resources

MDPI

Article

Perspectives on Closure and Revitalisation of Extraction Sites and Sustainability: A Q-Methodology Study

Stefanie Streit [1,*], Michael Tost [1] and Katharina Gugerell [2]

[1] Chair of Mining Engineering and Mineral Economics, Montanuniversität Leoben, 8700 Leoben, Austria
[2] Institute of Landscape Planning, Department of Landscape, Spatial- and Infrastructure Sciences, University of Natural Resources and Life Sciences, 1180 Vienna, Austria
* Correspondence: stefanie.streit@unileoben.ac.at

Abstract: Closure and revitalisation are essential steps in the life cycle of a mineral extraction site. Proper planning and execution can counteract potential negative impacts caused by extraction activities and allow a positive impact to be left on the post-closure region. Decisions on these steps are not made solely by the extraction company; legislators and the public also exert influence. Different opinions and expectations on closure and revitalisation can lead to tensions between actors. Thus, knowing diverse opinions and expectations and considering them in planning contributes to a successful implementation of measures. Using Q-methodology in a study focused on selected EIT RIS countries, we identified five viewpoints on the closure and revitalisation of an extraction site. The statements for this study have been developed based on international and company standards for closure and revitalisation, namely ICMM, IRMA, AngloAmerican and Rio Tinto, which we then also used for comparison in order to see how they relate to the five resulting viewpoints. Across all viewpoints, our results reveal a preference for environmental considerations, followed by social and economic concerns. Even though this paper considers closure and revitalisation separately from mineral extraction, these processes are intertwined. Thus, a sustainable planning and management of the extraction process itself contributes to a successful and sustainable post-closure landscape.

Keywords: mining; mineral extraction; closure and revitalisation; Q-methodology; sustainability; land use

Citation: Streit, S.; Tost, M.; Gugerell, K. Perspectives on Closure and Revitalisation of Extraction Sites and Sustainability: A Q-Methodology Study. *Resources* **2023**, *12*, 23. https://doi.org/10.3390/resources12020023

Academic Editor: Volker Beckmann

Received: 19 December 2022
Revised: 18 January 2023
Accepted: 26 January 2023
Published: 1 February 2023

1. Introduction

Up until the 20th century, it was common practice to abandon extraction sites after mineral extraction ceased, without the company initiating closure and revitalisation measures or addressing environmental consequences and long-term impacts on ecosystem services [1]. Additionally, potential risks for human and social welfare have frequently been ignored in the past [2]. Abandoned sites are the product of inadequate care, planning and regulations [1], but geological, economic, technical and political factors also play a role [1,3]. In many cases, the responsibility for remediating the resulting legacy sites has been delegated to the state and public [4]. There are thousands of abandoned sites globally. Well-known examples are the 'Minas de Ríotinto' in southern Spain, where the area is still struggling with acid water [5,6]; the Giant gold mine in the Northwest Territories of Canada, whose clean-up was undertaken by the state after bankruptcy of the company [7,8]; a uranium mine in eastern Germany, operated by Wismut GmbH under Soviet management, whose multi-billion Euro remediation was left to Germany [9]; and the Urgeiriça uranium mine in Portugal, leaving major socio-environmental liabilities after its closure in 2003 [10,11].

This practice has contributed to pressuring the extractive industry to improve its social and environmental performance [12]. As a result, sustainability in the extractive sector has been shifted into the spotlight [13–17], amplified through the United Nations Sustainable Development Goals [18] and Planetary Boundaries [19,20], as well as global and European

climate targets, e.g., the Paris Agreement [21] and European Green Deal [22], including phasing out coal in many countries [23–27].

Once mineral extraction activities have ceased, a site needs to be closed and revitalised, meaning that potential damages caused by extraction have to be remediated and the landscape transformed for a subsequent use [28,29]. Through the closure of an extraction site, the economic and social situation of the surrounding area is directly affected, e.g., loss of employment opportunities and income sources [30]. Especially in areas that have been strongly dependent on extractive industries, closure entails a number of changes and challenges related to degraded landscapes, reduced environmental quality and socio-economic concerns [2]. Typically, the closure phase starts with the restoration of safe conditions to limit risks to humans and the environment [28,29,31–33]. The revitalisation phase aims to stabilise a post-closure landscape from an economic, environmental and social perspective, e.g., ensuring public safety, preventing potential negative environmental and socio-economic impacts, and offering alternative employment opportunities and sources of income, as well as enabling adequate post-closure land uses [2,28,34].

The academic discourse covers different topics in the respective field, including post-closure landscapes in the context of sustainability [2,29,31], closure and revitalisation planning [35–37], environmental restoration [38,39], land-use-based landscape planning [28,33] and social aspects of closure and revitalisation [40–44]. Less attention has been paid to preferences and perspectives of involved actors. While the government sets the ground rules for closure and revitalisation and enforces them, and extractive companies are responsible for planning, implementation and financing, the public can exert a positive or negative impact on such processes [40,43]. Consequently, improved knowledge of actors' perspectives and potential preferences are key to better understanding closure and revitalisation processes and contributing to improved outcomes.

This paper explores actors' perspectives on the closure and revitalisation of an extraction site, with a focus on selected countries of the European Institute of Innovation & Technology (EIT) Regional Innovation Scheme (RIS) [45]. Q-methodology is applied, allowing examination and quantitative analysis of actors' views and positions, i.e., subjective opinions [46]. As a basis for the Q-study statements, international and company standards on closure and revitalisation were used, namely AngloAmerican's Mine Closure Toolbox [47], ICMM's Integrated Mine Closure: Good Practice Guide [48], IRMA's Standard for Responsible Mining [49] and Rio Tinto's Closure Approach [50]. The aim is to analyse how the resulting viewpoints relate to the standards used and to identify aspects of closure and revitalisation that are consistent or controversial across the viewpoints, thus contributing to a better understanding of potential tensions between actors.

2. Background

Extraction sites are closed when mineral reserves are depleted or exhausted, or when it is no longer economically viable to extract due to the costs exceeding market prices [51–53]. As mineral extraction is a finite process and, thus, a temporary land use with significant ecological, social and economic impacts, appropriate closure and revitalisation planning is crucial to avoid, or at least minimise and mitigate, potential adverse impacts [54,55]. Furthermore, an agreed post-closure land use needs to be ensured [56,57]. With the aim to provide a non-polluted post-closure landscape, closure and revitalisation planning has gained more prominence over the past decades [54,55].

While often perceived negatively, post-closure landscapes bear inimitable natural, cultural and economic potential [58]. Various types of post-closure land uses have been identified, such as pastures, aquaculture, wildlife habitats, educational, sport and leisure, and industrial uses [36,59,60]. There are also former extraction sites representing unique habitats that are, therefore, protected as monuments [44,61]. According to Vrablikova, Wildova, and Vrablik [62], the categories of possible subsequent post-closure land uses can be divided into (i) agricultural revitalisation, (ii) forestry revitalisation, (iii) hydrological revitalisation and (iv) all other forms of revitalisation, such as leisure, sport venues, parks,

energy production, education facilities (e.g., technology parks or research centres), tourist areas and landfills, as well as residential and office developments. Determining a suitable post-closure land use is dependent on the basic site characteristics and conditioned by a combination of various economic, social, demographic, cultural, environmental and technical factors [2]. The site's surrounding land use (e.g., infrastructure, forests, water) as well as the extraction site's overall previous impact and extent (e.g., soil contamination) are additional drivers [60,63,64]. Previous studies illustrate the importance of post-extraction land use for potential job creation and employment for a post-extraction brownfield development [28]. Hence, the process of developing an adequate post-extraction landscape requires the integration of different knowledge types, including expert knowledge, knowledge of local representatives and individual actors and administrative knowledge that plays a pivotal role in the overall process and implementation [25,32]. Appropriate investments and revenues from mineral extraction might unfold a positive effect long after the site has been closed, promoting human well-being and generating a sustainable income over time [65]. Mineral wealth can be used as an opportunity to accelerate economic growth and encourage the development of investment and infrastructure [66]. For economies dependent on mineral extraction, it is essential to sustain the benefits of the extraction phase during closure and revitalisation. Failing this, those economies are more likely to experience higher poverty and unemployment rates, as well as slower growth, than economies that have been successful in doing so [67].

Lamb et al. [68] identified two main obstacles facing the revitalisation of extraction sites: (i) fundamental technical difficulties in revitalising highly disturbed ecosystems and landscapes, and (ii) vaguely formulated guidelines that are leading to inconsistent practices across the extractive industry. It is inevitable that the landscape and ecosystem will be altered by the extraction of mineral resources, but this does not necessarily mean negative consequences. When an extraction site is abandoned or inadequately closed, it may continue to degrade the surrounding land, soil, water bodies and air [69]. The revitalisation of areas that have not been purged and remain polluted after closure should be of high interest from a socio-economic, natural conservation and sustainability perspective [25,32]. In these areas, economic and environmental factors of closure are particularly relevant [31,42,62,70].

Thus, the preparation of proper plans for closure and revitalisation is a crucial part of these processes. Based on a review of international guidelines for the closure of extraction sites, three principles for closure planning have been determined [37]: (i) environmental quality protection, (ii) restoration of land to ensure a post-closure land use compatible with local and regional requirements, and (iii) creation of a positive and lasting legacy for the community after closure. Nevertheless, while social and environmental dimensions are mentioned, actual practices show an emphasis on technical and environmental aspects, while socio-economic aspects are mostly neglected [71,72]. The support and involvement of local communities in the development of any site management plans, including closure and revitalisation plans, is essential [41], as they are impacted by both the benefits and drawbacks of closure and revitalisation [44]. Potential negative social impacts of closure and revitalisation can be mitigated or even prevented by involving, consulting and empowering actors from the earliest stage of the planning process, i.e., when planning extraction activities [73]. Moreover, actors can even contribute to the success of the revitalisation itself [40,43]. Involved actors prioritise the revitalisation of a landscape, respecting its ecological, economic and aesthetic values, while striving for sustainable development simultaneously [29].

Closure and revitalisation processes must adequately address environmental changes and impacts from previous stages and restore perturbated ecosystem services and ecological functions. In the past, only little or even no concerns were paid to social aspects and potential risks to humans and the environment [2,34,74,75]. The increasing attention has led to an improved consideration of economic, environmental and social aspects in closure and revitalisation planning [34,76–78]. Nowadays, extractive companies must implement high-quality revitalisation activities after the extraction site has been closed [57].

Beyond this, sustainability aspects are becoming increasingly relevant in long-term post-closure considerations, e.g., to provide adequate and meaningful post-closure landscape strategies [79]. The actual contribution to the sustainability of resource extraction only becomes apparent during and after the phase of closing the site [80].

Closure and Revitalisation Guidelines and Standards

Different requirements for closure and revitalisation have emerged in many countries, illustrating a rich diversity of aims, rules and regulations between but also within individual countries [81,82], which is also the case for the member states of the European Union [32]. Hence, a broad range of guidelines and standards at the national and international level exist for successful planning and implementing closure and revitalisation [32,48,83,84].

The International Council of Mining and Metals (ICMM) was established in 2001 to improve the performance of the mining and metal sector and to respond to changing societal expectations. Their guide for integrated closure contains twelve tools with feedback loops, good practice examples and case studies [48]. It aims to encourage companies to adopt a disciplined approach for integrated planning and to support the implementing of closure activities and address risks before they are significant, as well as increase the consistency of good practices across the sector. The focus lies on social and economic risks and opportunities to be managed through early and proactive planning and preparation of closure over the lifetime of the site.

The Initiative for Responsible Mining Assurance (IRMA) was set up in 2006 by a widely based coalition of actors and is backed by independent auditors in its advocacy for a socially and environmentally responsible extraction sector. The IRMA Standard for Responsible Mining [49], which includes closure and revitalisation, provides the benchmark for responsible extraction on an industrial scale. In closure and revitalisation, IRMA attaches importance to safeguarding long-term environmental and social values. Furthermore, it is of particular relevance to IRMA that closure and revitalisation costs are entirely covered by the extraction company.

Within the industry, large mining companies have created their own standards for mine closure. For instance, AngloAmerican's Mine Closure Toolbox [47] and Rio Tinto's closure approach [50] have been developed for internal usage. The closure toolbox of AngloAmerican was launched in 2007 and has since been revised twice, in 2013 and 2019. It is based on company guidelines (e.g., code of conduct, social, health and safety and environmental policies and guidelines) and ICMM principles and commitments, including ICMM's integrated closure guidelines. Rio Tinto's closure standards are also in line with ICMM principles and commitments, but they are less comprehensive and detailed than AngloAmerican's. Their approach is a dedicated closure team alongside the operations team to identify and address the risks associated with closure from the earliest planning stage. The objective of these company standards is the internal standardisation of closure planning and management, with particular emphasis on the social aspects of closure and revitalisation under economic considerations.

3. Materials and Methods

Studies using Q-methodology (also Q-study or Q-analysis) are popular in the social and natural sciences, but are increasingly conducted to analyse issues related to mineral resources. These include analysis of the socio-economic impacts of mineral extraction [85], policy development and frame conflicts in mineral extraction [86,87], community perceptions [44,88], perceptions of the impacts of resource development [89], and politics around extraction projects [90]. This study, using Q-methodology, aimed to capture different perspectives on the closure and revitalisation of an extraction site, involving actors from several Eastern and Southern European countries.

Q-methodology, developed by William Stephenson [91,92], is a combination of quantitative and qualitative research techniques. It analyses participants' individual Q-sorts, i.e., their personal opinion on the investigated topic. According to Q-methodology, opin-

ions are subjective and can be shared, measured and compared [92–95], allowing for a systematic analysis of subjectivity. Participants rank given statements on the research topic and, thus, express their personal viewpoint [95,96]. Data analysis is performed through correlation and factor analysis by person. Participants correlate with others sharing similar opinions based on their Q-sorts. Each participant's statements, ordered by their rank, are transformed into an array of numerical data, which is then correlated with all other participants' arrays. This results in a correlation matrix indicating which participants have sorted statements in a similar order. Through a factor analysis of the correlation matrix, highly correlated data arrays are grouped to identify factors that represent clusters of subjective perspectives among the pool of participants. The association of each participant with each of the identified opinion types is indicated by the factor loadings, variable between −1.00 and +1.00; the higher the factor loadings, the more a participant's statement array correlates with that factor. It should be noted that Q-methodology cannot provide generalisable data for a wider population.

Data Collection and Factor Analysis

After identifying the research topic, implementing Q-methodology comprises standardised steps: (i) identification of study participants (p-set); (ii) elaboration of study discourse and subjective statements (Q-set); (iii) data collection by ranking the statements of the Q-set by participants (Q-sort) and iv) data analysis and interpretation [46,96,97].

This Q-study was conducted as part of the EIT RawMaterials project 'ReviRis' (Revitalising Post-Mining Regions: Problems and Potential in RIS Europe [98]). Hence, the study was specifically distributed in selected European EIT RIS countries—Estonia, Greece, Poland and Portugal—and Austria via email, but the participation link was also shared publicly (i.e., project newsletter and LinkedIn), allowing people from other European countries to participate as well. With the aim of simplifying participation for people from the preferred countries, the Q-study was translated into six different languages: English, Estonian, German, Greek, Polish and Portuguese. The period of data collection was from 10 October 2021 to 24 November 2021. The participating actor groups were limited to (i) civil society and non-governmental organisations (CS and NGO), (ii) extractive industries (EI) and (iii) government (Gov); the former are affected by closure and revitalisation, extractive companies are the ones who should finance, plan and implement the closure and revitalisation, and the latter are responsible for legislation and inspection of its implementation in accordance with the law.

The p-set in this study comprises 40 participants, with 45% (18) of participants from the actor group extractive industry, 42.5% (17) civil society and NGO and 12.5% (5) from the group government. Of these, 35% (14) were female, 62.5% (25) male and one person (2.5%) did not indicate their gender. The country distribution of the p-set is the following: Greece (40%; 16), Austria (25%; 10), Portugal (17.5%; 7), Estonia (10%; 4), Poland (5%; 2) and Germany (2.5%; 1).

The Q-set consists of 36 statements developed on the basis of four current international and company standards/toolboxes on the closure and revitalisation of extraction sites: AngloAmerican's Mine Closure Toolbox [47], ICMM's Integrated Mine Closure [48], IRMA's Standards for Responsible Mining [49] and Rio Tinto's closure approach [50]. To develop the Q-set for this study, the items on closure and revitalisation of the standards/toolboxes mentioned were sorted into thematic areas, e.g., planning, social, environmental and economic, and items having the same, similar or related purpose were grouped to eliminate duplications. In addition, we omitted items that are too specific, such as internal company regulations, backfill of open pit and underground sites, pit lakes and specified requirements for water treatment. This systematic process resulted in 36 representative statements (listed in Table 1) regarding closure and revitalisation of extraction sites in different thematic areas. As the thematic areas in the standards used for developing the statements are covered unequally, the categories of the statements are also not of equal size.

Table 1. Statements and statement scores for each viewpoint (VP) ('factor array', detailed description for calculation presented below). Statements based on the following closure and revitalisation standards: AngloAmerican [47], ICMM [48], IRMA [49] and Rio Tinto [50].

Statements	VP1	VP2	VP3	VP4	VP5
#1. As part of closure planning, it is important to minimise the need for active water treatment of a post-extraction landscape.	2	−1	1	−1	−3
#2. It is important to have a solid knowledge base of the sites' environmental setting, for the planning of closure and revitalisation.	0	3	3	−3	2
#3. Negative environmental impacts and contamination after the closure of an extraction site need to be prevented.	5	2	2	2	4
#4. The post-closure ecosystem must deliver positive ecological/biodiversity value that is compatible with the proposed post-closure land use.	−2	1	3	−4	4
#5. It is important to limit long-term erosion and environmental degradation of a closed extraction site.	3	1	−1	0	1
#6. Stakeholders are expected to develop a shared vision with jointly agreed objectives for closure planning.	−3	2	−2	−1	−1
#7. Managing economic, social and environmental risks is equally important in post-closure planning.	1	1	1	1	0
#8. Risk and opportunity-based closure planning requires flexibility towards constantly changing economic circumstances.	0	−3	−3	2	1
#9. Integrated closure planning should consider ongoing revitalisation (extraction areas are already revitalised before the extraction site actually closes).	−1	3	1	−2	0
#10. Closure plans must be regularly reviewed and updated throughout the life cycle of the operation.	1	−2	2	1	0
#11. Closure plans must be aligned with long-term operational plans considering the full life of the operation.	3	2	−1	−3	−2
#12. Cradle-to-cradle (start closure planning as early as possible and envision a sustainable post-extraction site) is a fundamental characteristic in closure planning.	2	−1	4	−5	−2
#13. Closure is a complex challenge that requires a multi-disciplinary approach, including persons from social, engineering, economic, environmental and management.	−1	−2	5	3	−1
#14. Closure must be planned and implemented following the same rigorous processes as operational planning.	1	3	−4	−1	1
#15. Citizens and local/regional stakeholder must have full and open access to the most recent closure and revitalisation plans.	−3	−2	−2	5	1
#16. The sale of the extraction site to extend the life of the asset is an alternative to closure, but does not release the company from timely and appropriate closure planning.	−2	0	0	0	−4
#17. It is important for post-closure planning that the regional degree of prosperity remains at the same level as during operation.	−4	4	2	1	−5
#18. An appropriate and detailed determination of the costs for closure, revitalisation and post-closure care minimises unforeseen problems.	2	−4	−1	3	−1
#19. Companies must provide indefinite funding for residual risk management to ensure a risk-free post-closure land-use.	−5	−4	−4	1	−4
#20. Companies must guarantee sufficient financial sureties for the closure, post-closure care and monitoring of an extraction site throughout its lifetime.	1	0	0	1	−1
#21. It is important that the financial surety for post-closure and revitalisation is reviewed by an independent analyst.	−2	−5	1	−2	−1
#22. Stakeholders must have access to the results of the approved financial surety reviews relating to closure and revitalisation, excluding confidential business information.	−3	−3	−3	0	−2
#23. Post-closure monitoring programmes with performance criteria are important to demonstrate the successful closure of the extraction site.	0	−1	3	−2	−3
#24. Geotechnical stability and routine maintenance are important in monitoring post-closure facilities.	3	1	1	2	2
#25. Monitoring sites for surface and groundwater are important to detect possible contamination from post-closure extraction facilities.	1	0	0	0	1
#26. It is important to monitor post-closure landscapes biologically to detect damage to aquatic and terrestrial resources.	0	−2	0	−3	3
#27. In closure planning, it is important that post-closure landscapes are used beneficially and include economic activities, nature conservation or community use.	−1	4	2	0	3
#28. In environmentally sensitive and/or biodiversity rich areas, the potential natural vegetation must be restored.	−1	0	0	−1	5
#29. Closure requirements and expectations by supervisory authorities may change over the lifetime of an extraction site and need to be considered in regular reviews and updates.	2	0	−2	0	−2
#30. It is important that closure objectives are consistent with legal and regulatory requirements.	4	−1	−1	−4	2
#31. It is critical that sustainable livelihoods aligned with the underlying opportunities and constraints provided by the environment at closure are implemented to generate a positive legacy.	−1	0	−1	3	0
#32. Changing closure requirements and expectations of the community and other concerned stakeholders over the lifetime of an extraction site need to be considered.	−2	2	−5	−1	3
#33. A smooth transition from the socio-economic conditions that prevailed during the operation phase to that after the closure of the extraction site is important.	−4	5	−3	2	−3
#34. It is important to engage all stakeholders, including employees, traditional landowners, local communities and governments, in a timely manner and clearly stating their level of influence in the closure planning process.	0	−3	4	4	0
#35. Knowledge of the social setting, including requirements and agreements with or obligations to stakeholders, is important for closure planning.	0	−1	−2	4	0
#36. The physical stability of a closed extraction site is important to minimise safety risks and avoid accidents.	4	1	0	−2	2

Both the data collection and analysis were carried out using the online tool "Q Method Software" (https://qmethodsoftware.com/(accessed on 5 December 2022)). When collecting data, study participants had to sort the statements into the given Q-grid (see Figure 1) from "not important at all/I disagree" (−5) via "neutral" (0) to "very important/I fully agree" (+5). Furthermore, participants were asked to answer two short questionnaires—before and after the sorting. The first was to gather demographics, including age, gender, actor group and country. The second questionnaire addressed the ranking of the statements and gave the participants the chance to explain why exactly these statements had been ranked as "−5" and "+5", as well as to share further thoughts on the closure and revitalisation of an extraction site.

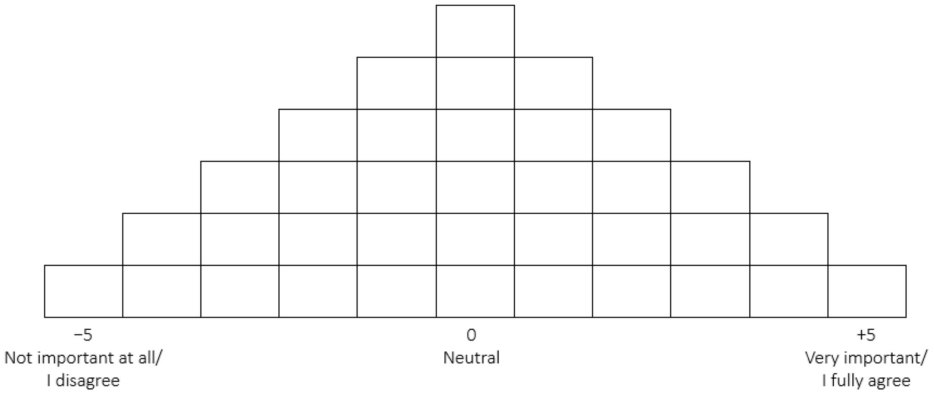

Figure 1. Q-grid for forced-choice rating of statements from −5 "not important at all/I disagree" via 0 "neutral" to +5 "very important/I fully agree".

For the analysis of this Q-study, Pearson's correlation matrix was used, a standardised measure of the linear relationships between two sets of scores. The factor analysis, meaning the identification of patterns and distinct factors, i.e., shared viewpoints, was performed according to principle component analysis (PCA) and a varimax rotation [46]. Selection criteria of the factors considered for further analysis are eigenvalue >1.0 and at least two Q-sorts loading significantly on the respective factor, with the significance level calculated at $p < 0.05$ using the equation $1.96 \times (1/\sqrt{\text{No. of items in the Q-set}})$ [99]; for the present Q-study, the calculated significant threshold is 0.327. In doing so, five viewpoints were extracted, accounting for an explained variance of 47.4%, with a minimum level of 35–40% [46] and a number of defined variables of 29, meaning the number of Q-sorts considered in the five extracted factors. Further, crib sheets [46] were used for data interpretation to identify the highest- and lowest-ranked statements for each viewpoint (VP) from the viewpoints' statement scores ('factor arrays', Table 1) and z-scores (i.e., normalised factor scores).

4. Results

The Q-study resulted in five distinctive viewpoints, with different perspectives on the closure and revitalisation of an extraction site: (1) limiting and preventing negative environmental impacts, (2) closure and revitalisation planning beyond economic aspects, (3) closure and revitalisation: a multi-disciplinary expert task, (4) transparent communication and full access to information and (5) ecology/biodiversity first. These five viewpoints account for 29 of the 40 participant sorts and explain 72.5% of the sample, meaning eleven sorts were not statistically relevant—two were not loading on any of the factors and nine loaded significantly on more than one factor. Viewpoint one and two together cover almost half of the participants sorts, specifically 24% (7) each. With 21% (6), viewpoint five represents the second largest number of participant sorts, followed by viewpoint four (17%, 5) and lastly viewpoint three (14%, 4).

Figure 2 illustrates the actor distribution, i.e., group and gender, of the five resulting viewpoints. It should be noted that, due to the anonymous data collection via an online tool,

the distribution of participants could not be influenced. As a result, the demographic distribution of respondents is skewed. Nevertheless, the findings of the study provide an initial overview of the situation and can be further sharpened through selective investigations.

Figure 2. Actor distribution by viewpoint (EI = extractive industries, Gov = government, CS and NGO = civil society and non-government organisation) (figure adopted from Kügerl et al. [87]).

4.1. Viewpoint 1—Limiting and Preventing Negative Environmental Impacts

This viewpoint follows the perspective of technical environmental protection at an operational level, with a focus on limiting and preventing any negative environmental impacts of a closed extraction site (#3/+5). Hence, techno-environmental aspects are considered important for closure planning, such as the physical stability of a closed extraction site to minimise safety risks and to avoid accidents (#36/+4), minimising active water treatment of the post-closure landscape (#1/+2) and limiting long-term erosion and environmental degradation (#5/+3). In this viewpoint, geotechnical stability and routine maintenance are important in monitoring post-closure facilities (#24/+3).

Closure plans must be aligned with long-term operational plans that consider the whole life cycle of an operation (#11/+3). In addition, closure objectives must be consistent with legal and regulatory requirements (#30/+4), as "legal requirements are the minimum that have to be met" (representative of the extractive industry). In this sense, changing regulatory requirements and expectations by supervisory authorities over the lifetime of an extraction site should be considered in regular reviews and updates of closure plans (#29/+2).

While environmental aspects are considered relevant in this viewpoint, socio-economic aspects play only a minor role, illustrated by the (i) low valuation of the development of a shared vision with jointly agreed objectives for closure planning (#6/−3) and (ii) a smooth socio-economic transition from the in situ to post-closure phase (#33/−4) with (iii) suitable and beneficial post-closure land use (#27/−1). Additionally, transparent and open access to the latest closure and revitalisation plans for citizens and local/regional actors (#15/−3) and the securement of indefinite funding by companies to ensure a risk-free post-closure land use (#19/−5) are considered of minor importance in this viewpoint.

4.2. Viewpoint 2—Closure and Revitalisation Planning beyond Economic Aspects

Viewpoint two focuses on the role of regional planning, and, thus, goes far beyond the consideration of purely economic aspects of closure and post-closure planning. Here, a smooth transition of socio-economic conditions and a beneficial use of the post-closure

landscape (#27/+4) from the operational to a post-closure phase (#33/+5) should be the outcome of a jointly developed shared vision (#6/+2) and the prosperity of the region should remain at a similar level to before the closure (#17/+4). This perspective emphasizes that closure planning must enjoy similar attention and rigor as operations planning (#14/+3). It is expected to implement ongoing revitalisation, which already brings revitalisation forward into the operational phase (#9/+3).

This viewpoint puts less emphasis on multi-disciplinary approaches (#13/−2) and regular reviews and updates of closure plans throughout the life cycle of an operation (#10/−2). It considers the timely involvement of actors in closure planning with a clear indication of their level of influence in the process (#34/−3) to be of minor importance. Financial aspects such as the need for appropriate and detailed costing for closure and post-closure activities (#18/−4) and the independent auditing of the planned financial sureties (#21/−5) are not a priority.

4.3. Viewpoint 3—Closure and Revitalisation: A Multi-Disciplinary Expert Task

Viewpoint three focuses also on the planning process of closure and post-closure activities. According to this viewpoint, this process is a multi-disciplinary expert task (#13/+5) "to provide the best possible version of this plan" (government representative). Performance criteria and post-closure monitoring programs (#23/+3) that are regularly updated throughout the operation's life cycle (#10/+2) are seen as a priority. More detailed objectives of closure and revitalisation (e.g., environmental protection or a smooth socio-economic transition) are not specified, since viewpoint three mainly covers general planning aspects. In this viewpoint, cradle-to-cradle is considered a fundamental characteristic in closure planning, as closure planning should start as early as possible and aim for a sustainable post-closure landscape (#12/+4). Additionally, the review of the financial surety for post-closure activities by an independent analyst (#21/+1) is considered an important aspect for closure and reclamation planning.

At the same time, there is no requirement that closure must be planned and implemented following the same rigorous processes as operational planning (#14/−4). While viewpoint three is focused on the planning process, environmental and social aspects are less important, illustrated by low rankings of long-term erosion and environmental degradation of a closed extraction site (#5/−1), knowledge of the social setting, including requirements and agreements with or obligations to actors (#35/−2), and changing closure requirements and expectations of the community and other concerned actors (#32/−5).

4.4. Viewpoint 4—Transparent Communication and Full Access to Information

This viewpoint is characterised by distributional aspects such as transparent communication and information flow. According to viewpoint four, citizens and local/regional actors should enjoy full and open access to closure and revitalisation plans (#15/+5) and to the results of the approved financial surety reviews, but without disclosing confidential commercial interests and information (#22/0). In addition, this viewpoint finds it crucial to establish sustainable livelihoods for the community aligned with the underlying opportunities and constraints provided by the environment at closure to generate a positive legacy (#31/+3). Consequently, the specific social settings should be considered appropriately in closure planning (#35/+4).

Representatives of this group expect the extraction companies to take responsibility for closure and revitalisation activities of an extraction site. Thus, companies should carefully assess potential costs for closure, revitalisation and post-closure care (#18/+3) and they should provide indefinite funding for residual risk management (#19/+1). In this line, flexibility in planning (i.e., risk and opportunity-based closure planning) is required due to constantly changing economic circumstances (#8/+2). Even though responsibility and accountability are expected from extraction companies, this viewpoint does not require closure objectives to be consistent with legal and regulatory requirements (#30/−4).

Although this viewpoint prioritises the generation of a positive impact, concrete environmental aspects seem to be of less importance. Hence, a solid knowledge base of the site's environmental settings (#2/−3) is not considered necessary in closure and revitalising planning, as well as a positive ecological/biodiversity value of the post-closure ecosystem that is compatible with the proposed post-closure land use (#4/−4). Additionally, the monitoring of post-closure landscapes to detect damage to aquatic and terrestrial resources (#26/−3) ranks low. This viewpoint also gives only slight emphasis to planning aspects, indicated by the low weight given to integrated closure planning with ongoing revitalisation (#9/−2), early closure planning and the envisioning of a sustainable post-closure site (i.e., cradle-to-cradle) (#12/−5), and closure plans that are aligned with long-term operational plans (#11/−3). The physical stability of the closed site is also not a priority in this viewpoint, even if it can minimise safety risks and avoid accidents (#36/−2).

4.5. Viewpoint 5—Ecology/Biodiversity First

Viewpoint five is characterised by a strong emphasis on environmental protection. Compared to viewpoint one, which represents a technical perspective of environmental protection, viewpoint five is characterised by the restoration of ecological values of the closed extraction site. Little attention is paid to economic and social components of closure and revitalisation. Thus, the management of economic, social and environmental risks is not considered equally important in post-closure planning (#7/0). It is considered important that the post-closure ecosystem delivers a positive ecological and biological value (#4/+4), that potential natural vegetation is restored in environmentally sensitive and/or biodiversity-rich areas (#28/+5) and that the post-closure landscape is biologically monitored to detect aquatic and terrestrial damage (#26/+3). However, changing closure requirements and actively including expectations of communities and other concerned actors should also play a role in closure planning (#32/+3).

Despite the focus on environmental protection and monitoring, the need for active water treatment of a post-closure landscape (#1/−3) is considered less relevant. This viewpoint does not require the company to provide sufficient financial sureties for closure, post-closure and monitoring activities (#20/−1) or to prepare timely and appropriate closure plans in the case of the sale of the site to extend the life of the asset as an alternative to closure (#16/−4), even if this could contribute to environmental protection. The maintenance of the regional degree of prosperity after closing the extraction site (#17/−5) is also less of a priority in post-closure planning according to viewpoint five, and the need for a post-closure monitoring program with performance criteria to demonstrate the successful closure (#23/−3) is ranked low.

4.6. Agreements and Disagreements within and across Viewpoints

All viewpoints agree that the prevention of negative environmental impacts and contamination after closure (#3), as well as geotechnical stability and routine maintenance in monitoring post-closure facilities (#24), are important. There is also consensus on the position that managing economic, social and environmental risks is equally important in post-closure planning (#7), with this being rated as neutral (0 and +1). Conversely, the need for actors to have access to the results of the approved financial surety reviews (excluding confidential business information) related to closure and revitalisation (#22) is challenged by all viewpoints (ranked between 0 and −3). With respect to the guarantee of sufficient financial sureties by companies for closure, post-closure and monitoring throughout the lifetime of an extraction site (#20; ranked between −1 and +1), as well as monitoring sites for surface and groundwater to detect possible contamination from post-closure extraction facilities (#25; 0 and +1), the five viewpoints are rather dispassionate.

Environmental aspects of closure and revitalisation (#2, 3, 4, 25, 26, 28) were generally ranked from slightly negative/neutral to highly important, with stronger emphasis on the positive side. While viewpoint five highlights all statements from this category, viewpoint four considers environmental settings (#2) and ecological/biodiversity value (#4, 26) irrel-

evant for site closure and revitalisation. On the other hand, statements of the categories social (#6, 15, 22, 31, 32, 33, 34, 35) and economy (#8, 16, 17, 18, 20, 21) were rated as neutral to unimportant, with the negative side predominant. Viewpoint five disagrees with all but one statement of the category economy: it only supports the flexibility of closure planning towards constantly changing economic conditions (#8/+1). Instead, viewpoints one and three tend to consider social aspects more negatively: viewpoint one disagrees with most of the statements of this category (#6, 15, 22, 31, 32, 33) or has an impartial attitude (#34, 35). For viewpoint three, the timely involvement of actors in the closure planning process, with their level of influence clearly indicated, matters (#34/+4); all other social aspects of closure and revitalisation are rejected by this viewpoint.

Opinions also diverge significantly between social and economic aspects: while viewpoints one and five neither focus on a smooth transition of socio-economic condition (#33; −4 and −3) nor on a remaining level of the regional degree of prosperity (#17; −4 and −5) during and after the extraction phase, viewpoint two rates both as highly relevant (#33/+5; #17/+4). On the other hand, viewpoint three is more biased (+2) towards the prosperity on the regional level (#17) but, at the same time, considers the smooth transition of socio-economic conditions as quite unimportant (#33/−3). The viewpoints also strongly disagree on whether citizens and local/regional actors should have access to closure and revitalisation plans (#15). Viewpoints one, two and three show a relatively negative stance towards this proposition (−3 and −2), whereas it is favoured by viewpoint four (+5). Considering changing closure requirements and expectations of communities and concerned actors (#32) is opposed by viewpoint three (−5), but agreed with by viewpoint five (+3).

There is also a noticeable deviation between the viewpoints regarding the principle of cradle-to-cradle (#12), as viewpoint three and four strongly disagree on whether this principle is a fundamental characteristic of closure planning (ranked +4 and −5). The consistency of legal and regulatory requirements with closure objectives (#30) also raises questions; according to viewpoint one, they should be in line (+4), viewpoint four disagrees (−4) and the other viewpoints are rather impartial (−1 and +2).

5. Discussion

In our research, Q-methodology led to five viewpoints on the closure and revitalisation of an extraction site related to selected European EIT RIS countries, emphasising environmental protection, a proper planning process or community involvement. An analysis across all viewpoints reveals agreement on the protection against negative environmental impacts and contamination through closure and revitalisation measures, and guaranteeing geotechnical stability and routine maintenance in post-closure facility monitoring, as well as on the confidentiality of the outcome of the financial assurance reviews for closure and revitalisation. Overall, the greatest attention is paid to the environmental aspects of closure and revitalisation; social and environmental aspects have been placed second and third. The main contradictory positions between the viewpoints are in terms of the extent of environmental protection and involvement of actors in closure and revitalisation planning.

The academic literature describes technical and environmental aspects as often taking precedence in closure and revitalisation processes while leaving social, economic and socio-economic factors behind [2,71,72]. This is reflected in the overall prioritisation and, in particular, in the approach of viewpoint one, which additionally stresses the company's responsibility for finance closure and revitalisation processes. An explanation for the preference given to operational aspects lies in the fact that this viewpoint is predominantly embodied by representatives of the extractive industry. In contrast, viewpoint five refers almost exclusively to the restoration and enhancement of ecosystem services. However, the consideration of community expectations and transparency are also demanded in this viewpoint. Two thirds of the representatives of viewpoint five belong to the group civil society and NGO, and one third to extractive industries. The strong favouring for environmental protection might also be due to the increasing presence and growing awareness of the importance of sustainability in general [18,21,22], but also in the extractive sector [16,17,77–79],

where environmental sustainability is emphasised in particular [12], i.e., environmental limits [20]. However, the still perceptible consequences of abandoned extraction sites from the past, which continue to pollute their surroundings [69], also account for this tendency.

Viewpoint three envisages comprehensive closure and revitalisation measures to be planned and implemented by experts aimed at achieving better results. The opposite perspective to this is viewpoint two, stressing the planning process of closure and revitalisation in a regional context and its importance in terms of (i) socio-economic transition, (ii) regional prosperity and (iii) a shared vision. With respect to this, viewpoint two is consistent with the academic discourse on the socio-economic transition from the extraction phase to the post-closure phase [28,42,67,80]. When it comes to the question of community involvement in closure and revitalisation planning, the academic literature is controversial. On the one hand, it is recommended that closure and revitalisation planning is performed by experts [25,32], but on the other hand, the community should be actively involved, consulted and even empowered, as they can influence the success of these processes [40,41,43,73]. A compromise, and possibly the response to this incongruity, is represented by viewpoint four, which has community involvement at its centre, in the sense of information flow and transparency, rather than the active participation of those concerned.

Even though social aspects of closure and revitalisation are perceived to be secondary across the viewpoints, they enjoy a high priority in all four standards considered in this study. Viewpoint three, with its approach of deploying experts for closure and revitalisation planning, fits with Rio Tinto dedicating a separate expert team for closure and revitalisation. Despite Rio Tinto's strategy, their closure and revitalisation standard specify an opportunity for actors to review and comment on the plans. Hence, the inclusion of experts does not preclude the active involvement of actors and a combination of expert knowledge and actor insights may be the ideal solution, with transparency and the provision of information as a minimum.

Similarly, economic aspects are regarded less important by study participants, but not by standards for closure and revitalisation: AngloAmerican, ICMM and Rio Tinto focus on securing but minimising closure and revitalisation funding, i.e., considering the situation from a company perspective. IRMA is concerned with ensuring the company can bear all closure and post-closure costs, which is also required by viewpoint one. Neglecting economic aspects might be related to the Eastern and Southern European focus of the study. Nowadays, apart from a few exceptions, the extractive sector in this region is of little economic importance at national, local and regional level, due to the decline in extraction activities. In contrast, the standards are internationally oriented and refer to areas where mineral extraction has a high economic relevance, especially to developing countries where the closure and revitalisation of a site holds many opportunities for the future of the country, but also risks [28,80].

Owing to the differences between the requirements of the internationally oriented standards and the societal expectations (e.g., responsibility and sustainability) or specifications (e.g., through environmental legislation including the European Green Deal) on the European extractive sector, a divergence occurs. While three of the four closure and revitalisation standards considered here—AngloAmerican, ICMM and Rio Tinto—prioritise social aspects under economic conditions ahead of environmental aspects, it tends to be the reverse for the viewpoints. Viewpoint five even goes far beyond the individual standards in its expectations for environmental protection, but comes closest to the approach of IRMA [49]. Conversely, the emphasis on the operational level of viewpoint one, in spite of its environmental focus, suggests a bias towards the company standards, i.e., AngloAmerican [47] and Rio Tinto [50].

From a company perspective, the focus on social and economic considerations is meaningful for two reasons: (i) social acceptance towards the extraction sector has a crucial impact [40,43] and (ii) extraction companies are responsible for financing closure and post-closure activities. Apart from the necessity of financial resources for closure and revitalisation activities, the transition from the extraction phase to the post-closure phase

is also linked to economic aspects [30,65–67]. Neglecting economic aspects affects the economy of the post-closure area [66] and also social conditions in the surroundings of the closed site [65,67]. Thus, economic aspects of closure and revitalisation should not only be of relevance for extraction companies responsible for closure and revitalisation and the municipality that wants to sustain or improve the regional prosperity, but also for local communities. The knowledge gap concerning the impact of closure and revitalisation on future economic prospects and livelihoods has already been pointed out by Bainton and Holcombe [42]. In turn, from a community perspective, highlighting environmental and social aspects is justified, as communities have to bear the after-effects of closure and revitalisation [44]. The interdependence between extraction companies and society requires collaboration to achieve a successful and sustainable closure and revitalisation.

6. Conclusions

By analysing actors' perspectives on the closure and revitalisation of an extraction site, this paper reveals the presence of different viewpoints and priorities and how they relate to the standards used in this study. Furthermore, the knowledge of consistent and controversial perspectives across the resulting viewpoints should contribute to a better understanding of possible tensions between actors. With the growing importance of sustainability in the extractive sector [12,16,17], increasing attention has been paid to environmental, social and economic aspects of closure and revitalisation [34,77,78], as well as society's expectations towards the sector. The precedence given to environmental aspects and the consensus of all viewpoints on the need to prevent any negative environmental impacts when closing an extraction site clearly demonstrates an awareness of the necessity to protect ecosystem services. Nonetheless, only one out of four standards, i.e., IRMA, addresses the environment as a core aspect in closure and revitalisation; the others focus on social aspects under economic considerations. Whilst civil society is more in line with IRMA [49], which is based on a multi-stakeholder process, companies tend to follow their own specific standards, e.g., AngloAmerican [47] and Rio Tinto [50], or standards with a corporate orientation, e.g., ICMM [48].

The closure and revitalisation activities are only small elements in the extraction site's life cycle. The various guidelines, standards and initiatives for a responsible and sustainable extractive industry are the baseline for improving the sector and shifting it towards sustainability, but their implementation is crucial. Vague wording of many guidelines [68] and the international orientation of the standards result in implementation difficulties in Europe and inconsistent practices. This suggests developing standards specifically targeted at the European extractive industry.

For this paper, post-extraction activities are considered separately from the actual process of mineral extraction. Of course, these processes are interlinked. By planning and managing the extraction process itself sustainably right from the start, the focus of closure and revitalisation can be placed more on the enhancement of ecosystem services and social welfare than damage control. Looking into these opportunities more closely would, however, be the scope of another study. Future investigations on technical aspects of site closure and revitalisation, including backfilling, pit lakes and requirements for water treatment, would also be of relevance due to the related challenges.

Author Contributions: Conceptualisation, S.S.; methodology, S.S., K.G. and M.T.; software, S.S.; validation, S.S. and K.G.; formal analysis, data curation and investigation, S.S.; writing—original draft preparation, S.S.; writing—review and editing, S.S., K.G. and M.T.; supervision and project administration, M.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by EIT RawMaterials, project agreement number 19075.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data available on request from the authors.

Acknowledgments: The authors acknowledge the contribution of the participants in the Q-study. We would also like to thank Mandy Kukovec for taking the time for a language revision.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. IIED and WBCSD. *Mining for the Future: Appendix C: Abandoned Mines Working Paper No. 28*; IIED: London, UK, 2002.
2. Kivinen, S. Sustainable Post-Mining Land Use: Are Closed Metal Mines Abandoned or Re-Used Space? *Sustainability* **2017**, *9*, 1705. [CrossRef]
3. Laurence, D. Optimisation of the mine closure process. *J. Clean. Prod.* **2006**, *14*, 285–298. [CrossRef]
4. Ashby, A.; van Etten, E.; Lund, M. Pitfalls of gold mine sites in care and maintenance. In Proceedings of the 11th International Conference on Mine Closure, Perth, Australia, 15–17 March 2016; Fourie, A.B., Tibbett, M., Eds.; Australian Centre for Geomechanics: Perth, Australia, 2016; pp. 313–324.
5. Davis, R.D., Jr.; Welty, A.T.; Borrego, J.; Morales, J.A.; Pendon, J.G.; Ryan, J.G. Rio Tinto estuary (Spain): 5000 years of pollution. *Environ. Geol.* **2000**, *39*, 1107–1116. [CrossRef]
6. Olías, M.; Nieto, J.M. Background Conditions and Mining Pollution throughout History in the Río Tinto (SW Spain). *Environments* **2015**, *2*, 295–316. [CrossRef]
7. Jardine, C.G.; Banfield, L.; Driedger, S.M.; Furgal, C.M. Risk communication and trust in decision-maker action: A case study of the Giant Mine Remediation Plan. *Int. J. Circumpolar Health* **2013**, *72*, 21184. [CrossRef] [PubMed]
8. Beckett, C. Beyond remediation: Containing, confronting and caring for the Giant Mine Monster. *Environ. Plan. E Nat. Space* **2021**, *4*, 1389–1412. [CrossRef]
9. Bundesministerium für Wirtschaft und Klimaschutz. Uranerzbergbausanierung/Wismut. Available online: https://www.bmwk.de/Redaktion/DE/Textsammlungen/Energie/wismut-uranerzbergbausanierung.html (accessed on 5 December 2022).
10. Carvalho, F.P.; Oliveira, J.M.; Malta, M. Analyses of radionuclides in soil, water, and agriculture products near the Urgeiriça uranium mine in Portugal. *J. Radioanal. Nucl. Chem.* **2009**, *281*, 479–484. [CrossRef]
11. Carvalho, F.P.; Oliveira, J.M.; Malta, M. Radiation exposure and environmental remediation at the Urgeiriça mine site, Portugal. In *Uranium—Past and Future Challenges*; Merkel, B.J., Arab, A., Eds.; Springer International Publishing: Cham, Switzerland, 2015; pp. 63–72; ISBN 978-3-319-11058-5.
12. Tost, M.; Hitch, M.; Chandurkar, V.; Moser, P.; Feiel, S. The state of environmental sustainability considerations in mining. *J. Clean. Prod.* **2018**, *182*, 969–977. [CrossRef]
13. Prno, J.; Slocombe, D.S. Exploring the origins of 'social license to operate' in the mining sector: Perspectives from governance and sustainability theories. *Resour. Policy* **2012**, *37*, 346–357. [CrossRef]
14. Onn, A.H.; Woodley, A. A discourse analysis on how the sustainability agenda is defined within the mining industry. *J. Clean. Prod.* **2014**, *84*, 116–127. [CrossRef]
15. Moran, C.; Kunz, N. Sustainability as it pertains to minerals and energy supply and demand: A new interpretative perspective for assessing progress. *J. Clean. Prod.* **2014**, *84*, 16–26. [CrossRef]
16. Bebbington, A.; Bebbington, D.H. Mining, movements and sustainable development: Concepts for a framework. *Sustain. Dev.* **2018**, *26*, 441–449. [CrossRef]
17. Elias, T.; Ayuk, A.; Pedro, M.; Paul, E. *Mineral Resource Governance in the 21st Century: Gearing Extractive Industries Towards Sustainable Development*; United Nations: New York, NY, USA, 2019; ISBN 9789280737790.
18. United Nations. *Transforming Our World: The 2030 Agenda for Sustainable Development*; United Nations: New York, NY, USA, 2015.
19. Rockström, J.; Steffen, W.; Noone, K.; Persson, Å.; Chapin, F.S., III; Lambin, E.; Lenton, T.M.; Scheffer, M.; Folke, C.; Schellnhuber, H.J.; et al. Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecol. Soc.* **2009**, *14*, 32. [CrossRef]
20. Steffen, W.; Richardson, K.; Rockström, J.; Cornell, S.E.; Fetzer, I.; Bennett, E.M.; Biggs, R.; Carpenter, S.R.; De Vries, W.; De Wit, C.A.; et al. Planetary boundaries: Guiding human development on a changing planet. *Science* **2015**, *347*, 1259855. [CrossRef] [PubMed]
21. United Nations Framework Convention on Climate Change. *Paris Agreement*; United Nations: Paris, France, 2015.
22. European Commission. *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: Brussels, Belgium, 2019.
23. Thomas, B.J.; Anand, P.; Nebojsa, N.; Luis, G.-E. *Global Energy Assessment (GEA): Toward a Sustainable Future*; Cambridge University Press: Cambridge, UK, 2012; ISBN 9781107005198.
24. Söderholm, P.; Svahn, N. Mining, regional development and benefit-sharing in developed countries. *Resour. Policy* **2014**, *45*, 78–91. [CrossRef]
25. Florkowska, L.; Bryt-Nitarska, I. The requirements for implementing Sustainable Development Goals (SDGs) and for planning and implementing Integrated Territorial Investments (ITI) in mining areas. *E3S Web Conf.* **2018**, *36*, 01004. [CrossRef]
26. Paola, A.; Yanguas, P.; Ganti, G.; Brecha, R.; Hare, B.; Schaeffer, M.; Fuentes, U. *Global and Regional Coal Phase-Out Requirements of the Paris Agreement: Insights from the IPCC Special Report on 1.5 °C*; Climate Analytics: Berlin, Germany, 2019.
27. United Nations. *World Economic Situation and Prospects 2020*; United Nations: New York, NY, USA, 2020; ISBN 978-92-1-109181-6.

28. Limpitlaw, D.; Briel, A. Post-mining land use opportunities in developing countries—A review. *J. South. Afr. Inst. Min. Metall.* **2014**, *114*, 899–903.
29. Mert, Y. Contribution to sustainable development: Re-development of post-mining brownfields. *J. Clean. Prod.* **2019**, *240*, 118212. [CrossRef]
30. Botezan, C.; Constantin, V.; Meltzer, M.; Radovici, A.; Pop, A.; Alexandrescu, F.; Stefanescu, L. Is there Sustainable Development after Mining? *A Case Study of Three Mining Areas in the Apuseni Region (Romania). Sustainability* **2020**, *12*, 9791. [CrossRef]
31. Lei, K.; Pan, H.; Lin, C. A landscape approach towards ecological restoration and sustainable development of mining areas. *Ecol. Eng.* **2016**, *90*, 320–325. [CrossRef]
32. Mazur-Belzyt, K. Re-thinking Post-Mining Areas Reclamation in 21st Century. *IOP Conf. Series Mater. Sci. Eng.* **2019**, *471*, 102055. [CrossRef]
33. Toumbourou, T.; Muhdar, M.; Werner, T.; Bebbington, A. Political ecologies of the post-mining landscape: Activism, resistance, and legal struggles over Kalimantan's coal mines. *Energy Res. Soc. Sci.* **2020**, *65*, 101476. [CrossRef]
34. Heikkinen, P.M.; Noras, P.; Salminen, R. (Eds.) *Mine Closure Handbook: Environmental Techniques for the Extractive Industries*; Geological Society of Finland: Vammalan Kirjapaino Oy, Finland, 2008; ISBN 9522170429.
35. Mackenzie, S.; Lacy, H. Benefits of Planned Versus Unplanned Mine Closure and Strategies for Both. In Proceedings of the First International Seminar on Mine Closure, Perth, Australia, 13–15 September 2006; Fourie, A.B., Mark, T., Eds.; Australian Centre for Geomechanics: Perth, Australia, 2006; pp. 227–235. [CrossRef]
36. Maczkowiack, R.; Smith, C.; Slaughter, G.; Mulligan, D.; Cameron, D. Grazing as a post-mining land use: A conceptual model of the risk factors. *Agric. Syst.* **2012**, *109*, 76–89. [CrossRef]
37. Sánchez, L.E.; Silva-Sánchez, S.S.; Neri, A. *Guide for Mine Closure Planning*; Instituto Brasileiro de Mineração: Brasília, Brazil, 2014; ISBN 978-85-61993-05-4.
38. Hendrychová, M.; Kabrna, M. An analysis of 200-year-long changes in a landscape affected by large-scale surface coal mining: History, present and future. *Appl. Geogr.* **2016**, *74*, 151–159. [CrossRef]
39. Zeng, S.; Chen, F.; Li, X.; Luo, Z.; Hao, S. Rethinking the Ecological Restoration of Mining Areas from the Perspective of Rural Revitalization. *IOP Conf. Series Mater. Sci. Eng.* **2018**, *392*, 042035. [CrossRef]
40. Metcalf, E.C.; Mohr, J.J.; Yung, L.; Metcalf, P.; Craig, D. The role of trust in restoration success: Public engagement and temporal and spatial scale in a complex social-ecological system. *Restor. Ecol.* **2015**, *23*, 315–324. [CrossRef]
41. Walsh, B.; van der Plank, S.; Behrens, P. The effect of community consultation on perceptions of a proposed mine: A case study from southeast Australia. *Resour. Policy* **2017**, *51*, 163–171. [CrossRef]
42. Bainton, N.; Holcombe, S. A critical review of the social aspects of mine closure. *Resour. Policy* **2018**, *59*, 468–478. [CrossRef]
43. Swart, J.A.A.; Zevenberg, J.; Ho, P.; Cortina, J.; Reed, M.; Derak, M.; Vella, S.; Zhao, H.; Van Der Windt, H.J. Involving society in restoration and conservation. *Restor. Ecol.* **2018**, *26*, S3–S6. [CrossRef]
44. Sinnett, D.E.; Sardo, A.M. Former metal mining landscapes in England and Wales: Five perspectives from local residents. *Landsc. Urban Plan.* **2020**, *193*, 103685. [CrossRef]
45. EIT. EIT Regional Innovation Scheme. Available online: https://eit.europa.eu/our-activities/eit-regional-innovation-scheme (accessed on 5 December 2022).
46. Watts, S.; Stenner, P. *Doing Q Methodological Research: Theory, Method and Interpretation*; SAGE Publications: London, UK, 2012; ISBN 9781849204156.
47. AngloAmerican. *Mine Closure Toolbox: Version 3*; AngloAmerican: London, UK, 2019.
48. ICMM. *Integrated Mine Closure: Good Practice Guide*; International Council on Mining and Metals: London, UK, 2019.
49. IRMA. *IRMA Standard for Responsible Mining: IRMA-STD-001*; Initiative for Responsible Mining Assurance: Seattle, WA, USA, 2018.
50. Rio Tinto. Our Approach to Closure. Available online: https://www.riotinto.com/-/media/Content/Documents/Sustainability/Corporate-policies/RT-Closure-approach.pdf?rev=bc321129cbc74e78903e604c387a74b7 (accessed on 5 December 2022).
51. Laurence, D. Establishing a sustainable mining operation: An overview. *J. Clean. Prod.* **2011**, *19*, 278–284. [CrossRef]
52. Pokhrel, L.R.; Dubey, B. Global Scenarios of Metal Mining, Environmental Repercussions, Public Policies, and Sustainability: A Review. *Crit. Rev. Environ. Sci. Technol.* **2013**, *43*, 2352–2388. [CrossRef]
53. Haque, A.; Topal, E.; Lilford, E. A numerical study for a mining project using real options valuation under commodity price uncertainty. *Resour. Policy* **2014**, *39*, 115–123. [CrossRef]
54. Parshley, J.; Bauman, W.; Blaxland, D. An evolution of the methods for and purposes of mine closure cost estimating. In Proceedings of the Fourth International Conference on Mine Closure, Perth, Australia, 13–15 September 2006; Fourie, A.B., Mark, T., Eds.; Australian Centre for Geomechanics: Perth, Australia, 2009; pp. 187–200. [CrossRef]
55. Franks, D.M. *Mountain Movers: Mining, Sustainability and the Agents of Change*, 1st ed.; Earthscan: Abingdon, UK, 2015; ISBN 9781315884400.
56. Otto, J.M. A national mineral policy as a regulatory tool. *Resour. Policy* **1997**, *23*, 1–7. [CrossRef]
57. Rosa, J.C.S.; Sánchez, L.E.; Morrison-Saunders, A. Getting to 'agreed' post-mining land use—An ecosystem services approach. *Impact Assess. Proj. Apprais.* **2018**, *36*, 220–229. [CrossRef]
58. Wirth, P. *Post-Mining Regions in Central Europe: Problems, Potentials, Possibilities*; Oekom: Munich, Germany, 2012; ISBN 9783865815002.

59. Pearman, G. *101 Things to Do with a Hole in the Ground*; Post-Mining Alliance: Cornwall, UK, 2009; ISBN 9780956221315.
60. Soltanmohammadi, H.; Osanloo, M.; Bazzazi, A.A. An analytical approach with a reliable logic and a ranking policy for post-mining land-use determination. *Land Use Policy* **2010**, *27*, 364–372. [CrossRef]
61. Tost, M.; Ammerer, G.; Kot-Niewiadomska, A.; Gugerell, K. Mining and Europe's World Heritage Cultural Landscapes. *Resources* **2021**, *10*, 18. [CrossRef]
62. Vrablikova, J.; Wildova, E.; Vrablik, P. Sustainable Development and Restoring the Landscape after Coal Mining in the Northern Part of the Czech Republic. *J. Environ. Prot.* **2016**, *7*, 1483–1496. [CrossRef]
63. Mills, C.; Simpson, I.; Adderley, W.P. The lead legacy: The relationship between historical mining, pollution and the post-mining landscape. *Landsc. Hist.* **2014**, *35*, 47–72. [CrossRef]
64. Palogos, I.; Galetakis, M.; Roumpos, C.; Pavloudakis, F. Selection of optimal land uses for the reclamation of surface mines by using evolutionary algorithms. *Int. J. Min. Sci. Technol.* **2017**, *27*, 491–498. [CrossRef]
65. Eggert, R.G. Economic Perspectives on Sustainability, Mineral Development, and Metal Life Cycles. In *Metal Sustainability: Global Challenges, Consequences, and Prospects*; Izatt, R.M., Ed.; John Wiley & Sons, Ltd: Chichester, UK, 2016; ISBN 9781119009115.
66. Auty, R.M.; Mikesell, R.F. *Sustainable Development in Mineral Economies*, 1st ed.; Clarendon: Oxford, UK, 1998; ISBN 0198294875.
67. Al Rawashdeh, R.; Campbell, G.; Titi, A. The socio-economic impacts of mining on local communities: The case of Jordan. *Extr. Ind. Soc.* **2016**, *3*, 494–507. [CrossRef]
68. Lamb, D.; Erskine, P.D.; Fletcher, A. Widening gap between expectations and practice in Australian minesite rehabilitation. *Ecol. Manag. Restor.* **2015**, *16*, 186–195. [CrossRef]
69. Venkateswarlu, K.; Nirola, R.; Kuppusamy, S.; Thavamani, P.; Naidu, R.; Megharaj, M. Abandoned metalliferous mines: Ecological impacts and potential approaches for reclamation. *Rev. Environ. Sci. Bio. Technol.* **2016**, *15*, 327–354. [CrossRef]
70. Yang, Y.; Li, Y.; Chen, F.; Zhang, S.; Hou, H. Regime shift and redevelopment of a mining area's socio-ecological system under resilience thinking: A case study in Shanxi Province, China. *Environ. Dev. Sustain.* **2019**, *21*, 2577–2598. [CrossRef]
71. Howard, A.J.; Kincey, M.; Carey, C. Preserving the Legacy of Historic Metal-Mining Industries in Light of the Water Framework Directive and Future Environmental Change in Mainland Britain: Challenges for the Heritage Community. *Hist. Environ. Policy Pract.* **2015**, *6*, 3–15. [CrossRef]
72. Gregory, G.H. Rendering mine closure governable and constraints to inclusive development in the Andean region. *Resour. Policy* **2021**, *72*, 102053. [CrossRef]
73. Dowd, P.; Slight, M. The Business Case for Effective Mine Closure. In Proceedings of the First International Seminar on Mine Closure, Perth, Australia, 13–15 September 2006; Fourie, A.B., Mark, T., Eds.; Australian Centre for Geomechanics: Perth, Australia, 2006; pp. 3–11. [CrossRef]
74. Fields, S. The earth's open wounds: Abandoned and orphaned mines. *Environ. Health Perspect.* **2003**, *111*, A154–A161. [CrossRef] [PubMed]
75. Sandlos, J.; Keeling, A. Aboriginal communities, traditional knowledge, and the environmental legacies of extractive development in Canada. *Extr. Ind. Soc.* **2016**, *3*, 278–287. [CrossRef]
76. Worrall, R.; Neil, D.T.; Brereton, D.; Mulligan, D. Towards a sustainability criteria and indicators framework for legacy mine land. *J. Clean. Prod.* **2009**, *17*, 1426–1434. [CrossRef]
77. Shen, L.; Muduli, K.; Barve, A. Developing a sustainable development framework in the context of mining industries: AHP approach. *Resour. Policy* **2015**, *46*, 15–26. [CrossRef]
78. Pimentel, B.S.; Gonzalez, E.S.; Barbosa, G.N. Decision-support models for sustainable mining networks: Fundamentals and challenges. *J. Clean. Prod.* **2016**, *112*, 2145–2157. [CrossRef]
79. Asr, E.T.; Kakaie, R.; Ataei, M.; Mohammadi, M.R.T. A review of studies on sustainable development in mining life cycle. *J. Clean. Prod.* **2019**, *229*, 213–231. [CrossRef]
80. Limpitlaw, D.; Hoadley, M. Faultlines in Mine Closure Planning in a Developing Country Context. In Proceedings of the First International Seminar on Mine Closure, Perth, Australia, 13–15 September 2006; Fourie, A.B., Mark, T., Eds.; Australian Centre for Geomechanics: Perth, Australia, 2006; pp. 803–809. [CrossRef]
81. Clark, A.L.; Clark, J.C. *An International Overview of Legal Frameworks for Mine Closure*; Environmental Law Alliance Worldwide: Eugene, OR, USA, 2005.
82. ICMM. *Planning for Integrated Mine Closure: Toolkit*; International Council on Mining and Metals: London, UK, 2008; ISBN 978-0-9553591-8-7.
83. Goodland, R. Responsible Mining: The Key to Profitable Resource Development. *Sustainability* **2012**, *4*, 2099–2126. [CrossRef]
84. Erdmann, M.; Franken, G. *Sustainability Standard Systems for Mineral Resources: A Comparative Overview*; Bundesanstalt für Geowissenschaften und Rohstoffe: Hannover, Germany, 2022; ISBN 978-3-948532-63-5.
85. Weldegiorgis, F.S.; Ali, S.H. Mineral resources and localised development: Q-methodology for rapid assessment of socioeconomic impacts in Rwanda. *Resour. Policy* **2016**, *49*, 1–11. [CrossRef]
86. Davies, W.; Van Alstine, J.; Lovett, J.C. 'Frame Conflicts' in Natural Resource Use: Exploring Framings Around Arctic Offshore Petroleum Using Q-Methodology. *Environ. Policy Gov.* **2016**, *26*, 482–497. [CrossRef]
87. Kügerl, M.-T.; Endl, A.; Tost, M.; Ammerer, G.; Hartlieb, P.; Gugerell, K. Exploring frame conflicts in the development of a new mineral resource policy in Austria using Q-methodology. *AMBIO* **2023**, *52*, 210–228. [CrossRef]

88. Nguyen, B.; Boruff, B.; Tonts, M. Indicators of mining in development: A Q-methodology investigation of two gold mines in Quang Nam province, Vietnam. *Resour. Policy* **2018**, *57*, 147–155. [CrossRef]
89. Chapman, R.; Tonts, M.; Plummer, P. Exploring perceptions of the impacts of resource development: A Q-methodology study. *Extr. Ind. Soc.* **2015**, *2*, 540–551. [CrossRef]
90. Vela-Almeida, D.; Kolinjivadi, V.; Kosoy, N. The building of mining discourses and the politics of scale in Ecuador. *World Dev.* **2018**, *103*, 188–198. [CrossRef]
91. Stephenson, W. Technique of Factor Analysis. *Nature* **1935**, *136*, 297. [CrossRef]
92. Stephenson, W. *The Study of Behavior: Q-Technique and Its Methodology*; University of Chicago Press: Chicago, IL, USA, 1953.
93. Steven, R.B. *Political Subjectivity: Applications of Q Methodology in Political Science*; Yale University Press: New Haven, CT, USA, 1980.
94. McKeown, B.B.; Thomas, D. *Q Methodology—Quantitative Applications in the Social Sciences*; SAGE Publications: Beverly Hills, CA, USA, 1988.
95. Brown, S.R. A Primer on Q Methodology. *Operant. Subj.* **1993**, *16*, 91–138. [CrossRef]
96. Robbins, P.; Krueger, R. Beyond Bias? *The Promise and Limits of Q Method in Human Geography. Prof. Geogr.* **2000**, *52*, 636–648. [CrossRef]
97. McKeown, B.; Thomas, D. *Q Methodology*, 2nd ed.; SAGE Publications: New York, NY, USA, 2013; ISBN 978-1-4522-4219-4.
98. EIT RawMaterials. ReviRis: Revitalising Post-Mining Regions: Problems and Potential in RIS Europe. Available online: https://eitrawmaterials.eu/project/reviris/ (accessed on 5 December 2022).
99. QMethod Software. Study Analysis. Available online: https://app.qmethodsoftware.com/docs/articles/study-analysis/analysis.html#step-32-factor-extraction (accessed on 5 December 2022).