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Mining Transition and Hydropower Energy in Greece—Sustainable Governance of Water Resources Management in a Post-Lignite Era: The Case of Western Macedonia, Greece

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Abstract: The present study explores the process of Greece's current decarbonisation transition and its energy policy regarding the country's two coal-mining areas. Using the Region of Western Macedonia as a case study, we aimed at providing a holistic approach—as until now only few attempts have been made to systematise the 'Just Transition Plans' in European Union (EU)—for raising awareness on issues related to water resource management in post-lignite areas and analysing the use of hydropower in Greece. Our research draws on a flexible method approach, serving as a tool to identify gaps in current knowledge and practices, based on two stages—first the analysis of existing literature, reviews, and sources from government's core strategies, as well as policy and decision-making papers, and then formulating research questions by synthesising relevant data. In Greece, both 'Just Transition Development Plan of Lignite Areas' and hydropower production practices overlook water resources management. By summarising our findings and identifying gaps that remain in current approaches, this work indicates future directions by suggesting processes necessary for addressing the complex issue of adoption of sustainable water resources management measures in post-lignite eras in accordance with EU's water policy.

Keywords: water management; post-lignite era; hydropower energy; innovation and international business; renewable energy resources

1. Introduction

The Europe 2020 strategy set out a package of three key targets to ensure that the EU meets its climate and energy targets of the Paris Agreement on Climate Change [1]. These targets are (a) 20% reduction in greenhouse gas (GHG) emissions (relative to 1990 levels), (b) 20% of EU energy to be produced from renewable sources, and (c) 20% improvement in energy efficiency [2]. Brown and Sovacool [3] noted that energy and development, on the one hand, and carbon and growth, on the other, do not remain tightly coupled even though electricity is the largest source of aggregate greenhouse gas emissions. They provided evidence from eight case studies that succeeded to reduce emissions of greenhouse gases, maintain economic growth, preserve the natural environment, and meet the challenges of climate change and energy security.

Large-scale extractive activities have widespread impacts on mining areas that require a multidimensional approach in order to maintain sustainability and keep net zero in reach.

In 'De re mettalica', the authoritative text on mining for more than 100 years, Georgius Agricola observed that the biggest criticism on mining regarded the harmful environmental impacts and that water used for mining destroyed aquatic life [4]. Mining activities cause also dramatic changes to the landscape associated with open cast mining and open-pit mining, and Le Cain [5] considered exploitation as a "mass destruction" as both mining and weapons rose from the same suspect technological and moral logic. Scholars have pointed out the socio-environmental (in)justice of mining activities based on testimonies of people from locally affected communities that live with the fear of loss of their crops, their houses, or potable water and eventually become landless [6]. This, in turn, may give rise to conflicts further fuelled by the possible restrictions of communal rights of democratic participation in decision making over land use and resource policies and working conditions [7].

Local communities and environmental groups may support different interests that could lead to conflicts between those who support the benefits of mine operation in a region and those who fear the potential impacts and costs [8]. Horowitz et.al. [9] examined the environmental, economic, and social impacts of mining activities and stated that surface environmental pollution through waste dumps and pits, and atmosphere pollution through dust emissions are direct and indirect impacts related to extractive processes, in addition to waterways pollution through toxic chemicals and heavy metals.

The power sector is the largest industrial water user, and all operations of mining directly or indirectly require water for their functioning. The operation of the Public Power Corporation (PPC) power plants requires enormous amounts of water to provide cooling and other process-related activities. Studies [10] have shown that cooling technologies are the leading water withdrawers and thermoelectric power plants boil water to create steam, which then spins turbines to generate electricity. Furthermore, mining operations can also have a severe impact on surface and groundwater water supplies, as huge quantities of solid waste, mainly overburden and rejects, are hazardous by-products of mining activities [11], and hydro-morphological factors, land use, and seasonality stream discharge affect mine water pollution of surface waters. Byrne et al. have provided a critical synthesis of scientific literature related to ecological and hydrological impacts of metal mining on aquatic ecosystems and highlighted the role of sediments in the storage and recycling of metal contaminants [12].

The transition from lignite to hydropower and other renewable resources will contribute to Europe 2020 strategy targets. According to Newell and Mulvaney [13], the call for a 'just transition' is often directed to states. Governments will have to play a key role to transition to lower-carbon forms of energy production and consumption and to take decisions and assess options between different energy sources in an equitable manner. Sustainable energy is therefore becoming a policy priority for many countries. However, transition to hydropower will inevitably lead to the transformation of labour or productive subjectivity of the working class at a national level—a challenge that remains to be addressed in order to preserve the structural integrity and sustainability of local communities [14]. Authorities now also need to consider water resource management and preserving water quality and quantity, which has become an increasingly critical area as the climate changes [15]. Furthermore, countries must face the severe impacts of both, mining operations and coal-fired power plants in the water supplies, involving contamination of nearby rivers, lakes, and aquifers with metals and acids.

The use of water to generate power, as a renewable source of energy, goes back centuries, with water wheels being used since the times of ancient Greece. Urban water management in ancient Greece resulted in many constructions. During oligarchic periods the emphasis was on the construction of large-scale hydraulic projects. In Greece, the first dam was built in ancient Alyzia (between 1st and 5th century BC) [16,17] which was constructed in distinct stages aiming to reduce the coarse sediments of the Varnakas stream deposited on the cultivated Mytikas plain. In communist countries, hydropower was fundamental for industrialisation and as a part of a new model of agriculture policy.

Lenin's vision of modernisation was based on electricity development as a basic feature of socialist development [18].

Today, hydropower plants are contributing towards European Union (EU) energy targets for 2020–2030 playing an important role in the implementation of the Renewable Energy Directive (RES) and CO_2 emissions reduction as they contribute less air pollution than power plants. Demand for power continues to grow globally, together with pressures for use of RES in order to address the environmental and socio-political consequences of mining emissions to climate change. Besides mines, dams are also infrastructure projects that affect livelihoods, health, and the environment [19]. Dams can also produce environmental impacts on sustainability and climate change, and sometimes, the hydropower's carbon footprint is not better than fossil fuels, especially in tropical climates [20]. Additionally, hydropower plants have many negative environmental effects on biodiversity, river flows, and aquatic communities, in addition to social costs as they cause changes in river morphology and riverine habitats [21].

Studies regarding mining activities and hydropower energy focus mostly on environmental, social, and economic costs and benefits. Hydropower systems provide cheap energy, water resources for irrigation, industrialisation opportunities, improvement of navigation, and, at the international level, the commitment of neighbouring states to develop friendly relations, as Cretan and Vesalon analysed for the case of Iron Gates [18]. Nevertheless, costs of transboundary hydropower are another significant factor for study as most scholars focus on water management and allocation and do not assess the distribution of transboundary hydropower benefits and effects [21].

EU policy for climate action and environmental-related challenges requires that each local economy dependent on lignite activity must take measures in accordance with the European Green Deal [22] to counter the long-term impacts of mining activities. Countries shift towards low carbon energy sources, and it is important to ensure a fair global 'just transition' socially and environmentally sustainable. According to a previous study, neither research nor a critical academic review has been conducted examining the closure plans of mining [23]. Although some attention has been paid to failures of past closures and mine abandonments, not much has been proposed about just transition development plans and water resources management in EU's post-lignite areas. Until now, only a few studies have been undertaken to systematise the just transition plans around EU and especially the plan for Greek lignite mines.

This study addresses this research gap combining data from studies regarding water resources management, hydropower energy [24–28], and the post-lignite era in Greece [29–31] with a special focus on the Region of Western Macedonia. In our research, we have chosen to include available data for different time periods concerning Western Macedonia, which is the largest energy hub in Greece, and analysed the 'Just Transition Development Plan—Master Plan of Lignite Areas' which was published in 2020.

Although the environmental effects of mining have received scholar's attention, there is an increasing need for the adaptation of legal and policy environmental tools suitable for monitoring post-mining landscapes. In order to frame this study, we developed three guiding questions: (a) How does Greece implement its own energy policy with regard to the development of hydropower? (b) What are the inadequacies of the just transition development plan of the Greek government as far as it considers the water resources management at the Region of Western Macedonia? (c) What are the challenges related to the implementation of WFD to achieve good water quality in water bodies at a post-lignite area in Western Macedonia, Greece?

At the EU level, Water Framework Directive 2000/60 (WFD) sets environmental objectives considering economic development, protection of inland surface waters transitional waters, coastal waters, and groundwaters (Article 1), and geographic and climatic conditions. WFD is the key point of the institutional framework of the third phase of EU water resources management, and its purpose is to establish an integrated management policy for all water resources in relation to previous directives dealing with the issue fragmentally and individually [32]. The directive promotes sustainable water use based by protecting available water resources, ensuring the progressive reduction of pollution of groundwater, preventing its further pollution, and aiming to enhanced protection and improvement of the aquatic environment, inter alia.

2. Methodology

Our research draws on a flexible method approach, serving as a tool to identify gaps in current knowledge and practices, based on two stages: first analysis of existing literature, reviews and sources from government's core strategies, policy and decision-making papers, and then formulating research questions by synthesising relevant data. We conducted an extensive review of the extant literature by consulting primary academic and legal databases. In searching grey literature, we adopted a modified strategy plan, as previously described [33]. Therefore, we used (a) grey literature databases, (b) customised Google searches, anf (c) targeted websites. More specifically, we compiled articles, reports, conference proceedings, and statistical data from international and EU authorities, agencies, and institutions. We further sourced data from governmental bodies in Greece, including the Ministry of Environment, Public Power Company (PPC), and Greek Committee on Large Dams, as well as stakeholders' policy documents.

We then analysed data on Greek hydropower production, definitions of WFD, and Greek legislation on water resources protection, as well as available data for the transition policy in Greece towards a climate-neutral economy, including the 'Just Transition Development Plan of Lignite Areas' in Greece. More specifically, we attempted to systematically evaluate and synthesise current knowledge and challenges related to water protection, hydro energy production, and long-term impacts of mining activities on environmental parameters, especially water resources, before and after the mine closures, in order to (a) identify gaps in transition policies, (b) reflect on certain issues raised by implementing sustainable water management, (c) formulate specific questions on the deficits of water and energy policy in Greece, and (d) propose particular classes of interventions to be delivered in the post-lignite era.

The paper is structured as follows: the first part is a literature review of major international, European, and Greek studies in the field of post-mining transition and hydropower. The second part is the methodological approach adopted in the study, while the third part presents the results of our data analysis for Greek Hydropower production, the data of the chemical and quantitative status of groundwater at lignite areas hydrological systems, definitions of the Water Framework Directive, and Greek legislation on water resources protection. The fourth part discusses the challenges to ensure a detailed roadmap regarding the attainment of specific energy and climate objectives by 2030 and faces the conflicts between hydropower utilisation and water protection in a post-lignite era. The approach that we developed is organised in four steps: (1) the case study of the Region of Western, (2) hydroelectric power generation in Greece (Section 3.2), (3) transition of lignite regions towards a climate-neutral economy (Section 3.3), and (4) sustainable Governance of water resources management in the post-lignite era of Western Macedonia, Greece (Section 3.4).

Figure 1 shows the sources of total energy installed capacity in Greece from 1990 to 2019. In 2019, natural gas was the largest contributor to energy generation, surpassing coal in 2018, and there is a downward trend in oil, which started in 2008 and stabilised in 2010 at lower levels, and lignite began to fall gradually from 2005 onwards. Hydroelectric power showed constant fluctuations and a relatively stable central trend from 2000 to and 2019. Biofuels and waste are at almost zero levels, with a small weak increase in 2018. According to the National Energy and Climate Plan (NECP), lignite-fuelled energy is expected to reach 0% in 2028.

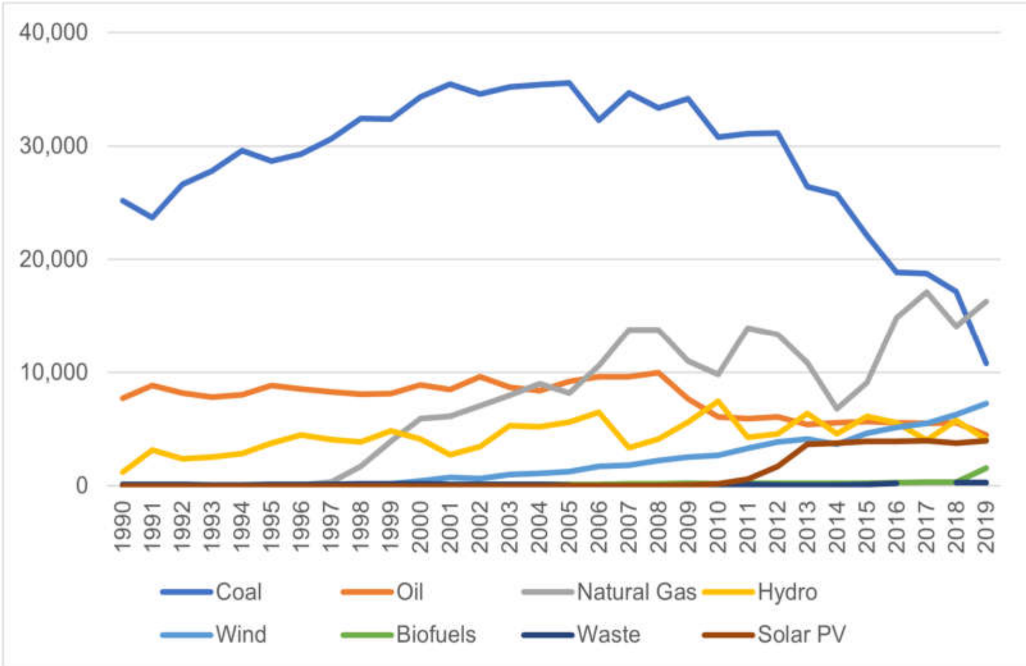

Figure 1. Electricity generation by Source in Greece 1990–2019. Source of data: International Energy Agency (https://www.iea.org/ accessed on 10 September 2020).

3. Case study Analysis

3.1. The Region of Western Macedonia

In Greece, the energy industry relies on lignite mining of the regions of Western Macedonia and Central Peloponnese. The Region of Western Macedonia is used as a case study to understand the impact of just transition policy to an energy hub of national importance. This area was chosen for the current study for several reasons: (a) its main exploitable lignite deposits reserve 1.8 billion tons, followed by the Drama area with 900 million tons and the area of Elassona with 169 million tons; (b) currently, there are four lignite steam power plants (TPPs) in operation, as the LIPTOL and Ptolemaida power stations have already closed; (c) hydropower operating facilities in the region consists of four large hydroelectric power plants (Polifitos, Sfikia, Asomata, and Ag. Varvara) that comprise the hydro generation complex of Aliakmonas, one pending activation (Ilarionas), and four hydroelectric stations of the Public Power Corporation (Makrichori, Vermio, Agra, Edeseos), as well as several small hydroelectric power stations.

The Greek government decided to withdraw, by 2028, all lignite plants of the country by implementing the Just Development Transition Plan (JDTP), a comprehensive multi-dimensional development roadmap for the Region of Western Macedonia and the Municipality of Megalopolis in Central Peloponnese. As a result of the activity of the energy sector in Western Macedonia, the region steadily participates in the country's GDP with a percentage ranging from 2.0 to 2.5% of total national income and did not exhibit the same downward trend as the national GDP during the past decade's economic crisis.

It is already pointed out that water pollution of mining and declining of water levels in mines due to drainage can threaten aquifers and have vital effects on rivers, agriculture, drinking water, and ecosystems due to the abundance of heavy metals and suspended solids. Industrial activity, with 205 industrial and artisanal units, in the River Basin District of Western Macedonia has strong negative consequences for climate change [34], water bodies, and environment, and therefore, 23 surface water bodies are recorded as sensitive concerning urban wastewater treatment.

3.2. Hydroelectric Power Generation in Greece

Into 2019, hydropower-based electricity production provided approximately 23% of renewable energy (renewable energy sources include wind, hydroelectric, solar, biofuels and waste). According to data analysed in Figure 1, the share of hydroelectric-powered energy remains steady, whilst wind and solar energy production show an increasing trend.

The total installed capacity in Greece for 2019 is 48,742 GWh. This is made up of coal/lignite (10,805 GWh), oil (4471 GWh), natural gas (16,303 GWh), hydroelectric power (4059 GWh), wind energy (7278 GWh), biofuels (1579 GWh), waste incineration (0.29 GWh) and solar photovoltaic (3961 GWh). This shows that hydroelectric accounts for 8.4% of the total installed capacity in Greece. Table 1 shows that the production of hydroelectric energy comes from 24 PCC dams [35].

Table 1. List of large Greek dams for the purpose of electricity generation based on data of Hellenic Committee of large dams.

	Name	Year of Construction	Construction Operator	Height	District or Country
1	Agia Varvara	2007	PPC-DEI	20	Imathia
2	Asomata	1985	PPC-DEI	52	Imathia
3	Dafnozonara	2010	TERNA ENERGIAKI	28	Aitoloakarnania
4	Thisavros	1996	PPC-DEI	172	Drama
5	Ilarionas	2012	PPC-DEI	130	Kozani
6	Kastraki	1969	PPC-DEI	96	Aitoloakarnania
7	Kremastra	1965	PPC-DEI	165	Aitoloakarnania
8	Ladonas	1955	PPC-DEI	56	Arkadia
9	Louros	1954	PPC-DEI	22	Preveza
10	Mesovouno	2009	Prefecture of Kozani	32	Kozani
11	Mesoxora	2009	PPC-DEI	150	Trikala
12	Metsovitikos	2011	PPC-DEI	11	Ioannina
13	Piges Aoou	1999	PPC-DEI	78	Ioannina
14	Platanovrysi	1998	PPC-DEI	95	Drama
15	Polifitou	112	PPC-DEI	112	Kozani
16	Pournari	1981	PPC-DEI	87	Arta
17	Pournari ii	1998	PPC-DEI	15	Arta
18	Pramoritsa	2007	Prefecture of Kozani	57	Kozani
19	Sisaniou	2006	Prefecture of Kozani	35	Kozani
20	Smokobo	1996	MRPBUD [1]	109	Karditsa
21	Stratos	1988	PPC-DEI	26	Aitoloakarnania
22	Sikia	2013	MRPBUD [1]	170	Trikala-Karditsa
23	Sfikia	1985	PPC-DEI	82	Imathia
24	Tayropos	2006	PPC-DEI	83	Karditsa

[1] Ministry of Regional Planning, Building and Urban Development.

Besides these dams, there are many other dams that serve irrigation and water supply which were constructed by the Ministry of Agriculture such as dams Apo, Akkias Rhodes (1989), Lefkogion Drama (1994), Doxa Feneou Korinthias (1996), and Livadiou Astypalea (1997).

3.3. Transition of Lignite Regions, towards a Climate-Neutral Economy

According to the OECD [36], the most important characteristics of climate policy to achieve climate goals include a stable climate and low-carbon innovation policies with regulatory support, research and development, and a sufficiently high price on carbon to make climate-neutral investment competitive. Assaad Ghazouani et al. [37] concluded that environmental and carbon tax regulations that are adopted in developed nations have a positive and significant impact on stimulating the reduction of carbon emissions. However, the impact of tax regulations on social welfare has a significant cost, and relying only on carbon taxes cannot be an effective policy tool for nations in a post-lignite era [38].

The Just Transition Mechanism and the Just Transition Fund (JTF) were established by the EU to ensure the gradual transition to a climate-neutral economy. The main milestones of this process include a minimum 50% reduction of carbon emissions by 2030 [39] and reduction of gas emissions from 80% to 9% by 2050, as compared to 1990 levels [40]. According to EU policy, all lignite areas must prepare, in line with their National Energy and Climate Plan (NECP), a territorial just transition plan as a pre-condition to utilise related EU funds and the tools of Just Transition Mechanism.

In November 2019, the Ministry of Environment in Greece drafted a National Energy and Climate Plan (NECP) which incorporates policy measures to terminate all lignite-fired power plants currently in operation by 2023, thereby reducing the share of lignite in power generation by 2028. As part of the NECP strategy, the Greek government adopted the 'Just Transition Development Plan—Master Plan of Lignite Areas' [41] which includes eight sections and is based on five development pillars as follows: clean energy, industry and trade, smart agricultural production, sustainable tourism, and technology and education. The strategy also includes directing investments towards photovoltaic parks, green hydrogen production, energy storage, waste processing, and healthcare services to create more jobs following strict implementation timelines.

The 'Just Transition Development Plan—Master Plan of Lignite Areas' [41] has also set targets for electricity generation from RES units till 2030 (Table 2). Greece has adopted EU legislation and taken supportive measures, gradually planning to increase the share of RES in final energy consumption to 38.1 TWh. Renewable energy usage rates are increased every 2 years, and by 2030, it is expected to surpass 2020 figures by two times. Hydro energy, in 2030, is expected to account for 6.4 TWh, which is a 0.9 TWh increase in 10 years.

Table 2. Electricity generation from renewable energy sources units in TWh.

RES Units	2020	2022	2025	2027	2030
Biomass and Biogas	0.4	0.5	0.8	1.0	1.6
Hydroelectric	5.5	6.2	6.3	6.3	6.4
Wind	7.2	10.0	12.5	14.3	17.1
Photovoltaic	4.6	6.3	8.5	10.0	12.1
Solar thermal stations	-	-	0.3	0.3	0.3
Geothermal	-	-	-	0.3	0.6
Total	17.7	23.0	28.4	32.2	38.1

A SWOT analysis conducted by the Greek Ministry of Environment and Energy as part of the 'Regional Strategy towards to the transition process of Western Macedonia', despite its limitations, identified the following as the most important weaknesses of the region: (a) local economy's high dependence on the lignite industry activities and fur industry, against other economic activities; (b) low development of innovation and research by local enterprises; (c) country's highest unemployment rate, especially in ages of 18–25; (d) lack of foreign investments [42].

However, the 'Just Transition Development Plan of Lignite Areas' overlooks water resources management in the context of lignite areas restoration and/or as a key element of planned large-scale investments at the region (industrial electric power parks, battery factory, and a large hydroponics unit). At the Region of Western Macedonia, as the economic development of the region is mainly dependent on mining industrial activities, water resources until recently faced growing pressure due to the operation of four lignite-fired power plants. The total confirmed lignite reserves account for 5 billion tons, mostly resourced in the Region of Western Macedonia (1.8 billion tons Ptolemaida, Amynteo, and Florina), followed by Eastern Macedonia (900 tons Drama) and Megalopolis in the Peloponnese (223 million tons).

3.4. Sustainable Governance of Water Resources Management in Post-Lignite Era of Western Macedonia, Greece

EUs' institutional framework of water resources management and protection was developed in three phases. The Water Framework Directive 2000/60 is the main tool of the third phase as it incorporates a more coherent policy and explicitly determines for the first time, the scope of the new legal framework for the protection of surface water, as well as transitional, coastal, and groundwater (Article 1) [43]. The main environmental objectives of the directive are to achieve 'good ecological and good chemical status' for surface water bodies in general and 'good ecological potential' as status for heavily modified or artificial water bodies, by 2015. WFD also requires the reduction and ultimate elimination of priority hazardous substances and the reduction of priority substances below the set quality standards.

According to No 23 of Article 2, 'Heavily modified water body, means a body of surface water which as a result of physical alterations by human activity is substantially changed in character, as designated by the Member State in accordance with the provisions of Annex II.' 'Member States may designate a body of surface water as artificial or heavily modified, when, based on Article 4 paragraph 3 a) the changes to the hydro-morphological characteristics of that body which would be necessary for achieving good ecological status would have significant adverse effects on activities for the purposes of which water is stored, such as drinking-water supply, power generation or irrigation.'

According to Article 4.7 of WFD, exemptions can be approved by the authorities for new modifications and sustainable human development activities that result in the deterioration of the status of the water body or that prevent the achievement of good ecological status potential or good groundwater status under certain conditions. This potentially includes new developments related to hydropower [44]. According to these provisions, all hydropower installations and projects are subject to environmental provisions of WFD to ensure their sustainability.

There are many environmental regulations and directives that have a complementary role to WFD regarding water resource protection, restoration of Europe's freshwater ecosystems, as well as design, construction, and operation of hydropower installations. Hydropower must conform to the requirements of WFD in addition to legal obligations that are laid down in the Nature Directives (92/43/EEC—preservation of natural habitats and the flora and fauna therein, the EU flora, fauna and habitat (FFH) directive, 79/409/EEC— bird protection), the Floods Directive (Directive 2007/60/EC), Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal market (RES-E Directive), 2001/77/EC (furtherance of renewable energy development), and 2003/35/EC (environmental impact assessments for specific projects) [45].

The harmonisation of Greek legislation with the Community Framework Directive 2000/60 / EC was achieved by the introduction of Law 3199/2003 on 'Water Protection and Management–Harmonisation with Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000', the Presidential Decree 51/2007 (Government Gazette 54/A/08.03.2007), and the Joint Ministerial Decision 146896/2014 (Government Gazette B' 2878), 'Categories of licenses for the use and execution of water utilisation projects. Procedure and conditions for issuing licenses, their content and duration and other relevant provisions.'

According to the recommendatory report for Law 3199/2003 on water protection and management, the main objectives are the following:

- Long-term protection of water resources, prevention of deterioration, protection and restoration/remediation of degraded water resources and wetlands;
- Reduction and, in cases, elimination of harmful and polluting effluents;
- Reduction of groundwater pollution and the prevention of its further deterioration as well as the mitigation of the effects of floods and droughts.

Article 10 of the law describes the different water uses and main sources utilisations prioritising irrigation, energy, and industrial use, as well as for recreational purposes over any other use. This article also makes the sole reference to the entire legislative text on the usage of water for the critical sector of energy production in Greece [46]. In relation to hydropower-generated electricity and water resources protection, Article 4(3) of WFD states that member States may designate a body of surface water as artificial or heavily modified when the changes to hydro-morphological characteristics of that body have significant adverse effects on achieving good ecological status. Heavily modified water bodies result from physical alterations, caused by human activities, that substantially change their main characteristics and cannot, therefore, meet 'good ecological status' (GES).

Greece has classified heavily modified water bodies (HMWBs) in accordance with the guidelines of the European Commission and the provisions of WFD implementing an early-stage identification of heavily modified water bodies and the measures need to achieve good status of the water body. The definitive decision of whether a water body is heavily modified or not is yet to be resolved. Therefore, management plans for river basins in Greek districts set the 'good ecological potential' as an environmental objective for HMWBs and artificial water bodies (AWBs) [47].

Law 3199/03 has also incorporated the 'polluter pays principle' and the 'good ecological status or potential' for all water resources and has provided a detailed identification of 13 river basin districts (RBDs) according to the administrative units of the country. Regarding the development of the river basin management plans, 'Special Secretariat for Water' which is the national competent authority, is responsible for the coordination of water management issues; implementation of WFD; monitoring of water quality and quantity; management and reuse of wastewater; floods management according to the Presidential Decree 24/2010 OJ A 56/15.04.2010 and Law 3199/2003 [48]. At the regional level, 7 decentralised administrations and 13 self-governed regions are identified as competent authorities with shared responsibilities.

Data of the first and second updates of the River Basin Management Plan (RBMP) of Western Macedonia River Basin District (GR09) [49] show that the operation of mining power plants has negative externalities on the status, hydrological regime, and quality of surface water and groundwater. The most impacts on water resources of the WMR include (a) quantitative pressures resulting from water abstraction for power plant activities, (b) qualitative pressures due to mining industrial wastewater, and (c) hydro-morphological pressures associated with changes to drainage areas to the beds and margins of watercourses and estuaries. Table 3 depicts the chemical and quantitative status and the main pressures at groundwater hydrological systems within the lignite areas of Western Macedonia.

Greek government's post-lignite 'Just Transition Development Plan' for the Region of Western Macedonia, as described in Section 3.2, should have incorporated all measures that are drawn up at the RBMP in accordance with the requirements of the Water Framework Directive 2000/60 and current Greek legislation. On the contrary, no references are present for restoring both surface water and groundwater bodies. Moreover, the development of a supplementary hydrological master plan as part of the Just Transition Development Plan is obligatory.

Table 3. Chemical and quantitative status of groundwater at lignite areas hydrological systems.

N	Name of Groundwater Hydrological System (Lignite Areas)	Chemical Status	Quantitative Status	Main Pressures
1	Amyntaion	Good	Bad	Agriculture Industry (PPC)
2	Substation. Ptolemaidas	Bad	Bad	Agriculture Industry (PPC)
3	Substation. South Pedio or Sarigiol	Bad	Bad	Agriculture Industry (PPC)
4	Substation Karioxoriou–Kleitous–Tetralofou.	Bad	Bad	Agriculture Industry (PPC)
5	Aridaias	Good	Good	Industry (PPC) Livestock Urban Waste Water Poultry
6	Nymfaion–Blastis	Good	Good	Agriculture Industry (PPC)
7	Perdikka–Filota	Good	Bad	Agriculture Industry (PPC)
8	Mesoellinikis Aylakas	Good	Good	Agriculture Industry (PPC)

4. Discussion

EU has set an ambitious and, at the same time, binding target of 32% for renewable energy sources in its energy mix by 2030 [50]. According to Greece's NCEP, as shown in Table 2, this goal is meant to be achieved by 2030. Despite that Greece has a low share of hydropower, as compared to other EU countries, total hydro energy generation approximates EUs' average of 12% (Table 4). In central and south-eastern Europe, including Greece, there is considerable potential for the construction of hydropower investments, as opposed to other EU countries that despite their high-water reserves, building new hydropower plants is considered unprofitable. Moreover, each country has a different potential for developing RES and cooperation that will benefit liberalisation and internationalisation of local markets [51].

According to data from the International Hydropower Association (IHA) [52], coal and gas remain the country's main energy sources; however, as national strategic planning dictates, Greece is to meet its obligations as an EU member state. As far as the development of hydropower plants is considered, Greece will be forced to face, numerous challenges such as the location of hydropower plants in naturally valuable areas, different hydrographic conditions, conflicts arising from social, economic, and environmental interests, specific requirements for the implementation of EU policy and insufficient financial resources [51].

Table 4 represents hydroelectric energy share in the energy mix of European countries. The largest percentage is observed in Albania, where energy supplies come entirely from hydroelectric power, followed by Norway with 96%. The last places are occupied by Hungary (1%), Poland (2%) and the United Kingdom (2%).

Water management associated with hydropower production is regulated by WFD and national legislation. Potential issues related to maintaining economic viability and ensuring good ecological status between hydropower utilisation and water protection, remain to be addressed. The transition from the general provisions of the directive to its implementation in HMWB is a particularly difficult task as ambiguities and questions continuously arise through legislation implementation feedback. Prompt planning and adaptation of measures deriving from WFD provisions on good ecological potential and HMWB could minimise the environmental impacts of hydropower use. However, legislation provisions and strict implementation of the WFD may cause potential conflicts with hydropower industries due to bureaucracy, decreasing revenues, cost inflation, and reduction of HP production.

Table 4. Ranking of European Countries by hydro percentage in total energy production. Source of data: IHA 2018.

Country	Electricity Generation			
	Hydro [GWh]	Total [GWh]	Hydro/Total %	Main Energy Source
European Union (28)	38,018	3,253,125	12%	Nuclear, Coal, Gas
Albania	7782	7782	100%	Hydro
Norway	144,005	149,333	96%	Hydro
Iceland	13,471	1855	73%	Hydro
Austria	42,919	68,336	63%	Hydro
Switzerland	36,689	63,172	58%	Hydro, Nuclear
Sweden	62,137	156,01	40%	Nuclear, Hydro
North Macedonia	1897	5629	34%	Coal, Hydro
Bosnia and Herzegovina	5641	17,767	32%	Coal, Hydro
Serbia	11,521	39,342	29%	Coal, Hydro
Portugal	16,909	60,28	28%	Hydro, Coal, Gas, Wind
Romania	18,536	65,103	28%	Hydro, Goal, Nuclear, Gas
Turkey	67,231	273,695	25%	Coal, Gas, Hydro
Slovak Republic	4606	26,934	17%	Nuclear, Hydro, Coal
Russia	18,664	1,090,973	17%	Gas, Nuclear, Coal, Hydro
Spain	39,865	274,671	15%	Nuclear, Gas, Wind
Italy	44,257	289,032	15%	Gas, Hydro, Coal
France	64,889	555,621	12%	Nuclear
Greece	5565	54,438	10%	Coal, Gas
Bulgaria	4568	45,243	10%	Coal, Nuclear
Ukraine	9304	164,494	6%	Nuclear, Coal
Germany	26,135	647,231	4%	Coal, Gas, Nuclear, Wind
United Kingdom	8354	339,399	2%	Gas, Nuclear
Poland	2322	166,568	2%	Coal
Hungary	259	37,781	1%	Nuclear

The main dilemma is whether to use water to produce renewable energy or to protect water resources and achieve good ecological potential according to WFD requirements. Understanding the linkages between the natural and socio-economic systems of hydropower electricity production can lead to improved and more sustainable management of ecosystems [53]. Hydropower, among other RES, is crucial in any transition towards low carbon energy solutions, but Greece's 'Just Transition Development Plan—master Plan of Lignite Areas' has set an inadequate target for hydro energy. There is a need for a new policy era in relation to hydropower to address global challenges of climate change by facilitating the incorporation and expansion of RES [54]. Given the lack of relevant assessment methods sensitive to hydro-morphological modifications, Greece still defines good ecological potential as equal to good ecological status. However, this is implausible from the point of view of WFD [55].

There are many advantages of hydroelectric power in comparison with other energy sources, namely, (a) it does not produce air pollutants and noise; (b) it is a 'clean' and renewable energy source saving foreign exchange and natural resources; (c) it is an inexhaustible source of energy that helps to reduce dependence on conventional energy resources; (d) reservoirs may meet needs related to water supply, irrigation, and leisure; (e) despite their high construction costs, most of the times the energy output absorbs this cost [56]. On the other hand, costly and time-consuming completion of dams and environmental alterations in the reservoir (possible movement of populations, degradation of areas, change in land use, in the flora and fauna of areas and the local climate, increase of seismic risk, etc.) are some of the disadvantages of hydropower production. This analysis showed that studying the benefits versus the costs of hydropower energy and the use of other renewable resources formulate the energy policy agenda setting of countries [21].

WFD is an appropriate instrument for a consistent European water policy taking into account the need for economic development in its purpose 'to promote sustainable water use' (Art. 1). WFD aims to strike a balance between environmental, climate, and socio-economic goals, and it should not hamper the operation or development of hydropower plants. Although it is beyond the scope of this study to analyse the benefits of hydropower, there is no doubt that most hydropower plants are part of the energy strategy for long-term climate protection and sustainable water management and a tool to achieve renewable targets.

The conflict between water resource protection, the good ecological potential of water, and hydropower production in Greece remains. Based on the information submitted in the report on the implementation of the Water Framework Directive by Greece in late 2014, "*. . . .the water uses that are linked to the water bodies designated as HMWB as well as the types of physical modifications leading to the designation are mentioned briefly in most but not all RBDs, with differences regarding the way relevant information is presented in each group of RBMPs."* Even though WFD provides regulation against economic interests of hydropower production installations, the lack of data (hydro-morphological, physicochemical, biological) in Greece makes river basin management, planning of measures, and establishing of monitoring systems for heavily modified surface water almost impossible. In Greece's report on WFD implementation, uncertainties are mentioned in general in most RBDs concerning the HMWB/AWB designation process, due to the lack of relevant monitoring data [57]. In general, the way the WFD has been implemented in practice has received major criticism from scientists, politicians, and policymakers in the EU [28,58,59].

5. Conclusions

This study highlights the necessity of inclusion of water resources management according to the EU policy in the just transition policy of Greece, but the findings may be relevant to all post-mining areas that have to implement the WFD. It further demonstrates that even planning of specific environmental interventions, such as mining rehabilitation, has to follow the principles of the integrated European environmental policy. In order to fulfil this goal, the Greek government should consider a master plan for the restoration and protection of surface water and groundwater at mining areas in Western Macedonia—a region having approximately 65% of the country's surface water potential. This plan has to be designed in accordance with both current national and European legislation to address RBMP priorities in Western Macedonia and enhance the public participation of local stakeholders. Effective public participation, from the agenda-setting stage until the final implementation, is an integral component of any strategy aimed to manage the most difficult environmental and socio-economic objectives [60]. The Greek government will implement planning of the national energy systems preparing comprehensive reports of renewable energy sources and balancing costs and benefits [51].

Water and energy are key factors for every economy. This study concludes that Greece is facing multiple challenges to the development of RES during the transition to a post-lignite era. Mutual cooperation between stakeholders, authorities, policymakers, and the public is mandatory to achieve sustainable development in accordance with EU energy and water policy. All the factors analysed in this study are dynamic since Greece is taking measures to meet climate and energy targets. In the future, we are planning to address the challenges by using modelling tools such as alternative scenarios of water management in the post-lignite area in accordance with the 'Just Transition Development Plan—master Plan of Lignite Areas' and the first and second updates of the River Basin Management Plan (RBMP) of Western Macedonia River Basin District (GR09).

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