Structural change as an opportunity for a post-mining region: The case of Pyhäjärvi, Finland

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Abstract: Many mining towns have faced or are about to face challenges regarding keeping their region economically stable and its image attractive. With mineral resources exhausted and mining activities shutting down, alternative opportunities for jobs are difficult to establish and the regional image may be unappealing and not eco-friendly. Furthermore, the closure of a mine comes with large maintenance costs. This is the case in the small town of Pyhäjärvi, where the underground operation of the Pyhäsalmi mine will shut down in 2021. The depth of the Pyhäsalmi mine, 1,445 m underground, offers a unique environment, with large-scale possibilities to utilise the infrastructure and resources, such as for the purposes of establishing a geothermal energy facility. Renewable, low-carbon energy sources are not only at the centre of the fight against climate change, but they also provide profitable and stable energy solutions. Therefore, using existing operation environments such as the Pyhäsalmi mine presents an opportunity to create and use green technology solutions, and thus transform an extractive industrial locality into a forerunner that offers new business opportunities in the clean energy sector.

Structural industrial change would require strong regional resilience. A resilient region is able to adapt its activities, markets and local political structures during the change; however, restructuring processes are challenging due to functional, cognitive and/or political lock-in when regions tend to fall into path dependency (Hasslink 2010a; Martin 2012). Recent developments in economic and social systems (caused by globalisation, decarbonisation and the rise of digital technologies) are influencing all regions that should be able create new paths (Giacometti and Teräs 2019; Hasslink 2010b). This study discusses whether the structural change of the region can be turned into an economical and environmental opportunity and what kind of social, economic and political conditions can either make this a reality or act as a hindrance.

Keywords: Geothermal energy, structural change, regional resilience, path creation

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Background

The mining industry has long had a positive impact on local economies by creating jobs in locations that are often peripheral. Consequently, such regions' economic competitiveness has been strongly dependent on mining activities. The situation is much the same in the case of Pyhäjärvi, where the Pyhäsalmi mine, the deepest metal mine in Europe, has been operating since 1962. The mining operations were started by Finnish company Outokumpu Oy as an open-cast mine but were relocated fully underground by 1975. Even though the ownership was transferred to a Canadian company in 2001, the mine has continued being a focal actor in the region as the biggest employer for over 50 years. Thus, its operation has been significant not only in the economic sense, but by extending industry countryside town and thus making Pyhäjärvi lively and active. After all, it is a small town with less than 5,300 inhabitants in a sparsely populated, rural region where a great majority of the companies are small, with only two other companies employing 20 persons or more (Statistics Finland 2019a). The mine and its related activities account for 30% of the tax returns of the town (Tekniikka & Talous (2019).

The mine's success is based on its effectiveness, partly due to Finnish high technology. However, exhausting mineral sources and thus closing the mine has been in discussion since at least 1998, when investigation estimates indicated that operations will last only until 2012 (Tekijä 2019). Though closure has been extended several times after that, the re-use discussion already has a long history. The most promising case in the past was the decade long, so-called Laguna project, which estimated Pyhäsalmi mine as the best location for a neutrino research centre worth several hundred million euros (Tekijä 2019).

Pyhäsalmi mine is based in a logistically well-located (in terms of national connections and accessible transport) small town in the middle of Finland. Overall, the region's population is decreasing, and as underground operations of the mine will cease completely by 2021, the effects of the structural change will be significant. With 216 employees, the Pyhäsalmi mine has been the biggest employer in the town, and its closure will lead to a loss of 400 jobs via its subcontractors and service providers; this amounts for more than 20% of the employed population of the town. Furthermore, if the indirect impacts of this closure, such as transportation, logistics and services, are taken into account, an additional (estimated) 200 provincial and 200 national jobs will be lost. In this paper we discuss how this kind of post-mining structural change could be turned into an economic, social and political opportunity.

Although the closure of the mine will present economic, social and political challenges, it might also signal the beginning of a new era in the region from the perspective of geothermal energy. The need to reduce greenhouse gases as fast as possible in order to avoid the most severe impacts of climate change on ecosystems and human health and well-being is commonly and globally recognised (IPP 2019). Nations around the world have committed to decreasing emissions of greenhouse gases to be able to reach the universal agreement to limit the average global temperature increase s to 1.5°C. Renewable energy (RE) sources offer the strongest prospect for both mitigating climate change and replacing fossil fuels. RE's share of energy consumption (17.5% in 2017 in the European Union) is indeed rising (EC 2019a). By 2030, the EU (and Finland as a member) has to decrease emissions from large industry and energy plants by 43% and emissions from other sectors by 30%. Additionally, the utilisation of RE needs to increase to 27% of all energy usage (EC 2014). The energy resources available will depend on the location, quality and variety of these sources (Balta-Ozkan *et al.* 2015) in future years and decades. These above-mentioned emission decreases and RE demands can present a post-mine opportunity for the Pyhäjärvi region by attracting new operations and inhabitants who base their business ideas or personal ideology on the usage of eco-friendly energy.

Interest in geothermal energy (heat derived from the sub-surface of the earth) has increased in past decades, as geothermal power is cost-effective, sustainable and environmentally friendly. Geothermal energy has also been regarded as a reliable source because it is capable of providing very high soil availability factors (Glassley 2010). One factor that is often overlooked is that geothermal energy is a viable option for the municipalities and for the mining industry itself. In areas of high geothermal potential, geothermal energy can provide a source of electrical power for a mining operation. Globally, geothermal energy is used for heating, cooling and the production of electricity.

In Europe, the interest in low-carbon energy has resulted in an increase in the usage of geothermal energy particularly for heating and cooling (EGEC 2019). Deep geothermal heat can be used for district heating, agri-food sectors as well as to process heat in industry. However, in northern countries such as Finland, the usage of geothermal energy is mainly concentrated on heating with shallow geothermal systems because of the cold climate. Shallow geothermal resources are usually assisted by heat pumps at very low geothermal energy temperatures. Although geothermal energy plays a niche role in the Finnish energy sector (Lauttamäki 2018), the theoretical geothermal energy potential is 300,000 TWh when calculating the energy potential between the surface and a depth of 300 m below the earth. 300,000 TWh is one thousand times the amount of power used in the whole of Finland (GTK 2018a). The theoretical potential indicates that only small amount of geothermal resources is used (see also figure 2), partly because of lack of standard solutions. Even though it cannot solve all the energy need even with advanced technological solutions, it has locally large potential, especially in large buildings such as apartment buildings and offices where, along with need of large amounts of heat, there is also need for cooling (Lauttamäki 2018). Thus, new technologies are seen potential so that geothermal energy is regarded as one of the most important ways to increase renewal, local energy usage (TEM 2019).

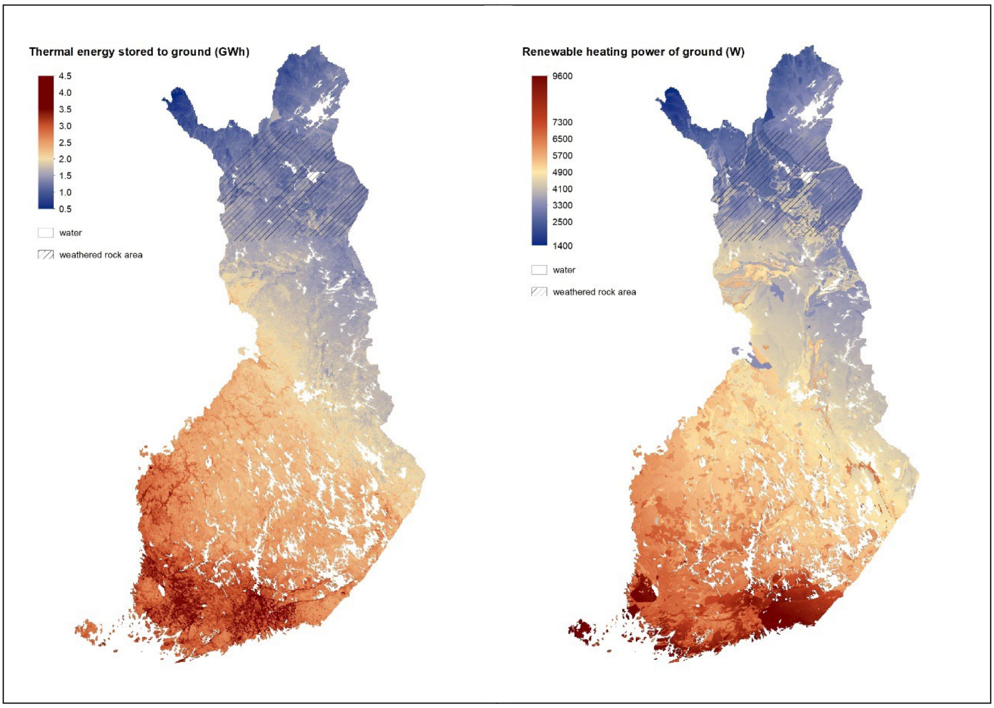

Figure 1. Geothermal energy potential in Finland (Source: Ahonen *et al.* 2019).

Theoretical background: Structural change, regional resilience and path dependency

Regions are affected by global, national and local developments. Additional shocks that affect local (sub-national) economies are related to internal decision-making processes; for instance, in the closure or relocation of key employers (Giacometti and Teräs 2019). A structural change is a long-term phenomenon affecting the economic condition of the region when an industry or market changes how it functions or operates (Krüger 2008). Normally undesired structural change relates to an industry's business collapses or other organizations of business. Structural change is nothing unusual, as it is a normal part of regional economic development and business renewal. However, if the economic structure in a region is narrow or highly dependent on one industry, the impacts of structural change can be dire. The regional development policies recognise importance of creation of new business operations, accelerating growth and internationalisation to be at the centre of regional industrial renewal (TEM 2019). This research suggests some practical course of conduct these policies into practise, how regional resilience can be supported during structural change. It is important to understand the regional context where these structural changes takes place, but also strengths and weakness of the region.

Resilience has many different definitions with competing underpinning theoretical frameworks. The concept of resilience based on its Latin root, resilire, which is to "leap back or rebound" (Martin 2011). Foster (2007) defines resilience as "the ability of an economy to anticipate, prepare for, respond to and recover from a disturbance". Thus, regional resilience in this paper is defined as a region's short-term capacity to overcome shocks as well as to its long-term capability to develop new growth. A resilient region has functional, cognitive and political ability to adapt its activities, markets and local political structures (Hasslink 2010a). However, many capacities are context-specific and place-based. Risks does not exist in isolation but are part of a broader context and interlinked with other risks. Furthermore, there are long-term trends that weaken the potential of a region and its actors to thrive, stress factors, weaken regional resilience. Recognized stress factors are over-dependence on single industries, ageing population, demographic decline, skills shortages, centralisation of services, unreliable transportation and weather conditions (Giacometti & Teräs 2019).

Path dependency does not limit policy makers capability to widen their way of working, but policy makers do tend to fail to learn from past experience and mistakes in their decision-making processes (Gertler 2005). Thus, the concept of path dependency explores organisational, institutional and political change processes, including the idea that historic events predict future ones, since economic decision-makers are likely to follow existing development paths and familiar procedures, which endangers competitiveness and economic growth (Schienstock 2011).

Whilst following the path ensures growth when the path is right, it is important to be aware of these structures and be able to break out and create new paths when needed, especially in a case of regional shock. However, all regions are not the same in their ability to change paths and alter the nature and direction of their economic trajectories over time; some are more dynamic than others. Adaptivity depends on issues such as the diversity of the region's economic structure and the availability of suitable labour, the ability to adapt new skills, the innovativeness of existing firms and their willingness to move on to new sectors (Carlsson *et al.* 2014; Martin 2012). Furthermore, the direction of the change is influenced by several factors, such as past experiences, decisions, and practices (Gertler 2005). According to Schienstock (2004), there are five 'building blocks' that are needed for path creation:" 1) a 'window of new opportunities' associated with a new techno-organisational paradigm, 2) the prospects of new businesses and new markets, 3) pressures coming from external socio-economic factors, 4) key change events and 5) the human will to change things."(Schienstock 2011:68)

The political-level actions come into focal interest in circumstances wherein the region is about to lose a significant employer. It could be that the reactions of the local politicians reflect fear or apathy, resulting in lack of courage or limited vision to create regional strategies aiming for longer time span. This would emerge in the sense that, for example, the changed situation is 'not sufficiently examined'in terms of regional strategies or that regional authorities are not investing in building new networks. Therefore, acts on the political level directly affect the local entrepreneurial situation, possibly hindering the emergence of new entrepreneurial activities. This illustrates a lack of support for companies from public authorities.

Maskell and Malmberg (1999) highlight that, in a modern knowledge-based economy, for regions' competitiveness it is equally important to be able to unlearn, especially in a situation of technological and industrial transformation, and search for new industries and refresh local competitiveness. Human and physical resources, the structures established and the institutions generated in the area over time make up the regional capabilities. It is then inevitable that regional capabilities change over time. To overcome the inevitable regional asset erosion, there should be a formation of new capabilities in the form of new resources, structures and institutions (Maskell & Malmberg 1999).

Regional resilience is a conceptual framework that helps to think of regions in a dynamic, holistic and systematic way. According to Swanstrom *et al.* (2009), "In the face of a stress or challenge, a system can change its structure and function, creating a new system. In the case of the foreclosure challenge, for example, resilient regions do not just return to the status quo ante but reinvent themselves with new relationships that are more likely to support healthy functioning housing markets" (pp. 2-3). Thus, resilience refers to a region's short-term capacity to overcome shocks as well as to its long-term capability to develop new growth. Short-term and long-term viewpoints are interrelated, as shocks may affect regions' capacity to develop new growth paths (Boschman 2015). According to Ciacometti and Teräs (2019), recent developments in economic and social systems, caused by globalisation, decarbonisation and the rise of digital technologies, are influencing all regions that have to act and think on a multi-scalar level. Figure 1 below demonstrates the role and impact areas of regional resilience required when facing industrial structural change.

Knowledge networks affect resilience in a region. Some networks are more sensitive to shocks than others, but some also have higher capacity to develop new growth paths. Regional capabilities, competencies and knowledge networks, as well as business cultures, expectations and existing supporting policies, are particularly important to how a region develops resilience (Figure 2). Adaptation, which refers to the short-term ability to react to shocks, is increased if the networks become inward-looking, which enhances control and efficiency within the network but prevents out-of-the-box thinking. Resistance is also dependent on the scale, nature and duration of the shock. The situation is different in the case of sudden shock, which might 'wake up' local decision makers. In the case of a slow burn, however, people may be aware of negative regional development and threats but are not necessarily forced to act and the wane is becoming merely a status quo (Carlsson *et al.* 2014).

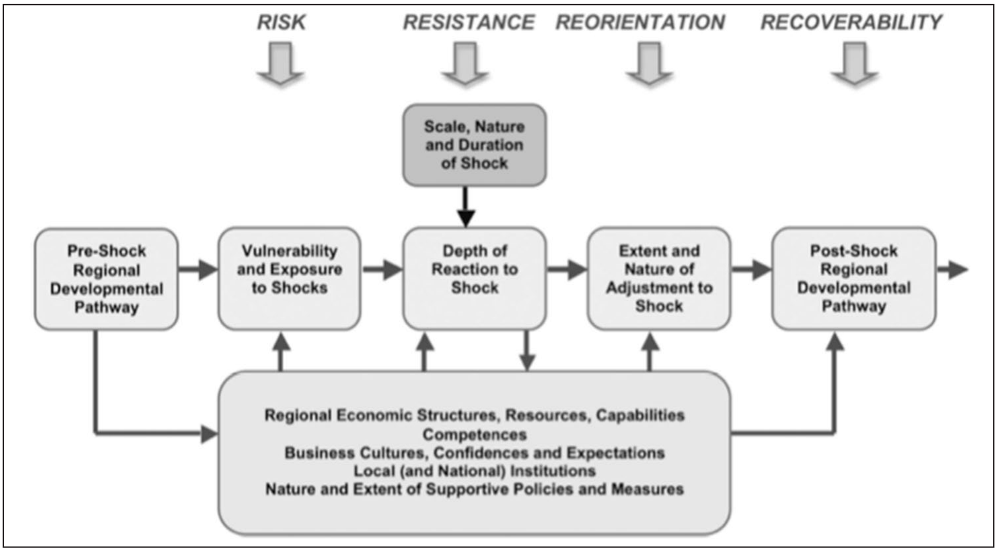

Figure 2. Regional resilience from recessions. Source: Martin *et al.* 2016

In addition, lock-in hinders adaptability; therefore, the region's abilities to react to shocks and find new development paths are weakened in the long run. This is typical in specialised regions like Pyhäjärvi. Furthermore, if the knowledge network structure is too fragmented, i.e., there is not much connectivity between the nodes in the local network structure, the region scores high in adaptability. However, this may come at the expense of low adaptation. The literature suggests that the optimum situation would be that the network structure would include cliques, that mean dense cooperation of different actors, but that there is also need for relationships between cliques that co-exists with structural holes (Fleming *et al.* 2007).

This is also highlighted by Bathelt *et al.* (2004) in their discussion on local buzz and global pipelines. They note that there needs to be enough connectivity between the local knowledge network nodes to enhance knowledge creation and activities in the region, but also enough active connections outside the local network to enable new ideas to stream into the region and refresh knowledge creation. From the institutional viewpoint, institutions such as laws, norms, attitudes and culture have a pivotal role, as they enable or hinder interactions that transverse knowledge networks and regional industries (Boschma 2015).

In this paper, we are looking ongoing structural change in Pyhäjärvi in the viewpoint of regional resilience. Geothermal energy potential of the closing mine especially during ongoing energy transformation offers a great opportunity to strengthen the regional resilience. However, as the idea of path dependency suggest, while economic systems changes over time, past decisions and events have influence on today's choices and events. Therefore, policy makers and their ability of recognize and renovate those operations that might have been workable in the past, but not in the future.

Re-use of mines

Though the closure of a mine is a dire situation for local business, the mine could continue its life-cycle in a novel form, offering new business opportunities for the region. The general reasons for shut downs include running out of the mined minerals and unprofitability. In Finland, former open-cast mines and mine areas are used for culture heritage and leisure time activities, such as mine museums, restaurants, cultural events and so on. Nature and animal-related activities have also been popular, e.g., nature trails, greyhound racing, golf courses and bird watching. In some cases, the closed mines have been transformed into industrial and infrastructure sites, acting as concrete element factories and sand/gravel pits. Other minor uses have been military facilities and spaces for fire rescue exercises (Kivinen 2017).

In Europe, in addition to re-using open-cast mines for leisure time activities on a large scale, e.g., in the Ruskeala Mountain Park (Ruskeala 2019), to be transformed the area to a forest (Sklenicka & Charvatova 2003), there is a growing interest in utilising open-cast mines for aquaculture (Larondelle & Haase 2012). In the global perspective, the latest business innovation comes from China. There, an 88 m deep open-cast mine is being transformed into a luxury five-star hotel at the end of 2019. The hotel will be located near Shanghai and is being built to stand on the wall of the former mine. 16 of the 18 floors of the hotel are under the surface in the former mine pit, and two floors are under water (DailyMail 2019).

The re-use of underground mines is also concentrated on utilisation for education and research, e.g., in physics, geology and engineering (Sanfordlab 2019). For example, in Canada, in an underground mine two km below the surface, there is an underground science laboratory for neutrino and dark matter physics (Snolab 2019).

Case: Structural change in Pyhäjärvi

The closing of Pyhäsalmi mine will have a multifaceted impact on the surrounding region. Pyhäjärvi mine is one of the biggest employers in the area. The loss of the mine would mean a significant increase in unemployment, which will lead to growing net emigration of working-age people and thus an ageing population. The total number of lost jobs is evaluated to be around 800, including jobs in the mine, subcontractors and services, as well as indirect regional and national jobs. In addition, growing unemployment may affect social services. Whilst unemployment would probably require a new, different kind of social service, there is a risk that, due to reduced tax revenues, there will be limited municipal social service offerings available and all kind of activities would decrease to a minimum.

In comparison with the other municipalities in the region, the unemployment rate (10%) is highest in this sub-region (ELY 2019) and the net income of the population is lower than the average in Finland. Also, the level of education is significantly lower amongst the people in the Pyhäjärvi municipality than in the country as a whole (Statistic Finland 2019b). Furthermore, mining towns are often associated with negative images of environmental degradation, pollution and old-fashioned working practices. All regions facing structural changes need to find innovative solutions to overcome economic, social and environmental challenges, but these obstacles affect smaller towns in sparsely populated regions much more severely; here, the number of lost jobs is relatively high and they are difficult to replace (Harfst 2015). Furthermore, based on 52 participants of a questionnaire carried out in spring 2019 amongst entrepreneurs in the region, existing companies do not seem to grow (The Federation of North Ostrobotnia Enterprises 2019). One third of the respondents said that the closing of mines does have an impact on their operations and almost 40% answered that their activities will decrease somewhat. Over 50% of the respondents were not prepared for the mine closing at all. Only 20% of the companies expressed a need for new employees.

However, as Pyhäjärvi mine is 1,445 m deep, its geothermal energy potential is huge. Generally, geothermal fluids from northern mines can provide energy for space heating (Patsa *et al.* 2015). In Pyhäjärvi, geothermal energy is planned to be utilised via up-pumped groundwater reheating the mine's ventilation system (Ahonen *et al.* 2019). Geothermal energy use has increased across Europe to meet energy needs, partly due to technological innovations that allow for more diverse applications, and thus new markets (EC 2019a). More advanced geothermal technologies are central in supporting the development of low-carbon energy solutions and thus working towards the adoption of the new framework of the EU climate and energy policy by 2030. However, there are still technological and service needs that must be resolved. Combining this demand with Finnish technological expertise, the unique operational environment and low-cost shallow geothermal energy make Pyhäsalmi mine optimal for piloting these applications.

The University of Oulu, together with the Council of Oulu, has been part of a consortium setting up the S3 Partnership Geothermal Energy 2.0 network to promote these possibilities and overcome the abovementioned problems (EC 2019b), as well as to expand the use of geothermal energy and increase the use of the earth's heat. Dumas *et al.* (2019) has set the goal to be 5 €ct/kWhth for heat by 2025, aiming to prove that price to be realistic with piloting places in different geographical areas in the Europe. There is an ongoing research project in this area in Pyhäsalmi mine, but even thought the results are not final, it has already been calculated that utilising the energy of pumped water via a geothermal energy powerplant would have lower costs than those of the selected pilot locations, so it would be optimal one of the piloting places. There are several different technical solutions to utilise the geothermal energy, but ongoing research has shown that the best technical and business-friendly solution is to build the geothermal well field at the deepest point of the mine, circulate water from several wells and collect the heat using heat exchangers (Ahonen *et al.* 2019).

By seizing this opportunity, the region would not only strengthen its regional resilience, but it would boost itself into another level, which would have many economic, environmental, political and social implications. Based on existing conditions, utilising the power of the pumped water is one option. The other option is to utilise the existing unused mine galleries. Currently, underground farming is getting increasingly common (in the form of test projects for insect and plant farming). The circumstances for any kind of farming are ideal in the mine galleries; on the deepest level the temperature is 20-30^{o}C. For example, London has utilised former World War II shelters to grow microgreens and salads (Growing Underground 2019). In Stockholm centre's tunnels, underground farming has been developed to grow (mainly) herbs near the consumers, replacing export from faraway countries (Plantagon 2019). The utilisation of unused underground tunnels and galleries seems to be an environmentally friendly and sustainable solution that is focused on feeding a growing population.

Local resources, which include competencies, hidden knowledge, technologies and the physical mine itself, should all be seen as potentials for a bright future. In the short-term, adaptation is required, but it should not preclude long-term adaptability. The tension between adaptation and adaptability is substantial for different perspectives on the region, which include individuals, organisations, industries, networks and institutions (Boschman 2015).

Geothermal usage possibilities

Geothermal technologies are divided into two categories: shallow geothermal heat and deep geothermal energy. Shallow geothermal heat is used on the household level for heating, hot water provision and cooling (Bleicher & Gross 2015). The heat pump and air-based pump technology has been generally used since 1910 to replace fossil fuels and is utilised mainly on the household level (Lund *et al.* 2011). Shallow geothermal energy (geoenergy) is defined as energy from the sun by energy bound in the terrestrial surface (GTK 2018a).

Since the 1970s, large-scale installations producing electricity via geothermal energy have increasingly attracted attention as environmentally friendly systems. For example, hydrothermal technology applications make use of hot water reservoirs and applications of petrothermal technology exploit injected and heated water, both at depths of several thousand metres (Bleicher & Gross 2015).

Another noteworthy possibility is to utilise the heat of underground water. Currently, pumped ground water is utilised in heating air supply piped into a network of caves, but other possibilities need to be considered in the future. Deep geothermal energy is the heat originating from the core of the earth. The estimated average temperature of the water is +17^{o}C, and thus only the pumped drying water of the mine offers the power of 1.3 MW (GTK 2018b).

The usage of drilled holes produces more heat energy. For example, the Geological Survey of Finland has calculated that a thermal capacity of ten holes on the level of 1,000 m is 160 kW (the power of one hole is 9 kW, the needed power to reach 95°C is 7 kW, thus 10 holes x (9 kW +7 kW) = 160 kW), and energy power is thus 0.96 GWh (160 kW x 6000 h, using hours/a) (GTK, 2018b). In theory, the soil offers energy of 60 TWh per year, when an average power is 10 MW. The calculated energy is based on geothermal heat flux (area of approximately 12 km^2 and 500 kW in Pyhäsalmi mine when the volumetric capacity of a ball limited sound zone is 10 km^2, and the thermic content of the ball is thus 6 TWh/K (GTK 2018b)). This heating energy could offer many business opportunities in the mine area for companies needing high-temperature heat, such as laundries and drying units (e.g., grain dryers). Pyhäsalmi is located in the middle of Finland, close to a busy main road (E4) that starts from southern Finland and ends in the north. The road serves Finnish and international traffic, which logistically enables many extractive industry operations (e.g., grain, wood, manure drying) and heat-related services (laundries, other warm water-related industries). For example, hospital textile care is concentrated into a few laundries, and the closeness of the main road (E4) in Finland enables accessibility.

Additionally, the mine offers low-temperature heat, which could be utilised for many industrial operations. The mine heat is renewable energy and is an important option for mitigating climate change. Some usage possibilities wherein the heat is generated in the soil from underground sources and used on superterranean sites include growing spices and special plants, underground training and research purposes. Some unusual usages has already taken place as the Callio Extreme Run—happening testing runners physic skills such as running 11 km from the bottom of the mine up to the soil with 1.5 km's slope and using the premises to film TV programmes (Tekniikka & Talous 2019).

Energy transitions have traditionally been associated with broad social change, such as industrialisation, urbanisation and the growth of the consumer society. There is no doubt that the ongoing transition towards low-carbon sources would be no less significant, considering its social, technological and geographical implications (Bridge *et al.* 2013). However, there is a limited amount of energy transition research focusing on the socio-economic characteristics of the location (Balta-Ozkan *et al.* 2015; Bridge *et al.* 2013). It is essential to take into account regional differences regarding not only energy sources and transportation, but also the larger scale of spatial aspects, including both absolute and relative viewpoints (Balta-Ozkan *et al.* 2015). These include political, environmental, social, economic and legal issues. It should also be noted that urban and rural regions have different demands, perceptions and potential.

Discussion

Facing structural change has been inevitable destiny of Pyhäjärvi, which has had a strong dependency of mining industry in regional economics more than 50 years. Losing this kind of big employer will have significant impact on the region. Narrowness of the economic activities makes this region vulnerable to shocks. As known, scale, duration and nature of the shock play on important role in creating resistance. Large-scale, long time shock, so called “slow burn” situation is more difficult for regional resistance than fast shocks. In spite of hard work in anticipate on closing the mine and finding several solutions, the decisive path has not been opened yet. In the case of Pyhäjärvi, structural change could also be turned into a great opportunity if the strengths of the situation could be acknowledged and exploited.

The large facilities with consistent warm temperatures that the mine offers would be ideal for many purposes, such as growing different kinds of plants and even laundry services, to name a few. There is a possibility to seize the current energy transformation and move from a traditional industrial locality into a forerunner of clean energy technology. As one of the deepest mines in Europe, there is also potential for Pyhäsalmi to be exploited by using the depth differences. In fact, there have been calculations on what kind of hydroelectric power plant could possibly be built there and after several years of work, the first demo plant is in the planning phase. Strengths also include a wide existing network of drilling holes, which could be utilised in energy generation (not to mention the possibility of drilling new ones).

There are also clear challenges in the case of the Pyhäsalmi mine—the population in the region is sparse and is less educated than the national average, and jobs provided by the mining company have been crucial. Rural municipalities surround the town, and there are no unique attractive features except for the mine facilities. Yet, the surrounding environment is clean and beautiful, which is an enormous advantage during a time when more people are putting a higher value on things like untouched nature, clean air and natural products, due to a rising awareness of environmental problems. In spite of being a sparsely populated region, Pyhäjärvi is logistically situated very well, almost at the crossroads of one of the most important national roads and the railway. Therefore, in addition to activities such as piloting, tourism services, farming and laundry using geothermal energy and cutting down emissions (and thus being ecological-friendly), logistical solutions could be optimised.

In a region with only one large employer, the social responsibility of employing people naturally falls on them, and local community actors are easily satisfied with the situation and neglect the region’s further business development. In the case of a mine shut down, local community actors also need to fulfil a “Social License to Re-Develop”, putting effort in to reclaim their role as the region’s developers. Actions on the political level come to focus in the circumstances where the region is about to lose a significant employer. However, these actions directly affect the local entrepreneurial situation, possibly hindering new entrepreneurial activities and representing a lack of support for companies from public authorities. Resilience means being able not just to adjust to a changing environment, but also to take advantage of the changes and chances opening trough them.

Using Schienstock’s (2004) framework to break out from path dependency, there are already several building blocks in place, including a window open for new opportunities associated with a new techno-organisational paradigm, the prospects of new businesses and new markets and pressures coming from external socio-economic factors. The key change event—closing the mine after several extensions—seems to be inevitable. Current attempts to find reuse opportunities for mining premises have seemed to follow a path dependency and actors may not even have realising to fall into the lock-in situation, which is challenging to break.

Too much weight regarding the welfare of the region should not be put on the shoulders of one big company, nor should the aim be to replace it with another new big player. There likely will not be municipal or governmental actors to take over mine facilities as such. However, the town could systematically support new and existing entrepreneurs in the region e.g. by providing premises and business services. Also, there could be an incubator that would focus on different technologies and services for new energy solutions. By this kind of openings, the local actors would foster a culture with an enthusiastic 'entrepreneurial orientation' (a firm-level term referring to innovativeness, proactiveness and risk taking), which would make the region attractive for companies.

Hand-in-hand with the political and economic development of the region, there ought to be development actions taken regarding the social environment. There needs to be investment in the comfort and aesthetics of the environment in order to make the area appeal to more people nationally and internationally. Luckily, the old mine surroundings have great potential for this type of development as well and there has already been large scale of imaginary ideas, what kind of activities could be organised in the open-cast mine, as well as the inner-mine facilities — from different entertainment parks to maturing cheese and wine, just to give a few examples.

However, to make some of these ideas to reality calls for courage to be open-minded and to focus on possibilities; to take action and risk, and to recognize that building regional resilience also takes time. Courage and energy are required to build the necessary networks and to find relevant partners both nationally, in Europe and around the world. There would be possibility to create the old mine and its surroundings as an international clean energy competence hub. In practice, that would require local political willingness and national funding to support a variety of clean energy initiatives and innovations. It could be carried out by creating a cooperative working environment and company networks with versatile local and global collaboration and by recognizing clean energy as part of municipal (and possible national) strategies.

As mentioned earlier, it is important to be able to think in new ways, especially in a situation of technological and industrial transformation, to search for new industries and to refresh the local competitiveness. Learning, in its nature, is interactive and often arises from trial and error. To enhance this kind of collective learning and knowledge, open communication and networking actions are needed between the companies, municipal authorities and other institutions.

References

Ahonen, L., Ala-Rämi, K., Lehtinen, U., Leppiniemi, N. & A. Martinkauppi (2019). *Pyhäsalmen kaivos geotermisen energiantuotannon mahdollistajana ja vähähiilisen energian demonstraatiokohteena*. Oulun yliopiston Kerttu Saalasti Instituutin julkaisuja.

Balta-Ozkan, N., Watson, T. & E. Mocca (2015). Spatially uneven development and low carbon transitions: Insights from urban and regional planning. *Energy Policy* 85, 500–510.

Bathelt, H., Malmberg, A., & P. Maskell (2004). Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation. *Progress in human geography* 28: 1, 31–56.

Bleicher, A. & M. Gross (2015). User motivation, energy prosumers, and regional diversity: sociological notes on using shallow geothermal energy. *Geothermal Energy* 3:12, <https://doi.org/10.1186/s40517-015-0032-6> (Accessed 25 August 2019).

Boschma, R. (2015). Towards an evolutionary perspective on regional resilience. *Regional Studies* 49: 5, 733–751.

Bridge, G., Bouzarovski, S., Bradshaw, M. & N. Eyre (2013). Geographies of energy transition: Space, place and the low-carbon economy. *Energy Policy* 53, 331–340.

Carlsson, E., Steen, M., Sand, R. & S.K. Nilsen (2014). Resilient peripheral regions? The long-term effects of ten Norwegian restructuring programmes. Norsk Geografisk Tidsskrift - *Norwegian Journal of Geography*, 68:2, 91–101, DOI: 10.1080/00291951.2014.894565

DailyMail (2019). Mail Online. DailyMail, Available online: <https://www.dailymail.co.uk/news/article-6303745/Luxury-hotel-opens-ground-inside-ABANDONED-QUARRY-Shanghai.html> (Accessed 15 August 2019).

Dumas, P., Torsello, L. & F. Batini (2019). Providing the Agora - The institutional building for a stronger European geothermal sector. Presentation in Workshop “Geothermal energy: The regional approach - information, inspiration and activation in the field of geothermal energy” , 20.6.2019.<https://s3platform.jrc.ec.europa.eu/documents/20182/351202/Dumas_Torsello_Batini.pdf/d7d88e98-f7ee-491e-ba04-a999cf6a271a> (Accessed 15 August 2019).

EC (2014). European Council, 2014. Conclusions – 23th and 24th October 2014. <http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/fi/ec/145409.pdf> (Accessed 30 August 2019).

EC (2019a). Infographics: Energy. <https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-4c.html> (Accessed 30 August 2019).

EC (2019b). Smart Specialization Platform: Geothermal energy. <https://s3platform.jrc.ec.europa.eu/geothermal-energy> (Accessed 30 August 2019).

EC (2019c). S3 Energy Partnerships: Geothermal energy. <https://s3platform.jrc.ec.europa.eu/partnership-geothermal-energy> (Accessed 30 August 2019).

EC (2019d). European Commission. <https://www.digitallytransformyourregion.eu/develop-entrepreneurial-culture> (Accessed 30 August 2019).

EGEC (2019). EGEC geothermal: The Voice of Geothermal in Europe. <https://www.egec.org/about/#aboutgeot> (Accessed on 28 November 2019)

ELY (2019). ELY-keskus, Työmarkkinat. <http://www.ely-keskus.fi/documents/10191/39485749/Tkat_EN_syyskuu_2019.pdf/59c2ec02-ffd3-4807-8a46-2b141270aa60> (Accessed on 25 November 2019)

The Federation of North Ostrobotnia Enterprises (2019). Unpublished presentation of survey results.

Fleming, L., Mingo, S. & D.Chen (2007) Collaborative brokerage, generative creativity and creative success. *Administrative Science Quarterly* 52, 443–475.
Fortum (2019). Fortum web pages. <https://www.fortum.fi/media/2017/11/suomenojan-voimalaitos-lammittanyt-espoota-ja-lahikuntia-jo-40-vuotta-kehitys-kohti> (Accessed 30 August 2019).
Foster, K. (2007). A case study approach to understanding regional resilience. Working Paper prepared for the Building Resilient Regions Network, Berkeley IURD. <https://escholarship.org/content/qt8tt02163/qt8tt02163.pdf> (Accessed 23 October 2019).
Gertler, M. (2005). Tacit knowledge, path dependency and local trajectories of growth. *In* Fuchs, G. & P. Shapira (Eds.): *Rethinking Regional Innovation and Change: Path Dependency or Regional Breakthrough?* pp.23–42. Springer, New York..
Giacometti, A. & J. Teräs (2019). *Regional economic and social resilience: an exploratory in-depth study in the Nordic countries*. Nordregio report 2019:2.
Glassley, W.E. (2010). Geothermal energy: renewable energy and the environment. CRC Press.
GTK (2018a). Suomessa on valtava puhtaan energian varasto. Geological Survey of Finland, <http://www.gtk.fi/ajankohtaista/media/uutisarkisto/index.newsType=PressReleases&number=857> (Accessed 5 August 2019)
GTK (2018b) Geoenergia / Energiakaivos. Presentation, Asmo Huusko(Geologian tutkimuskeskus GKT, 29.10.2019.
Harfst, J. (2015). Utilizing the past: Valorizing post-mining potential in Central Europe. *Excavation Industries and Society* 2: 2, 217–224.
Hassink, R. (2010a). Regional resilience: a promising concept to explain differences in regional economic adaptability? *Cambridge Journal of Regions Economy and Society* 3: 1, 45–58.
Hassink, R. (2010b). Locked in decline? On the role of regional lock- ins in old industrial areas. *In* Boschma, R. & R. Martin (Eds.): *Handbook of evolutionary economic geography*. Edward Elgar, Cheltenham, 450–468.
IPP (2019). The intergovernmental panel on climate change: media reports. Available online <https://www.ipcc.ch/sr15/chapter/chapter-1/> (Accessed 27 August 2019).
Kivinen, S. (2017). Sustainable post-mining land use: Are closed metal mines abandoned or re-used space? Available online: <https://erepo.uef.fi/bitstream/handle/123456789/5825/sustainability-09-01705.pdf?sequence=2&isAllowed=y> (Accessed 5 September 2019).
Krüger, J.J (2008). Productivity and structural change: a review of the literature. *Journal of Economic Surveys*, 22: 2, 330–363.
Larondelle, N. & D. Haase (2012). Valuing post-mining landscapes using an ecosystem services approach— An example from Germany. *Ecological Indicators* 18, 567–574.
Lauttamäki, V., (2018). Geoenergia kiinteistöjen lämmitysratkaisujen markkinoilla Suomessa energiakriisin ajoista 2030-luvulle. University of Turku. Ser. E, tom. 29.
Lund J.W., Freeston D., Derek H. & T.L. Boyd (2011). Direct utilization of geothermal energy 2010 worldwide review. *Geothermics* 40, 159–180.
Martin, R. (2012). Regional economic resilience, hysteresis and recessionary shocks. *Journal of Economic Geography* 12, 1–32.
Martin, R., Sunley, P., Gardiner, B., & P. Tyler (2016). How Regions React to Recessions: Resilience and the Role of Economic Structure. *Regional Studies*, 50:4, 561–585, DOI: 10.1080/00343404.2015.1136410
Maskell, P. & A. Malmberg (1999). Localised learning and industrial competitiveness. *Cambridge journal of economics* 23: 2, 167–185.

Patsa, E., Van Zyl, D., Zarrouk, S. & N. Arianpoo (2015). Geothermal energy in mining developments: synergies and opportunities throughout a mine's operational life cycle. Proceedings World Geothermal Congress. Melbourne, Australia. 19–25 April.

Ruskeala (2019). Ruskeala Mountain Park. Web pages, <https://ruskeala.ru/> (accessed on 5 Sept. 2019).

Sanford Underground Research Facility (2019). Available online: <http://sanfordlab.org/facility> (Accessed 6 September 2019).

Schienstock, G. (2004). From path dependency to path creation: A new challenge to innovation system research. *In* Schienstock, G. (Ed.): *Embracing the Knowledge Society. The Transformation of the Finnish Innovation System,* pp.1–27. Edward Elgar: Cheltenham, UK & Northampton, MA.

Schienstock, G. (2011). Path Dependency and Path Creation: Continuity vs. Fundamental Change in National Economies. *Journal of Futures Studies, June 2011*, 15:4, 63 – 76.

Sklenicka, P. & E. Charvatova (2003). Stand continuity— A useful parameter for ecological networks in post-mining landscapes. *Ecological Engineering* 20: 4, 287–296.

Snolab (2019). Mining for knowledge. Available online: <https://www.snolab.ca/> (Accessed 6 September 2019).

Statistics Finland (2019a). Toimipaikkalaskuri <http://pxnet2.stat.fi/PXWeb/pxweb/fi/Toimipaikkalaskuri/Toimipaikkalaskuri__Toimipaikkalaskuri/tmp_lkm_kunta.px/table/tableViewLayout1/> (Accessed 28 November 2019)

Statistics Finland (2019b). StatFin online service. <https://www.stat.fi/tup/statfin/index_en.html > (Accessed 25 November 2019)

Swanstrom, T., Chapple, K. & D. Immergluck (2009). Regional resilience in the face of foreclosures: Evidence from six metropolitan areas. Working Paper, No. 2009. University of California Development (IURD)

Taipale-Eravala, K., Heilmann, P., & H. Lampela (2014). SME competence transformation – a case study on industrial structural change*, International Journal of Business Innovation and Research*, 8: 3, 265–281.

Tekniikka & Talous (2019). 1445-metrisen Pyhäsalmen kaivoksen toiminta loppuu - Mistä uusi käyttötarkoitus: pumppuvoimala, kasvimaa, datakeskus vaiko juoksurata...? Available online: <https://www.tekniikkatalous.fi/uutiset/1445-metrisen-pyhasalmen-kaivoksen-toiminta-loppuu-mista-uusi-kayttotarkoitus-pumppuvoimala-kasvimaa-datakeskus-vaiko-juoksurata/031672bf--67f2-38a9-a98e-6dcda93982ce> (Accessed 25 November 2019).

Tekijä (2019). Reportaasi: Pyhäsalmen kaivoksen pitkät jäähyväiset – ”Varmaan moni miettii, mitä rupeaisi tekemään, kun on ikänsä ollut täällä”. Teollisuusliiton lehti Tekijä. Available online <https://tekijalehti.fi/2019/06/26/reportaasi-pyhasalmen-kaivoksen-pitkat-jaahyvaiset-varmaan-moni-miettii-mita-rupeaisi-tekemaan-kun-on-ikansa-ollut-taalla/> (Accessed 1 September 2019).

TEM (2017). Government report on the National Energy and Climate Strategy for 2030. Publications of the Ministry of Economic Affairs and Employment. <http://julkaisut.valtioneuvosto.fi/handle/10024/79247> (Accessed 31 December 2019).

TEM (2019). Structural change. Ministry of Economic Affairs and Employment of Finland – web pages. <https://tem.fi/en/structural-change> (Accessed 1 September 2019).