Kilintzis *et al.*
Journal of Innovation and Entrepreneurship (2023) 12:87
https://doi.org/10.1186/s13731-023-00354-4

Journal of Innovation and Entrepreneurship

RESEARCH Open Access

The role of Green Public Procurements in energy transition: the case of Western Macedonia

Pavlos Kilintzis[1*], Elpida Samara[2], Lefteris Topaloglou[3], Giorgos Avlogiaris[4] and Dimitrios Kafetzopoulos[5]

*Correspondence:
pkilintzis@uowm.gr

[1] Department of Mechanical Engineering, Active Urban Planning Zone (ZEP), University of Western Macedonia, 50100 Kozani, Greece
[2] Department of Accounting and Finance, University of Western Macedonia, Kozani, Greece
[3] Department of Chemical Engineering, University of Western Macedonia, Kozani, Greece
[4] Department of Statistics and Insurance Science, University of Western Macedonia, Kozani, Greece
[5] Department of Business Administration, University of Macedonia, Kozani, Greece

Abstract

This paper aims to assess the level of implementation of Green Public Procurements (GPP) in the Region of Western Macedonia—Greece, which is currently under energy transition from lignite to a RES-based energy model. By that assessment, a linkage between the GPP framework and energy transition is created, revealing the distinct GPP criteria that should be adopted by energy-transition regions, which have the potential to strengthen the transition process. Rather than implementing the total number of the GPP criteria, literature and methodology findings indicated that specific GPP criteria are directly connected to energy transition and should be primarily adopted by policymakers in comparison to the rest. These criteria are Electricity, Road Transport, Waste Water Infrastructure and Road Lighting and Traffic Signals. By assessing a sample of 31 procurement officials and scientific experts in the five major municipalities of the region, the implementation level of GPP criteria was measured average-to-low, implying that there is a considerable scope by the region's main municipal authorities to adopt them to a greater extent. Statistical correlations using Spearman's rank correlation analysis between specific GPP criteria were also identified, indicating distinct interconnections between the criteria pairs that imply commonalities in the implementation framework of GPP. The paper's implications for future research led to the identification of specific GPP criteria in the public procurement process, that have the potential to enhance green sustainability and boost energy transition.

Keywords: Green Public Procurement, Green energy transition, GPP criteria

Introduction

Public procurement sector has been an intrinsic factor of effective public administration, highly affecting other key general policy sectors such as economic development, entrepreneurial innovation, healthcare, transportation, and the justice sector (Zabala-Iturriagagoitia, 2022). The total effectiveness of a public procurement from the planning to the implementation stage is vital, as well as the distinct effectiveness of every key segment related to a procurement such as the economic benefit for the (public) procurer, the quality/effectiveness of products/services being procured and the wider social benefits for the public (Martinez Romera & Caranta, 2017). However, the harsh effects

of environmental change required a distinct procurement type that must be designed and implemented according to precise environmental protection and environmental sustainability principles, allowing public bodies to incorporate green practices to the whole chain of a public procurement. The Green Public Procurement (GPP) framework encompasses all the necessary prerequisites that may allow a public body to procure goods and services with a minimized environmental impact throughout their life cycle, in comparison to products/services that could be produced, independently of their environmental impact (Cheng et al., 2018). Moreover, GPP is considered one of the main forms of sustainable public procurement which is directly linked to sustainable business models that should be adopted by public organizations (Witjes & Lozano, 2016), in order to strengthen organizational effectiveness (Kilintzis et al., 2020).

The Region of Western Macedonia is one of the two regions in Greece that are under an energy transition process. The region is currently undertaking a mega task of abandoning all lignite-based electricity production and decommissioning local power plants, until 2028 (SDAM, 2021). Greece's Just Transition Development Programme (JTDP) is part of European Green Deal and Just Transition Mechanism, which in turn foresee a series of measures that both national and local authorities of coal regions must plan and implement, with the full participation of the business, academia/research, and the society sector. JTDP foresees the transition of the local production framework to the creation of a new development paradigm of a climate-neutral economy that exploits green innovative practices. GPP is the primary mean of the national and local public bodies to plan a structured framework in acquiring products and services that fulfil the JTDP initiatives, in the process of implementing post-lignite transition at the most effective level. This paper investigates the level of implementation of GPP in the energy transition process that the Region of Western Macedonia is currently going through. The backstage scope is to uncover the elements of GPP that have either already integrated or have the potential to be integrated in the energy transition process and reveal those GPP aspects that need special attention by policymakers, as potential key elements for the promotion of an effective energy transition. The reasoning for that is dual: first we attempt to bibliographically connect the principles of energy transition to the GPP framework. Despite the fact that energy transition principles are known and scientifically established, there is a notable gap in the scientific literature on the connection of those principles to the GPP criteria. Questions on how a procurement should be implemented in order to ease and accelerate energy transition, what are the specific energy transition principles that should be incorporated into the GPP framework and which are the GPP criteria categories that are mostly related to energy transition principles constitute the major research questions of this research. Since the implementation of GPP criteria to the procurement process of energy transition can actually constitute a key performance indicator of the energy transition process itself, this paper specifically contributes to the closure of this theoretical gap.

Secondly, the choice of Western Macedonia as a sample region may provide significant scientific feedback on the research. Despite its limitations in terms of its geographical extent and population coverage, the Region of Western Macedonia currently implements one of the largest energy transition programmes in Europe considering the region's size (budget of 1,63 billion €), and it also has a few distinctive characteristics as a region, such

as being the region with the highest unemployment rate in Europe in the age group of 18–29 (Tranoulidis et al., 2022). Furthermore, due to its highly specialized content, a scope research based on the GPP framework could be most effectively conducted with the participation of specialized procurement officials of municipalities and similar governing authorities. For this reason, we have used a restricted sample in this research, since these are the individuals that have the exclusive role of initiating and implementing procurements in the major municipalities of the Region of Western Macedonia and could provide a higher validity to the research results.

The study constitutes a methodological approach to link GPP framework and specific GPP criteria to energy transition and measure their implementation levels in an energy transition region. Its ulterior aim is to reveal the specific GPP criteria that should be implemented by public procurers in order to strengthen energy transition. The paper initially investigates the background framework behind energy transition as a scientific and political practice currently implemented by the European Union (EU). Next, the paper examines the latest literature initiatives and implementation practices of GPP, underlining key elements that must be given attention by public procures and policymakers. The correlation of GPP with energy transition, in terms of distinct GPP aspects that are included as 'must' practices in a holistic energy transition framework, follows. This section reveals which of the GPP criteria are theoretically linked to energy transition initiatives according to literature and should be prioritized by public procurers. The paper concludes with specific policy recommendations.

The empirical part of the paper explores the level of GPP adoption by the five major municipalities of the Region of Western Macedonia (Kozani, Eordaia, Florina, Grevena, Kastoria), indicating the magnitude of GPP implementation of specific criteria of GPPs, set by the European Commission (EC) (European Commission, 2020). Methodologically, typical average values and a Spearman's Correlation Analysis are being implemented, indicating the level of GPP adoption in the region amongst different GPP criteria, as well as their correlations. The main research question that is addressed, is about examining the level of GPP adoption in the energy transition process as well as the directions that public procurements shall take on the procurers' behalf, in order to fully exploit the opportunities that arise from the transition for the involved regions under a 'green' footprint.

Literature review

Prioritizing energy transition

According to the EU principles, there is a common energy policy defined by the well-known energy policy objectives in the EU that is binding for all EU Member States. However, what is actually found in practice is that Member States have 27 different sets of interests based on their own energy policies. That is so due to several reasons, mainly regarding their financial, societal, geographical and political backgrounds (Demski et al., 2018). Leaving the particularities and the specific policy conditions of each country aside, two distinct clusters of EU Member States can be identified (Pérez et al., 2019). The first cluster consists of countries that are highly concerned about security of energy supply and the diversification of sources, particularly natural gas. These countries have considered stability in energy supply as a prime issue, and they have been more hesitant

in fully adopting an absolute Renewable Energy Sources (RES) swift so far. Moreover, the two primary energy sources of those countries are lignite and natural gas. The first energy source is highly domestic while natural gas until recently was most imported from Russia. Furthermore, the energy infrastructures of these countries are lacking capacity and effectiveness while they also lack in diversified interconnection levels with other countries for energy supply (Pérez et al., 2019). The current RES infrastructure of those countries is also low in comparison to the second cluster, while their energy workforce is mainly engaged in the fossil fuels industry, mostly lignite production. These countries also suffer from higher capital costs in comparison to the energy-friendly clusters and their citizens have less disposable income.

The second cluster consists of the EU countries that have put energy transition to RES and environment-friendly energy sources as a top policy priority, regardless of their level of energy dependence or current electricity mix. These countries, belonging to the so-called 'green cluster' primarily including the northern EU countries, have accelerated core measures such as early lignite power plants' abandonment and wide RES installations. More specifically, the countries belonging to the green cluster perceive EU as a tool to tackle climate change and see RES as a business opportunity, while they also try to diversify the energy mix and improve import energy dependence from third non-EU countries (Pérez et al., 2019). They have a higher GDP per capita in comparison to the EU average, higher level of energy infrastructures and their consumers are less price sensitive and can tolerate higher environmental costs (Eurostat, 2019). They also have a current higher level of RES contribution to their energy mix, and a considerable portion of their workforce is occupied with the installation, maintenance, and operation of RES projects (Papież et al., 2018).

While the distinction between the two clusters in the energy transition approach has been apparent, the ongoing military conflict in Ukraine already has and it is expected to further change the structural focus of both clusters. The cluster consisting of the countries that put security of energy supply through the importation of natural gas from Russia as a priority, has already started quickly adopting alternative energy sources (RES included) while the cluster already implementing energy transition at high volumes, is expected to accelerate this policy even further (Nerlinger & Utz, 2022).

According to the official EU authorities, decarbonizing the EU's energy system has already been considered a critical mean to reach the prime target of reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. The EU's siege to conquer the clean energy transition is the European Green Deal, a set of policy initiatives focusing on the EU's long-term strategy to achieve carbon neutrality by 2050. The prime policy principles of the European Green Deal are the securement of EU's energy supply at affordable terms, the development of EU's energy market in ensuring interconnection and digitization at adequate levels and the prioritization of energy efficiency by strengthening the energy performance of buildings and building a power sector primarily based on RES (European Commission, 2019). Moreover, the key objectives to accomplish the aforementioned policy principles are the decarbonization of the gas sector and the promotion of smart integration between sectors, the promotion of new infrastructure and innovative technologies, the improvement of energy efficiency and ecological design of products, the development of the EU's offshore wind energy, the creation of

interconnected energy systems and more effective integration of grids that support RES, the global promotion of EU energy technologies and standards, and finally the contribution to EU countries and empowerment of European consumers to tackle energy poverty (European Commission, 2019).

The EU Green Deal aims to operate as the ultimate umbrella effectively directing the advancements in the rapidly evolving sector of environmental policy and to deal comprehensively with the growing environmental issues such as climate change, biodiversity decline, soil demotion and the lack of water resources. According to the EU Green Deal, the latest environmental objectives that have been affiliated in distinct policy areas, such as climate change, circular economy and decarbonization of economy, drastically test the effectiveness of the existing EU environmental policy tools. Consequently, for the EU policymakers and governments to succeed in these significantly ambitious environmental goals, "demand-side policies"—such as the GPP—can prove to be extremely effective tools (Martinez Romera & Caranta, 2017).

The typical development framework under which energy transition should be implemented, incudes specific distinct stages. According to Markard (2018) there are two phases of energy transition. Phase 1 deals with the exploitation of new energy-friendly technologies, primarily RES and similar categories. In that specific stage, there is an imbalance between novel and established technologies, where the later are preferable for direct implementation. For that reason, they are more widely (but not exclusively) applied in pilot projects regarding energy transition. In organizational terms, phase 1 may include the entry of new businesses (start-ups, suppliers, service providers, etc.) and the development of innovation clusters that may contend knowledge diffusion. Established companies such as utility companies are directly affected or involved in that initial stage since they often ignore or oppose the usage of new evolutionary technologies.

Phase 2 includes the maturity stage for the implementation of new technologies, and the decline of established older technologies. This implies that an energy transition process cannot and should not directly start with the implementation of too immature technologies that have not been adequately tested, at least for its basic operations such as energy production. On the contrary, novel technologies may be implemented for secondary—but equally effective—activities such as energy storage and energy conversion (energy hubs, power-to-gas transformation, etc.) from day one. Phase 2 drastically affects incumbent organizations, such as public services and public procurements, since new or evolutionary technologies may significantly affect existing business models and procedures in the transition process, while new businesses and start-ups may adopt the new procedures from day one, becoming extremely competitive that way. In this phase, the adoption of sector level matters such as grid stability/flexibility and RES integration is present, implying that the transition has already gone through the implementation towards the maturity stage. As a result, public organizations must adopt new technologies in energy applications or business models in their public procurements, in order to become adequately competitive while specific sectors such as farmers can implement high-tech approaches like smart agriculture (Markard, 2018).

The literature debate around energy transition also focuses on the energy cost, especially for the poorer households and citizens belonging to weak groups. Apart from the green direction, the actual cost of energy constitutes a significant factor regarding

economic development as well as social cohesion that must be seriously taken into account by the policymakers. Literature has indicated that in multiple occasions, energy transition has negatively affected households by forcing citizen groups—especially the weaker and those who are in the poverty threshold—to pay significantly higher amounts for energy consumption in comparison to the recent past, when energy production by RES was negligible (Frondel et al., 2015; Neuhoff et al., 2013). This indicates the need for any distinct direction of energy transition, such as the green public procurement, to take into account the easing of social income and the economic relieve of social groups.

Region of Western Macedonia has been considered for decades as the "energy generator" of Greece. From 1961 to 2005, the lignite powers plants in Greece had been producing more than 50% of the total energy outcome, while 75% of those power units were specifically located in the Region of Western Macedonia (Kaldellis et al., 2009). Nowadays Western Macedonian's local economy is still involved in lignite mining and lignite-fired power generation at large shares. More specifically, approximately 17% of the local workforce are directly or indirectly related to lignite mining, while more than 40% are employed in activities that are directly affected by the income created by the lignite mining (Vatikiotis, 2021). However, since 2010, there has been a constant decline in the production of lignite power plants of the region while only three out of six power plants are still operational. At the same time, the EU Emissions Trading System (ETS) has been constantly incrementing the costs to produce lignite-originated electricity over the last years. In accordance with its commitments to push for climate actions, Greece was found in the need to quickly transform its energy production system towards clean energy technologies, by implementing a demanding energy transition programme. Thus, the whole transition process in Western Macedonia is implemented according to the Just Transition Development Programme (JTDP) (SDAM, 2021), which constitutes a cogwheel of a broader mechanism consisting of the "European Green Deal", and the "Energy Roadmap for 2050". JTDP was designed in compliance with the "National Energy Plan and Climate Plan", indicating the Greek government's strategic plan for climate and energy issues (Hellenic Ministry of the Environment & Energy, 2019).

JTDP's precursor is the Just Transition Development Plan, which constituted a development roadmap for the Region of Western Macedonia, purposing to build incentives and opportunities for the restart of the local economy after decarbonization. It consists of specific pillars of growth which are i) clean energy, ii) technology and education, iii) industry, small industry, and trade, iv) sustainable tourism and v) smart agriculture. These are based on incentive allowance, developing physical and digital infrastructure, reskilling, and upskilling activities, entrepreneurial consulting services, and innovative methods for land management and land repurposing. The implementation of the JTDP, which is primarily focused on its key natural and educational assets, is aimed to boost research innovation and production of clean energy under a differentiated economic model. It has been designed as a means to exploit the existing human resources at the most effective way and creates new job opportunities (SDAM, 2021).

Green Public Procurement

Green Public Procurement (GPP) is defined by the European Commission (2008) as *"a process whereby public authorities seek to procure goods, services and works with a*

reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured." However, the term includes multiple aspects of the "green" dimensions of a procurement type that can be implemented by a local, regional, national, European, or international authority.

GPP is a process that can be embedded to contracts both above and below the threshold for implementation of the European Procurement Directives (Directive 2014/24, 2014). This constitutes the first set of a distinct EU legislation framework that allowed EU public authorities to take the environmental aspect into consideration. This is mainly taking place during the pre-procurement stage. Rules and procedures related to exclusion and selection, have been created to obtain a minimum level of compliance with the environmental legislation framework, by both contractors and sub-contractors. Methodological techniques such as designation of sustainable production procedures, life cycle costing and the use of environmental award criteria are included in order to help public authorities identify environmentally attractive bids.

In fact, the public contracting authorities can use their purchasing power as a mean to choose goods and services under a significantly lower environmental impact, making a crucial contribution towards local, regional, national, and international sustainability goals that way (Horbach et al., 2012). GPP can be used as a crucial mean for producing innovation, providing at the same time the business sector real incentives for deploying green products and services (Pouikli, 2021). This is especially true in sectors where public authorities constitute a major "player" in the market (e.g. transportation, healthcare, construction). GPP has also a great potential to provide financial gains for public organizations, especially if the full life-cycle costs of a public contract are considered. For instance, purchasing energy-efficient and water-saving products, can contribute to the significant reduction of utility bills. Decreasing dangerous substances in products can also reduce disposal costs. Public authorities which actively practice GPP, can be significantly strengthened to face evolving environmental challenges, such as reducing greenhouse gas emissions or effectively move towards a circular economy (European Commission & ICLEI, 2016). Moreover, GPP may constitute a significant tool in the toolkit of the governments and policymakers, by implementing policies that can either directly affect environmental goods or focus on obtaining the adopted environmental objectives (Pouikli, 2021).

To push for consistency and adoption of GPP by the EU Member States, the European Union has set distinct GPP criteria for 21 procurement sectors, including Electricity, Road Transport, Construction, Waste Water Infrastructure and others (European Commission, 2020). The purpose of the standardization is to increase the availability of environmental criteria (European Commission, 2008). Consequently, most of the member states have adopted their National Action Plans, which include GPP targets and purchasing goals to a large extent (European Commission, 2016), as well as innovation targets from procurement implementation (Rainville, 2017). However, there is still a large margin of the local authorities to adopt specific key criteria, or every single criterion included in the 21-criteria GPP list.

The general innovation type that can be procured through GPP, is always considered 'green' or 'eco-innovation', consisting of several heterogeneous elements that are

directly related to positive effects on the environment. According to Authority and Allé (2012), the eco-innovations can be incremental, disruptive, or radical, all designed to ease sustainable development through direct or indirect green interventions. Incremental innovation is designed to modify and improve already existing technologies, raising effectiveness of energy and resource usage, without significantly altering the underlying key technologies. Disruptive innovation changes the way specific functions are implemented, without changing the core technological regime itself. Radical innovation premises a critical switch in the technological regime of a national or local economy. This innovation type often includes both technological and non-technological changes such as the creation of revolutionary new technologies or the reconfiguration of existing products or services (Authority & Allé, 2012). The implementation is promoted through the mobilization of diverse actors that are primarily related to the scientific/technological status, the financial situation, and the social circumstances.

However, there are critical barriers that hinder the promotion of key GPP initiatives and the proper implementation of GPP practices. The most prominent barrier is the general lack of awareness about GPP that is identified, as this could have a positive and significant impact on the likelihood of adopting GPP practices (Cheng et al., 2018). In this regard, the general aspect of familiarity with GPP policies and practices is considered by Testa et al. (2016) as the most significant barrier compared to others.

GPP elements in energy transition

In theory, GPP aims at promoting procurements by public bodies, regarding every single category of product or service, under a process that leaves a positive environmental footprint (Lee et al., 2016). EU has sufficiently broadened the GPP framework, by initiating a set of distinct GPP criteria for 21 purchasing sectors, covering almost every single sector of products or services that a public procurer can acquire. However, both literature and policy practice indicate that a few of those purchasing sectors have a superior significance in the energy transition process in comparison to others, since advancements and investments in those sectors are either included as proposed measures or indicators in most of the current energy transition frameworks of the EU member states (Lee et al., 2016). Moreover, regardless of the scheduled transition to a low-carbon energy supply by the EU that includes the aforementioned holistic framework of GPP, several international organizations and national governments have already set a path towards environmental sustainability in the public procurements' sector. This path includes specific measures and policies highly related but not always identical to EU GPP framework. Indeed, governments have officially acknowledged the role of public procurement to support sustainability, including a distinct reference in the Sustainable Development Goals which are to promote sustainable public procurement practices in accordance with national priorities and policies (Lee et al., 2016).

However, EU has prioritized GPP as a core mean to promote energy transition, initiating a few primary procurement activities as key transition measures. According to Tagliapietra et al. (2019) one of the key priorities to foster the EU energy transition is the effective preparation of the national electricity systems. This can be accomplished through the implementation of a set of factors which can drive R&D specialization, including policy factors like 'technology-push' measures. These types of factors may

include innovation subsidies, and 'demand-pull' measures such as public procurement. In fact, market pull is considered one of the four core functions of the energy-technology innovation. To allow the entry of new green products into markets, policymakers must line up incentives through the innovation value chain and inform the markets that the new green technologies can be profitable (Gunasekaran et al., 2015). GPP is considered a primary policy instrument for that purpose (IEA, 2019). Moreover, the policies that are needed to drastically promote long-term decarbonization of industry in EU, should prioritize the creation of climate-friendly market options such as the increase of GPP level, by using shadow carbon prices on the offers' evaluation or by setting specific limits on carbon intensity (Tagliapietra et al., 2019).

Another example of the implementation of a specific GPP criterion in energy transition programmes in the EU, is the direct and indirect inclusion of electric mobility in road transportation under a specific procurement framework. This can be implemented through the acquisition of electric vehicles (EVs) by the public authorities for transportation purposes or by the design and installation of networks of solar charging stations, operating with photovoltaic panels (European Commission, 2021). Moreover, extended criteria have been set for Road Lighting and Traffic Signals, which promote another category of intervention for energy transition infrastructures. This specific GPP criteria category aims to reveal the key environmental impacts associated with the technological concept, installation, and operation of this kind of equipment. More specifically, for Road Lighting, the criteria are broadly divided into three categories: energy consumption, light pollution, and durability aspects (Donatello et al., 2019).

A significant GPP criterion is Waste Water Management which is also considered a significant mean of promoting energy transition. Amongst the most common Waste Water Infrastructures are the waste water plants. Turning waste water treatment industrial units into efficient renewable energy generators is an effective measure to accomplish the current goals of boosting the EU economy and its energy market. A modern waste water management plant typically produces two types of energy: biogas from methane and CO_2, and electricity through biogas combustion. However, an efficient GPP-based waste water management has the potential of turning those industrial units into energy neutral or energy positive plants. The most prominent technological solutions that this can be achieved, are the reduction of internal energy demand by using technologically advanced plant control solutions, the increase of biogas production from sewage sludge, the removal of nitrogen by using innovative solutions other than the typical denitrifying process and the effective biogas utilization into financially viable forms of energy (Alhola et al., 2019).

Secondary procurement activities such as food catering services, computers and hardware acquisition, data centres, etc., are also included in the EU GPP criteria and leave an environmental footprint which should be adjusted to the maximum possible 'green' levels. However, these types of procurements represent secondary acquisitions by the public bodies (mainly at municipal level) and they do not have a high possibility to be 'green' compared to heat or transportation means (Yu et al., 2020). Moreover, literature review and policy practice indicate that those procurement activities are not directly included in the current energy transition frameworks of the EU as key measures, possibly due to

the reduced environmental footprint in comparison to the procurement activities initially analysed in current chapter.

Methodology

The main research method used in this study was fieldwork. A questionnaire consisting of a personal/demographic data section (Section A) and the main section of nineteen (19) Likert-scale questions (Section B), was structured for the analysis. The questionnaire was structured according to the findings accrued from two pilot questionnaires fulfilled by 31 procurements' officials and experts from the Region's five main municipalities. The final version of questionnaire was initially sent to 34 participants and 31 of them fully answered it. The sample consists of 12 procurement employees of the five major Western Macedonia municipalities (Kozani, Eordaia, Kastoria, Grevena, Florina) who have been directly involved in the procurement process. In comparison to other municipalities in the region, those specific municipalities have been chosen because they constitute more than 80% of the region's total population and they have separate procurement departments or experts' teams that are exclusively engaged with the procurements in each municipality. The remaining 19 individuals are municipal scientific experts who have contributed to procurement processes, through the justification and further feedback provision, regarding their specific scientific and policy expertise in the municipalities. The questionnaire was prepared and distributed through the *google docs* online tool.

In order to follow the formal statistical sampling selection process and the typical questionnaire structuring process, an introductory questionnaire was prepared aiming to reveal the most prominent GPP criteria according to the experts' views, amongst the total of the 21 criteria. After assessing explanatory information on the total of the 21 GPP criteria, the experts had to answer on which specific GPP criteria consider the most prominent and conceptually linked to energy transition. Next, a pilot version of the main questionnaire was sent to an approximate 30% of the total sample (9 procurement experts) in order to form the final format of the questions regarding the distinct four GPP criteria that have been chosen to be evaluated. In the final version of the questionnaire, further contact data were provided and 4 officials contacted the authors through telephone for further clarifications of the questionnaire's content and the purpose of the research. The main questionnaire of the research (Section B) is quoted in the Appendix. The research was conducted in the year of 2022 and the questionnaires were distributed and received in the second semester of the year.

Purposive and availability sampling was used, based on the administrative size of the agency, indicating the five municipalities in the region as the ones especially involved in the procurement processes. The participants in the sample can be characterized as highly qualified in their field as well as highly educated. The questions that structure the questionnaire are derived from four different thematic sections, which are, respectively, based on the four synonymous general criteria of the GPP. These criteria for each of the 21 categories are divided into 'core' and 'comprehensive' criteria (European Commission, 2020). The first category refers to the criteria that were developed and reflect how easy it is to implement GPP, targeting the key areas of a product/service's environmental performance. The second category refers to more specific criteria that address environmental

or technical aspects, aiming to achieve environmental innovation at the highest level. The questions in this questionnaire are drawn from both core and comprehensive criteria, and aim to examine the level of integration of GPP into regional practices in Western Macedonia, revealing the linkage between GPP criteria and energy transition at a wider scope.

To assure questionnaire's reliability, a Cronbach's alpha analysis was conducted. Cronbach's alpha is a formula of internal consistency of a scale, pointing out the degree of correlation a set of items has as a group. The statistical formula of Cronbach alpha is:

$$a = \frac{K}{K-1} * \left(1 - \frac{\sum_{i=1}^{K} \sigma_{\Upsilon i}^2}{\sigma_{\mathrm{X}}^2}\right),$$

where '*K*' is the number of scale items, 'σ_{X}^2' is the variance of the observed total test scores and '$\sigma_{\Upsilon_i}^2$' is the variance of component *i* for the sample. In practice, values of $\alpha \geq 0.8$ indicate a good level of consistency while values of $0.6 \leq \alpha < 0.8$ indicate an adequate level of consistency. A Cronbach alpha value of $\alpha < 0.6$ needs further clarification while $\alpha < 0.5$ is an indication of poor consistency (George & Mallery, 2003). The items represent the calculations that were automatically performed by SPSS software.

The Spearman's rank correlation coefficient determines the monotonic relationship between two variables. This test was used in our study in order to uncover the statistic relationship between specific GPP criteria and detect parallel tendencies regarding whether the implementation of one criterion tends to "drug" the implementation of another or in simple words whether local authorities tend to implement specific groups of criteria. Spearman's values exist in the spectrum of {-1 + 1}. The correlation between two variables is expected to be high when observations have a similar (or identical for values equal to 1) rank, between the two variables. The test is non-parametric and it is mostly used for categoric variables (such as Likert scales) or purely quantitative variables when there is no precondition for normal distribution of the observations of the two variables. The formula for Spearman's correlation coefficient '$\boldsymbol{r_s}$' is:

$$r_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n^3 - n},$$

where 'd_i' is the difference between the two ranks and '*n*' is the number of observations. Spearman's coefficient is a measurement of the strength of a monotonic relationship between groups of data. It is constrained according to the mathematical relationship: $-1 \leq r_s \leq 1$. The closer r_s is to the value of ± 1, the stronger the monotonic relationship can be considered. The strength of the correlation is scaled according to the following scale:

- 0.00—0.19—> "very weak"
- 0.20—0.39—> "weak"
- 0.40—0.59—> "moderate"
- 0.60—0.79—> "strong"
- 0.80—1.0—> "very strong"

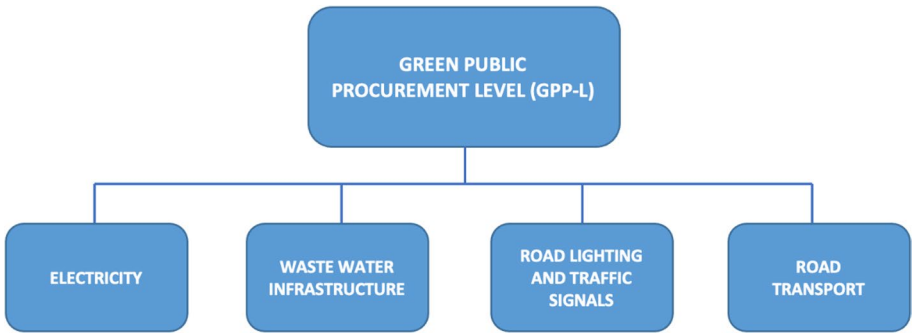

Fig. 1 Structure of the GPP-L variable (source: authors)

To decide which variables should be included in the GPP level (GPP-L variable), the findings of the literature review and the findings from the introductory questionnaire were considered. The questionnaire was structured in this way to include a set of discrete questions on the criteria of the CAP set by the EU (European Commission, 2020). As already referred, the questions do not cover all 21 criteria, as both the policy practice of the existing EU energy transition frameworks as well as the specific energy transition plan of Western Macedonia do not include each individual criterion as a mean of promoting and implementing the energy transition. Moreover, the initial questionnaire indicated the specific four general criteria that should be linked to energy transition according to the experts' views. These are the Electricity criterion, the Waste Water Infrastructure criterion, the Road Lighting and Traffic Signals criterion and the Road Transport criterion. The GPP criteria list is constantly updated by the EC, including and excluding criteria from procurement sectors that possess an increased (or at the time decreased) environmental impact. The rest of the GPP criteria that have been excluded from this research according to the experts' perceptions include sectors that vary from hardware equipment (computers, data centres, etc.) to maintenance sectors (public buildings, infrastructures, etc.) (European Commission, 2020). Literature review and the pilot questionnaire at the regional level revealed that the criteria of Electricity, Road Transport, Street Lighting and Signals, and Sanitation Infrastructure can be included in the GPP-L composite variable. These criteria were identified to a greater extent in most texts and strategies of regions undergoing energy transition (Alhola et al., 2019; Donatello et al., 2019; SDAM, 2021; Tagliapietra et al., 2019). These criteria are also amongst the most common types of "green potential" procurement, at municipal and regional level and those specific criteria were indicated by the procurement experts of the municipalities as the most directly related to energy transition in the study's pilot phase. Figure 1 presents the structure of the GPP-L variable, consisting of four variables, representing the four GPP criteria selected for the analysis of this paper.

Results

The general picture of findings from the case study of West Macedonia shows an average-to-low level of GPP criteria implementation in the Region with statistical correlations being observed in specific criteria. Cronbach a has been calculated equal to:

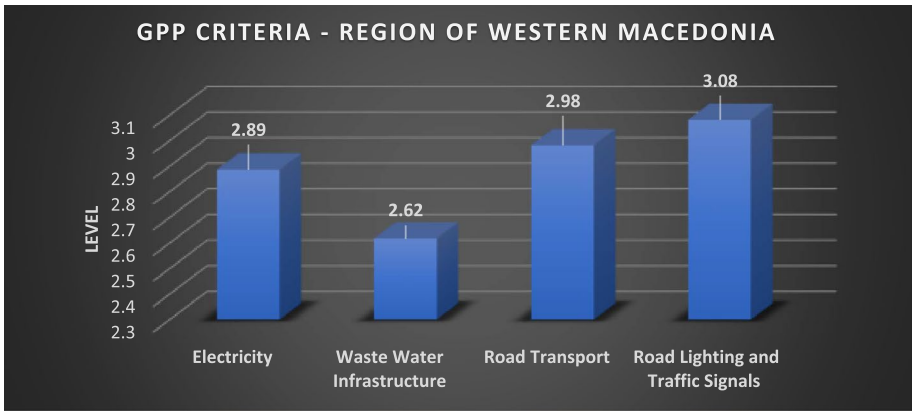

Fig. 2 GPP criteria—level of implementation in Western Macedonia

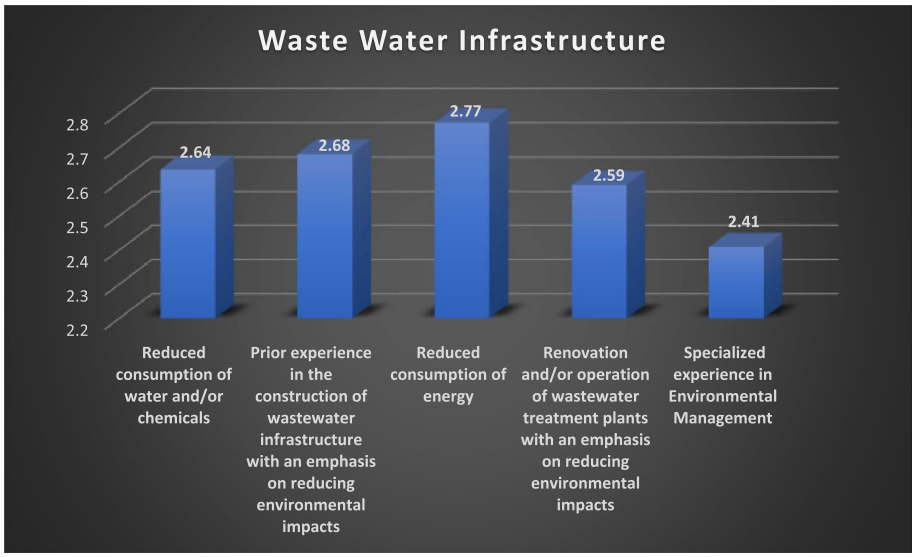

Fig. 3 Level of implementation for Waste Water Infrastructure sub-criteria

- Cronbach $\alpha_{\text{Electricity}} = 0{,}699$
- Cronbach $\alpha_{\text{Road Transport}} = 0{,}911$
- Cronbach $\alpha_{\text{Waste Water Infrastructure}} = 0{,}948$
- Cronbach $\alpha_{\text{Road Lighting and Traffic Signals}} = 0{,}938$

indicating a high level if internal consistency amongst the questions, representing study's variables in the study's questionnaire.

The overall picture of the results is presented in Fig. 2, which shows the average scores according to the procurement experts' responses. According to the results, the most applicable general procurement GPP criterion in the 5 municipalities is that of Road Lighting and Traffic Signals ($AVG_{\text{Road Lighting and Traffic Signals}} = 3{,}08$), with Road Transport and Electricity following closely behind with similar scores. The least applicable GPP criterion is that of Waste Water Infrastructure ($AVG_{\text{Waste Water Inftastructure}} = 2{,}62$). According

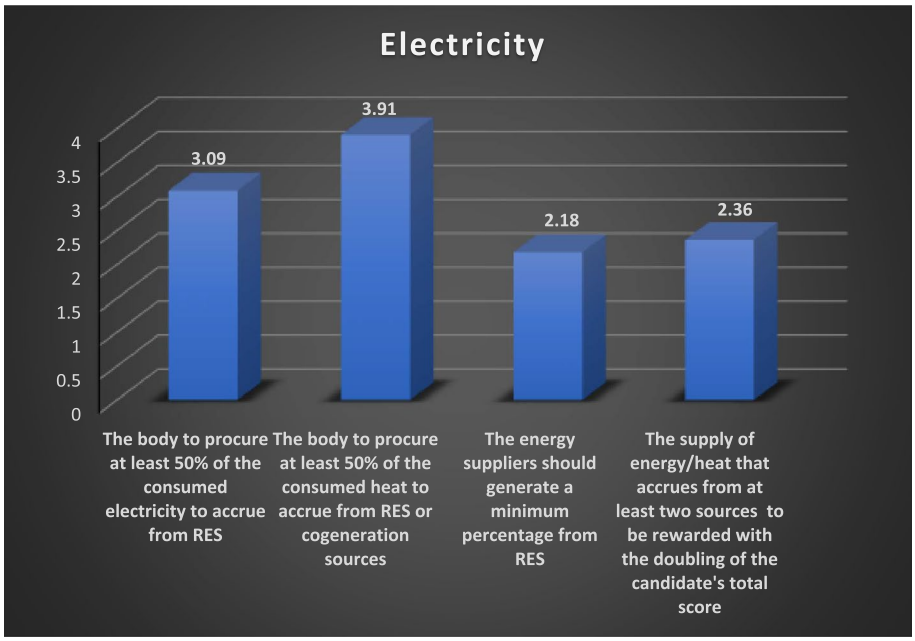

Fig. 4 Level of implementation for Electricity sub-criteria

to Fig. 2, the average score of GPP criteria is $AVG_{GPP\text{-}L} = 2{,}89$, indicating an average to adequate level of implementation of GPP in the region of Western Macedonia.

When analysing the individual sub-criteria of the least applicable criterion (Fig. 3), it is observed that municipalities apply the sub-criteria of reduced energy consumption (2.77) and renovation of waste water treatment plants (2.59), while usually the existence of specialized experience in environmental management on the part of the contractors of construction/renovation/wastewater treatment projects is not required (2.41). Prior experience on the part of suppliers in the construction/renovation/operation of wastewater treatment plants in such projects also appears at low rates (2.68), while finally reduced energy/water and chemical consumption is a criterion that also appears at low rates (2.64).

For the Region of Western Macedonia as the main energy-producing region of Greece, the Electricity criterion could be considered the most critical. However, the analysis revealed contradictory results, with some sub-criteria being applied to a relatively high degree, while others being applied to a relatively low one. As shown in Fig. 4, the sub-criterion of requiring a body to have at least 50% of the heat it consumes come from renewable energy sources or cogeneration is applied to a significant extent. This specific finding is clearly related to the district heating systems that have been operating for decades in the two largest municipalities of the region (Kozani & Eordaia), which have been supplying energy from this particular source. The supply of energy exclusively from RES also shows a high percentage, as this obviously relates to the energy mix consumed by the municipalities, which is largely from RES (3,09). On the contrary, the supply of energy from a subjective minimum percentage of RES, specifically set by each Municipality, shows a particularly low percentage (2,18). This contradictory result is directly related to the first sub-criterion, according to which the municipalities choose to apply the precise EU criterion that demarcates the percentage to a value of at least 50%. In

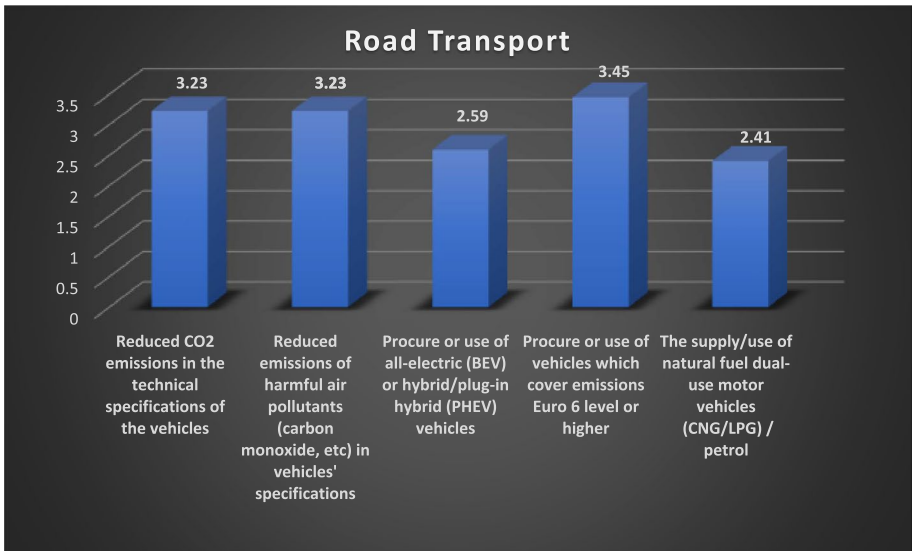

Fig. 5 Level of implementation for Road Transport sub-criteria

addition, the sub-criterion of the obligation for each public body to double the score of each candidate offering energy supply from two different RES sources (e.g. photovoltaic and wind) also shows a relatively low level of implementation (2.36).

Regarding the general criterion of Road Transport (Fig. 5), which scored the second highest, the most applicable sub-criterion is the obligation to comply with the Euro 6 or higher emission level for the acquisition of vehicles, procured by the municipality (3,45). However, it is obvious that most new vehicles introduced into the Greek market are of Euro 6 level, but the introduction of this sub-criterion in the GPP criteria for public procurement is important. In addition, the provision of a requirement for reduced CO2 emissions in the technical specifications of vehicles is also implemented at a satisfactory level (3.23), while the provision of a requirement for reduced emissions of harmful pollutants in the technical specifications of vehicles is implemented to the same extent. This provision specifically concerns particularly harmful pollutants such as such as carbon monoxide, nitrous oxide, etc. (European Commission, 2020). Reduced amounts appear in the categories of procurements of exclusively electric or hybrid vehicles and dual-fuel petrol and liquefied petroleum gas (LPG)/ compressed natural gas (CNG) internal combustion engine vehicles. These two vehicle categories are considered intermediate categories of sustainable mobility vehicles, in the sense that they use fossil fuels but non-harmful pollutants (Aosaf et al., 2022; Hawkins et al., 2012; Raslavičius et al., 2014).

Finally, for the criterion of Road Lighting and Traffic Signals (Fig. 6), the highest score (3,08) is observed amongst the four general criteria of the GPP. The most applicable sub-criterion of the general criterion concerns the 120lm/w performance of the street lighting lamps provided (3,95). This is followed by the sub-criterion for lighting systems, whose power does not exceed 0,90. The power factor (lumen) of the lamp describes the ratio between actual and apparent power. Devices with a low power factor increase losses in the electricity distribution network and in the energy cost of

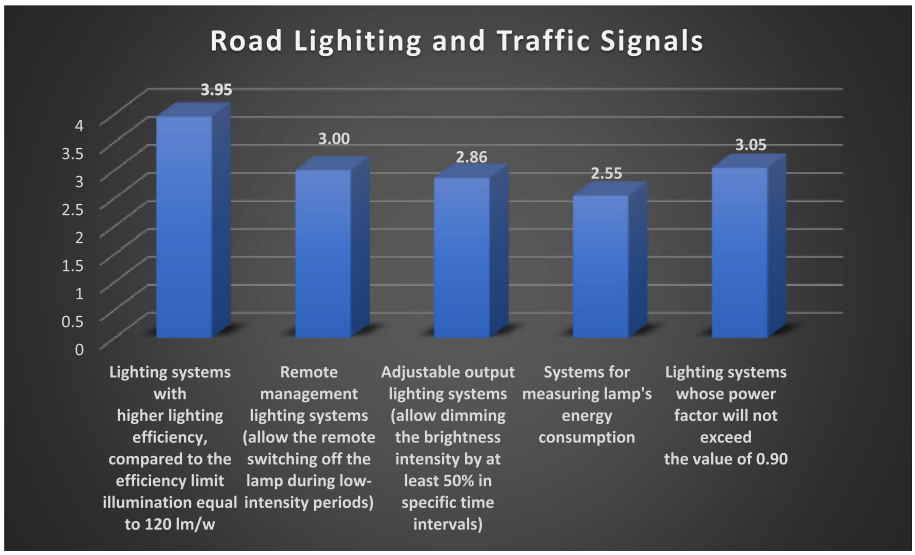

Fig. 6 Level of implementation for Road Lighting and Traffic Signals

Table 1 Test of normality of general GPP criteria

Tests of normality						
	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	df	Sig	Statistic	df	Sig
Electricity	0.175	31	0.077	0.917	31	0.065
Road Transport	0.176	31	0.073	0.930	31	0.124
Waste Water Infrastructure	0.190	31	0.037	0.935	31	0.153
Road Lighting and Traffic Signals	0.136	31	0.200*	0.929	31	0.119

* This is a lower bound of the true significance

[a] Lilliefors significance correction

the device. This is explained by the fact that these devices require a higher apparent power supply from the grid to meet their energy needs in terms of active power (European Commission, 2020). The procurement of remote-controlled lighting systems that allow for programmed switching off during periods of low traffic intensity during night-time road use (detecting the absence of traffic and switching off the lamps) is also at a relatively high rate (3.00). Similarly, the supply of minimum regulation lighting systems that allow programming to dim the light intensity by at least 50% at specific times of their daily operation is also rated at a medium level (2.86). Finally, the supply of a system that can measure the specific energy consumption of the lighting system was rated at 2.55.

Describing the relationship between the pairs of GPP criteria in the analysis, a Spearman's correlation coefficient test was conducted. Before the conduction of the Spearman's Correlation Coefficient, a normality test had to be conducted. The conduction of the Kolmogorov–Smirnov and Shapiro–Wilk tests is depicted in Table 1. At a significance level of $\alpha = 0{,}05$, the values of the four variables representing the general criteria show adequate levels of normality (SW).

Table 2 Spearman's correlation coefficients on GPP criteria pairs

	Electricity, Waste Water Infrastructure	**Electricity, Road Transport**	**Waste Water Infrastructure, Road Transport**
Correlation coefficient r_s	0.754*	0.124	0.422
Sig. (2-tailed)	**0.000**	0.582	0.050
N	31	31	31
	Electricity. Road Lighting and Traffic Signals	**Road Transport. Road Lighting and Traffic Signals**	**Waste water Infrastructure. Road Lighting and Traffic Signals**
Correlation Coefficient r_s	0.293	0.745*	0.676*
Sig. (2-tailed)	0.184	**0.000**	**0.000**
N	31	31	31

* All correlation coefficients are significant at the 0,01 level (2-tailed)

Based on the Spearman's rank correlation analysis, the researcher can uncover whether the relationship between variables is significant or not and also to obtain information on the close relationship and sign of the relationship between selected variables. Table 2 shows the relationships between the six GPP criteria pairs and the bold values indicate the statistical significant cases. The hypothesis of a considerably strong ($r_s = 0{,}754$), statistically significant (sig. < 0,01) linear correlation between the ranks of the GPP criteria of Electricity and Waste Water Infrastructure is accepted, while the case is similar for the ranks of the GPP criteria of Road Transport and Road Lighting and Traffic Signals ($r_s = 0{,}745$, sig. < 0,01). Likewise, a strong positive linear relationship is also observed in the case of the GPP criteria of Waste Water Infrastructure and Road Lighting and Traffic Signals ($r_s = 0{,}676$, sig. < 0,01), while the other 3 pairs do not show any signs of strong or statistical significance amongst the GPP criteria. There are some obvious findings considering the nature of each GPP criterion in the table above, while other relationships seem to be unexpected at the first sight, demanding a wider interpretation.

Discussion

The main objective of this study was to assess the level of integration of GPP criteria in public procurement procedures amongst the five largest municipalities of the Region of Western Macedonia. Considering that the region is currently undergoing a green energy transition, there is a growing sense of urgency about the need for a green radical transformation of the regional economy. Furthermore, in line with the provisions of SDAM on the implementation of green investments in the region (SDAM, 2021), we conclude that the level of integration, as it emerges from the analysis, cannot be considered sufficient. An average GPP-L score of just below 3 (2.89) indicates that there is significant room for improvement in the basic procurement processes in the participating large municipalities. The findings can be considered even more pessimistic if one takes into account the fact that only four of the 21 GPP criteria were used in the present analysis for evaluation, as only for these only findings were identified in the Region of Western Macedonia.

The general criterion of Electricity is implemented to a marginally above average level ($AVG_{ELECTRICITY} = 2{,}89$). However, this cannot be considered adequate, considering

some specific circumstances such as the special characteristics of the region as the main electricity producer in Greece, the relative simplicity in the implementation of the criterion's sub-criteria and the specific provisions of JTDP which foresees the abandonment of fossil-fuel generated electricity with RES installations (SDAM, 2021). More specifically, an imbalance is noticeable regarding the gap between the high gained value of the sub-criterion of "the procurement of at least 50% of the consumed heat from RES or cogeneration sources" with the rest of the sub-criteria which have gained considerably low values. That can be explained due to the fact that the two most populated municipalities in Western Macedonia (Kozani and Eordaia) use district heating to cover their heating needs for decades while Municipality of Florina is currently also building a district heating system, implying the three out of five are already familiar with such systems. On the contrary, the rest of the sub-criteria are insufficiently implemented, meaning that there are no criteria to reward energy from RES sources.

The criterion of Waste Water Infrastructure is insufficiently applied and it is the least implemented amongst the four general criteria ($AVG_{\text{WASTE WATER INFRASTRUCTURE}} = 2{,}62$). Its five sub-criteria are all graded below average. They vary, between the consumption levels of the water and the chemicals needed to become potable, the energy needed for the water supply to the network or the experience needed by the operator of the water supply and its environmental expertise. Considering the fact that the efficient use of natural resources is a prerequisite of JTDP, foreseeing significant budget and emblematic investments for these purposes (SDAM, 2021), this specific criterion should constitute a top priority for the municipalities of the region.

The general criterion of Road Transport received the second highest score. The nature of the procurement sub-criteria mainly regards vehicles used for transportation purposes within the municipality's boundaries, garbage-collection vehicles, utility vehicles, etc. They concern the request of green characteristics of the vehicles, regarding its emissions, engine type (electric, non-electric) or fuel type (petrol, CNG, LPG, PHEV). Taking into account the low procurement cost for relatively small municipalities, the score gained is also considered low. The only sub-criterion that is implemented at adequate levels is the criterion of the procurement of Euro-6 standard vehicles, a characteristic that most vehicles traded in the EU possess anyway. The other sub-criteria about the purchase of battery electric vehicle (BEV), plug-in hybrid electric vehicle (PHEV) and LPG/GNG vehicles is not implemented, implying the municipalities still primarily choose internal combustion engine vehicles, using petrol or diesel fuel for covering their needs.

Road Lighting and Traffic Signals criterion showed a below-average level of implementation in all but one sub-criteria. More specifically, the purchase of modern light emitting diode (LED) low-energy-consumption lights by the municipalities for the Road Lighting seems to be implemented at an adequate degree in the procurements. On the contrary, sub-criteria representing more advanced lighting systems such as remote control, adjustable brightness or automatic operation according to traffic or natural light systems do not seem to be used as criteria for the candidate contractors in the procurements of Road Lighting. A preliminary explanation could be that investments in LED lights are relatively low-cost to acquire and instal and offer a high value-for-money. Especially with the recent rise in the cost of energy worldwide, this could be a one-way

solution for all road lighting operators. On the other hand, more costly lighting systems that require higher expertise in their installation and maintenance do not seem to be followed on Western Macedonia's case by the major municipalities.

Spearman's rank correlation analysis led to expected as well as contradictory findings. At first, there has been a (positive) statistical correlation noted between the variables of Road Transport and Road Lighting and Traffic Signals. This can be interpreted by the tendency of the municipalities to improve municipal transport infrastructure and comply with the ongoing energy transition principles set by the JTDP. According to the paper's findings, it seems that procurements about public transport in Western Macedonia follow a parallel path, regarding their "green" level too. Electricity and Waste Water Infrastructure general criteria showed a monotonic relationship too. While there is no direct connection between the two variables in terms of the typical interpretation of the criteria, indirect characteristics of the procurements such as the higher cost and higher expertise of such procurement types could justify the statistical tendency as well as their low overall scores. A higher sample of procurement experts could provide the researcher a more solid conclusion regarding their statistical correlations. The Waste Water Infrastructure and the Road Lighting and Traffic Signals is the last pair of variables that showed statistical correlation. This could be justified by the similarity of the overall scores in their average values that the two variables initially obtained. No statistical correlations were found between the other pairs of variables, however a significantly larger sample of experts could provide a clearer picture on whether public bodies tend to go forward with procurements with similar contexts.

Conclusion

The paper's aim is dual: the direct aim of the paper is to uncover the current implementation level of the GPP in the Region of Western Macedonia, as an indicator that is connected with the ongoing project of energy transition that is implemented in the region. At the same time, the indirect aim of the paper is to reveal those specific GPP criteria that can act as "boosters" of energy transition. In that perspective, both literature and study's findings indicated that those specific GPP criteria that have the potential of decreasing energy costs, promoting environmental sustainability and strengthening financial activity at the most effective level, can be considered as energy transition pillars. In fact, literature review indicates that sustainable development has to be promoted through the promotion of green investments (Dutta et al., 2020), which in turn may be effectively implemented through GPP framework in the public sector. Moreover, a few major determinants of green investments are energy efficiency and low-emission energy supply (Eyraud et al., 2013), concepts which can be directly considered as GPP energy criteria. In that framework energy transition that currently takes place in the Region of Western Macedonia through JTDP, has to practically include and strengthen GPP procurement principles in the implementation measures and investments that are currently being implemented or they are planned to be implemented in the near future. The fact that than main policy bodies of the region—the major municipalities—do not adopt those GPP principles to an adequate extent, implies that they lack of perspective and abilities to implement JTDP at a sufficient degree. In total, all four investigated GPP

criteria can be considered significant for energy transition and should be adopted by energy-transition regions. However, the general picture of the implementation level of GPP in the Region of Western Macedonia is average-to-low, implying that policymakers of the region should definitely strengthen support mechanisms of conducting procurements under the GPP umbrella.

Moreover, policy-making and the green energy strategy require a combination of actions in several policy domains, such as the establishment of feed-in tariffs, carbon pricing schemes, renewable energy portfolio standards (some of which are included in the framework of the GMP), biofuel mandates and carbon pricing schemes. In terms of maximizing the benefits of GPP, regional policymakers and scientists should implement the recommendations set out in the scientific literature and policy practice (Rüdenauer et al., 2007), adopting the principles of GPP into both processes and outcomes of the regional policy agenda. These should focus on communicating good practices on life cycle costing (LCA) and GPP to local public society and stakeholder groups. In addition, public bodies could expand the scope of products/services in which GPP principles could be directly adopted in the procurement process by removing the requirement for the public body or supplier to know detailed technical information (e.g. the reduced required energy consumption of a product). The GPP framework could be a major booster in Western Macedonia's Green Transition, acting as a financial instrument suitable for any investment that can generate a green footprint. Thus, the principles of GPP could be applied on a wider scale. In addition, high impact from major interventions is anticipated by the procurement organizers, who could provide practical assistance, examples of best practices and any potentially useful information in order to help potential contractors to implement and adopt the principles of GPP.

Despite the clear findings of the study, distinct limitations of the methodological process still prevent for safe conclusions to be extracted. The critical limitation of the study is the small sample of the 31 procurement officials, which is considered low to extract solid statistical tendencies. The main research stake demanded the participation of high-level procurement officials from regional authorities which, for the Region of Western Macedonia, could only accrue from low population municipalities which suffer from lack of distinct procurement departments and specialized experts. A higher sample, which could potentially accrue from high population municipalities and regional authorities of larger regions in energy transition, could significantly strengthen statistical conclusions towards the distinction of GPP criteria that are compatible to energy transition and can operate as transition boosters. The second limitation of the study is the content of the GPP framework, which is updated very frequently by the EC. A GPP criterion can be characterized as outdated in a just few years' time and a new one to be added in the modern GPP framework. This makes it complex for researchers to deepen implications of the GPP in energy transition and other key socioeconomic sectors. And it also makes it complicated for the EU procurement officials to fully adopt and perfect GPP implementation in their procurement mechanisms. However, this study still constitutes a fully novel research effort in total, primarily for the energy transition/GPP framework interaction as well as the GPP criteria embedment in the distinct characteristics of the Region of Western Macedonia.

Appendix

Section B—main questionnaire on green public procurement

A) Electricity

1. [1]In accordance with the relevant EU Green Public Procurement criterion, the body should supply at least 50% of the consumed electricity from renewable sources (Photovoltaic, Wind, Geothermal, Aerothermal, Hydro, Biomass). To what extent do you consider that your body fulfilled this criterion for the year 2021?

1—Not at all ☐	2—Slightly ☐	3—Moderately ☐	4—Very ☐	5—Extremely ☐

2. In accordance with the relevant EU Green Public Procurement criterion, the body should supply at least 50% of the heat consumed from renewable or cogeneration sources (e.g. district heating). To what extent do you consider that your body fulfilled this criterion for the year 2021?

1—Not at all ☐	2—Slightly ☐	3—Moderately ☐	4—Very ☐	5—Extremely ☐

3. [2]In accordance with the relevant EU Green Public Procurement criterion, energy suppliers should generate a minimum percentage from renewable sources. To what extent do you consider that your body gives bonus (procurement) points to suppliers that produce a higher percentage of energy from renewable sources?

1—Not at all ☐	2—Slightly ☐	3—Moderately ☐	4—Very ☐	5—Extremely ☐

4. In accordance with the relevant EU Green Public Procurement criterion, if the supplier offers energy/heat from at least two different sources (Photovoltaic, Wind, Geothermal, Aerothermal, Hydro, Biomass), it is rewarded with a corresponding multiplication of bonus points. To what extent is your organization considered to have fulfilled this criterion for the year 2021?

1—Not at all ☐	2—Slightly ☐	3—Moderately ☐	4—Very ☐	5—Extremely ☐

B) Waste water infrastructure

5. [3]In accordance with the relevant EU Green Public Procurement criterion, for the construction of wastewater treatment plants, sewerage and treatment systems, reduced consumption of energy, water and/or chemicals must be included as a subsidized criterion. To what extent do you consider that your body has fulfilled this criterion over the last four years?

[1] Purchase of at least 50% electricity from renewable energy sources (RES-E) and/or high efficiency cogeneration.

[2] Additional points will be awarded in proportion to the electricity to be supplied from renewable energy sources above the minimum requirement in the specification.

[3] Construction and/or operation of waste water treatment plants, sewage systems and sludge treatment plants with reduced energy, water and chemicals consumption and, possibly, a higher level of waste water treatment than required by law.

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

6. [4]In accordance with the relevant EU Green Public Procurement criterion, the contractors of the projects in question 5, which have prior experience in the construction of wastewater infrastructure with an emphasis on reducing environmental impacts (experience in special sewerage systems, wastewater treatment know-how, etc.), will be rewarded. To what extent do you consider that your organization has fulfilled this criterion during the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

7. [5]In accordance with the relevant EU Green Public Procurement criterion for the renovation and/or operation of wastewater treatment plants, sewerage systems and treatment plants, reduced consumption of energy, water and chemicals is included as a required criterion. To what extent do you consider that your body has fulfilled this criterion over the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

8. [6]In accordance with the relevant EU Green Public Procurement criterion, the selected project contractors in question 7 had to have prior experience in the renovation and/or operation of wastewater treatment plants with a focus on reducing environmental impacts (specific items in sewerage systems, wastewater treatment, etc.). To what extent do you consider that your organization fulfilled this criterion during the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

9. [7]In accordance with the relevant EU Green Public Procurement criterion, for participants of the calls for proposals in questions 5 and 7, if they have specialized experience in Environmental Management, this should be scored as an additional (bonus) criterion. To what extent do you consider that your body has fulfilled this criterion during the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

[4] Experience in construction of waste water infrastructure with focus on reduction of environmental impacts (specific items within sewer systems, waste water treatment and sludge treatment should be specified).

[5] Renovation and/or operation of waste water treatment plants, sewage systems and sludge treatment plants with reduced energy, water and chemicals consumption and, possibly, a higher level of waste water treatment than required by law.

[6] Renovation and/or operation of waste water treatment plants, sewage systems and sludge treatment plants with reduced energy, water and chemicals consumption and, possibly, a higher level of waste water treatment than required by law.

[7] Experience in environmental management of a construction site.

C) Road transport

10. [8]In accordance with the relevant EU Green Public Procurement criterion, relevant procurements for the supply of vehicles or transport services must include a requirement for reduced CO2 emissions (TS1) in the technical specifications of the vehicles. To what extent do you consider that your body has fulfilled this criterion over the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

11. [9]In accordance with the relevant EU Green Public Procurement criterion, the relevant procurements for the supply of vehicles or transport services must include a requirement for reduced emissions of harmful air pollutants (TS2—carbon monoxide, hydrocarbons, nitrous oxide, combined hydrocarbon/ oxide and particulate matter) in the technical specifications of the vehicles. To what extent do you consider that your body has met this criterion over the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

12. [10]In accordance with the relevant EU Green Public Procurement criterion, the relevant procurements for the supply of vehicles or transport services must provide for the supply/use of all-electric (BEV) or hybrid/plug-in hybrid (PHEV) vehicles. To what extent do you consider that your municipality has fulfilled this criterion over the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

13. [11]In accordance with the relevant EU Green Public Procurement criterion, for those procurements about the supply of vehicles or transport services, the supply/use of vehicles that meet or exceed the Euro 6 emission level must be included. To what extent do you consider that your body has fulfilled this criterion over the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

14. [12]In accordance with the relevant EU Green Public Procurement criterion, for those procurements about the supply of vehicles or transport services, the supply/use of

[8] TS1 (CO2 emissions and energy efficiency).

[9] TS2 (Air pollutant emissions).

[10] Natural gas buses and zero-emission capable vehicles, i.e. cars and LCVs able to drive a minimum range of 50 km without emitting any tailpipe emissions, plug-in hybrid electric vehicles (PHEV), battery electric vehicles (BEV) for buses and L-category vehicles, and fuel cell electric vehicles (FCEV) for buses.

[11] Cars and vans that have an emission performance better than Euro 6 standard.

[12] OEM dual-fuel natural gas vehicle with a gas energy ratio over the hot part of the world harmonized transient cycle (WHTC) test-cycle of at least 50%.

dual-fuel (CNG/(LPG)/petrol powered vehicles must be included. To what extent do you consider that your municipality has fulfilled this criterion over the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

D) Road lighting and traffic signals

15. In accordance with the relevant EU Green Public Procurement criterion, the relevant procurements for the supply of lamps include a provision to meet a higher lighting efficiency,[13] compared to the lighting efficiency threshold of 120 lm/w. To what extent do you consider that your body has fulfilled this criterion over the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

16. In accordance with the relevant EU Green Public Procurement criterion, the relevant procurements for the supply of lamps include a provision for the supply of remote-control lamps (allowing for scheduled switch-off during time intervals of low intensity night-time street use). To what extent do you consider that your body has fulfilled this criterion over the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

17. [14]In accordance with the relevant EU Green Public Procurement criterion, the relevant procurements for the supply of lamps include a provision for the supply of minimum adjustable efficiency lamps (allowing for the programming of a reduction of the brightness intensity by at least 50% at distinct time intervals—e.g. during sunrise/sunset periods or certain periods of time when there is a limited amount of light). To what extent do you consider that your municipality has fulfilled this criterion over the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

18. In accordance with the relevant EU Green Public Procurement criterion, the relevant procurements for the supply of integrated lighting systems include a provision for the acquisition of a system for measuring the energy consumption of the lighting system. To what extent do you consider that your body has fulfilled this criterion over the last four years?

[13] Refers to the luminous efficacy factor of a lamp expressed by the amount of luminous flux (lm) delivered by the lamp for each watt of electrical power consumed (lm/W).

[14] TS3 (Minimum dimming performance)—All light sources and luminaires shall be installed with fully functional dimming controls that are programmable to set at least one pre-set level of dimming down to at least 50% of maximum light output.

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

19. In accordance with the relevant EU Green Public Procurement criterion, the relevant procurements for the supply of lighting systems include a provision for the supply of luminaire systems with a power factor not exceeding 0.90.[15] To what extent do you consider that your body has fulfilled this criterion over the last four years?

1—Not at all ☐ 2—Slightly ☐ 3—Moderately ☐ 4—Very ☐ 5—Extremely ☐

Abbreviations

GPP	Green Public Procurement
JTDP	Just Transition Development Programme
EC	European Commission
EU	European Union
RES	Renewable energy sources
ETS	Emissions trading system
EV	Electric vehicle
LPG	Liquefied petroleum gas
CNG	Compressed natural gas
BEV	Battery electric vehicle
PHEV	Plug-in hybrid electric vehicle
LED	Light emitting diode
LCA	Life cycle costing

Acknowledgements
None.

Author contributions
The first author and the third author contributed to data collection and analysis, whereas the second, the third, the fourth and the fifth author contributed to developing, reviewing, and sharpening theoretical contributions.

Funding
This research has been funded by the "Responsible Research and Innovation in Territories" (RRI-LEADERS) project from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006439.

Availability of data and materials
Available upon request.

Declarations

Competing interests
The authors declare that they have no competing interests.

Received: 4 August 2023 Accepted: 24 November 2023
Published online: 08 December 2023

References

Alhola, K., Ryding, S. O., Salmenperä, H., & Busch, N. J. (2019). Exploiting the potential of public procurement: Opportunities for circular economy. *Journal of Industrial Ecology, 23*(1), 96–109. https://doi.org/10.1111/jiec.12770

Aosaf, M. R., Wang, Y., & Du, K. (2022). Comparison of the emission factors of air pollutants from gasoline, CNG, LPG and diesel fueled vehicles at idle speed. *Environmental Pollution, 305*, 119296. https://doi.org/10.1016/j.envpol.2022.119296

[15] TS6 (Power factor)—The power factor for the luminaire to be installed shall be ≥ 0.90. The power factor of the luminaire describes the ratio between the actual and apparent power. Devices with a low power factor increase the losses in the electricity distribution network and the energy cost of the device. This is explained by the fact that these devices require a higher apparent power supply from the grid to meet their energy needs in active power.

Authority, D. B., & Allé, L. (2012, January). The future of eco-innovation: The role of business models in green transformation. OECD/European Commission/Nordic Innovation Joint Workshop: Copenhagen, Denmark. https://www.oecd.org/sti/inno/49537036.pdf

Cheng, W., Appolloni, A., D'Amato, A., & Zhu, Q. (2018). Green public procurement, missing concepts and future trends–a critical review. *Journal of Cleaner Production, 176*, 770–784. https://doi.org/10.1016/j.jclepro.2017.12.027

Demski, C., Poortinga, W., Whitmarsh, L., Bohm, G., Fisher, S., Steg, L., Umit, R., Jokinen, P., & Pohjolainen, P. (2018). National context is a key determinant of energy security concerns across Europe. *Nature Energy, 3*(10), 882–888. https://doi.org/10.1038/s41560-018-0235-8

Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC Text with EEA relevance, (2014), http://data.europa.eu/eli/dir/2014/24/oj

Donatello, S., Rodríguez, R., Quintero, M. G., Ow, J. R. C., Van Tichelen, P., Van, V., & Hoof, T. G. (2019). *Revision of the EU green public procurement criteria for road lighting and traffic signals*. Luxembourg: Publications Office of the European Union.

Dutta, A., Jana, R. K., & Das, D. (2020). Do green investments react to oil price shocks? Implications for sustainable development. *Journal of Cleaner Production, 266*, 121956. https://doi.org/10.1016/j.jclepro.2020.121956

European Commission. (2008). *COM (2008) – 400. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Public procurement for a better environment.* https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52008DC0400&from=EN

European Commission. (2016). *National green public procurement purchasing strategies.* http://ec.europa.eu/environment/gpp/pdf/national_gpp_strategies_en.pdf

European Commission. (2019*). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions:* The European Green Deal. https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

European Commission. (2020). *EU GPP Criteria.* https://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm

European Commission & ICLEI. (2016*). Buying green! A handbook on green public procurement. 3rd Edition.* https://doi.org/10.2779/246106

European Commission. (2021). *Procuring solar vehicle-to-grid (V2G) charging stations for electric vehicles.* GPP In Practice, 104. https://ec.europa.eu/environment/gpp/pdf/news_alert/Issue_104_Case_Study_192_AMB.pdf

Eurostat. (2019). *Electricity prices for household consumers – bi-annual data (from 2007 onwards).* http://ec.europa.eu/eurostat

Eyraud, L., Clements, B., & Wane, A. (2013). Green investment: Trends and determinants. *Energy Policy, 60*, 852–865. https://doi.org/10.1016/j.enpol.2013.04.039

Frondel, M., Sommer, S., & Vance, C. (2015). The burden of Germany's energy transition: An empirical analysis of distributional effects. *Economic Analysis and Policy, 45*, 89–99. https://doi.org/10.1016/j.eap.2015.01.004

George, D., & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference. 11.0 update* (4th ed.). Allyn & Bacon.

Gunasekaran, A., Subramanian, N., & Rahman, S. (2015). Green supply chain collaboration and incentives: Current trends and future directions. *Transportation Research Part E: Logistics and Transportation Review, 74*, 1–10. https://doi.org/10.1016/j.tre.2015.01.002

Hawkins, T. R., Gausen, O. M., & Strømman, A. H. (2012). Environmental impacts of hybrid and electric vehicles—a review. *The International Journal of Life Cycle Assessment, 17*(8), 997–1014. https://doi.org/10.1007/s11367-012-0440-9

Hellenic Ministry of the Environment and Energy. (2019). *National Energy and Climate Plan.* OECD publishing. https://energy.ec.europa.eu/system/files/2020-03/el_final_necp_main_en_0.pdf

Horbach, J., Rammer, C., & Rennings, K. (2012). Determinants of eco-innovations by type of environmental impact—the role of regulatory push/pull, technology push and market pull. *Ecological Economics, 78*, 112–122. https://doi.org/10.1016/j.ecolecon.2012.04.005

IEA. (2019). *Clean energy transitions: Accelerating innovation beyond 2020.* Paris: IEA. License: CC BY 4.0. https://www.iea.org/reports/clean-energy-transitions-accelerating-innovation-beyond-2020

Kaldellis, J. K., Zafirakis, D., & Kondili, E. (2009). Contribution of lignite in the Greek electricity generation: Review and future prospects. *Fuel, 88*(3), 475–489. https://doi.org/10.1016/j.fuel.2008.09.021

Kilintzis, P., Samara, E., Carayannis, E. G., & Bakouros, Y. (2020). Business model innovation in Greece: Its effect on organizational sustainability. *Journal of the Knowledge Economy, 11*, 949–967. https://doi.org/10.1007/s13132-019-0583-z

Lee, B. X., Kjaerulf, F., Turner, S., Cohen, L., Donnelly, P. D., Muggah, R., & Gilligan, J. (2016). Transforming our world: implementing the 2030 agenda through sustainable development goal indicators. *Journal of Public Health Policy, 37*, 13–31. https://doi.org/10.1057/s41271-016-0002-7

Markard, J. (2018). The next phase of the energy transition and its implications for research and policy. *Nature Energy, 3*(8), 628–633. https://doi.org/10.1038/s41560-018-0171-7

Martinez Romera, B., & Caranta, R. (2017). EU public procurement law: purchasing beyond price in the age of climate change. *European Procurement & Public Private Partnership Law Review, 12*(3), 281–292. https://doi.org/10.21552/epppl/2017/3/10

Nerlinger, M., & Utz, S. (2022). The impact of the Russia-Ukraine conflict on the green energy transition–A capital market perspective. *Swiss Finance Institute Research Paper,* (22–49). https://doi.org/10.2139/ssrn.4132666

Neuhoff, K., Bach, S., Diekmann, J., Beznoska, M., & El-Laboudy, T. (2013). Distributional effects of energy transition: impacts of renewable electricity support in Germany. *Economics of Energy & Environmental Policy, 2*(1), 41–54.

Papież, M., Śmiech, S., & Frodyma, K. (2018). Determinants of renewable energy development in the EU countries. A 20-year perspective. *Renewable and Sustainable Energy Reviews, 91*, 918–934. https://doi.org/10.1016/j.rser.2018.04.075

Pérez, M. D. L. E. M., Scholten, D., & Stegen, K. S. (2019). The multi-speed energy transition in Europe: Opportunities and challenges for EU energy security. *Energy Strategy Reviews, 26*, 100415. https://doi.org/10.1016/j.esr.2019.100415

Pouikli, K. (2021, January). Towards mandatory Green Public Procurement (GPP) requirements under the EU Green Deal: reconsidering the role of public procurement as an environmental policy tool. In *ERA Forum* (Vol. 21, No. 4, pp. 699–721). Berlin/Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/s12027-020-00635-5

Rainville, A. (2017). Standards in green public procurement–a framework to enhance innovation. *Journal of Cleaner Production, 167*, 1029–1037. https://doi.org/10.1016/j.jclepro.2016.10.088

Raslavičius, L., Keršys, A., Mockus, S., Keršienė, N., & Starevičius, M. (2014). Liquefied petroleum gas (LPG) as a medium-term option in the transition to sustainable fuels and transport. *Renewable and Sustainable Energy Reviews, 32*, 513–525. https://doi.org/10.1016/j.rser.2014.01.052

Rüdenauer, I., Dross, M., Eberle, U., Gensch, C. O., Graulich, K., Hünecke, K., Tepper, P. (2007). Costs and Benefits of Green Public Procurement in Europe. *General Recommendations. Freiburg: report on behalf of DG Environment (http://ec. europa. eu/environment/gpp/pdf/eu_recommendations. pdf , accessed December 1, 2008)*, *49*.

SDAM. (2021). *Just Transition Development Programme 2021–2027.* https://www.sdam.gr/node/306

Tagliapietra, S., Zachmann, G., Edenhofer, O., Galant, J. M., Linares, P., & Loeschel, A. (2019). The European union energy transition: Key priorities for the next five years. *Energy Policy, 132*, 950–954. https://doi.org/10.1016/j.enpol.2019.06.060

Testa, F., Grappio, P., Gusmerotti, N. M., Iraldo, F., & Frey, M. (2016). Examining green public procurement using content analysis: Existing difficulties for procurers and useful recommendations. *Environment, Development and Sustainability, 18*(1), 197–219. https://doi.org/10.1007/s10668-015-9634-1

Tranoulidis, A., Sotiropoulou, R. E. P., Bithas, K., & Tagaris, E. (2022). Decarbonization and transition to the post-lignite era: Analysis for a sustainable transition in the region of Western Macedonia. *Sustainability, 14*(16), 10173. https://doi.org/10.3390/su141610173

Vatikiotis, L. (2021). Energy Poverty in Small and Medium Enterprises in Greece. *desinged by: Giannis Misentzis*.

Witjes, S., & Lozano, R. (2016). Towards a more circular economy: Proposing a framework linking sustainable public procurement and sustainable business models. *Resources, Conservation and Recycling, 112*, 37–44. https://doi.org/10.1016/j.resconrec.2016.04.015

Yu, C., Morotomi, T., & Yu, H. (2020). What influences adoption of green award criteria in a public contract? An empirical analysis of 2018 European public procurement contract award notices. *Sustainability, 12*(3), 1261. https://doi.org/10.3390/su12031261

Zabala-Iturriagagoitia, J. M. (2022). Fostering regional innovation, entrepreneurship and growth through public procurement. *Small Business Economics, 58*(2), 1205–1222. https://doi.org/10.1007/s11187-021-00466-9

Publisher's Note