Climate change impacts on the Greek mining industry: perceptions and attitudes among mining industry practitioners operating in the Mediterranean islands of Cyclades.

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Abstract
The extractive industry plays an important role in Greece's economy. Nevertheless, in the years to come Greek mining enterprises may face economic losses from climate change. This study aims, for the first time, to explore perceptions and attitudes of Greek mining practitioners towards climate change and to investigate existing and foreseeing adaptation and mitigation actions. To this end, a bottom-up survey by means of face-to-face interviews was conducted, involving all operating mines in Cyclades area, Greece. According to the results, mining enterprises are already experiencing negative impacts due to extreme weather events. The major vulnerabilities are related to the management of excess rainwater, strong winds, and high or low temperatures. Nevertheless, adaptation actions are not systematic or are not always labeled as such, while mitigation actions are mostly implemented for improving energy efficiency and achieving better economic outcomes. Even though the mining sector perceives climate change as a threat to its activities, it has not invested the necessary resources for adapting to future climate. Further, scientific knowledge of the phenomenon is limited among mining practitioners. To this end, governments and institutional stakeholders should promote climate change awareness and disseminate successful adaptation actions so as to increase future resilience of the mining sector.
Keywords: mining sector; climate change; perceptions; attitudes

1. Introduction

Working Group I of the Intergovernmental Panel on Climate Change (IPCC) declares in its Fifth Assessment Report (AR5) that the observed climate changes attributed to human activities are related to snow melting and reduced snow cover, permafrost thaw, air temperature increase, more frequent temperature extremes, droughts increase, frequency increase of intense precipitation, flooding, hurricanes, tornadoes and other extreme weather events, sea level rise and more frequent wildfires [1]. These phenomena affect the mining sector in many ways.
Intense rainfall negatively affects mine geomorphology and drainage causing among others: stability problems to mine benches, waste disposal areas and tailing dams; overflow of ponds, dams, reservoirs, ditches and culverts; damage or loss of machinery and equipment; damage to haul roads; operations disruptions and personnel risk injury [2–9]. On the other hand, prolonged droughts may adversely affect mine water withdrawals and exacerbate water use pressures to water-intensive processes [6,10–12], causing increased irrigation needs for the rehabilitation works and more frequent wildfires which could threaten mine equipment or assets [13,14]. Increased temperature with decreased rainfall may impact hydro-dependent mines [13], as well as water-dependent mine tailings facilities [15]. Extreme high temperatures may negatively affect the mining industry by declining productivity and rational decision making along with increased personnel absenteeism and risk of heat-related illnesses like malaria [11–13]. Moreover, temperature rise in the high latitudes induces permafrost thaw causing infrastructure static problems and shrinkage of the operational ice road season, which increases arctic mines transportation costs [16–19]. Extremely windy and rainy conditions could lead to toxic wastes overtopping or uncontrolled discharges from tailing dams [8,15] and problems to electric power generation and transmission, causing a significant risk to mining companies [13,14]. Finally, sea level rise and storm surges may affect port facilities leading to supply chain disruptions [12,13,20–22]. These climate change implications have significant economic impacts on the mining industry. For instance, the Diavik's diamond mine in Canada's Northwest Territories suffered an extra transportation cost of CAD11.25m by the shortened ice road season, in 2006 [17]. In 2008, floods cost to Ensham coal mine in Central Queensland, Australia, around AUD300m and several months of lost production [7]. Further, the devastating floods of January 2011 in eastern Australia caused serious disruptions to 45 out of 57 Queensland's coal mines and resulted in a 32% drop of Australia's metallurgical coal export for 2011's Q1 or around AUD2.5b loss of export earnings [23,24]. Further, Damigos [2] performed top-down research for assessing the impacts of climate change in the Greek mining sector and estimated that Greece's mining industry could face economic losses from climate change as high as USD0.8 billion. Nevertheless, it is worth mentioning the fact that many companies

tend to hide past adverse climate change impacts because top management is afraid of investors, a possible market share drop or even damage to company's public image [11]. Of course, there are certain occasions where climate change may be advantageous for the mining sector. One such is in arctic environments where expected temperature rise and reduced snow coverage could increase all year round opportunities for prospecting, operations and shipping [12,13,26–28].

As Ford et al. [16] note, the scientific community has alarmed the mining sector for possible climate-related impacts since 2000. Yet, public pressure and strict Carbon Tax schemes pushed mining companies towards mitigation strategies only. This mitigation-focused strategy prevailed on the first position statement for climate change of the institutional stakeholder International Council on Mining & Metals (ICMM), in 2006 [29], but changed a few years later prompting mining companies for adaptation actions [30,31].

Following Ford's et al. [16] argument regarding climate change, that, perceptions and behaviors or actions are interlinked, several scientific efforts worldwide have been accomplished trying to answer how the mining sector perceives, experiences and responds to climate change. To this direction, the Canadian mining sector's vulnerability to climate change as well as the perceptions, attitudes, adaptation and mitigation strategies of Canadian mining practitioners have been extensively studied [17–19,32]. Similar research efforts regarding climate change-related impacts, adaptation strategies, perceptions, and future expectations have been conducted in Australia [7,8,33–35].

The present work aims to add to the above-mentioned scientific literature by drawing information about the impacts of the changing climate to the Greek mining sector. More specifically, the survey, using a bottom-up approach, explores the perceptions and attitudes of Greek mining practitioners about the present (perceived) and future (anticipated) climate-related impacts and examines undertaken or scheduled adaptation and mitigation actions. The rest of the paper is structured as follows. Section 2 describes the research approach. Section 3 presents the results of the survey. Finally, Section 4 discusses the main findings and the conclusions drawn from the survey.

2. Methodology

2.1 Study area

According to Moustakas *et al.* [40], the Greek mining sector plays an important role in worldwide mineral production. Several hundred business entities across the country produce bauxite, nickel, caustic calcined magnesite, marble, perlite, bentonite, pumice, and lignite [36]. Greece is the leading bentonite producer in Europe and the world's leading producer of unexpanded perlite. Although the past three decades revealed a decreasing sectoral significance to the national economy, mining still contributes 3.4% of the Greek Gross Domestic Product (GDP) with €6.2b [37]. Mining is also an important source of direct investment and employment as well as an economic pillar for local economies and regional development [37].

The research focuses in particular on the Region of Cyclades, where there are numerous mining companies operating for decades. In terms of mineral products, Cyclades demonstrate an impressive mining activity for major mineral commodities like perlite, bentonite, kaolin, pozzolan, silicate, and zeolite (extracted in the islands of Milos and Kimolos), marble (in Tinos, Naxos, and Paros), as well as shale slabs and aggregates. To wit, the most important deposits of bentonite and perlite are located in Milos Island allowing an annual export of almost 1.5 million tons of bentonite and perlite from a sole producer [38]. In terms of size, operating mining companies range from micro-sized single-person Limited Liability Companies, family-type businesses with small production and an annual turnover of few thousand euros, up to large multinational corporations listed on international stock exchanges with hundreds of personnel, millions of tons of annual production and turnover of hundreds of millions of euros. These characteristics allow drawing conclusions about the effects of climate change on the Greek mining industry for a wide variety of companies.

2.2 Survey design

In order to collect the required information a survey questionnaire was created, including both closed and open-ended questions, which was administered via face-to-face semi-structured interviews to selected key practitioners of all the companies located in the study area. A list of all the extractive enterprises operating in the Cyclades islands was provided by the Prefecture of South Aegean. More specifically, at the end of 2012, eight, seven, five and three mining companies were operating in Naxos, Milos, Tinos, and Paros islands, respectively. Further, two mining companies operated in each of Kea and Sifnos islands and one in each of Kimolos, Kythnos and Syros islands. According to European Union's (EU) definition of small and medium-sized enterprises (SMEs) [39] and depending on company's headcount, 25 of those 30 companies are considered micro-sized, 4 small-sized and 1 is considered Large Enterprise. It is noted that there are companies, operating on more than one islands, as well as

companies that have mining activities outside the Cyclades complex. Finally, there are companies that have many activities on the same island, i.e. many active quarries, multiple operations, and different mineral commodities.
The survey questionnaire was divided into three distinct sections. The first section explored the current climate change vulnerability. The scope was to investigate whether the mining companies of the sample have been someway affected in the past by climatic events, and to collect useful data on the cost of impacts and of potential adaptation measures. In more detail, question 1 investigated whether mining companies have been affected by climate-related events and to what extent. Participants were provided with a list of harsh phenomena that affect Greece according to Giannakopoulos *et al.* [43]. Question 2 explored the vulnerability of mining activities from the indicated phenomena, and question 3 collected quantitative data for each of the indicated phenomena (e.g. incident frequency, cost of impacts upon the occurrence, cost of taken adaptation measures, etc.).
The second section aimed at investigating awareness, attitudes, perceptions, and beliefs of the respondents about changes in the local climate during the past 10-20 years and for the next 20-30 years. In particular, question 4 examined the knowledge of global climate change and its consequences. Question 5 explored past climate change awareness, asking respondents to report observed changes in the local climate, if any, in terms of intensity, frequency, duration, etc. The climatic events under consideration were wind, droughts, rainfall and snowfall, and temperature. Questions 6 and 7 asked respondents to express their beliefs about the potential impact of future climate change on their activities. Questions 8, 8a and 8b examined adaptation perceptions, past or scheduled adaptation measures, adaptation strategies and adaptation barriers. Following, questions 9, 9a and 9b examined mitigation attitudes, past or scheduled mitigation measures and mitigation drivers. Questions 10 to 12 documented participants' attitudes and perceptions about the significance of climate change and the vulnerability of their operations and facilities to climate change using a series of closed-ended questions. Finally, the third section included a set of demographic questions.
Upon completion of the design of the questionnaire, pilot pre-testing sessions took place with mining practitioners to assess the clarity and appropriateness of each question.

2.3 Survey administration and analysis

The data collection began in February 2014 and was completed in August 2014. As mentioned, the survey population included thirty mining companies operating in the Cyclades islands. Each company was contacted by telephone and after an explanation of the scope of the survey, an appointment was set with the selected practitioner(s). In total, 41 mining practitioners were interviewed by 30 companies. More specifically, in family-type businesses, only one person, namely the owner who's also the decision maker, was interviewed. In larger companies and companies with operations in more than one island, more than one people (e.g. production managers, financial managers, etc.) were interviewed. The interviews were conducted at the premises of each company. The average interview time was about one hour.
Data collected were entered into a database and then transferred to statistical software for further analysis. Univariate and bivariate statistical analyses were conducted to provide a summary of the data collected from the survey and to determine the potential empirical relationship between critical variables. Given the relatively small sample size, Fisher's exact tests were performed to examine the significance of the association between variables of interests instead of chi-squared tests.

3. Results

3.1 Sample characteristics

Table 1 summarizes the main characteristics of the surveyed companies. The average age of the respondents is about 49 years old, ranging from 30 up to 80 years old. More particularly, 36% of the respondents are under 40 years old, 47% are between 41 and 60 and 17% are above 60 years old. The average work experience of the respondents is 25 years (16% up to 10 years, 16% between 10 and 15 years, 40% between 16 and 30 years, and 28% more than 30 years), indicating the participation of practitioners with great experience in the mining sector. Furthermore, the majority of the respondents are well-educated with more than 60% having completed tertiary education, while 22% of the respondents had minimal primary education. More than half of the respondents (56%) were owners of the mining company, 29% were mine engineers, responsible for the day-to-day operation of the mine and the rest had an executive role (e.g. mine planning manager, processing manager, operation manager, etc.).

Table 1 *Characteristics of the surveyed companies*

Mine/quarry location	**N (%)**
Island	
Kea	2 (5)
Kimolos	2 (5)
Kithnos	1 (2)
Milos	16 (39)
Naxos	9 (22)
Paros	3 (7)
Sifnos	2 (5)
Syros	1 (2)
Tinos	5 (12)
Mineral commodity	
Aggregates and shale slabs	15 (37)
Industrial minerals	18 (44)
Marble	8 (19)
Company size	
Micro i.e. below 10 persons	25 (60)
Small – sized	8 (20)
Large	8 (20)

3.2 Key results

3.2.1 Exposure to climatic events

Cyclades mining companies are vulnerable to climate-induced extreme events. Among the 41 survey respondents, 34 (81% of the total respondents) replied that heavy rainfall and storms have negatively affected their business (Fig. 1). Moreover, 31 respondents (76%) said that they are affected by extreme, stormy winds, 21 (51%) by heat waves during the summer season and 12 (29%) by cold spells during the winter season. It was found that heat waves were positively correlated with respondent's age (p = 0.033) and work experience (p = 0.028) and cold spells answers were correlated with work experience (p = 0.011). There were no other significant associations with demographic characteristics. The experienced impacts of the reported phenomena were assessed by 70% of the respondents to be moderately or highly affecting their operations. On the contrary, 10% of the interviewees reported not being affected. The severity of past impacts was found to be correlated with the size of the company (p = 0.006). The latter may indicate that the size of the company affects the degree of awareness of its personnel.

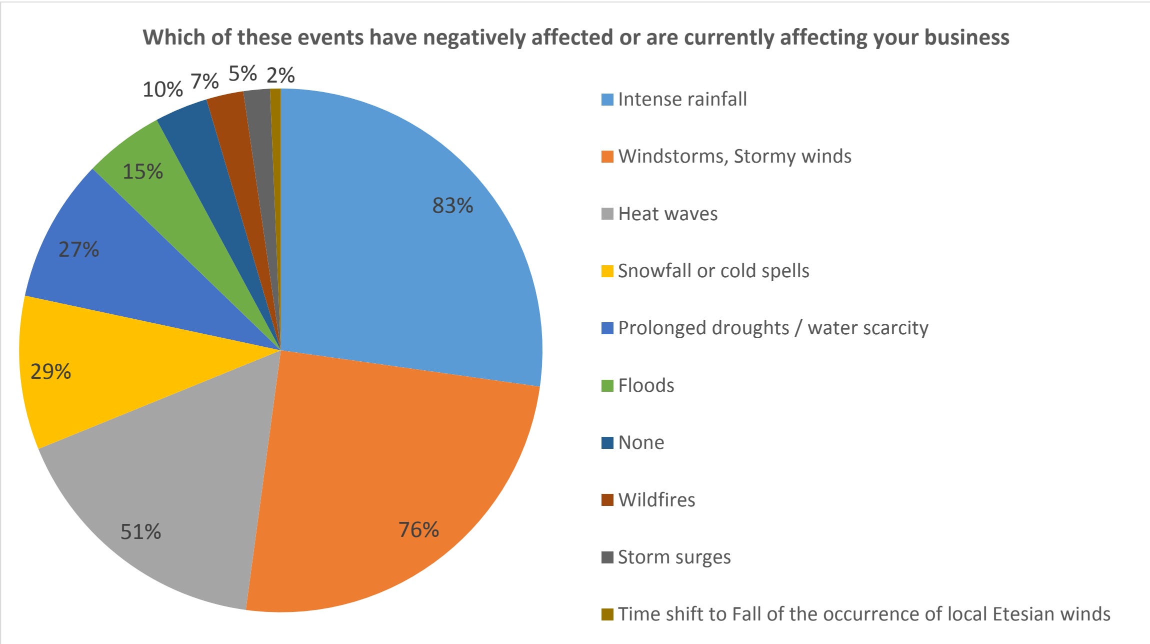

Figure 1 *Respondents' answers relating to experienced climate-related events*

3.2.2 Climate-induced events frequency, vulnerability, and cost

On average, respondents reported an annual frequency of 12 days of intense rainfalls and 31 days with extremely windy weather. Furthermore, the practitioners reported 9 days with extremely high temperatures and 6 days with extremely low temperatures, on an annual basis. Vulnerabilities include bench stability problems, damages to mining infrastructures, haul roads, culverts, machinery, equipment, ports and other facilities, loss of semi-finished products and destruction of rehabilitated areas. Furthermore, climate-induced extreme events cause delays and even total disruptions in certain operations or value chains. Some practitioners stated that in certain cases of extremely intense events, these disruptions led to the total suspension of all operations for several days. These impacts cause a significant cost to the surveyed mining companies. For example, based on the estimates provided by several participants, the average annual cost of impacts from intense rainfalls ranges from €50k for small companies up to €150k for large corporations with multiple mine sites and intense mining activity and the respective cost from windstorms ranges from €35k up to €115k for small and large companies, accordingly.

3.2.3 Scientific knowledge, past climate change awareness, future climate change perceptions and attitudes

Following the most recent AR5 findings [1], one could argue that an integrated scientific knowledge about global climate change and its impacts should comprise the following distinct concepts: (i) increase of average temperature of the planet or global warming or greenhouse effect; (ii) extreme weather events; (iii) sea level rise or glacial retreat; (iv) greenhouse gases or carbon dioxide; and (v) drought or desertification or rainfall decrease. The answers regarding the scientific knowledge of climate change of the surveyed Greek practitioners, revealed that 17 interviewees (42%) were able to state at maximum only one of the above five concepts, 10 respondents (24%) stated only two of the above concepts and 34% of the respondents could identify three or more of the above concepts. Climate change knowledge was found to be associated with past events ($p = 0.006$) and education level ($p = 0.019$). Further, associations were found between climate change scientific knowledge and respondent's age ($p = 0.009$) and experience ($p = 0.041$), and the size of the company ($p = 0.002$).

Regarding respondents' observation about local changes of climate during the past 10-20 years, 45 distinct responses were stated by 23 practitioners (Fig. 2). The most reported climatic event was the temperature increase (18%), followed by rainfall intensity increase (13%), draught frequency increase, rainfall frequency decrease and rainfall variability increase (all representing equally the 9% of responses). The respondents of older age ($p = 0.039$) and with higher work experience ($p = 0.009$) recalled more climatic events. In fact, 20 out of the 23 interviewees had more than 16 years of working experience in the mining sector. There were no other significant relationships between perceived local climate change and other respondent characteristics.

The beliefs and expectations about future climate change impacts are divided. In particular, 39% of the respondents (16 out of 41 respondents) believe that they will be negatively affected, while the same proportion believes that they will not be affected at all. Interestingly, 9 respondents (i.e. about 22%) expect to take advantage of climate change due to milder winters that will allow increased operating time and reduced operating costs in the drying process (Table 2). The main reason triggering pessimistic beliefs about future climate change is practitioners' experiences by past adverse climatic events. Those who have a neutral or optimistic stance believe that changes in future climate will have none or insignificant impact on the mining activities (11 respondents or 27%) and that the small size of their operations will prevent them from getting harmed (9 respondents or 22%). It is noteworthy that respondents from large size operations were found to believe that future climate change will affect them positively ($p = 0.005$). Regarding the significance of the impacts, only 5 out of 41 respondents (12%) said that future climate change impacts are expected to be highly significant. Interestingly, 3 out of those 5 respondents believe that climate change will be advantageous for their company. The majority of the respondents (i.e. 41%) expect a moderate significance. Finally, 11 respondents (i.e. 27%) believe that the impacts will be of low significance and the rest (8 respondents or 20%) expect insignificant impacts. There were no significant associations between beliefs and expectations and respondents characteristics.

The participants were shown a scenario of projected climate changes and were asked to identify if those changes would affect their operations and to indicate which aspects of operations they believed that would be most impacted. The most harmful climate regime changes for the mining sector were related to extreme rainfalls and extreme winds followed by heat waves. The most susceptible aspects of mine operations are mine quarrying, operations management (scheduling), road networks, machinery and equipment operations, waste and rehabilitation management and loading/unloading processes. Those findings of susceptibility to projected changes are quite similar to those reported in the first section of the survey regarding past climate-induced events. This indicates that mining practitioners shape their beliefs mainly, not to say solely, by their past experiences. Or,

inversely, the past experiences define in a tremendous way their beliefs and expectations, a finding common in other similar studies [32].
Almost all of the respondents would like to know more about the mid-21st-century climate, its impacts on their companies and available adaptation options with their associated costs. Those who are more interested in this information are more likely to be of higher age ($p = 0.036$). Furthermore, scientific research on the impacts of climate change on the mining sector is moderately and strongly desired by 34% and 46% of the respondents, respectively. The respondents seeking more research have been more seriously impacted by adverse climatic events in the past ($p = 0.013$) and believe future climate change will affect them negatively ($p = 0.037$).

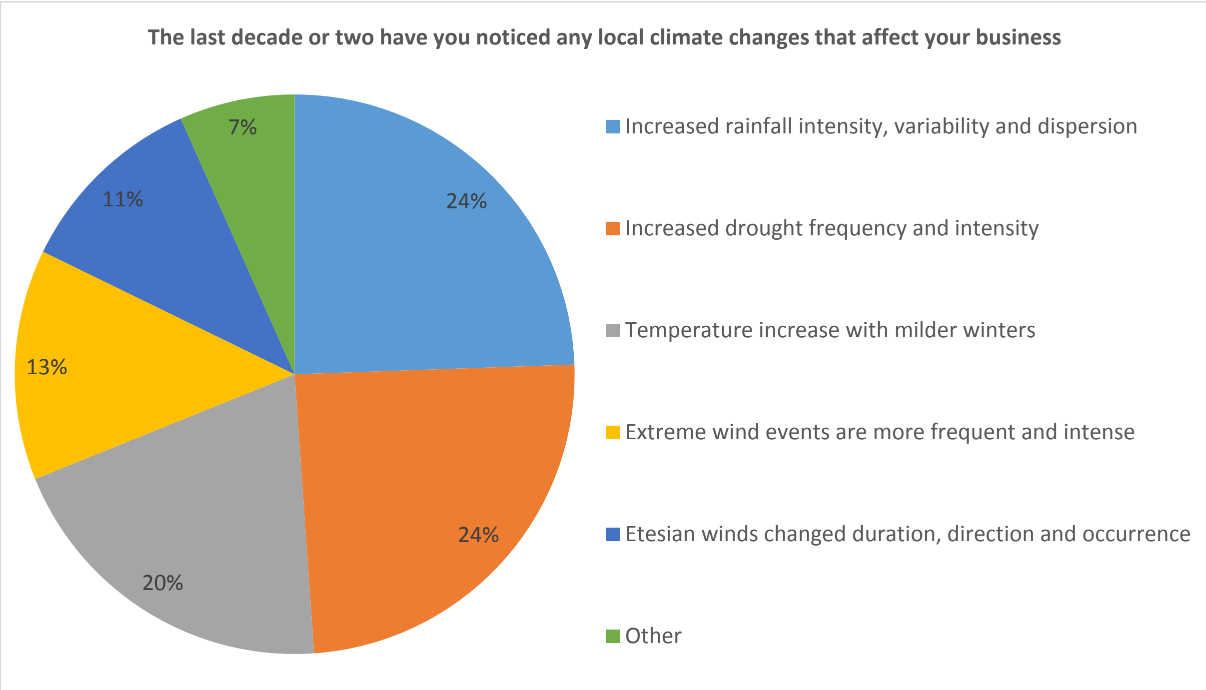

Figure 2 *Respondents' answers relating to observed local changes in climate*

3.2.4 Climate change adaptation measures, strategies, and barriers

Surveyed mining practitioners were asked to state if they have taken or plan to take adaptation measures and the reasons for doing so. Only 10 participants (24%) stated that they have already taken adaptation actions against the impacts of climate change. Absence of past adverse climate change impacts and ignorance about the phenomenon were the most common reasons for the lack of measures.
Those who reported that their companies have taken measures to adapt to climate change were additionally asked to characterize the nature of the measures as well as to identify the most common adaptation barriers. The most mentioned adaptation responses were related to engineering measures e.g. construction of culverts, drainage systems, pumping stations and anti-lightning systems, construction of new storage facilities, structural strengthening of ship loading facilities, haul road enhancements, etc. Three respondents (Table 2) mentioned behavioral measures e.g. cleaning of forests and moving of machinery and heavy equipment to safer areas before storm events. Finally, four respondents reported technological measures like the planning of a new method for drying minerals. The most common reported adaptation barrier is the cost of adaptation (38%) followed by the financial uncertainty (25%) and the uncertainty about climate change impacts (17%). Respondents also reported institutional uncertainty, short mine lifespan, and technological limitations as being reasons of minor significance for constraining adaptation actions (Table 2).

3.2.5 Climate change mitigation actions and mitigation drivers

Almost half of the participants (49%) said that their companies are taking actions to reduce GHGs, while almost the same proportion said the opposite, with ignorance playing the predominant role (89%) for doing so (Table 2). When asked the reasons for choosing to mitigate, the respondents indicated primarily economic reasons (33%), followed by moral (24%) and "obligatory" ones (24%). Interestingly, the economic driver for mitigation actions is a common finding in relevant studies, worldwide [19]. Among the respondents whose companies make efforts to reduce climate GHGs, the most common strategy for mitigating climate change (cited by 15 out of 20 practitioners, representing 52% of total strategies) was the energy efficiency increase, either by replacing old machinery and equipment with newer one, or by introducing heat exchangers for reducing wasted energy from exhausts. Other strategies implemented include the use of Renewables (28%), carbon capture technologies (17%) and outsourcing of emission-intensive activities. Mitigation actions were found to be correlated with the mineral commodity (p = 0.007), the size of the company (p = 0.000), the educational level of the respondent (p = 0.016) and his professional relation with the company (p = 0.005).

Table 2 *Cyclades mining sector survey selected responses*

Questions	**Respondents, *N* (%)**
Q6. Do you believe future climate change will affect your activities and how (*n* = 41)	
Yes, negatively. Frequent adverse effects, like increased rainfalls or heat waves, increase costs and harm business.	16 (39)
No, I will not be affected because climate changes are insignificant and the nature, size, volumes and mine life span of my company are such that cannot be affected	16 (39)
Yes, positively. Increased temperatures and more mild winters increase operating time and reduce operating costs affecting us positively	9 (22)
Q8. Did you take or plan to take in the near future (next 5-10 years) any adaptation measures and why (*n* = 41)	
Yes, for reversing negative impacts	3 (7)
Yes, proactively and for prevention reasons	3 (7)
Yes, for reasons of competitiveness, sustainability or efficiency	4 (10)
No, for not being affected	12 (29)
No, because of ignorance	12 (29)
No, for economic reasons	4 (10)
No, for uncertainty reasons	2 (5)
No, for taking advantage of benefits	1 (3)
Q8a. Type of adaptation measures (only those who previously answered positively) (*n* = 17)	
Engineering (e.g. infrastructure strengthening, flood defenses)	8 (53)
Technological (e.g. equipment replacement, changes in methods or characteristics of quarrying and processing)	4 (21)
Behavioral (e.g. more mild slopes, better haul roads drainage, updating engineering design specifications)	3 (21)
Administrative or legal (e.g. insurance against climate risks)	2 (5)
Q8b. Adaptation barriers (only those who previously answered positively) (*n* = 24)	
Adaptation cost	9 (38)
Financial uncertainty due to market fluctuations / overall economy	6 (25)
Uncertainty about climate change impacts	4 (17)
Uncertainty about institutional and regulatory regime framework	2 (8)
Quarry's short lifespan	2 (8)
Technological limitations	1 (4)
Q9. Did you take or plan to take actions to reduce GHGs (*n* = 41)	
Yes	20 (49)
No	19 (46)
Don't know	2 (5)
Q9b. Type of actions to reduce GHGs (only those who take mitigation actions) (*n* = 20)	
Increasing the energy efficiency of infrastructure, machinery, and operations (e.g. in quarrying, buildings, or transportations)	15 (52)
Using renewable power resources (biofuels, solar and wind energy)	8 (28)
Using emissions sequestration technologies (e.g. carbon capture)	5 (17)
Offsetting carbon emissions or purchasing of emissions permits	1 (3)

4. Discussion - Conclusions

Previous research efforts based on top-down estimates show that the Greek mining sector may prove to be sensitive to climate change. This is an issue that deserves attention since the extractive industry plays an important role in Greece's economy, fostering regional development, restraining urbanism and providing stability to its workforce with a year around employment. The present study, as a step forward, aims to measure climate change related perceptions, beliefs, and attitudes of Greek mining practitioners through a bottom-up approach.

The results show that mining enterprises in the study area are threatened by extreme weather events and slow onset events, like temperature increase, precipitation decrease or changes of dominant local weather patterns. The degree of sensitivity varies among companies and depends on factors like company size, mineral product and local characteristics like the extent of mining activities. The above findings are in accordance with relevant Canadian and Australian studies [19,33,34]. Climate-induced phenomena bring an extra cost to mining companies' daily operations. For example, the delayed occurrence of the Etesian wind, best known as Meltemi in the Aegean Sea (Cycladic summer prevailing wind) on September-October, reduces the efficiency of the natural sun-drying process of extracted industrial minerals. The estimated cost, in fuel consumption, for drying the material by artificial means is 560,000€, annually.

The survey also revealed that there is a scientific knowledge deficit on climate change among mining practitioners. This is exacerbated among the owners of small companies despite their multifaceted and critical role for business sustainability. Moreover, many participants believe that future climate change will not affect them negatively. This is interesting if one considers that respondents affiliated mainly with small-sized companies stated that during adverse weather events their operations were suspended for several days. This means that in case of increased demand, some companies will bear an extra burden due to climate change that it has not yet been anticipated. It is also interesting that more than half of the respondents have already noticed and perceived local climate changes. This makes us skeptical about the disassociation between experiences, perceptions, and expectations, an attitude similar to those of Australian mining companies who *"may be inclined to 'forget' their past experience and excessively discount the likely severity of future weather events"* [33].

Adaptation actions have been implemented mainly from companies which have experienced some negative impacts from climate events in the past. The respondents from these companies also believe that future climate change will affect them negatively. This finding coincides with relevant studies in Canada [19,32]. Further, the survey showed that even though practitioners admitted to being repeatedly harmed by previous climate change manifestations, they were reluctant on taking any adaptation measures. This *"adaptation deficit"*, as coined by Ford *et al.* [19], is a common feature of the mining sector worldwide and is the reason behind the International Council on Mining and Metals (ICMM) urge for pro-active rather than reactive adaptation [11,29]. Nevertheless, some survey participants during interviews provided specific examples of adaptive management that worked well in their companies such as: (i) careful designing of slopes when creating haul roads, flat areas, etc. to avoid damages from the water run-offs, (ii) protection of machinery and equipment in a safe areas before the outbreak of predicted extreme weather events, (iii) cleaning of surrounding forest areas before summer period, and (iv) collection, use and reuse of rainwater run-offs. Ford *et al.* [32] mention that many practitioners, as found in the present study, under-report adaptation actions, probably considering these actions as a part of maintaining daily operations.

More than half of the respondents indicated their companies are taking some mitigation actions, like electricity generation outsourcing (which resembles emission transferring) and mass introduction of heat exchangers for harnessing wasted thermal energy from chimneys, a finding observed in other studies, as well [19,32]. This attitude towards mitigation rather than adaptation could be easily explained by the fact that most mitigation measures involve efficiency enhancements, which have a positive outcome on the company's bottom line. Replacing old equipment with new, more efficient and more environmentally friendly one is a win-win strategy of adaptive management, which enhances business' overall resilience, regardless of climate outcomes [41].

It is worth noting that the timing of the survey administration coincided with an extremely politically and financially volatile period in Greece, so notions such as "climate change adaptation" often sounded like a luxury to some striving Greek mining practitioners. In any case, the present study revealed a number of knowledge gaps that present opportunities for future research initiatives. Therefore, the mining community would appreciate scientific efforts to grasp how potential climate change could impact the sector at the mine site level. Furthermore, the mining industry wants scientists to focus their research on adaptation strategies that will be based on robust economic and climatic data. If mining companies embraced these strategies as part of the daily operations, then the sector could be more climate resilient in the future. The role of governments and institutional stakeholders on promoting the above-described agenda is emphasized, along with their responsibility on mainstreaming climate

change awareness and disseminating successful adaptation actions and ways to increase future resilience of the mining sector.
The results of the present study should be interpreted with caution before drawing any conclusions for the Greek mining sector, in general, given that the survey sample was limited to a specific region. Therefore, future research efforts could include a more representative sample, covering the entire Greek territory. Moreover, future research could be complemented with some case studies focused on economic data, in order to derive more robust conclusions on climate change impacts and adaptation options of the national mining sector.

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