Hydrothermal Liquefaction and Catalytic Hydrotreating of Food-Waste

Angelos Sotiropoulos[1], Christos Michalopoulos[1] and George Xydis[2]

Abstract: Institutional catering facilities generate large, continuous streams of food waste whose disposal carries environmental and economic costs, particularly in Mediterranean settings where landfill capacity and waste-management infrastructure are increasingly constrained. This work reports an integrated, experimentally grounded waste-valorization pathway that converts pre-sorted food waste from a Greek military academy canteen into a hydrotreated bio-oil, developed within the MARINES project. In the first stage, hydrothermal liquefaction (HTL) of the waste was carried out in 300–600 mL batch reactors at 280–320˚C, 100–130 bar, 10–20 wt% solids loading and 30–60 min residence time. Bio-crude higher heating value (HHV) increased with temperature, reaching approximately 39 MJ/kg at 320˚C, while the highest bio-crude quantities were obtained at 310˚C. In the second stage, a pooled bio-oil sample (baseline HHV 39.1±0.4 MJ/kg, O 7.5±0.2 wt%) was catalytically hydrotreated at 300–340˚C and 70–100 bar for 2 h using zeolite, aluminum(III) oxide and nickel(II) nitrate hexahydrate (5 wt% loading). At the optimum point (320˚C, 90 bar), the nickel-based catalyst performed best, raising HHV to 40.8±0.2 MJ/kg while lowering oxygen content to 6.4±0.1 wt%, outperforming aluminum oxide (HHV 40.4 MJ/kg, O 6.7 wt%) and zeolite (HHV 40.1 MJ/kg, O 6.8 wt%). Read together, the two data sets define a coherent production-to-upgrading chain and the operating windows in which each stage performs best. Beyond its technical content, the study is directly relevant to this journal's focus on Mediterranean sustainability: it provides empirical, policy-relevant evidence for circular-economy valorization of an everyday institutional waste stream, with implications for waste-management planning, energy security, and decarbonization of public-sector facilities in Mediterranean-type economies.

Keywords: Hydrothermal liquefaction, bio-oil, catalytic hydrotreating, food-waste valorization, circular economy, Mediterranean.

1. Introduction

Food waste is one of the largest and most persistent organic waste streams in the Mediterranean region (Alhebri et al., 2022; Lemonakis et al., 2020; Petropoulou et al., 2024; Ragazou et al., 2024b; Yiannoulis, Vortelinos and Passas, 2025), generated continuously by households, the hospitality sector, and large institutional catering operations such as hospitals, schools, and military facilities (Vardopoulos, Abeliotis and Lasaridi, 2025). When landfilled, this waste stream contributes to methane emissions and represents a lost energy resource (Vardopoulos et al., 2021); when converted through thermochemical routes, it can instead become a feedstock for renewable fuels, closing a material loop that is central to circular-economy and green-economic-development agendas (Angelaki et al., 2025; Maravelaki et al., 2021; Petropoulou, Garefalakis and Passas, 2026; Ragazou et al., 2026; Zafeiriou et al., 2023) in Mediterranean-type economies (Castagna et al., 2025; Doukas et al., 2026). Hydrothermal liquefaction (HTL) is particularly well suited to this feedstock because it processes wet biomass directly, without the energy-intensive drying step required by pyrolysis or gasification, and yields an energy-dense bio-crude oil together with aqueous, gas, and solid co-products (Angelaki et al., 2026; Panagiotopoulos, 2026; Ragazou et al., 2022a; Sarker et al., 2025; Sitzimis et al., 2025; Wang et al., 2026; Zaroulea and Kyriakogkonas, 2026).

However, HTL bio-crude cannot be used directly as a drop-in fuel. It typically retains 10–20 wt% oxygen in the form of acids, aldehydes, ketones, and phenolics, which is responsible for its high acidity, thermal instability, and comparatively

[1]*National Technical University of Athens, Greece*
[2]*Aarhus University, Denmark*
E-mail: angeluoi81@gmail.com
Corresponding Author: George Xydis; E-mail address: angeluoi81@gmail.com

Handling Editor: Marinos Stylianou

Received 6 January 2026, Accepted 26 February 2026; Published Online: 04 November 2026.

Citation:
Sotiropoulos, A., Michalopoulos, C., & Xydis, G. (2025). Hydrothermal liquefaction and catalytic hydrotreating of food-waste. *Sustainability Research in the Mediterranean*, *1*(4), 225–234. https://doi.org/10.13052/srm2795-0514.017

© 2026 River Publishers

low heating value relative to petroleum fuels (Gil, Sancho-Sanz and Korili, 2024). Catalytic hydrotreating – the addition of hydrogen over a solid catalyst under elevated temperature and pressure – is the established route for removing this oxygen (hydrodeoxygenation, HDO) and saturating reactive unsaturated bonds, thereby producing a more stable, higher-energy-density oil that can be blended into diesel, heating oil, or, with further processing, aviation fuel (Cheliatsidou et al., 2023; Li et al., 2024; Papademetriou et al., 2023; Ragazou et al., 2022a; Stavropoulou et al., 2023; Summers et al., 2024; Xu et al., 2025; Zisoudis et al., 2022).

This paper reports experimental results from the two stages of this production-to-upgrading chain, generated within the MARINES project (Valorization of Organic Residues and By-products of the Hellenic Armed Forces for the Production of Renewable Transport, Heating and Aviation Fuels, funded under the Greek National Recovery and Resilience Plan). The feedstock is pre-sorted food waste from the canteen of a Greek military academy – a representative, continuously-generated institutional waste stream. A companion study within the same project applies the same HTL route to source-separated dried household food waste, providing a direct point of comparison for feedstock effects (Sotiropoulos et al., 2026). The first data set concerns the HTL production of bio-oil from this feedstock; the second concerns the catalytic hydrotreating of the resulting bio-oil using three low-cost catalysts (zeolite, aluminum(III) oxide, and nickel(II) nitrate hexahydrate). By presenting the two stages together, this paper aims to (i) quantify the operating windows that maximize bio-oil yield and quality at each stage, (ii) identify which catalyst delivers the best upgrading performance under the tested conditions, and (iii) situate the results within the broader discussion of circular-economy waste valorization (Garefalakis et al., 2026; Passas et al., 2022; Ragazou et al., 2022b; Vortelinos et al., 2024a; Zopounidis et al., 2020) and energy-security policy for institutional facilities in the Mediterranean.

2. Materials and Methods

2.1. Feedstock and HTL Bio-Oil Production

The feedstock consisted of pre-sorted, uncontaminated food waste (fruit and vegetable peels, cooked food residues, vegetable oils) collected from the canteen of the Hellenic Army Academy and homogenized by grinding/blending prior to use (Kagias et al., 2022; Passas and Ragazou, 2022; Ragazou, Passas and Garefalakis, 2022; Vortelinos et al., 2024b). Its average dry-basis composition is summarized in Table 1.

HTL experiments were carried out in two stainless-steel Parr Instrument Company batch reactors (300 mL and 600 mL), each operated at 50% fill to keep the working pressure between 100 and 130 bar. Reaction temperature was varied between 280°C and 320°C, solids content between 5 and 20 wt%, and residence time between 30 and 60 min (10-min steps). Temperature and pressure were monitored continuously through in-reactor sensors and a PLC control system; at the end of each run the reactor was depressurized gradually and cooled before opening. The recovered bio-crude was washed with hexane (over 4 h), separated by rotary evaporation, weighed at room temperature, and stored for physicochemical analysis; the solid residue and gas fraction were isolated and weighed but not further characterized.

Table 1. Average chemical composition of the food-waste feedstock (dry basis, wt %)

Parameter	Content (%)
Moisture	72±10
Organic matter	88±2
Protein	22±0.5
Lipids	18±0.18
Carbohydrates	48±6
Ash	12±0.6
Water-soluble substances (total)	32.0±0.5
Cellulose	11.2±0.6

 https://doi.org/10.13052/srm2795-0514.017

Table 2. Physicochemical properties of the pooled bio-oil feedstock used for hydrotreating

Parameter	Value
Higher Heating Value, HHV (MJ/kg)	39.10±0.40
Lower Heating Value, LHV (MJ/kg)	36.59±0.40
Nitrogen, N (%)	1.95±0.45
Hydrogen, H (%)	12.30±0.80
Oxygen, O (%)	7.52±0.20

Table 3. Bio-crude yield and quality as a function of HTL temperature (ranges across all tested solidscontent × residence-time combinations)

Temp. (°C)	Bio-oil quantity, g (5% ds)	N (%)	H (%)	O (%)	HHV (MJ/kg)
280	20.5±2.0 (at 5% ds)	2.02 – 5.72	5.65 – 11.80	10.21 – 19.70	20.95 – 34.55
290	24.8±2.3 (at 5% ds)	2.02 – 5.85	5.15 – 8.61	10.34 – 19.86	20.25 – 34.58
300	25.4±2.2 (at 5% ds)	2.10 – 5.63	5.09 – 8.90	10.31 – 19.66	20.27 – 32.13
310	34.2±3.1 (at 5% ds)	2.05 – 5.85	5.31 – 8.95	10.56 – 19.74	20.68 – 39.00
320	33.4±1.9 (at 5% ds)	2.23 – 5.73	5.85 – 9.30	10.25 – 19.70	20.40 – 39.22

ds = dry solids content (wt%).

2.2. Catalytic Hydrotreating (Upgrading) of the Bio-Oil

For the upgrading stage, a pooled bio-oil sample of stable composition, collected across the HTL trials described above, was used as feedstock without further pretreatment; its baseline physicochemical properties are given in Table 2. Hydrotreating experiments were performed in a 600 mL fixed-bed, high-pressure batch reactor at the National Technical University of Athens, equipped with a PID-controlled heating jacket, digitally regulated H_2/N_2 supply, and a catalyst basket. Reaction temperature was varied between 300°C and 340°C and hydrogen pressure between 70 and 100 bar (10-unit steps in both variables), with a fixed residence time of 2 h. Three catalysts were tested, each at 5 wt% loading: zeolite, aluminum(III) oxide, and nickel(II) nitrate hexahydrate. After reaction, the product was recovered, washed with hexane (over 4 h) to strip the catalyst, and separated by rotary evaporation prior to analysis.

2.3. Analytical Methods

Higher and lower heating values (HHV, LHV) were determined by bomb calorimetry following ASTM D240-19 (ASTM International, 2019). Carbon, hydrogen, and nitrogen content were determined by combustion elemental analysis following ASTM D5291-21 (ASTM International, 2021); oxygen content was obtained by difference. All reported values are means of replicate measurements ± one standard deviation.

3. Results and Discussion

3.1. Effect of HTL Operating Parameters on Bio-Crude Yield and Quality

Table 3 summarizes the range of elemental composition and heating value obtained across all tested solids-content and residence-time combinations at each HTL temperature, together with the bio-crude quantity recorded at the lowest (5%) solids loading.

Across all 80 tested conditions, mean bio-crude properties were $N = 3.99 \pm 0.29\%$, $H = 7.11 \pm 0.29\%$, $O = 14.72 \pm 0.60\%$, and $HHV = 28.32 \pm 0.66$ MJ/kg. Temperature was the dominant variable: HHV rose from a 280°C average in the mid-to-high 20s MJ/kg to a maximum of 39.2 MJ/kg at 320°C, while hydrogen content declined slightly over the same range (from around

11% at 280˚C to 9.3% at 320˚C), consistent with progressive dehydration and aromatization reactions at higher severity. Nitrogen content was comparatively low and stable at 280–290˚C (as low as 2.02%) but increased at 300˚C and above, reaching 5.85%, most plausibly reflecting greater breakdown of the protein fraction of the feedstock and incorporation of nitrogenous fragments into the bio-crude – a pattern broadly consistent with the protein-rich, high-nitrogen character typical of mixed food waste (Bayat et al., 2024). Solids loading showed a secondary but consistent effect: low loading (5%) improved heat and mass transfer and gave more uniform bio-crude, whereas high loading (20%) increased HHV but also nitrogen content, likely due to incomplete hydrolysis or protein condensation at higher substrate density. Short residence times (30 min) tended to leave more residual oxygen, consistent with incomplete depolymerization of lignocellulosic fragments, while the longest residence time (60 min) reduced HHV, suggesting the onset of secondary repolymerization or cracking reactions beyond the optimal reaction window. The highest bio-crude quantity, approximately 30% of feedstock dry mass, was obtained at 310˚C, identifying this temperature – rather than the highest tested temperature – as the practical optimum when both yield and quality are considered jointly (Kagias et al., 2023; Passas, 2024a; Ragazou, Passas and Sklavos, 2022; Vortelinos et al., 2025a), a trade-off consistent with recent kinetic analyses of HTL severity (Wang et al., 2026). The corresponding temperature response for source-separated dried household food waste processed by the same route is reported separately (Sotiropoulos et al., 2026).

3.2. Catalytic Hydrotreating: Heating Value and Deoxygenation

Table 4 compares the three catalysts at the jointly optimal hydrotreating point identified across the full experimental matrix (320˚C, 90 bar, 2 h).

Nickel(II) nitrate hexahydrate consistently gave the best upgrading performance across nearly all tested temperature-pressure combinations, and reached its own optimum at 320˚C and 90 bar: relative to the baseline bio-oil (HHV 39.10±0.40 MJ/kg, O 7.52±0.20%), HHV increased by approximately 1.7 MJ/kg and oxygen content fell by approximately 1.1 percentage points, corresponding to roughly 15% relative deoxygenation. Aluminum (III) oxide produced a smaller but still positive improvement (HHV 40.37 MJ/kg, O 6.68%), consistent with its more moderate hydrogenation activity and its known sensitivity to hydrothermal deactivation in oxygenate-rich environments (Gil, Sancho-Sanz and Korili, 2024). Zeolite, by contrast, showed essentially no net improvement in HHV relative to the feedstock and only marginal deoxygenation (O 6.84%), indicating that, under these mild, purely acid-catalyzed conditions and without an added hydrogenation-active metal, it contributes little to the HDO chemistry responsible for oxygen removal. These trends mirror the broader literature on Ni-based catalysts for bio-oil hydrotreating, which consistently report superior hydrogenation and deoxygenation activity for nickel-containing systems relative to purely acidic or inert supports, while noting the importance of temperature-pressure balance to avoid excessive coking (Kagias et al., 2024; Li et al., 2024; Passas, 2024b; Ragazou et al., 2022c; Vortelinos and Papaioannou, 2025a; Xu et al., 2025).

Across the full 300–340˚C/70–100 bar matrix, the relationship between severity and upgrading performance was non-monotonic: increasing temperature and pressure improved HHV and deoxygenation up to 320˚C/90 bar, beyond which performance for all three catalysts plateaued or slightly declined, most likely due to the onset of secondary cracking and coke deposition competing with the desired hydrodeoxygenation and hydrogenation pathways – a balance also highlighted in recent studies of industrial Ni-based hydrotreating catalysts (Xu et al., 2025). The present work relies on conventional thermochemical hydrotreating with an external hydrogen supply; membrane-less electrochemical hydrogenation, which uses the HTL process water itself as the hydrogen source, has recently been proposed as a lower-infrastructure alternative for partial bio-crude upgrading and may be worth exploring in future extensions of this pathway (Pelosin et al., 2024).

Table 4. Catalyst comparison at the optimal hydrotreating point (320˚C, 90 bar, 2 h, 5 wt% catalyst loading)

Catalyst	HHV (MJ/kg)	LHV (MJ/kg)	N (%)	H (%)	0 (%)
Zeolite	40.05±0.24	37.62±0.22	1.95±0.05	12.16±0.12	6.84±0.09
Aluminum(III) oxide	40.37±0.21	37.81±0.19	1.93±0.06	12.24±0.13	6.68±0.10
Nickel(II) nitrate hexahydrate	40.80±0.24	38.27±0.30	1.90±0.05	12.35±0.14	6.42±0.07

3.3. An Integrated Production-to-Upgrading Perspective

The two data sets outline a coherent two-stage pathway from institutional food waste to an upgraded, energy-dense bio-oil. HTL at 310–320˚C, 100–130 bar, and moderate solids loading (10–15%) delivers the best combination of bio-crude yield and initial quality (HHV up to approximately 39 MJ/kg on a best-case basis), and the pooled product from this stage, once stabilized, becomes a suitable feedstock for hydrotreating. Subsequent catalytic hydrotreating with a nickel-based catalyst at 320˚C and 90 bar further raises the heating value toward diesel-range fuels (∼40.8 MJ/kg) while reducing oxygen content, improving stability and compatibility with existing liquid-fuel infrastructure. This combination directly targets the recognized bottlenecks that keep HTL bio-crude out of transport-fuel applications – oxygen content, corrosivity, and instability – through an upgrading route that uses comparatively lowcost, commercially available catalysts rather than noble metals, an approach increasingly explored for scalable HTL-to-fuel pathways (Karagiannopoulou et al., 2023a; Passas, 2025; Ragazou et al., 2022d; Summers et al., 2024; Vortelinos and Papaioannou, 2025b).

From a circular-economy and Mediterranean-policy perspective, the results are relevant beyond their immediate chemical-engineering content. Institutional catering facilities – military bases, hospitals, university campuses, and similar large kitchens – generate food waste as a continuous, predictable stream, unlike more seasonal agricultural residues (Karagiannopoulou et al., 2023b; Passas and Garefalakis, 2025; Ragazou et al., 2023a; Vardopoulos, Abeliotis and Lasaridi, 2025; Vortelinos, Yiannoulis and Bourantas, 2026). Converting this stream on-site or regionally into a renewable fuel precursor reduces landfill dependence, offsets fossil-fuel consumption for transport, heating, and potentially aviation, and generates a locally produced energy resource of particular relevance to island and remote Mediterranean communities (Loizia et al., 2021; Vardopoulos, 2018) and to defense and public-sector facilities seeking to reduce their carbon footprint under EU Recovery and Resilience Facility and Green Deal commitments (Castagna et al., 2025; Doukas et al., 2026). The technology readiness demonstrated here – batch-scale but process-representative reactors, standard analytical methods, and catalysts that are inexpensive and readily available – supports the case for pilot-to-demonstration scale-up as a concrete, evidence-based contribution to regional waste-to-energy policy (Kopsidas et al., 2026; Passas et al., 2025; Ragazou et al., 2023b; Xanthos et al., 2020).

The main limitation of the present study is its batch, laboratory-pilot scale and the absence of continuous mass-and-energy-balance closure across the two stages; residence time was not varied in the hydrotreating experiments, and catalyst deactivation and regeneration were not assessed. Future work should address continuous-flow operation, techno-economic and life-cycle assessment of the integrated pathway, and blending trials of the upgraded bio-oil with conventional diesel or aviation fuel to confirm compliance with relevant fuel-quality standards (e.g., EN 590).

4. Conclusions

This study reports experimental results from two linked stages of a food-waste-to-fuel valorization chain developed for a Mediterranean institutional waste stream. Hydrothermal liquefaction of pre-sorted canteen food waste achieved bio-crude yields of up to approximately 30 wt% and heating values of up to approximately 39 MJ/kg, with 310–320˚C, moderate solids loading, and moderate residence time identified as the practical optimum. Catalytic hydrotreating of the resulting bio-oil with a low-cost nickel(II) nitrate hexahydrate catalyst at 320˚C and 90 bar further raised the heating value to 40.8 MJ/kg while lowering oxygen content to 6.4 wt%, outperforming both aluminum(III) oxide and zeolite catalysts under the same conditions. Together, these results define an experimentally validated operating envelope for converting institutional organic waste into an upgraded renewable fuel precursor, and support the case for treating such waste streams as a circular-economy resource with direct relevance to energy security and decarbonization policy in the Mediterranean region (Lampropoulos et al., 2025; Passas, 2026; Ragazou et al., 2024a; Xenaki et al., 2026).

Acknowledgements

This research was carried out within the MARINES project (Valorization of Organic Residues and By-products of the Hellenic Armed Forces for the Production of Renewable Transport, Heating and Aviation Fuels; project code: TAEDK-06194), funded by the Greek National Recovery and Resilience Plan “Greece 2.0”, financed by the European Union – NextGenerationEU, with

the support of the National Bank of Greece and under the coordination of the Managing Authority for R&D Intervention Programs (EYDE-ETAK/MIA-RTDI).

References

Alhebri, A., Radwan, A., Garefalakis, A., Passas, I., and Ragazou, K. (2022). Impact of ELMS-based CL on the quality of accounting education. *Webology*, *19*(2), 4833–4854.

Angelaki, E., Garefalakis, A., Kourgiantakis, M., Sitzimis, I., and Passas, I. (2025). ESG integration and green computing: A 20-year bibliometric analysis. *Sustainability*, *17*, 3266. https://doi.org/10.3390/su17073266

Angelaki, E., Garefalakis, A., Sitzimis, I., Rompogiannakis, I., and Passas, I. (2026). Greener cities, brighter future: The critical role of green buildings. In I. Vardopoulos and I. Passas (Eds.), *Futureproofed sustainability amidst climate change polycrisis: Advancing SDGs and ESG for the cities of tomorrow* (pp. 137–174). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3373-2327-5.ch005

ASTM International. (2019). *ASTM D240-19: Standard test method for heat of combustion of liquid hydrocarbon fuels by bomb calorimeter*. ASTM International.

ASTM International. (2021). *ASTM D5291-21: Standard test methods for instrumental determination of carbon, hydrogen, and nitrogen in petroleum products and lubricants*. ASTM International.

Bayat, H., Dehghanizadeh, M., Loya Lujan, A., and Brewer, C. E. (2024). Adding value to food waste hydrothermal liquefaction: Use of the aqueous phase for compost and the char for adsorption of lead, copper, and nitrate. *Energy & Fuels*, *38*(19), 18748–18762. https://doi.org/10.1021/acs.energyfuels.4c03026

Castagna, A., Aboudia, A., Guendouz, A., Scieuzo, C., Falabella, P., Matthes, J., Schmid, M., Drissner, D., Allais, F., Chadni, M., Cravotto, C., Senge, J., Krupitzer, C., Canesi, I., Spinelli, D., Drira, F., Ben Hlima, H., Abdelkafi, S., Konstantinou, I., and Coltelli, M.-B. (2025). Transforming agricultural waste from Mediterranean fruits into renewable materials and products with a circular and digital approach. *Materials*, *18*(7), 1464. https://doi.org/10.3390/ma18071464

Cheliatsidou, A., Sariannidis, N., Garefalakis, A., Passas, I., and Spinthiropoulos, K. (2023). Exploring attitudes towards whistleblowing in relation to sustainable municipalities. *Administrative Sciences*, *13*(9), 199. https://doi.org/10.3390/admsci13090199

Doukas, Y. E., Maravegias, N., Zorpas, A. A., Sotiropoulos, A., and Vardopoulos, I. (2026). Integrating circular economy principles in the European farm-to-fork strategy for food waste prevention. *Journal of Agribusiness in Developing and Emerging Economies*. https://doi.org/10.1108/JADEE-10-2025-0512

Garefalakis, A., Despoina, K., Angelaki, E., Papademetriou, C., and Passas, I. (2026). Navigating ESG challenges: The role of chartered accountants in corporate sustainability. *Risks*, *14*(3), 47. https://doi.org/10.3390/risks14030047

Gil, A., Sancho-Sanz, I., and Korili, S. A. (2024). Progress and perspectives in the catalytic hydrotreatment of bio-oils: Effect of the nature of the metal catalyst. *Industrial & Engineering Chemistry Research*, *63*(27), 11759–11775. https://doi.org/10.1021/acs.iecr.4c00747

Kagias, P., Garefalakis, A., Passas, I., Kyriakogkonas, P., and Sariannidis, N. (2024). Whistleblowing based on the three lines model. *Administrative Sciences*, *14*(5), 83. https://doi.org/10.3390/admsci14050083

Kagias, P., Kourgiantakis, M., Passas, I., Ragazou, K., and Bakeas, S. (2022). CG and prosperous investment decisions: The paradigm of mergers and acquisitions. In E. Galariotis, A. Garefalakis, C. Lemonakis, M. Menexiadis, and C. Zopounidis (Eds.), *Governance and financial performance: Current trends and perspectives* (pp. 275–299). World Scientific. https://doi.org/10.1142/12926

Kagias, P., Sariannidis, N., Garefalakis, A., Passas, I., and Kyriakogkonas, P. (2023). Validating the whistleblowing maturity model using the Delphi method. *Administrative Sciences*, *13*(5), 120. https://doi.org/10.3390/admsci13050120

Karagiannopoulou, S., Ragazou, K., Passas, I., Garefalakis, A., and Sariannidis, N. (2023a). The impact of the COVID-19 pandemic on the volatility of cryptocurrencies. *International Journal of Financial Studies*, *11*(1), 50. https://doi.org/10.3390/ijfs11010050

Karagiannopoulou, S., Sariannidis, N., Ragazou, K., Passas, I., and Garefalakis, A. (2023b). Corporate social responsibility: A business strategy that promotes energy environmental transition and combats volatility in the post-pandemic world. *Energies*, *16*(3), 1102. https://doi.org/10.3390/en16031102

Kopsidas, O., Panagiotopoulos, P., Passas, I., Doukas, Y. E., Salvati, L., and Vardopoulos, I. (2026). Integrating externalities into economic systems for long-term environmental sustainability. In *Spatial analysis for complex territorial systems* (pp. 201–213). Elsevier. https://doi.org/10.1016/B978-0-443-44133-2.00018-1

Lampropoulos, S. D., Thanasas, G. L., Garefalakis, A., and Passas, I. (2025). Harmonizing sustainability and resilience: The integral role of internal audit in ESG implementation – A review. *International Journal of Financial Studies*, *13*(4), 194. https://doi.org/10.3390/ijfs13040194

Lemonakis, C., Garefalakis, A., Ballas, P., Balla, V., and Passas, I. (2020). Exploring firms' accounting viability during economic turmoil: Best practices for SMEs entrepreneurship. *Interdisciplinary Journal of Economics and Business Law*, *9*(4), 98–122.

Li, Z., Yi, W., Li, Z., Bai, X., Fu, P., Tian, C., and Zhang, Y. (2024). Hydrodeoxygenation of bio-oil and model compounds for production of chemical materials at atmospheric pressure over nickel-based zeolite catalysts. *Energy sources, part a: Recovery, utilization, and environmental effects*, *46*(1), 8417–8429. https://doi.org/10.1080/15567036.2020.1765901

Loizia, P., Voukkali, I., Zorpas, A. A., Navarro Pedreño, J., Chatziparaskeva, G., Inglezakis, V. J., Vardopoulos, I., and Doula, M. (2021). Measuring the level of environmental performance in insular areas, through key performed indicators, in the framework of waste strategy development. *Science of the Total Environment*, *753*, 141974. https://doi.org/10.1016/j.scitotenv.2020.141974

Maravelaki, A., Zopounidis, C., Lemonakis, C., and Passas, I. (2021). Corporate governance as a tool for fraud mitigation. In *Machine learning applications for accounting disclosure and fraud detection*. IGI Global. https://doi.org/10.4018/978-1-7998-4805-9

Panagiotopoulos, P. (2026). Dataset of 1503 tourists' survey concerning their attitudes towards sports, economy and sustainability. *Sustainability Research in the Mediterranean*, *1*(1), 67–72. https://doi.org/10.13052/srm2795-0514.005

Papademetriou, C., Ragazou, K., Garefalakis, A., and Passas, I. (2023). Green human resource management: Mapping the research trends for sustainable and agile human resources in SMEs. *Sustainability*, *15*(7), 5636. https://doi.org/10.3390/su15075636

Passas, I. (2024a). Bibliometric analysis: The main steps. *Encyclopedia*, *4*, 1014–1025. https://doi.org/10.3390/encyclopedia4020065

Passas, I. (2024b). The evolution of ESG: From CSR to ESG 2.0. *Encyclopedia*, *4*, 1711–1720. https://doi.org/10.3390/encyclopedia4040112

Passas, I. (2025). From digital twins to digital triplets in economics and financial decision-making. *Encyclopedia*, *5*, 87. https://doi.org/10.3390/encyclopedia5030087

Passas, I. (2026). Opening the sustainability research in the Mediterranean. *Sustainability Research in the Mediterranean*, *1*(1), i–ii.

Passas, I. and Garefalakis, A. (2025). The impact of fraud perception and ESG-washing on investment trust: Integrating corporate governance theory and empirical evidence. *Accounting and Auditing*, *1*(3), 9. https://doi.org/10.3390/accountaudit1030009

Passas, I. and Ragazou, K. (2022). CG and viable corporate debt. In E. Galariotis, A. Garefalakis, C. Lemonakis, M. Menexiadis, and C. Zopounidis (Eds.), *Governance and financial performance: Current trends and perspectives* (pp. 155–170). World Scientific. https://doi.org/10.1142/12926

Passas, I., Ragazou, K., Zafeiriou, E., Garefalakis, A., and Zopounidis, C. (2022). ESG controversies: A quantitative and qualitative analysis for the sociopolitical determinants in EU firms. *Sustainability*, *14*(19), 12879. https://doi.org/10.3390/su141912879

Passas, I., Vortelinos, D. I., Lemonakis, C., Dragomir, V. D., and Garefalakis, S. (2025). Impact of environmental, social, and governance (ESG) scores on international credit ratings: A sectoral and geographical analysis. *Sustainability*, *17*, 9755. https://doi.org/10.3390/su17219755

Pelosin, P., Longhin, F., Hansen, N. B., Lamagni, P., Drazevic, E., Benito, P., Anastasakis, K., and Catalano, J. (2024). High-temperature high-pressure electrochemical hydrogenation of biocrude oil. *Renewable Energy*, *222*, 119899. https://doi.org/10.1016/j.renene.2023.119899

Petropoulou, A., Angelaki, E., Rompogiannakis, I., Passas, I., Garefalakis, A., and Thanasas, G. (2024). Digital transformation in SMEs: Pre- and post-COVID-19 era: A comparative bibliometric analysis. *Sustainability*, *16*, 10536. https://doi.org/10.3390/su162310536

Petropoulou, A., Garefalakis, A., and Passas, I. (2026). Leveraging artificial intelligence, blockchain, and FinTech to enhance ESG compliance and urban governance. In I. Vardopoulos and I. Passas (Eds.), *Futureproofed sustainability amidst climate change polycrisis: Advancing SDGs and ESG for the cities of tomorrow* (pp. 43–72). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3373-2327-5.ch002

Ragazou, K., Garefalakis, A., Pardalos, P. M., Zopounidis, C., and Passas, I. (2026). A hybrid DEMATEL–fuzzy AHP–MARCOS framework for evaluating digital servitization strategies in supply chains. *Annals of Operations Research*. https://doi.org/10.1007/s10479-026-07231-9

Ragazou, K., Garefalakis, A., Zafeiriou, E., and Passas, I. (2022a). Agriculture 5.0: A new strategic management mode for a cut cost and an energy efficient agriculture sector. *Energies*, *15*(9), 3113. https://doi.org/10.3390/en15093113

Ragazou, K., Lemonakis, C., Passas, I., Zopounidis, C., and Garefalakis, A. (2024a). ESG-driven ecopreneur selection in European financial institutions: Entropy and TOPSIS analysis. *Management Decision*. https://doi.org/10.1108/MD-12-2023-2425

Ragazou, K., Passas, I., and Garefalakis, A. (2022). It is time for anti-bribery: Financial institutions set the new strategic "roadmap" to mitigate illicit practices and corruption in the market. *Administrative Sciences*, *12*(4), 166. https://doi.org/10.3390/admsci12040166

Ragazou, K., Passas, I., Garefalakis, A., and Dimou, I. (2022a). Investigating the research trends on strategic ambidexterity, agility, and open innovation in SMEs: Perceptions from bibliometric analysis. *Journal of Open Innovation: Technology, Market, and Complexity*, *8*(3), 118. https://doi.org/10.3390/joitmc8030118

Ragazou, K., Passas, I., Garefalakis, A., Galariotis, E., and Zopounidis, C. (2023a). Big data analytics applications in information management driving operational efficiencies and decision-making: Mapping the field of knowledge with bibliometric analysis using R. *Big Data and Cognitive Computing*, *7*(1), 13. https://doi.org/10.3390/bdcc7010013

Ragazou, K., Passas, I., Garefalakis, A., Kourgiantakis, M., and Xanthos, G. (2022c). Youth's entrepreneurial intention: A multinomial logistic regression analysis of the factors influencing Greek HEI students in time of crisis. *Sustainability*, *14*(20), 13164. https://doi.org/10.3390/su142013164

Ragazou, K., Passas, I., Garefalakis, A., Zafeiriou, E., and Kyriakopoulos, G. (2022b). The determinants of the environmental performance of EU financial institutions: An empirical study with a GLM model. *Energies*, *15*(15), 5325. https://doi.org/10.3390/en15155325

Ragazou, K., Passas, I., Garefalakis, A., and Zopounidis, C. (2022d). Financial analytics and decision-making strategies: Future research prospects from Bibliometrix based on R package. In P. Alphonse, K. Bouaiss, P. Grandin, and C. Zopounidis (Eds.), *Essays on financial analytics*. Springer.

Ragazou, K., Passas, I., Garefalakis, A., and Zopounidis, C. (2023b). Business intelligence model empowering SMEs to make better decisions and enhance their competitive advantage. *Discover Analytics*, *1*, 2. https://doi.org/10.1007/s44257-022-00002-3

Ragazou, K., Passas, I., Garefalakis, A., and Zopounidis, C. (2024b). ESG in construction risk management: A strategic roadmap for controlling risks and maximizing profits. In K. Petroutsatou and C. Zopounidis (Eds.), *Financial evaluation and risk management of infrastructure projects*. IGI Global. https://doi.org/10.4018/978-1-6684-7786-1.ch003

Ragazou, K., Passas, I., and Sklavos, G. (2022). Investigating the strategic role of digital transformation path of SMEs in the era of COVID-19: A bibliometric analysis using R. *Sustainability*, *14*(18), 11295. https://doi.org/10.3390/su141811295

Sarker, T. R., Sarker, B., Saha, B., Khatun, M. L., and Dalai, A. K. (2025). Hydrothermal liquefaction: Transforming waste into renewable fuels and high-value bio-chemicals. *Renewable and Sustainable Energy Reviews*, *222*, 115974. https://doi.org/10.1016/j.rser.2025.115974

Sitzimis, I., Dimou, I., Xanthos, G., and Passas, I. (2025). Seaplane adoption in Greece: From ordinal intent to firth-penalized logistic inference. *AppliedMath*, *5*(4), 152. https://doi.org/10.3390/appliedmath5040152

Sotiropoulos, A., Michalopoulos, C., Vardopoulos, I., and Xydis, G. (2026). Bio-crude oil produced from source-separated dried household food waste through hydrothermal liquefaction. *Biofuels*. https://doi.org/10.1080/17597269.2026.2719060

Stavropoulou, E., Spinthiropoulos, K., Ragazou, K., Papademetriou, C., and Passas, I. (2023). Green balanced scorecard: A tool of sustainable information systems for an energy efficient business. *Energies*, *16*(18), 6432. https://doi.org/10.3390/en16186432

Summers, S., Yang, S., Wang, Z., Si, B., Kawale, H., and Zhang, Y. (2024). Multi-stage pretreatment of hydrothermal liquefaction biocrude oil as a precursor for sustainable aviation fuel production. *Fuel Processing Technology*, *263*, 108118. https://doi.org/10.1016/j.fuproc.2024.108118

Vardopoulos, I. (2018). Multi-criteria decision-making approach for the sustainable autonomous energy generation through renewable sources: Studying Zakynthos Island in Greece. *Environmental Management and Sustainable Development*, *7*(1), 52–84. https://doi.org/10.5296/emsd.v7i1.12110

Vardopoulos, I., Abeliotis, K., and Lasaridi, K. (2025). A systematic informetric analysis and literature review of food waste quantification studies in the food service industry. *Sustainability*, *17*(1), 103. https://doi.org/10.3390/su17010103

Vardopoulos, I., Konstantopoulos, I., Zorpas, A. A., Limousy, L., Bennici, S., Inglezakis, V. J., and Voukkali, I. (2021). Sustainable metropolitan areas perspectives through assessment of the existing waste management strategies. *Environmental Science and Pollution Research*, *28*(19), 24305–24320. https://doi.org/10.1007/s11356-020-07930-1

Vortelinos, D., Floros, C., Apostolakis, A., and Passas, I. (2025a). Hotel sales during COVID-19. In *Data analysis and related applications 5* (pp. 333–348). Wiley. https://doi.org/10.1002/9781394401604.ch21

Vortelinos, D., Menegaki, A., Passas, I., Garefalakis, A., and Viskadouros, G. (2024a). Heterogeneous responses of energy and non-energy assets to crises in commodity markets. *Energies*, *17*(21), 5438. https://doi.org/10.3390/en17215438

Vortelinos, D. I., and Papaioannou, A. (2025a). Efficiency of mergers and acquisitions (M&A): The case of Greek banks. *Sustainability Research in the Mediterranean*, *1*(1), 1–16. https://doi.org/10.13052/srm2795-0514.001

Vortelinos, D. I., and Papaioannou, A. (2025b). External audit quality: A comprehensive literature review of determinants, indicators, and implications. *Sustainability Research in the Mediterranean*, *1*(1), 31–44. https://doi.org/10.13052/srm2795-0514.003

Vortelinos, D., Passas, I., Floros, C., and Garefalakis, A. (2024b). Corporate social responsibility and country governance: An international comparative study amid the COVID-19 pandemic. *International Journal of Financial Studies*, *12*(4), 110. https://doi.org/10.3390/ijfs12040110

Vortelinos, D. I., Yiannoulis, Y., and Bourantas, N. S. (2026). Sustainability and environmental governance in listed companies: Comparative insights into climate and resource management. *Sustainability Research in the Mediterranean*, *1*(1), 17–30. https://doi.org/10.13052/srm2795-0514.002

Wang, Z., Wang, Z., Summers, S., Paul, S., Mirzaei, D., and Zhang, Y. (2026). Scalable kinetic modeling for hydrothermal liquefaction towards commercial application. *Energy Conversion and Management*, *364*, 121713. https://doi.org/10.1016/j.enconman.2026.121713

Xanthos, G., Zopounidis, C., Garefalakis, A., and Passas, I. (2020). Distinguish regional performance with the use of shift-share analysis and MCDA methods: A gross value-added perspective. *Operational Research: An International Journal*. https://doi.org/10.1007/s12351-020-00582-6

Xenaki, M., Dimou, I., Drakaki, E., and Passas, I. (2026). SIRAF: From sustainability assessment tools to reflective sustainability implementation in higher education. *Sustainability*, *18*(7), 3208. https://doi.org/10.3390/su18073208

Xu, X., Chen, S., Wang, Y., Lv, P., Guo, W., and Shu, Y. (2025). Investigation of the temperature influence on the catalytic hydrogenation upgrading of bio-oil using industrial nickel-based catalyst RZ409. *Scientific Reports*, *15*, 28360. https://doi.org/10.1038/s41598-025-14087-9

Yiannoulis, Y., Vortelinos, D., and Passas, I. (2025). Exploring audit opinions: A deep dive into ratios and fraud variables in the Athens Exchange. *Accounting and Auditing*, *1*(1), 3. https://doi.org/10.3390/accountaudit1010003

Zafeiriou, E., Garefalakis, A., Passas, I., and Ragazou, K. (2023). Illicit and corruption mitigation strategy in the financial sector: A study with a hybrid methodological approach. *Sustainability*, *15*(2), 1366. https://doi.org/10.3390/su15021366

Zaroulea, T., and Kyriakogkonas, P. (2026). What influences job satisfaction among front office customer service employees? *Sustainability Research in the Mediterranean*, *1*(1), 45–66. https://doi.org/10.13052/srm2795-0514.004

Zisoudis, N., Zafeiriou, E., Garefalakis, A., Passas, I., and Ragazou, K. (2022). The role of a well-established food retail firm in Greek economy in the era of economic crisis. *Journal of Governance & Regulation*, *11*(4), 215–223. https://doi.org/10.22495/jgrv11i4siart2

Zopounidis, C., Garefalakis, A., Lemonakis, C., and Passas, I. (2020). Environmental, social and corporate governance framework for corporate disclosure: A multicriteria dimension analysis approach. *Management Decision*, *58*(11), 2473–2496. https://doi.org/10.1108/MD-10-2019-1341