Stockholm Environment Institute

Navigating coal mining closure and societal change: learning from past cases of mining decline

SEI working paper
July 2019

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Cover photo: Fish and Coal Building in King's Cross, London
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Introduction

Over the next decade, coal mines will likely close across the world, as many countries shift their energy systems away from fossil fuels and towards cleaner energy. This will not only be driven by climate policies designed to reduce greenhouse gas emissions, but also by other factors that diminish the appetite for coal-fired electricity generation. These other factors include the rapidly falling costs of renewable energy and concerns about air pollution and water scarcity, as well as global shifts in the areas of coal demand and where it is mined. More than 80% of known coal reserves will have to be left in the ground to have a 60% chance of keeping warming to 2°C, according to some estimates (McGlade and Ekins 2015).

A potentially rapid decline in coal production (Carbon Tracker Initiative and Grantham Institute 2017; Mercure et al. 2018) raises important questions about the impacts on workers, mining communities and producing countries, as highlighted by the growing debate on "just" transitions (Evans and Phelan 2016; Newell and Mulvaney 2013). These impacts will be potentially disruptive and unevenly distributed across society; planners will need to grapple with how to plan and implement strategies to mitigate these impacts, and how to create alternative social and economic foundations that can sustain coal-dependent areas (Green 2018).

Some researchers have started to look into historical cases of regional transitions away from coal in order to draw out lessons for future coal transitions (Sartor 2017; Schwartzkopff and Schulz 2015). While useful, this evidence base is limited to a few empirical examples from the coal sector in mostly high-income countries. But other examples – from economies centred not only on coal but also on other natural resource extraction – can help shed light on the current situation facing coal mining regions around the world. Many communities in both high- and low-income countries have experienced the impacts of declining production, workforce redundancies, and mine closure. This study explores what can be learned from these cases.

In this paper, we assess the existing knowledge base to better understand the economic, social and political consequences of mine closure at the national and subnational scales, as well as the measures taken by different actors to mitigate these impacts. To do so, we systematically mapped published literature on the social, economic and political impacts of declining extractive-based economies. From these historical cases, we extract some lessons that might help guide communities and governments in current coal production areas as they prepare for an end to mining.

Our review focuses on how transitions have historically affected demographics, employment and national and subnational economies, as well as the resulting changes in infrastructure, political institutions, collective identities and social networks. We also ask how, if at all, these impacts were managed or mitigated, what actors were involved and what strategies were tried, and to what extent outcomes are documented.

In this paper, we assess the existing knowledge base to better understand the economic, social and political consequences of mine closure at the national and subnational scales

In this paper, we first provide an overview of our methodology and then describe what geographic areas and natural resources are covered in the literature. We then distil some insights about the causes of decline and the impacts experienced locally or at a national level, and we look at the responses of different actors. Finally, we identify some research gaps that, if filled, could provide further insights to support transitions away from the extraction of coal and other fossil fuels.

Review method

A systematic approach to literature review is very valuable to synthesize existing knowledge, clarify controversies, and identify evidence gaps or clusters (Haddaway and Pullin 2014). Systematic mapping is a method used to describe the state of knowledge across a wide topic of interest, in a robust, comprehensive and repeatable way (James et al. 2016). It consists of collating, describing and cataloguing available evidence on the topic of interest (Clapton et al. 2009). It can answer questions about the state of available evidence on a given topic in the literature, such as the amount and location of evidence, the types of interventions or outcomes that have been studied, or the methods used to investigate the topic of interest (James et al. 2016). The evidence collected can lead to the development of new theories, concepts or understandings (Gough et al. 2012). The studies included in a systematic map can also help identify

evidence for policy-relevant issues, knowledge gaps to steer future primary research, and knowledge clusters that could be appropriate for secondary research (Bates et al. 2007; James et al. 2016).

In this study, we first developed a protocol and criteria for evaluating the relevance of the literature for review. We then relied on several research databases and other additional sources, including literature recommended by peers, to find both peer-reviewed and grey literature about mining transitions in English and Spanish published up to September 2017. We used a specialized software, EPPI-Reviewer 4, to organize our review and collected literature documenting the impacts of mine closure. We filtered out literature that did not discuss socio-economic impacts of closure or strategies to address these impacts.

Mining closures often also leave behind a legacy of environmental contamination and clean-up costs (Andrews-Speed et al. 2005; Caldecott et al. 2017; McGuire 2003). These are important and need to be considered by policy-makers, and in our review, we found that a vast number of articles deal with some aspect of the environmental impact of mining sites and mine closure (we screened out over 2,200 publications about environmental legacy/rehabilitation of former mines). In this brief, however, we do not focus on environmental issues, partly because they already have been the subject of comprehensive reviews (Gastauer et al. 2018; Mhlongo and Amponsah-Dacosta 2016), with legal frameworks, practical guidelines and rules[1] being developed to oversee the rehabilitation of the environment when extraction ceases (Clark and Cook Clark 2005; ICMM 2018; World Bank 2004).

Using an iterative approach, we developed a coding framework to extract specific information on the nature of the literature, the nature of the cases documented, the documented effects of mining decline[2], and the strategies used to address such decline. We then coded all relevant references accordingly. When coding the nature of the cases documented, we recorded the geographic location of the cases and used the World Mining Conference's list of minerals and most produced metals[3] to record the type(s) of resource extracted (Reichl, et al. 2017). For coding the different categories of impacts, we drew on and created broader categories from those used by Measham, Fleming, and Schandl (2016) to assess the socio-economic impacts of extractive industries. Regarding the type of actors responding to mine closure, we started from the main actors in international political economy (Broome 2014), and added provincial and municipal governments as they appeared as key actors in the literature; we focused on miners and households for what Broom refers to "everyday actors", as these also stood out in the literature. Types of responses were coded openly. More details about the methodology (including the coding framework) and the literature reviewed can be found in the Appendix.

This primary analysis allowed us to catalogue the available evidence to portray the current state of the knowledge on the socio-economic impacts of mine closure (up to August 2017). It also enabled us to single out knowledge gaps and to identify topics that are suitable for further, future analysis. Then, in a secondary analysis, we distilled insights from the literature about the type of measures taken to address the implications of mine closure (and their outcome).

Findings: what do we know from past mine closure?

Countries and resources studied in the literature

We screened more than 11,000 pieces of literature – including journal articles, books, reports, and other papers – and found 154 that dealt with the social, economic and/or political dimensions of historical transitions in natural resource economies. Together, this literature described 181 country case studies (several were multi-country analyses). As Table 1 illustrates[4], much of the literature is concentrated on the Global North (81% of the country cases), especially the United Kingdom, Canada, the United States and Germany. There is also significant attention to Central and Eastern European cases, as many of these countries' industrial bases were rapidly transformed in the 1990s, with strong implications for the coal

1 The effectiveness of such frameworks is not guaranteed, of course, but this is beyond the scope of this brief.
2 For this study, we use "mine closure", "mining downscaling" and "mining decline" (or variations of these) interchangeably to refer to cases with drastic downscaling or full cessation of non-renewable natural resources extraction.
3 Any ferrous, non-ferrous and precious metal whose production was over 1 million metric tons in 2015 was included in the list of codes. Any other material was coded as "other".
4 The table shows the 10 countries featured in the most publications. Appendix 3 shows publications per type of resources for the 38 countries with case studies included in the review.

mining sector in particular. There are far fewer studies examining closure in the Global South, though cases in China, Chile and South Africa stand out. These cases of historical mining transitions cover 24 different natural resources. Coal mine closures received by far the most attention, followed by iron, copper and gold.

Table 1. Geographical and resource coverage of the literature

Country	# Publications	Coal	Copper	Iron	Gold	Silver	Lead	Nickel	Zinc	Uranium	Oil	Other	Not specified
United Kingdom	32	31					1						
Canada	15	1	3	7	2	2	3	2	3	1		1	
Germany	15	13	2	1									1
United States	14	4	3	3	3	1					2		
South Africa	11	4			7								
Australia	8		3	2	3	3	3	3	2			1	
Chile	8	7										1	
Spain	8	5	3									4	
Poland	7	6											1
China	6	6									1		
...	...	...	...	...	...	...	...	...	...	...	...	...	...
TOTAL	181	104	21	22	17	7	7	5	9	2	5	15	5

Note: Some publications referred to multiple countries, accounting for the difference between the 154 publications included in the review and the 181 total publications in the table (which includes repeats).

Causes of decline

The most common causes of decline or closure identified in this body of literature are economic (mentioned in two-thirds of the publications), particularly the loss of economic competitiveness. The reasons for this were sometimes linked to important political changes. Examples include the fall of the iron curtain in Eastern Europe and the end of the apartheid regime in South Africa – both of which led to a rapid increase of international competition (Marais 2013; Suchá and Malinovský 2012) – as well as the removal of subsidies and liberalization of the coal sector in the UK and in several central and eastern European countries (Matei et al. 2016; Morawski 1994; Perchard 2013; Haney and Shkaratan 2003). Other causes of mining decline included environmental concerns, labour conditions and mining accidents, or financial issues and organizational mismanagement (altogether accounting for 10% of the references) (e.g. Gümüş and Adanalı 2014; Trovato and Castello 2016; Wu and Rii 2017).

Less than 5% of the articles mentioned resources depletion as a key driver of decline. This highlights that the existence of significant remaining reserves is not a sufficient condition for extraction to continue. It also draws attention to the fact that some drivers of a mining decline are structural and not under the control of policy-makers. Several cases describe how structural factors affect resources demand and drive decline. For instance, changes in the energy mix have already driven coal closures in South Korea (Wu and Rii 2017), France (Scargill 1991) and Japan (Lim 2016). One study described how the emergence of alternative fertilizer sources led to the closure of the salt mines in Spain (Saurí-Pujol and Llurdés-Coit 1995). This mirrors what we see in today's changing global coal market, where structural factors contribute to coal's decline, including: climate policy that aims to curb emissions from power generation; the rapidly increasing competitiveness of renewable technologies; the rationalization of excess heavy industrial capacity in China; overcapacity in power production in China and India (where in the past, new coal power plants significantly contributed to global coal demand); and the switch in some developing countries from industry-based economies to service-based ones, implying a lower growth in global coal demand (Sartor 2018).

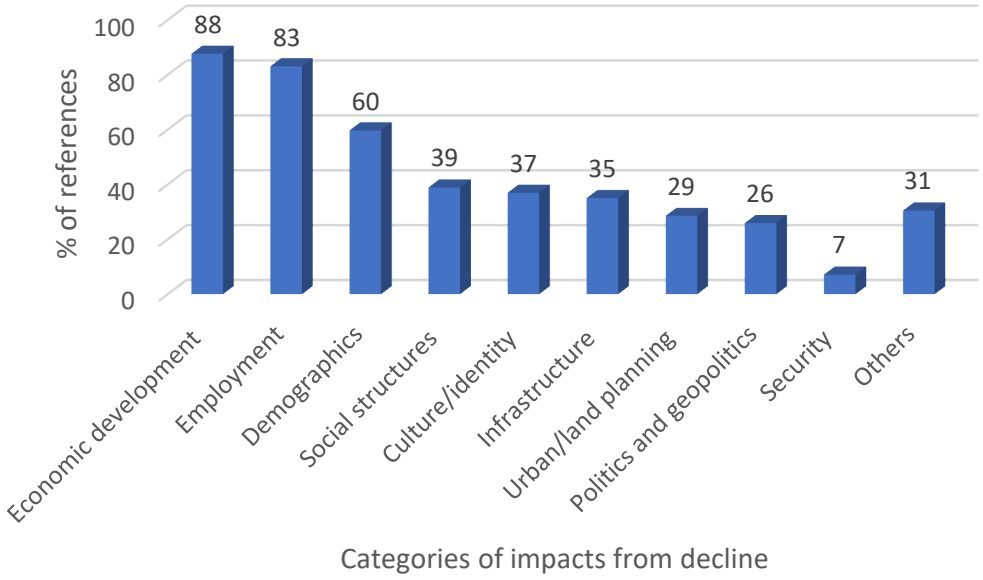
Repercussions of closure

In our review, we specifically examined the following categories of impacts to capture the social, economic and political factors associated with mining decline: economic development, employment, demographics, social structures, culture and identity, infrastructure, urban and land planning, and (geo)politics and security. We noted other types of impacts when mentioned.

The most documented impacts of closure in the literature are *economic*. These include impacts on the local or national economy and impacts on employment, including job loss and labour shifts. Demographic consequences of mining decline, especially migration rates, attract considerable attention as well. Far less documented are impacts on *social structures* (such as how workers and household members interact), *culture* (including the identity of individuals or communities), *infrastructure*, and *urban and land planning*. Miners also often share a strong sense of identity (Della Bosca and Gillespie 2018), and closure can have important psychological effects on individuals and communities (Pini et al. 2010). We know that all social groups are unlikely to experience the same difficulties or access the same opportunities in transition, yet in the literature there is little attention to the distributional effects of mine closure (Aung et al. forthcoming).

Less studied implications from mining decline also include the *political and security* impacts. Several publications look into issues related to power distribution, political influence and political struggle, mostly in the UK and the US (e.g. Malone 1985; Thorleifsson 2016; Swyngedouw 1996). Other types of impacts were also raised in the literature, such as changes in energy policy or repercussions on the housing market.

Figure 1. Percentage of publications addressing various categories of impacts from mining decline.



Societal responses to closure

A coal mining transition is complex and involves numerous actors with distinct interests. From the literature we systematically mapped, we distilled which actors took steps to address the potential and actual impacts of mining decline and what types of measures they took.

Over 90% of the references explore in depth the role of one or more actors in addressing the impacts and/or challenges associated with declining production or mine closure. International organizations, national and local governments, civil society, mining companies, and households were all mentioned. Table 2 summarizes the types of responses each of these actors took, as depicted in the reviewed literature.

Public institutions at various levels have taken a wide range of roles in these historical cases. *International organizations* have been involved in funding economic regeneration projects, new infrastructure, and research on regional economic shifts. The European Union, for instance, has supported former coal mining regions in the UK with the Objective One European funding and the

Table 2. Attention to societal actors and typical responses

Type of actors	% of publications	Type of responses
International institutions	9	Funding for economic diversification programs and infrastructure Funding for research Support in designing response measures
National governments	52	Financial support to workers through welfare programs and (co)-funding of severance packages Other support to workers through design, funding and implementation of training and labour mobility schemes Funding for and support in in designing economic diversification programs and infrastructure Funding for research Institutional arrangements to design, coordinate and implement responses to decline
Provincial governments	50	Financial support for regional economic development programs Institutional support for designing and implementing local responses
Local governments		Design and implementation of economic diversification measures Mobilization of existing national and/or regional financial and capacity building streams Coordination efforts (sometimes through creating new institutional arrangements) with other affected municipalities
Private sector	32	Progressive reduction of workforce Diversification of core activities Support to initiatives for economic diversification Funding and participation in research and financing schemes for eocnomic diversification Abandonment of communities
Civil society	20	Design and implementation of diversification measures and socio-cultural cohesion Mobilization of existing public and private funding streams for economic and social measures
Households and miners	15	Staying/leaving Keeping/changing economic activity

RECHAR programs (Beatty et al. 2007; Fothergill 2017). Affected areas in Germany, Austria, Slovenia and Spain have also received EU support, notably through programs such as RECORE (Regenerating Europe's Coalfield Regions) or Phare (Wirth et al. 2012). The Nordic Council also has supported research on economic diversification in mining regions (Johansson et al. 1991). International financial institutions also have played a role in designing plans to address the impacts of mining decline, notably in Central and Eastern Europe (Haney and Shkaratan 2003).

National governments have typically been involved in providing targeted support to mine employees, through welfare programs – such as early retirement and individual subsidies – (co-)funding severance packages, and measures to retrain and redeploy the workforce (see Keyes 1991 for Canada; Kok 2018 for the U.S.; Rodríguez Torrent and Medina Hernández 2011 for Chile; Karbownik and Stachowicz 1994 for Poland). Another key role has been providing financial resources for economic regeneration projects, infrastructure development and research on economic diversification. For instance, in Chongqing, China, authorities responded to the closure of small-scale coal mines by fostering commercial agriculture and animal husbandry; they offered low interest loans and grants and financed the construction of infrastructure, such as roads and water supplies (Andrews-Speed et al. 2005). Another way to support communities affected by mining decline has been to provide financial relief, through servicing municipal debt in Canada (Keyes 1991) or taking on environmental liabilities in Poland, for instance (Szpor 2017).

In some places, specific contextual measures were set up to support transitions. In Kiruna, Sweden, the central government established a special agency to deal with unemployment linked to an iron mining decline in the 1980s (Liljenäs 1991). In France and the UK, the Coalfield Land-Planning Agency (La Mission Bassin Minier) and the Coalfields Task Force were created to lead integrated planning and coordinate efforts as coal mines were closing (Metsaots, et al. 2011; Beatty et al. 2007). In South Africa – after a decline in gold production in the Free State led to a disastrous economic and social situation

– the government required mining companies to submit social and labour plans, which establish how companies intend to share some of the benefits that flow from mining operations to local communities. These plans include measures to build a diversified economy (Marais 2013).

There are also examples where *local governments* have taken action to buffer the impacts of mine closure. Some accounts document municipal authorities resisting mine closure (Neil and Lea 1992; Nygren and Karlsson 1992); however, in many cases, local governments have taken – or were left with – responsibility for the crafting and implementation of economic regeneration initiatives. In Finland, local authorities in Outokumpu tapped into pre-existing mechanisms for regional industrial development to finance new economic activities (Talman and Tykkylainen 1992). In the Coal-Rim Cluster in South Africa, local and provincial authorities established innovative local economic development initiatives to restructure their economies and create new employment opportunities, notably making changes to urban planning policy to support farming (Nel et al. 2003). Local authorities have also played an important role in mobilizing other levels of government and public finance streams during a transition (Nygren and Karlsson 1992; Talman and Tykkylainen 1992). Relationships between municipalities in depressed areas appear important too. In Tasmania, Australia, competition between municipalities worked against efforts to address the impacts of mine closure (Neil and Lea 1992), while collaboration was essential for successful economic conversion in Germany and Poland (Wirth et al. 2012).

Between local and central authorities, *provincial or state governments* have played a hybrid role, both supporting with financial resources or institutional expertise, and designing and implementing initiatives for economic conversion and heritage conservation. For instance, Canada's Quebec Province appointed a special mediator in Schefferville to support the negotiation between workers and their employer, and created a task force to identify possible diversification paths and to determine which municipal services needed to be maintained after the mine's closure. Together with the federal government, Quebec also set up manpower adjustment committees to plan the downsizing of the labour force and address employment issues (Archer et al. 1991). In the UK, the Welsh and Scottish governments, together with municipalities, set up the Coalfields Regeneration Trust to support communities in navigating the job and health implications of mine closure (Murray et al. 2005).

Measures by the *private sector* also receive significant attention in the literature. Besides strategies to progressively reduce the workforce (Archer et al. 1991) or to diversify their core activities (Hospers 2004; Molotch et al. 1998), mining companies have regularly played a role compensating and supporting the workers' transition, often together with the national government (Keyes 1991 for Canada; Turnbull and Wass 1997 for the UK). Several cases document the participation of (mining and non-mining) private companies in the development of heritage tourism in former mining regions in Spain (Lorca 2017; María del Carmen 2004), in Canada (Stern and Hall 2010) and in South Africa (Nel et al. 2003). In Zasavje, Slovenia, the private sector has also been involved in a regional development centre created to identify strategic sectors for the future and support regeneration measures (Marot 2012). In Kiruna, Sweden, private enterprises set up a local financing company to increase available risk capital for new economic activities (Liljenäs 1991).

There are also accounts of less constructive behaviour from the private sector, notably in the case of Ravensthorpe, in Australia, where the nickel mining company did not warn workers and inhabitants in advance that they were considering closure. Once closure was announced, the company rapidly distanced itself from the community; workers reported that company leaders introduced daily alcohol testing, characterized some responses as too emotional, and refused to attend community meetings. The company had once worked to create an emotional connection with its employees, and their sudden distance and behaviour effectively negated the emotional responses of workers, family and community, making the transition harder to navigate for them (McDonald et al. 2012; Pini et al. 2010).

Civil society organizations have also contributed to designing responses to mine closure, though their role has been far less documented. For example, they have created citizen committees that provide input on issues such as housing, public services or economic diversification (Archer et al. 1991). In Yubari, Japan, the city government set up a Yubari Regeneration Citizens Council to help promote citizen activities in the field of public services and community management following coal mine closure (Martinez-Fernandez et al. 2012). Civil society has also supported the creation of new economic

activities, especially leisure and tourism activities (see Liesch 2016 and Sutherland 2015 for examples in the US; López Meza and Vidal Gutiérrez 2012 for Chile; and Binns and Nel 2003 for South Africa). In the US, grassroots organizations and their national political representatives got support through Superfund, a program to clean up contaminated land, and used the rehabilitation fund to create a historical park on former copper mining land in the Keweenaw Peninsula of Michigan (Liesch 2016).

However, civil society's role has gone beyond managing the economic and public service implications of mine closure, as they have also helped navigate regional identity changes. The social impacts of mine closure can result in social instability, alienation and apathy (Haney and Shkaratan 2003). Many coal miners in the UK experienced a strong sense of social isolation and loss of identity when mines closed; their workplaces had provided social structures that served as the basis for class, locality and family relations (Strangleman 2001). Communities lost their sense of industrial pride and distinctiveness, and without that shared experience, suffered from a social void (Scott 2009). In Durham, civil society organizations have rededicated old miners' lodge banners and other coal mining objects to give the community a sense of folk memory and local distinctiveness; the aim is to build a new identity, one that moves away from the notion that the community exists because of an industry (Scott 2009).

In the literature about mining transitions, *labor unions* are often identified as resisting closure, in cases like the US, Germany, South Africa, Romania and Ukraine (Bruha et al. 2005; Hennings and Kunzmann 1990; Lovei 1998; Shepherd-Powell 2017; Binns and Nel 2001). But unions have also been important enablers of transition in some places. In the Netherlands, despite some conflict, unions agreed that changes were necessary (Gales and Hölsgens 2017). In Germany, the industrial guild for mining, chemicals and energy (IG Bergbau, Chemie, Energie, or IG BCE) was well positioned to demand "just" transition measures when underground mining was phased out (Abraham 2017).

Little has been documented regarding the responses of *households* and *miners* to mine closures, though individual reactions are an important factor in how the impacts are experienced and managed. One study suggests former miners can be reluctuant to learn a new professional skill and often prefer to seek re-employment elsewhere in the coal industry (Haney and Shkaratan 2003). A few publications document how and why mine workers decide to stay in or leave a mining town (Strangleman in the UK 2001; Walsh 2012 in Madagascar; Eikeland 1991 in Norway). Another article argues that manual workers are less likely to move than professional workers; it thus suggests that strategies relying on miners to out-migrate after the decline of mining are unlikely to be successful (Hollywood 2002). A few articles observe the types of employment activities of former miners (Hilson 2010 in Ghana; Tambwe, Rudolph, and Greenstein 2011 in Democratic Republic of Congo).

Other actors, such as universities, also receive occasional attention in the literature. In Michigan, in the US, universities have supported mining transitions by helping to identify new economic opportunities, and by contributing to the design and implementation of strategies and measures to address the negative impacts of mining decline. One example is the Northern Initiative Enterprise Center at Northern Michigan University (NMU), which offers business development services to local (especially small) businesses (West 2010). Another is Michigan Technological University, which supported efforts to set up the Cuyuna Country State Recreation Area, using their expertise with industrial heritage to help local stakeholders find ways to reactivate the local economy while celebrating the region's rich past (Sutherland 2015).

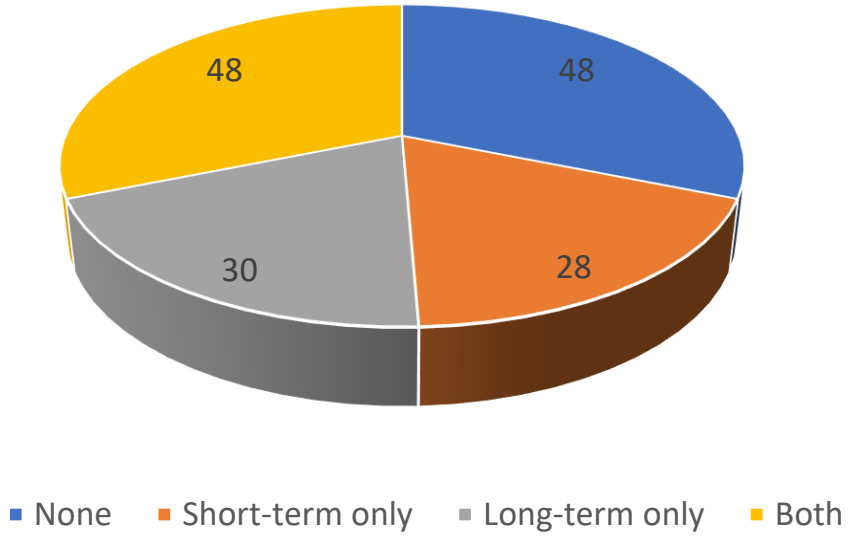
Overall, much more has been documented about the role of national and subnational governments and private companies than about the role of communities in responding to the challenges of mine closure. There is also relatively little attention paid to trade unions, beyond documenting their resistance against transition.

Outcomes of response measures

To be able to learn from past cases of mining transitions, it is essential that information is available not only about the type of challenges that closures generate and the measures put in place to address these challenges, but also about the effectiveness of such measures. Unfortunately, at least one-third of the reviewed literature does not provide any information about the outcome of the measures implemented to address mining decline.

The articles that do contain such information were nearly equally split between short-term (up to 5 years) and long-term outcomes of response measures. Less than a third of the studies documented both short- and long-term outcomes (Fig.2). However, a detailed analysis of outcomes is important, given that short-term and long-term consequences of policy implementation might differ (Sandberg 2015; United States Congress, Joint Economic Committee 2009). A long-term outlook can also provide the opportunity to make further adjustments to policies. One example is the German Rustbelt, where literature has documented several waves of measures to deal with long-term structural decline in the coal sector and related heavy industries. After attempts in the 1960s and 1970s to attract foreign investment to diversify the economy, local authorities moved to a technology-oriented industrial policy, with a special emphasis on environmental technology (Hennings and Kunzmann 1990; Hospers 2004). While this approach has been deemed as successful in transforming the economic structure of the area, challenges still remain, with inhabitants feeling that the transition is not yet complete; efforts continue to create new economic opportunities and jobs (Taylor 2015).

Figure 2: Number of publications documenting the short-term and/or long-term effects of transition responses



The outcome of various response measures of course depends on multiple contextual factors. Still, two factors are frequently mentioned in the literature and seem to help regions navigate mining decline as smoothly as possible.

First, *a high level of involvement and leadership from local governments* appears to be an important factor for success (Neil, Tyykkyläinen, and O'Faircheallaigh 1992). A corollary of this is that local technical and financial capacity is essential for responding to mining decline, and the lack thereof has led to failure in some efforts at social and economic rejuvenation (Hegadoren and Day 1981).

Another important component of a mining transition is *making appropriate financial mechanisms available* to support different types of responses, which involves collaboration between various levels of government. More broadly, the coordination between various public and private actors is a key factor to success (Wirth et al. 2012). This links to the need for a shared vision towards which different societal actors can aspire and which guides collective efforts. In Chile, for instance, the absence of such a vision led to the failure of labor and productive conversion programs (Barahona 2014).

Implications for policy and research on planning coal transitions

To our knowledge, this study is the first that catalogues the available evidence about the socio-economic impacts of past mining transitions in a comprehensive and transparent way. As "just transitions" is a relatively new term and is gathering increasing attention in both policy and academic circles, what such transitions entail and how they can be delivered remain widely debated. As we show here, it is valuable to collect, distill and reflect on the findings and insights from past mining transitions, which have been documented in close to 40 countries.

One key insight from the literature is that bringing previous mining areas back to economic vitality is a lengthy process that takes at least a decade or more. Relatively successful cases of mining transitions – such as in Atikokan in Canada (Keyes 1991) or Matlosana in South Africa (Marais et al. 2017) – took more than a decade, and up to several decades (Gales and Hölsgens 2017). Over this time, these places were able to introduce alternative sources of employment and economic activity, as well as contain declines in employment rates and the population.

In such successful cases, we identified at least two important obstacles to early transition planning. One is that planning for a managed mining transition takes longer than the typical electoral cycle.

A second obstacle is much more specific to mining transitions: the timing and non-transparency of mine closures. In the past, policy measures often came after the initial impacts of decline. In an analysis of over 1,000 closures between 1981 and 2009, Laurence (2011) found that around 75% of mine closures were unplanned or premature. But early planning is particularly important in times of economic uncertainty; at such times, the unplanned and premature closure of mining sites is more likely (Blackman et al. 2009)

When there is planning for closure, the complexity of the challenges requires the attention of more than only the environment and mining ministries. The wide range of socio-economic impacts from closure implies the involvement of many sectoral authorities across levels, which represents a challenge in itself. To help coordinate efforts across government authorities and other societal actors, some countries have set up special institutions to deal with a coal phase-out (BMU 2018). In Australia, for instance, the Latrobe Valley Authority was set up as a partnership between the community, industry and government to help coal workers access training and employment services, facilitate new business development, and invest in infrastructure improvements (Wiseman et al. 2017).

An important step in planning for mine closure is to define realistic goals and measures of effectiveness across environmental, economic and social dimensions. It is important to build a shared vision between societal actors, to steer efforts towards the same direction and reduce resistance.

Our review suggests some significant gaps in the research literature about what happens when natural resource economies go into decline and how these societies buffer the impacts or take advantage of new opportunities. There is considerable knowledge available about coal mining closure, especially in the UK and other European countries. This geographic focus on developed countries is mirrored in the broader literature on natural resource declines. As economic and political institutions in developing countries often differ from those documented cases in Europe and the US, the challenges and options are likely to unfold differently. Further research of historical cases in different contexts would be valuable.

Economic and employment impacts of closure are much more thoroughly documented in the literature than social and political impacts. On economic impacts, more attention needs to be paid to the distributional impacts of mine closure, because a smooth and "just" transition requires design measures that target the specific vulnerabilities of different groups in mining areas. Reducing social inequality is likely to be a particularly important success factor in post-mining transitions, especially in developing countries, where mining regions have often been characterized by high wealth concentration and very limited (if any) benefits in terms of human or social development (Meyersfeld 2017). Political and social impacts of closure have also been understudied.

In terms of response measures and their effectiveness, most analysis tends to focus on the roles played by governments. There is sparse published literature about the long-term outcomes of different types of responses, and little discussion on what criteria can be used to evaluate their effectiveness, not only in terms of economic regeneration, but also in terms of the social and political changes.

Closure sometimes seems far off. But what we decide today has long-term implications. Policy decisions that are made now – including how governments manage royalties, the rules for how companies should manage and communicate mining closures, and broader policies about infrastructure and economic regional development – are key determinants in how the downscaling process can be managed later on. As mentioned earlier, an essential factor for navigating mine closure is strong local leadership and capacities. Unfortunately, in places with poor institutional capacity, natural resources extraction tends to impede institutional development (Wiens 2014).

In summary, there is a great opportunity to learn more from research on closures over the past four decades in order to better navigate future coal and other fossil fuel transitions. However, important research gaps remain. Future research efforts should seek to better understand the effects of declining extractive industries in the Global South and the strategies to address them; the social, cultural and political implications of mining demise around the world; and the specific roles of the private sector, trade unions and civil society in navigating such transitions. Future research on the outcomes and effectiveness of all kind of implemented responses is also crucial.

This study suggests a number of steps of immediate value to policymakers. These include: involving (and coordinating) a wide range of public authorities across sectors and levels in planning for a decline; establishing realistic goals and a criteria of success to ensure a shared vision across actors and stakeholders; and strengthening the financial and technical capacities of local authorities to anticipate and mitigate the wide range of effects from closure or downscaling. With millions of households and numerous communities around the world still dependent on coal mining, it is crucial that these lessons are translated to policy.

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Appendix 1: Method Description

Objectives and design of the study

The objective of the literature review was to map the empirical evidence of mining closure's non-environmental and non-ecological impacts, from the local to the national level, as well as how these impacts have been addressed in the past. Therefore, the primary research question for this review was: *Globally, what have been the collective social and economic impacts of the end (or drastic downscaling) of non-renewable natural resources extraction (specifically minerals, oil and gas) on the local, regional and national scales?* This review also explored the following secondary question: *Who has been involved in addressing and/or managing the impacts from mining closure and decline?*

A literature search was conducted to identify potentially relevant studies to answer the review questions. The primary question guided the elaboration of the search string. We looked for references documenting the impacts of mine closure, and then filtered out references that did not discuss socio-economic impacts and/or strategies to address these impacts.

The reviewing team included three researchers at the Stockholm Environment Institute (the three authors of this publication). To strengthen transparency and replicability of the review and to reduce bias, the method applied in this study incorporated some principles and methodological steps used in systematic reviews. To increase comprehensiveness, we reviewed both peer-reviewed and grey literature. To increase transparency and replicability of the study, we reproduce below in detail the methodology that was applied. We also sought to reduce bias and increase consistency by elaborating an a priori protocol and by performing a consistency check before starting the screening process.

Search Protocol

The first step of the review was to design a literature search protocol. The protocol is available in Appendix 2.

Literature search

The literature search was conducted between August 10 and 22 in 2017. It included both scientific and grey literature to broaden the scope of relevant studies (Mahood, Van Eerd, and Irvin 2014). First, a search string was built using a combination of search terms relating to (a) mining types, (b) closure types, and (c) exclusionary keywords and categories. The latter was based on selection and exclusion criteria, which are described in the following section.

Before using the search string, 10 academic papers meeting the review's selection criteria were identified through a keyword search on the EBSCO search engine. These papers helped determine the appropriate keywords that would yield relevant results. The search string was then tested in the Scopus and Web of Science databases to verify that the search string picked these papers up.

The search string was then applied to a series of computerized databases: Scopus, Web of Science, ProQuest thesis repository, Social Science Research Network, SciELO and Redalyc (see Table 1). Boolean operators, such as "OR" and "AND", were used to look for search terms in sets. In several cases, the databases could not accommodate all the search terms of the search string. Therefore, the search was adapted through using only pairs of search terms, from each (a) and (b) sets, separated by "AND". When Boolean operators could not be used, the search terms initially only pertained to set (a), and the results were further refined using a "search within" function. In addition, to refine the search, limiters – selected according to the inclusion and exclusion criteria – were used. These referred to language (specifying only English and Spanish), discipline, publication date, and the specific terms to be excluded.

Table 1. Search string

Database	Search Options	Search String	Date
Scopus (Title, keywords, abstract)	Topic refining: Refined by: [excluding] WEB OF SCIENCE CATEGORIES: (GEOSCIENCES MULTIDISCIPLINARY OR RADIOLOGY NUCLEAR MEDICINE MEDICAL IMAGING OR MINING MINERAL PROCESSING OR CHEMISTRY ANALYTICAL OR GEOCHEMISTRY GEOPHYSICS OR CHEMISTRY MULTIDISCIPLINARY OR SPECTROSCOPY OR ENGINEERING OCEAN OR COMPUTER SCIENCE SOFTWARE ENGINEERING OR MINERALOGY OR CHEMISTRY PHYSICAL OR GEOLOGY OR MATHEMATICS INTERDISCIPLINARY APPLICATIONS OR ENGINEERING CHEMICAL OR MATHEMATICS APPLIED OR ENGINEERING GEOLOGICAL OR ENGINEERING INDUSTRIAL OR CHEMISTRY APPLIED OR OPTICS OR METALLURGY METALLURGICAL ENGINEERING OR COMPUTER SCIENCE THEORY METHODS OR MATERIALS SCIENCE MULTIDISCIPLINARY OR MECHANICS OR PHYSICS MULTIDISCIPLINARY OR ENGINEERING PETROLEUM OR LIMNOLOGY OR ENGINEERING CIVIL OR FOOD SCIENCE TECHNOLOGY OR SOIL SCIENCE OR ENGINEERING ELECTRICAL ELECTRONIC OR THERMODYNAMICS OR MATERIALS SCIENCE CHARACTERIZATION TESTING OR ENGINEERING MECHANICAL OR ENGINEERING MARINE OR MATHEMATICAL COMPUTATIONAL BIOLOGY OR PALEONTOLOGY OR PHYSICS APPLIED OR ENGINEERING MULTIDISCIPLINARY OR AUTOMATION CONTROL SYSTEMS OR POLYMER SCIENCE OR COMPUTER SCIENCE ARTIFICIAL INTELLIGENCE OR PHYSICS NUCLEAR OR PHYSICS CONDENSED MATTER OR COMPUTER SCIENCE INTERDISCIPLINARY APPLICATIONS OR ELECTROCHEMISTRY OR NUCLEAR SCIENCE TECHNOLOGY OR CHEMISTRY INORGANIC NUCLEAR OR PHYSICS ATOMIC MOLECULAR CHEMICAL OR ENGINEERING MANUFACTURING OR NANOSCIENCE NANOTECHNOLOGY OR COMPUTER SCIENCE INFORMATION SYSTEMS) AND [excluding] WEB OF SCIENCE CATEGORIES: (CHEMISTRY ORGANIC OR ASTRONOMY ASTROPHYSICS OR CHEMISTRY MEDICINAL OR MATERIALS SCIENCE CERAMICS OR NEUROSCIENCES OR MATERIALS SCIENCE COATINGS FILMS OR ENGINEERING BIOMEDICAL OR CLINICAL NEUROLOGY) AND [excluding] WEB OF SCIENCE CATEGORIES: (ENGINEERING AEROSPACE OR BIOCHEMICAL RESEARCH METHODS) AND [excluding] WEB OF SCIENCE CATEGORIES: (STATISTICS PROBABILITY OR ROBOTICS) AND [excluding] WEB OF SCIENCE CATEGORIES: (COMPUTER SCIENCE CYBERNETICS) AND [excluding] WEB OF SCIENCE CATEGORIES: (CRYSTALLOGRAPHY) Language: English; Spanish	(coal OR oil OR gas OR "tar sands" OR "oil sands" OR uranium OR iron OR cobalt OR manganese OR nickel OR titanium OR aluminium OR bauxite OR copper OR lead OR zinc OR gold OR silver OR diamond OR salt OR sulphur OR sulfur OR phosphate OR gypsum OR "mineral*" OR "mining site*") AND (mining OR "oil field" OR oilfield OR gasfield OR coalfield OR "gas field" OR "coal field" OR "fossil fuel* extraction" OR "mining production" OR "mining industry" OR "fossil fuel* industry" OR "gas industry" OR "oil industry" OR extractivism OR "extractive industr*") AND (closure* OR closing OR "shut down" OR "shut-down" OR decline* OR declining OR abandon* OR fall* OR transition* OR phase-out* OR "phase out" OR "industry collapse" OR "changing dynamics" OR "land use change" OR "land-use change" OR transformation OR crisis OR legacy OR inheritance* OR heritage*) AND NOT (sediment*OR "chemical characteri$ation" OR chemistry)	22 August 2017
Web of Science (Title, keywords, abstract)	Topic refining: (EXCLUDE (SUBJAREA , "EART") OR EXCLUDE (SUBJAREA , "ENGI") OR EXCLUDE (SUBJAREA , "MAT") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "CENG") OR EXCLUDE (SUBJAREA "CHEM") OR EXCLUDE (SUBJAREA , "COMP") OR EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , NURS") OR EXCLUDE (SUBJAREA , "NEUR") OR EXCLUDE (SUBJAREA , "DENT")) Language: English; Spanish		22 August 2017

ProQuest	Topic refining: NOT (computer science AND mechanical engineering AND computer engineering AND materials science AND geotechnology AND chemical engineering AND artificial intelligence AND bioinformatics AND information science AND information technology AND mechanics AND biogeochemistry AND mathematics AND molecular biology AND biomedical engineering AND applied mathematics AND genetics AND information systems AND microbiology AND analytical chemistry AND biochemistry AND physical chemistry AND biophysics AND geology AND geochemistry AND civil engineering AND archaeology AND geological AND mineralogy AND surgery AND epidemiology AND gerontology AND medicine) Exclude “data mining” theme Language: English, Spanish	all(mining) AND all(closing) OR all(shut down) OR all(closure) OR all(declin*) OR all(transition*) OR all(phase out) OR all(collapse) OR all(crisis) OR all(transformation)	10 August 2017
	Topic refining: NOT (petroleum engineering AND chemical engineering AND mechanical engineering AND geology AND materials science AND geophysics AND electrical engineering) Language: English, Spanish	all("oil production") AND all(peak) OR all(closing) OR all(closure) OR all(declin*) OR all(transition*) OR all(phase-out) OR all(collapse) OR all(shutdown)	
	Topic refining: NOT (chemical engineering AND petroleum engineering AND mechanical engineering AND mechanics AND computer science AND electrical engineering AND analytical chemistry) Language: English, Spanish	all("oil industry") AND all(peak) OR all(closing) OR all(closure) OR all(declin*) OR all(transition*) OR all(phase-out) OR all(collapse) OR all(shutdown)	
	Topic refining: NOT (petroleum engineering AND chemical engineering AND materials science AND mechanical engineering AND electrical engineering AND petroleum geology AND geophysics AND analytical chemistry AND applied mathematics) Language: English, Spanish	all("gas industry") AND all(peak) OR all(closing) OR all(closure) OR all(declin*) OR all(transition*) OR all(phase-out) OR all(collapse) OR all(shutdown)	
	Topic refining: NOT (petroleum engineering AND chemical engineering AND geology AND mechanical engineering AND materials science AND microbiology AND geochemistry AND biogeochemistry AND astrophysics AND astronomy AND computer science) Language: English, Spanish	all("gas production") AND all(peak) OR all(closing) OR all(closure) OR all(declin*) OR all(transition*) OR all(phase-out) OR all(collapse) OR all(shutdown)	
SSRN (Title, Abstract, Keywords and Authors)	Incl. the following collections: ERN, LSN, FEN, PRN, SRPN, MRN, HUM, AARN, CGN) Search within results (e.g. search for “mining” and then within results, for “transition”). Language: English, Spanish	Mining Transition; Collapse; Decline; Closure; Closing; Abandon; Abandoned; Shutdown; Crisis; Phase	11 August 2017
		Oil Transition; Collapse; Closure; Abandoned; Declining Gas Closure; Declining; Abandon; Collapse; Transition	14 August 2017
Redalyc (Title and Keywords)	Search of small combinations of keywords at a time.	Cierre AND Minería Cierre AND Mina Minería AND Transición Petróleo AND Cierre OR Abandono Mina and Abandono mina OR minería AND cese OR declive	28 August 2016

Scielo (all indexes)	Search of combinations of two keywords at a time.	Minería AND Cierre; Mina AND Cierre; Mina AND Abandono; Mina AND Abandonada; Mina AND Declive; Mina AND Suspender; Mina AND Pasivo; Minería AND Declive; Minería AND Transición; Minería AND Transformación; Minería AND Herencia; Minería AND Terminar; Minería AND Caída; Minería AND Crisis; Minería AND Legado; Minería AND Eliminación; Minería AND Pasivo; (Pasivo ambiental) AND minero; Petróleo AND Cierre; Pozo AND Cierre; Yacimiento AND Cierre; Yacimiento AND Abandono; Yacimiento AND Declive; Yacimiento AND Transición; Yacimiento AND Transformación; Yacimiento AND Crisis; Yacimiento AND Herencia; Yacimiento AND Legado; Hidrocarburos AND Pasivo; Hidrocarburos AND Transición; Mineral AND Extracción; Post-extractivismo	28 August 2016

To complement the literature database search and identify grey literature, specialist sources were consulted as well. Three organizations were identified – the World Bank, E3G, and the justtransition.org network (this website, which collected relevant publications regarding just transitions, is no longer available). Their websites were searched using a hierarchical approach, with the original search string being scaled down to single search terms. Three networks and platforms – ResearchGate, Summernet and GOXI (a platform for "sharing in governance of extractive industries") – were also consulted through an electronic request for relevant literature. We also reached out to two large, ongoing, multi-national and interdisciplinary research projects on our topic of interest: the Resource Extraction and Sustainable Arctic Communities (REXSAC) and the Coal Transitions projects.

Screening process and review criteria

The screening process was performed in three steps. First, duplicates from the database search were automatically removed using EPPI-Reviewer 4 software. We then screened the remaining items by applying pre-determined selection and exclusion criteria to the references' titles and, subsequently, abstracts. A few additional duplicates were identified during the screening process and were excluded. Titles and abstracts were directly screened together for specialist sources, for recommendations from networks' members, and for searches in the Redalyc, SSRN, World Bank, and Scielo databases.

Since three researchers took part in the screening process and items were not double-screened, a consistency check was performed to reduce the risks of bias and inconsistency across the team. The three researchers all screened the same 200 titles. Discrepancies were then discussed among all team members, and the criteria were further specified on this basis – all before the broader screening process began.

For all sources, full-text articles were retrieved when eligibility could not be determined from the abstract alone. In a third round, full-text papers were assessed according to the eligibility criteria. Unfortunately, some records could not be accessed. Figure 1 summarizes the search strategy, showing the different tiers involved.

The following inclusion criteria were applied to the references captured by the search.

- *Type of study*: The review only included actual past cases where mines were closed or experienced a significant and long-term decline. References without empirical applications that addressed only hypothetical cases and theories or conceptual frameworks were left out.
- *Date range*: The review included cases happening no earlier than the 19th century.
- *Language*: The review only included articles written entirely in English or Spanish.
- *Relevant subject*: The review included references that addressed the impacts of mine closure and decline and/or strategies to manage mining transitions. Publications and documents whose scope focused on avoiding closure, on the technical and engineering aspects of mine closure or rehabilitation and on the re-use of pits for energy production were excluded. References that focused only on the environmental and health impacts of mining closure where also discarded.

Data extraction and synthesis

Data extraction was performed by two researchers single-coding through an Excel coding form. These codes allowed for a detailed characterization of the available literature on mining transitions from a socio-economic perspective. The form was designed in accordance with the Review Protocol to identify studies' characteristics in terms of the methodological characteristics of the paper; the geographical, temporal, resource and scalar nature of the documented case; the types of impacts documented; and the information related to responses to a closure or decline.

Coding Framework

The coding framework aimed to collect information that answered the following questions:

- What cases in the literature describe the impacts of a decline of extraction?
- Where is the literature on the review's topic concentrated?
- Which aspects of mining decline and transitions have been investigated?

The framework thus consists of one set of codes regarding the nature of the publication, including the bibliographic information, type of publication, and methods used. The second set of codes relates to the nature of the cases documented, including geography, reason(s) for closure, type of resource, time period and scale. The last set of codes captures information about impacts, responses and their outcomes.

Table 2. Coding Framework

Nature of the literature		
Bibliographic information	Author(s) Title Year of publication Publication outlet Language	
	Type of publication	Journal paper-original research; PhD/master thesis; Conference paper; Working paper or equivalent (e.g. brief, report); Other.
Nature of the case		
Geography	Country(ies) Province(s) Specific site/area(s)	
Causes of decline	Economic, demand collapse, financial, ran out of reserves, population opposition, environmental disaster, (geo)political changes, mismanagement, others	
Type of resources	Coal, oil, gas, tar/oil sands, uranium, iron, cobalt, manganese, nickel, titanium, aluminum, bauxite, copper, lead, zinc, gold silver, diamonds, salt, sulphur, phosphate, gypsum, other.	
Effects of decline		
Presents empirical information about the effects of decline	Yes/No	
If it does, category of effects	Employment	Changes in (un)employment rate, sectoral share of employment, labor mobility
	Economic development	Impacts on growth, income and poverty level, export level, economy structure, living standards Need for promotion of alternative economic activities
	Demography	Changes in population levels, age structure, migration rates, distribution of population (rural/urban)
	Social structures	Changes in patterns of social relations (e.g. family interactions, social networks composition)
	Culture and collective identity	Changes in shared knowledge, values, and practices and sense of belonging of miners or other inhabitants of producing regions
	Political	Political struggle, distribution of power, political representation and electoral behavior, changes in public institutional arrangements and interactions, effect on future narratives.
	Security	Incidence of conflict, civil unrest and explicit mentions of "security"
	Urban/land planning	Changes in land use, changes in urban and land planning policy
	Infrastructure	Changes in the quality of infrastructure and/or delivery of public services
	Other	Open coding

Distributional perspective		
Are the distributional effects of decline and/or response measures documented?	Yes/No	
Responses to decline		
Is there information about responses to mining decline?	Yes/No	
If there is, whose responses are described?	International organizations	International governmental and non-governmental institutions
	Public national	National government institutions (incl. State-owned enterprises)
	Public sub-national	Local, provincial/departmental and other sub-national public institutions
	Private sector	Companies, business associations, companies' foundations
	Civil society	NGOs, citizen groups, community associations
	Households	Families or group of people living together
	Miners	Employees of mines (form a collective perspective)
	Trade unions	Worker associations
	Other	
And what are the responses?	Open coding	
Resistance to mining decline		
Is resistance to mine decline and/or response measure documented?	Yes/No	
If it is, from whom?	Open coding	
Outcomes		
Are short-term outcomes of response measures documented?	Yes/No	
Are long-term outcomes of response measures documented?	Yes/No	

Results

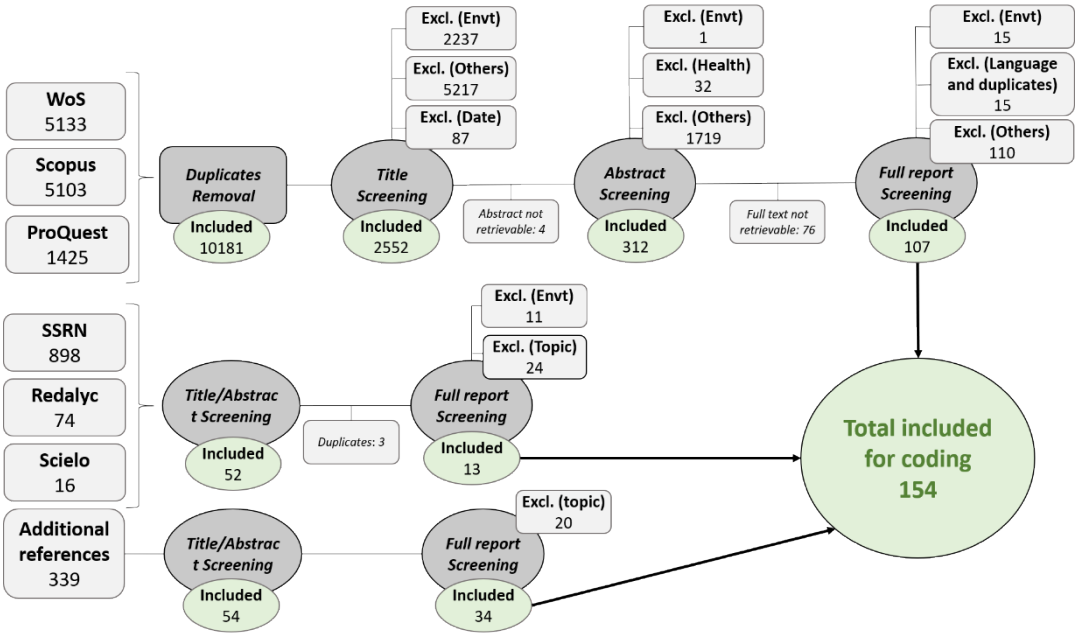
The search results are presented in Figure 1. We collected 11,661 papers through the initial literature search in three scientific databases (ProQuest, Scopus and Web of Science). After removing duplicates automatically, 10,181 papers went through the title and abstract screening; 312 then went to full paper screening. After full paper screening, 107 papers were included in the review. Many of the papers were discarded because their main topic was not the impacts or responses to mine closure[5] (some focused on the impacts of mining operations, the technical aspects of mine closure, or the ways to delay closure, for instance) or because they did not empirically study past cases of mining transitions. Various papers, for instance, discuss the potential impacts of a shift away from natural resources extraction in the future (Rixen and Blangy 2016; Side 1997; Tarigan et al. 2017).

Additional publications and documents were collected through other databases and sources. After duplicates were removed, they were screened simultaneously by title and abstract and then by full report. Forty-seven of them were included in the review for coding.

Altogether, 154 publications and documents met all the inclusion criteria.

5 For this study, we use "mine closure" and "mining decline" (or variations of these) interchangeably to refer to cases with drastic downscaling or full cessation of non-renewable natural resources extraction.

Figure 1. Search Strategy



Methodological limitations

In this review, our limited resources did not allow for the double-screening of the initial search results. The consistency test we performed beforehand aimed to reduce the risk of bias during the screening process, but double-screening would have been more effective in this regard. We were also limited in our research for grey literature, and in the future, our study could be strengthened by updating the literature base and widening the search for non-academic literature through web searches and through the possible inclusion of news articles. Adding languages (especially Russian, French and Portuguese) might also bring about additional relevant studies.

Full list of publications included for data extraction

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Appendix 2: Literature Search Protocol

Background and purpose

More than 80 percent of coal reserves will have to remain underground in order to keep global warming under 2°C (McGlade and Ekins 2015). This understanding has spurred considerable work on the economic implications of transitions away from the production of coal – and other fossil fuels – in line with the technological- and cost-oriented focus that has been dominating green/low-carbon transition studies. However, in parallel, attention has recently been given to transitions' impacts on different social groups. The debate on just transitions is an example of it.

Climate change mitigation policy (and other environmental and social imperatives) is likely to spur a series of coal mine closures across the world, a delicate political process which will require careful planning and implementation, as well as political negotiations. This constitutes a daunting challenge, which some have started to look into, notably by drawing lessons on past cases of coal transitions (Caldecott, Sartor, and Spencer 2017). Still, policy discourses on transitions tend to rely heavily on theory and only on a few empirical examples, most of them in developed countries.

Within this context, it is essential to have a clear overview and understanding of the existing empirical evidence on the causes, management and outcomes of mine and pit closures, as well the limitations of this evidence base. This will help to ensure a critical appraisal of policy discourses and proposals about local transitions and to identify clusters and gaps of knowledge on the topic. This study thus aims to collect and assess existing empirical evidence about the causes, processes and outcomes of transitions away from non-renewable resources extraction. Based on the literature reviewed, it also aims to draw key insights about the political dynamics and management of past mines and pit closures.

Research Question

Globally, what have been the social, economic and/or environmental impacts of the end (or drastic downscaling) of natural resources extraction (specifically minerals, oil and gas) on the individual, local, regional and national scales?

Secondary questions

- Coverage: What is the geographical range and the types of resources covered in the cases described in the literature about the impacts of the decline and downscaling of resources extraction?
- Impacts: What were the impacts of closure?
- Cause: How did the closure come about?
- Response: What types of measures (such as financial/training/relocation policies) have been implemented by governments, companies or other actors (not individuals) to address socio-economic and environmental impacts?
- Resistance: What kinds of resistance or opposition was there to closure and/or associated measures and by whom?
- Outcomes: What have been the short-term and/or long-term impacts of response measures?

Search string and databases

PICO: Population, Intervention, Comparison, Outcome

Subject	Intervention	Comparison	Outcome
Global level	Mine/field closure (or fishery collapse)	NA	Socio-economic impacts
No implication on search string	*Mining + synonyms in search string AND closure + synonyms*		*Not specified in the search to allow for picking up on broad range of impacts*

Elements of the search string

Substance	Mining	Closure	AND NOT
Coal	Mine	Closure	Sediment
Oil	Mining	Closing	
Gas	"Oil/gas/mining production"	Decline	
"Tar sands"	"oil/gas Field"	Abandon	
Uranium	Mining/oil/gas industry	Transition	
Iron	Extractivism/extractive industry	Phase-out	
Cobalt		Collapse	
Manganese		Fall	
Nickel		"Changing dynamics"	
Titanium		"Land use change"	
Aluminium		Legacy	
Bauxite		Heritage	
Copper		Inheritance	
Lead			
Zinc			
Gold			
Silver			
Diamond			
Salt			
Sulphur			
Phosphate			
Gypsum			
Mineral			
Mining site			

Selection of minerals based on data from the World Mining Congress (World Mining Data 2017)

Mineral fuels	*All of them*
Ferrous Metals	*Over 1 million metric tons produced in 2015*
Non-Ferrous Metals	*Over 1 million metric tons produced in 2015*
Precious Metals	*Over 1 million metric tons produced in 2015*
Industrial Metals	*Over 50 million metric tons (carats for diamonds) produced in 2015*

Search string:

(coal OR oil OR gas OR "tar sands" OR "oil sands" OR uranium OR iron OR cobalt OR manganese OR nickel OR titanium OR aluminium OR bauxite OR copper OR lead OR zinc OR gold OR silver OR diamond OR salt OR sulphur OR sulfur OR phosphate OR gypsum OR "mineral*" OR "mining site*") AND (mining OR "oil field" OR oilfield OR gasfield OR coalfield OR "gas field" OR "coal field" OR "fossil fuel* extraction" OR "mining production" OR "mining industry" OR "fossil fuel* industry" OR "gas industry" OR "oil industry" OR extractivism OR "extractive industr*") AND (closure* OR closing OR "shut down" OR "shut-down" OR decline* OR declining OR abandon* OR fall* OR transition* OR phase-out* OR "phase out" OR "industry collapse" OR "changing dynamics" OR "land use change" OR "land-use change" OR transformation OR crisis OR legacy OR inheritance* OR heritage*)

Exclude results per field of research:

Chemistry, Physics, Earth and Planetary Sciences/Geosciences, Maths, Computer sciences, Engineering, Geology, Mineralogy, Limnology, Neurosciences, Nursing, Mineral processing, Materials, Nanosciences.

Databases:

- Scopus
- WEB of science, core collection
- ProQuest
- SSRN
- Scielo
- Redalyc
- Additional sources:
- GOXI network
- REXSAC
- Research Gate
- SUMERNET
- E3G work on transitions
- World Bank Publications database
- Coal Transitions Project

Screening process

Inclusion/Exclusion criteria:

Type of study: The review only included actual past cases of the closure or significant and long-term decline of mines. References addressing only hypothetical cases and theories or conceptual frameworks to study mining transitions without empirical application were left out.

Date range: The review included cases happening no earlier than the 19th century.

Language: The review only included articles written entirely in English or Spanish.

Relevant subject: The review included references that address the impacts of mine closure or decline and/or strategies to manage mining transitions. Publications and documents that were focused on avoiding closure, on the technical and engineering aspects of mine closure and rehabilitation, and on the re-use of pits for energy production were excluded. References focusing on environmental and health impacts of mining closure were also discarded.

Software:

EPPI Reviewer

Appendix 3: Countries and types of resources covered in the literature

Country	# Publications	Coal	Copper	Iron	Gold	Silver	Lead	Nickel	Zinc	Uranium	Oil	Other	Not specified
Australia	8		3	2	3	3	3	3	2			1	
Austria	3			3									
Belgium	1	1											
Canada	15	1	3	7	2	2	3	2	3	1		1	
Chile	8	7										1	
China	6	6									1		
Czech Republic	4	4											
Democratic Republic of Congo	1		1									1	
Estonia	2											2	
Finland	3		2	1					1				1
France	5	5											
Germany	15	13	2	1									1
Ghana	1											1	
Greece	1								1				
Guyana	1												
Hungary	2	1											1
Iran	1										1		
Italy	1											1	
Japan	3	3											
Madagascar	1											1	
Mexico	3		1								1		1
The Netherlands	1	1											
Norway	4	1	2	3		1			2				
Palestine	1											1	
Papua New Guinea	1				1								
Poland	7	6											1
Romania	3	2								1			
Russia	1	1											
Slovenia	4	4											
South Africa	11	4			7								
South Korea	1	1											
Spain	8	5	3									4	
Sweden	3		1	2									
Taiwan	1				1								
Turkey	1											1	
United Kingdom	32	31					1						
United States	14	4	3	3	3	1					2		
Ukraine	3	3											
TOTAL	**181**	**104**	**21**	**22**	**17**	**7**	**7**	**5**	**9**	**2**	**5**	**15**	**5**

Countries in the Global South are italicized.

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