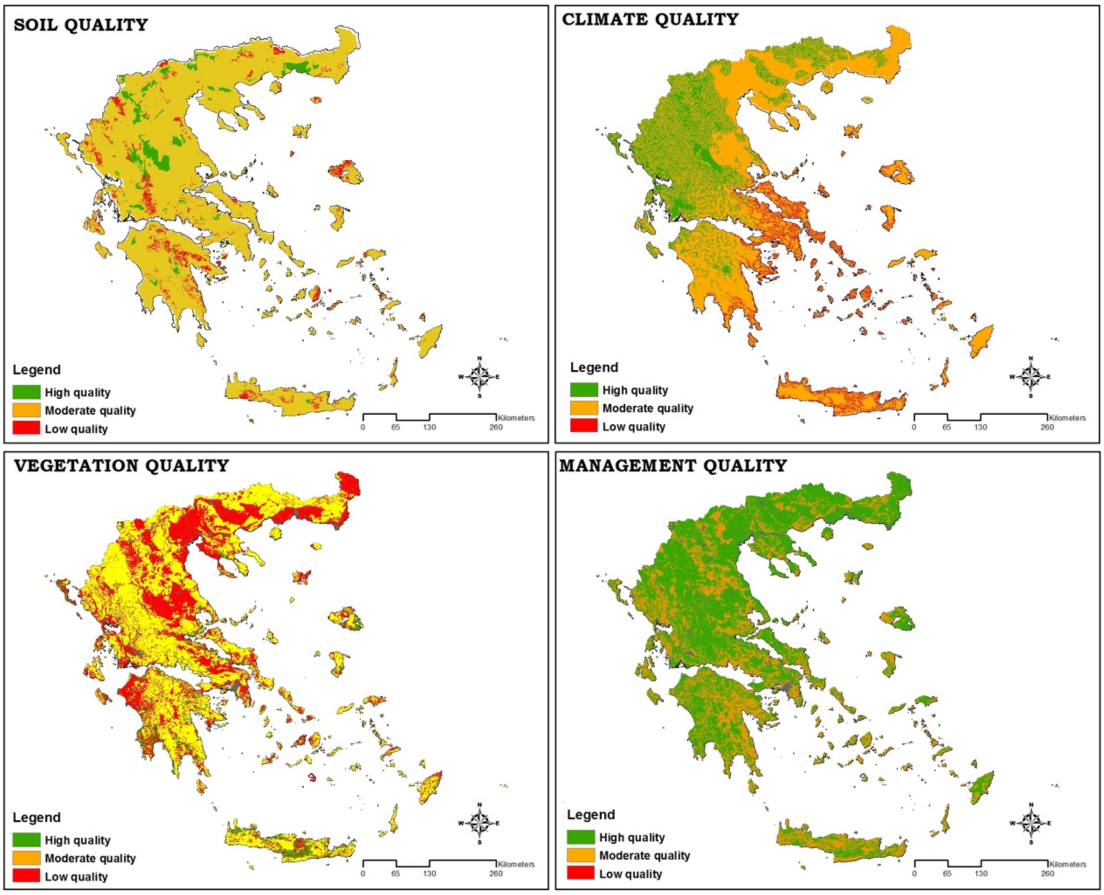


**Figure 2:** *Soil, Climate, Vegetation and Management Sub-Indices of ESAI.*

Soil Quality was calculated on the basis of the geometric mean equation, and soils were categorized according to the Soil Quality categories. Only a 5.22% percentage out of the total is included in the first

class (High quality), an 88.87% in the second class (Moderate quality) and the third class only contains a percentage of (High quality) 5.9%. According to Figure 2, a percentage of 24.9% ranks on the high-quality climate scale and appears in green on the map, while the moderate one (68.19%) appears in orange. Finally, the low quality is highlighted in red, and amounts to 6.91%. It is noted that low quality vegetation occurs in a higher percentage (34.55%) in relation to climate and soil quality. In the middle class corresponds a 56.41% and finally only a 9.03% stands in high quality.
The picture shown on the Management Quality is better compared to the other three qualities. Specifically, two classes appear, there is no low quality class at all, and the rates for high and average quality are 64.06% and 35.94%, respectively.

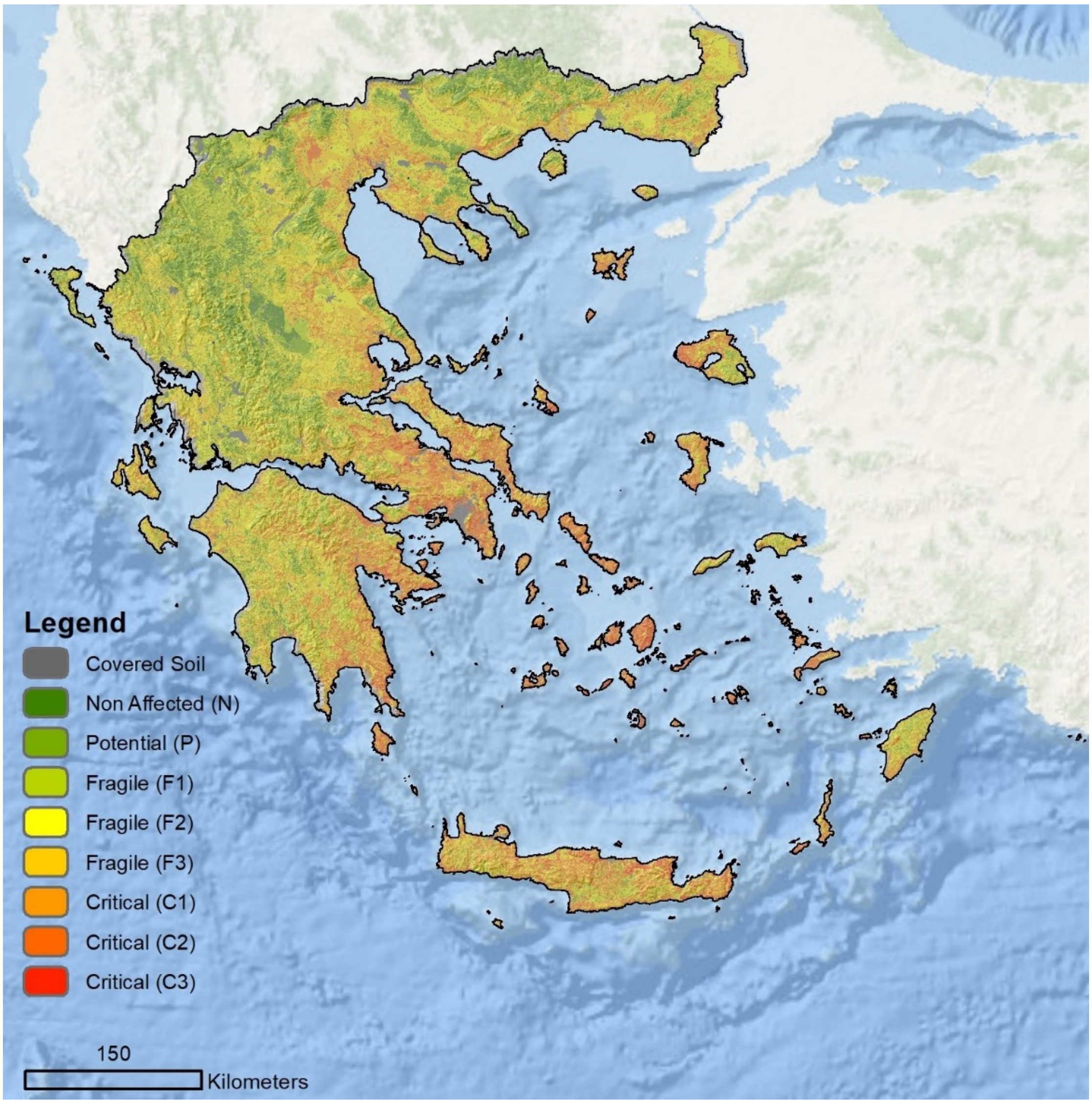


***Figure 3:*** *Desertification Vulnerability Map based on ESAI (1983 – 1996).*

The desertification of Greece is a phenomenon that has been going on for about three millennia and concerns the depletion of soil productivity and available water reserves. This extreme degradation of these two great resources, occurs in the olive plant spread zone, and has already been extended to more than 20% of its total area. Areas threatened by desertification account for 30% of the country's total area, while 49% are in the process of possible desertification. The greatest threat is found in Crete, Lesvos, Eastern “Sterea Hellas” and Peloponnese, but also in parts of Thessaly and Thrace. Despite the adverse

natural conditions prevailing in the European Mediterranean, desertification occurs only if reckless human action is observed. Therefore, both in Greece and in the other countries of the region, desertification is found in sensitive areas, is characterized by overexploitation of territorial, water, and in general, natural resources. The phenomenon evolves very slowly and shows temporal and local discontinuity. Thus, unfortunately, it is not immediately perceived by the societies concerned, until it will irreparably affect them. The situation has already reached an all-time high and the development of the phenomenon has accelerated significantly in recent years, mainly due to the industrialization of agricultural holdings and the overconsumption of water.
Using the four indicators (Soil, Climate, Vegetation and Management), relation equation 1 was applied, and by the results that have accrued, it was made possible to evaluate the Environmentally Sensitive – in desertification – Areas. This map was also calculated in a GIS environment, and finally, Table 5.28 was created. According to the categorization of the index, eight categories are presented: Areas that are not sensitive to desertification, the potentially sensitive ones, the sensitive ones (F1, F2 and F3) and, finally, the critical areas (C1, C2 and C3), which is in possible for them to be restored (especially class C3).
By analyzing Figure 7. 9, we see that the first class (non affected) has an appearance rate of 8.07%, the second class (potential) 11.91%, for sensitive areas the total percentage is 53.43% (19.54%, 18.72% and 15.17% for F1, F2 and F3, respectively) and, finally, for critical areas it is 26.59% (10.36%, 14.53% and 1.7% for C1, C2 and C3, respectively).

## 4. Conclusions

Desertification has a major environmental and socioeconomic impact, since by degrading natural resources, the productivity of a place is reduced, as well as the rural income does, and thus displacing the population to areas with more employment opportunities. In particular, desertification entails: loss of the biodiversity of a region, reduction of soil productivity, alternation in local climatic conditions, decrease in the availability of fresh water, increase in the frequency and magnitude of floods in the lower regions, sedimentation of dams, reduction of rural income, abandonment of land and migration of the population.
The main consequence of desertification is the abandonment of land, which follows the reduction of soil productivity. Olive groves are usually found in a climatic and elevation zone that is particularly sensitive to desertification. As shown in Figure 2, olive oil production in Lesvos has decreased by about a third with an increase in the degree of degradation and desertification of the land. Reduced production combined with low market prices of the product, leads to land abandonment and population migration to urban centers or other agricultural areas where a better quality of life is ensured. This migration puts wider social and economic pressures on immigration areas, resulting in rapid urban housing expansion, pollution and other environmental problems, unemployment, and extreme behavior.

The application of the ESA index in Greece highlighted the following:

Amongst the Cyclades, part of Central Greece, Western Lesvos and Western Evia, the worst picture is the one of the Cyclades, due to soil, vegetation and climate, with the qualities of the parameters classified from moderate to low, leading to the deterioration of the phenomenon of desertification.
• Central Greece is characterized by areas potentially threatened and sensitive (F1, F2 and F3). The quality of the climate seems to affect the image of the region, as it is characterized by moderate to low quality. On the contrary, the soil is presented in the majority as of medium quality with the exception of some low points. The quality of vegetation is from low to moderate due to the fact that there is no significant protection of the soil from erosion, and the drought resistance is low.

• Crete has problems and is characterized mainly by sensitive areas (F2, F3) and Critical (C1), with the most significant problem appearing in the area of Heraklion. The quality of climatic conditions, poor soil quality and existing vegetation are a burden on the situation.
• The Western Peloponnese appears in good condition with little vulnerability to desertification. On the contrary, the eastern side shows considerable vulnerability. In particular, Skala Laconia, Argolida and Corinthia seem to have a strong tendency to desertification.
• Northern Greece seems not to suffer so much from desertification, except in certain areas, such as the valley of Serres, Thessaloniki, Edessa, as well as the region of Evros.

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# LISTS OF PARTICIPANTS

## PARTICIPATING BODIES
### Academic and Research Institutions & Organizations

| | |
|---|---|
| 1 | Agricultural University of Athens |
| 2 | Aristotle University of Thessaloniki |
| 3 | Athens University of Economics and Business |
| 4 | ATHENA Research Center |
| 5 | Centre for Renewable Energy Sources and Savings |
| 6 | Democritus University of Thrace |
| 7 | Eötvös Loránd University |
| 8 | Harokopio University |
| 9 | Harper Adams University |
| 10 | Hellenic Open University |
| 11 | Leibniz University Hannover |
| 12 | Linkoping University |
| 13 | Manchester Metropolitan University |
| 14 | National Agricultural Organization DEMETER |
| 15 | National Technical University of Athens |
| 16 | Panteion University of Social and Political Sciences |
| 17 | Small Enterprises of GSEVEE |
| 18 | UN SDSN |
| 19 | UNIDO |
| 20 | Universitat de Girona |
| 21 | University of Gavle |
| 22 | University of Gothenburg |
| 23 | University of Patras |
| 24 | University of Southeastern Norway |
| 25 | University of the Aegean |

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|---|---|
| 26 | University of Thessaly |
| 27 | University of West Attica |
| 28 | Vocational School (EPAL) of Edessa |

## Academic and Research Participants

| No | Full Name | University/Organization |
|---|---|---|
| 1 | Andreopoulou Zacharoula | Aristotle University of Thessaloniki |
| 2 | Arabatzis Garyfallos | Democritus University of Thrace |
| 3 | Arvanitidis Paschalis | University of Thessaly,<br>Hellenic Open University |
| 4 | Bithas Kostas | Panteion University of Social and Political Sciences |
| 5 | Botzoris George | Democritus University of Thrace |
| 6 | Chatzistamoulou Nikos | Athens University of Economics and Business,<br>University of Patras |
| 7 | Choropanitis Ioannis | Centre for Renewable Energy Sources and Saving |
| 8 | Danatskos Christos | Aristotle University of Thessaloniki |
| 9 | Daoutis Christodoulos | Democritus University of Thrace |
| 10 | Diamantis Vasileios | Democritus University of Thrace |
| 11 | Do Manh Hung | Leibniz University Hannover |
| 12 | Dritsas Sophocles E. | University of Thessaly |
| 13 | Economou Agisilaos | Hellenic Open University,<br>National Technical University of Athens |
| 14 | Economou Athina | University of Thessaly |
| 15 | Economou Emmanouil M.L. | University of Thessaly |
| 16 | Eftaxias Alexandros | Democritus University of Thrace |
| 17 | Evangelinos Konstantinos | University of the Aegean |
| 18 | Falk Martin Thomas | University of Southeastern Norway |
| 19 | Fotiadis Stefanos | University of the Aegean |
| 20 | Gareiou Zoe | Hellenic Open University |
| 21 | Georgatzi Vasiliki V. | University of Thessaly |
| 22 | Giannarou Sofia | Hellenic Open University |
| 23 | Gkargkavouzi Anastasia | University of Thessaly |
| 24 | Grote Ulrike | Leibniz University Hannover |
| 25 | Gutiérrez Olesti Jacinta | Universitat de Girona |
| 26 | Halkos George | University of Thessaly |
| 27 | Hatjina Fani | National Agricultural Organization DEMETER |
| 28 | Helgadóttir Guðrún | University of Southeastern Norway |

| | | |
|---|---|---|
| 29 | Hortay Olivér | Eötvös Loránd University |
| 30 | Iliopoulou Polixeni | University of West Attica |
| 31 | Ioannou Konstantinos | National Agricultural Organization DEMETER |
| 32 | Kantartzis Apostolos | Democritus University of Thrace |
| 33 | Karasmanaki Evangelia | Democritus University of Thrace |
| 34 | Karavitis Christos A. | Agricultural University of Athens |
| 35 | Karytsas Constantine | Centre for Renewable Energy Sources and Saving |
| 36 | Karytsas Spyridon | Harokopio University,<br>Centre for Renewable Energy Sources and Saving |
| 37 | Katsardi Vanessa | University of Thessaly |
| 38 | Kitsos Christos | University of West Attica |
| 39 | Koliouska Christiana | Aristotle University of Thessaloniki |
| 40 | Kostakis Ioannis | Harokopio University |
| 41 | Koundouri Phoebe | Athens University of Economics and Business,<br>ATHENA Research Center,<br>UN SDSN |
| 42 | Kounetas Kostas | University of Patras |
| 43 | Kyriazis Nicholas C. | University of Thessaly |
| 44 | Latinopoulos Dionysis | Aristotle University of Thessaloniki |
| 45 | Leal Walter | Manchester Metropolitan University |
| 46 | Leonti Aikaterini | Harokopio University |
| 47 | Liakou Hariklia | University of West Attica |
| 48 | Liotiris Christos | Aristotle University of Thessaloniki |
| 49 | Malesios Chrisovalantis | Agricultural University of Athens |
| 50 | Maragkaki Vasileia | Hellenic Open University |
| 51 | Marnasidis Simeon | Democritus University of Thrace |
| 52 | Maroulis Georgios | Panteion University of Social and Political Sciences |
| 53 | Matsiori Steriani | University of Thessaly |
| 54 | Mentis Charalampos | Panteion University of Social and Political Sciences |
| 55 | Michmizou Maria | University of Thessaly |
| 56 | Mitoula Roido | Harokopio University |
| 57 | Moll de Alba Jaime | UNIDO |
| 58 | Naxaki Anastasia | Aristotle University of Thessaloniki |

| | | |
|---|---|---|
| 59 | Nguyen Duy Linh | Leibniz University Hannover |
| 60 | Nguyen Thanh Tung | Leibniz University Hannover |
| 61 | Nguyen Trung Thanh | Leibniz University Hannover |
| 62 | Nikolaou Ioannis | Democritus University of Thrace |
| 63 | Nisiotis Constantinos-Symeon | University of West Attica |
| 64 | Oikonomou Theoni | Centre for Renewable Energy Sources and Saving |
| 65 | Papaspyropoulos Konstantinos | Aristotle University of Thessaloniki |
| 66 | Papavasileiou Angelos | Harokopio University |
| 67 | Paraschi Dionysia Evgenia | Hellenic Open University |
| 68 | Polyzou Olympia | Centre for Renewable Energy Sources and Saving |
| 69 | Profillidis Vassilios | Democritus University of Thrace |
| 70 | Rigas Nikos | University of Patras |
| 71 | Sardianou Eleni | Harokopio University |
| 72 | Skouloudis Antonis | University of the Aegean |
| 73 | Spiliotopoulos George | University of Thessaly |
| 74 | Stamboulis Yeoryios | University of Thessaly |
| 75 | Stathi Eleni | Aristotle University of Thessaloniki |
| 76 | Stefkovics Ádám | Eötvös Loránd University |
| 77 | Stergiou Eirini | University of Patras |
| 78 | Sterner Thomas | University of Gothenburg |
| 79 | Theodoropoulou Eleni | Harokopio University |
| 80 | Thollander Patrik | Linkoping University,<br>University of Gavle |
| 81 | Todorov Valentin | UNIDO |
| 82 | Trevlopoulos Nikolaos | Democritus University of Thrace |
| 83 | Tsadiras Athanasios | Aristotle University of Thessaloniki |
| 84 | Tsalis Thomas | Democritus University of Thrace |
| 85 | Tsantopoulos Georgios | Democritus University of Thrace |
| 86 | Tsatiris Michael | Democritus University of Thrace |
| 87 | Tsekouras Kostas | University of Patras |
| 88 | Tsesmelis Demetrios E. | Hellenic Open University,<br>Agricultural University of Athens |
| 89 | Tsilika Kyriaki | University of Thessaly |

| | | |
|---|---|---|
| | | Hellenic Open University |
| 90 | Tsipouras Leonidas | University of Thessaly |
| 91 | Vatikiotis Leonidas | Hellenic Open University,<br>Small Enterprises of GSEVEE |
| 92 | Verikouki Efstathia | Vocational School (EPAL) of Edessa |
| 93 | Vougioukalakis Emmanouil | Hellenic Open University |
| 94 | Vouros Panagiotis | University of the Aegean |
| 95 | Xenitidis Kleanthis | Democritus University of Thrace |
| 96 | Zervas Efthimios | Hellenic Open University |