The Norrbotten Technological Megasystem: Impact on Society and Environment

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The *Kaptensgropen* at Malmberget.

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Introduction

1.1 Norrbotten at Present

Norrbotten, the northernmost precinct of Sweden, has always been a critical frontier for Swedish society. In antiquity, Norrbotten was a path to the North Pole, a treacherous passage to be tamed by enterprising Swedish explorers. In centuries past, it was colonized, settled, and tamed. Today, cars, indoor heating, and other technology have made Norrbotten positively hospitable. Yet industry continues to advance Sweden's final frontier, deep within the earth.

The mining industry in Norrbotten is the backbone of the Swedish state. Today, weak regulations, environmental transgressions, and an unstable community threaten Norrbotten's people, land, and livelihood. To understand the current issues affecting Norrbotten, its industry, and what has been termed the *Norrbotten Technological Megasystem*, we must first consider the history of the region.

1.2 A History of Norrbotten

Archaeological findings in Norrbotten area show humans to have lived there for more than 10,000 years. But more recently are the Samí people, who colonized the region around 1200 years ago. The Samí herded reindeer at small scales for their milk, as well as hunted them for food. The Samí traded with the people around Lofoten in Norway, where there were English and German tradesmen. But the Sami also traded with those stationed in Norrbotten by the Swedish government to collect taxes.

Around 800 years ago people from Finland and southern Sweden started to colonize Norrbotten for its arable land. However, Norrbotten didn't become heavily populated until the end of the 19th century. This was due to a combination of the growing mining industry and the building of the railroad from Luleå to Narvik. [25]

1.3 A History of Industry in Norrbotten

The industry of mining in Sweden dates back to the early 11th century. Copper was mined in Falun, and iron ore in Bergslagen. Mining has provided for Sweden, and given the country a stable financial foundation for centuries. In 1750, the export of iron ore accounted for 70% of total goods exported from Sweden.

The first discovery of Norrbotten's iron ore fields was during 1660, when the first sample was taken from Malmberget, a small town near Gällivare. In 1696, iron ore was discovered in Kiirunavaara and Luossavaara. Demand for iron ore grew into the 19th century. LKAB (Luossavaara and Kiirunavaara Co.), the largest iron mining company in Sweden, was founded in 1890. Today it is government owned. The biggest mining company in Sweden is Boliden. Boliden founded the Aitik mine, and produces copper, silver, and gold there. [32]

To excavate and transport the iron ore, a larger transportation network between north Sweden and the rest of Europe would be needed. In 1882, the Swedish state commissioned a railroad connecting Luleå and its western neighbor Narvik, just across the Norwegian border. Thus began what would become the Norrbotten Technological Megasystem. In 1888 the first train travelled from Gällivare to Luleå, and in 1902 the first tran travelled from Kiruna to Narvik. [18]

Construction on the railroad had been arduous and expensive. An English company, The Northern Europe Railway Co. Ltd., had assumed the role of developer and financier of the railway. By the time they went bankrupt in 1889, the railway from Gällivare to the Luleå harbour had been finished. The Swedish state bought the railway and harbour alike, and all the surrounding English infrastructure. [18]

1.4 Defining the Norrbotten Megasystem

The megasystem is composed of five regions and five key actors. They are:

1. the harbour in Luleå,
2. the mines at Kiruna and Gällivare (including Kiirunavaara, Malmberget, Aitik, Svappavaara, etc.),
3. the hydropower station at Porjus,
4. the military fortification in Boden, and
5. the harbour at Narvik.

All the key actors except the military fortification at Boden are still in use today.

A megasystem is a group of megascale technological systems closely connected to one another. A megasystem is also defined by it's impact on the people around it. The concept of the Norrbotten megasystem was created in 1990, when Staffan Hansson at the University of Luleå connected them all via the railroad. Today, the Swedish National Heritage Board proclaims the Norrbotten Technological Megasystem to be one of the ten most important industrial heritage sites in Sweden. [18]

1.5 The Place of Community and Environment in the Norrbotten Technological Megasystem

In this essay, we will consider the Norrbotten Technological Megasystem both as actor and victim. Industry in Norrbotten is run by and supplies for those it affects most. Specifically, we aim to address the place of community and environment in an industrialised region. The megasystem must be able to be held accountable for its destructive

Figure 1.1: The Norrbotten Technological Megasystem and key actors. [18]

tendencies. The ultimate goal is not to dismantle the system, but to better understand its flaws and improve upon them in coming years.

We explore the complex intermingling of community and environmental issues via a number of techniques. In addition to standard research, the authors had the privilege of studying the Norrbotten Megasystem first-hand, during a period of extended field work. This field work included tours of the mines at Aitik, Malmberget, and Kiruna, as well as guided lectures on Norrbotten's environment and history. Meeting and interviewing residents of the effected areas and seeing the environmental damage for ourselves allowed for unique insights into the source material, which we hope come across in this essay as passion and expertise.

So how does the Norrbotten Technological Megasystem force its surrounding community to adapt to it?

Chapter 2

Community

2.1 Adapting to a Megasystem

A community is an organic thing, difficult to quantify or even measure. To properly evaluate the ways in which the Kiirunavaara mine, the infrastructure it supports, and its related industries (collectively, the Norrbotten megasystem) have impacted the small communities of Norrbotten, we must classify community behaviours into one of two categories. First, we will explore the repercussions of industry within a community: both the the physical and psychological harm caused by the Norrbotten megasystem. This category will include economic and political reliance within the community. Second, we will examine acts of resistance: which are political, grassroots, or spiritual reactions to the Norrbotten megasystem. To illustrate these categorisations, we will consider examples such as the impending relocation of Kiruna, the disruption of the Samí reindeer-herding industry, and the desertion of Malmberget.

2.2 The Norrbotten Community

Consider the distinction between rapid-onset and slow-onset disasters. Rapid-onset disasters occur quickly and without warning, transpire rapidly, and leave a long tail of destruction. Hurricanes and nuclear meltdowns are both rapid-onset disasters. Slow-onset disasters often occur after decades of warning and transpire over long periods of time. Pollution, global warming, and the peculiar industrial accidents we will examine in Kiruna and Malmberget are all slow-onset disasters. Rapid-onset disasters inspire fear and are easier to explain, fund, and plan for. Slow-onset disasters, which can take generations to become understood, are often seen as inevitable. We will return to this theme when examining the effects of sub-level caving in Norrbotten.

2.2.1 A Short History of Kiruna

Kiruna is a small town, with just over 18,000 residents. The majority of Kiruna's residents live or work in an industry related to mining, either directly or indirectly. [8] To understand why this is, we turn to the history of Kiruna and of Norrbotten.

The indigenous Samí people lived in Norrbotten since antiquity. They used the regions around the Kiirunavaara for reindeer migration, but rarely for settlement. The Samí told Swedish settlers of the abundant iron ore deposits in Kiirunavaara before the 1800s, but the region remained unsettled. This may be due to the high phosphorus content

and geographic isolation of the region, which made it unprofitable to mine for iron ore. This would change in 1878, when British chemists Gilchrist and Thomas patented and released the Gilchrist-Thomas process, a method for industrial iron ore purification. [7] Iron ore could now be purified and the phosphorus removed. The prospect of mining at Kiirunavaara was now a profitable one.

Industry became a necessity. A railway was built by foreign British investors and sold to the Swedish government. A privately-owned company, Luossavaara-Kiirunavaara Aktiebolag (LKAB, for short) began construction on and operations of what would become known as the Kiruna mine. [19] At the foot of Kiirunavaara, LKAB built a shantytown. There laborers and alike began to settle. Transportation within Norrbotten was difficult, so the shantytown was originally built at close proximity to the center of the mine. When the mine proved profitable in the early 1900s Kiruna was dismantled and rebuilt on the same spot. This fast, largely unplanned growth is repeated throughout the histories of our other areas of interest, Gällivare and Malmberget.

2.2.2 A Controlling Interest

For the first few years in the life of any mining community, it is often dependent upon the company for sustenance. In the company towns of Malmberget and Kiruna, LKAB itself built dormitories, churches, schools, hospitals, and stores. They also built and maintained the civil infrastructure: streets and sewers; roads and railways in and out of town; police and fire stations. Up until the 1950s, LKAB was wholly responsible for city planning, construction, and maintenance. In the 1950s, the Swedish state bought a controlling interest in LKAB. Since then, questions of responsibility have become more subtle. The citizens of Kiruna run local town government and elect their regional national government, and the Swedish state runs LKAB. Thus LKAB reports to the citizens of Kiruna. In theory, this puts community health at first priority, but in practice financial health often comes first. This is one of several consequences to industrialization. Another is the common Norrbotten mindset of anti-LKAB us-versus-them rhetoric which pervades local politics and city government.

2.3 Kiruna, Gällivare/Malmberget, and Aitik

Communities suffer repercussions from, rely upon, and attempt to resist industry in a myriad of ways. Thus we examine three prominent examples. First, we consider the relocation of the town of Kiruna due to an impending surface collapse. Second, we consider the irreparable damage caused to the town of Malmberget, and the migration of its residents to the neighboring town of Gällivare. Third, we consider the present mining operations at Aitik, and discuss potential explanations for a relative lack of community impact. Taken as a whole, these examples serve as a microcosmic reflection of the interactions between generalized industrial megasystems and their surrounding communities in Norrbotten and in Sweden at large.

2.3.1 The Relocation of Kiruna

The Kiirunavaara mine employs sub-level caving, a relatively novel mining practice. Sub-level caving involves a matrix of tunnels cut at regular heights throughout the depth of an ore body. At a given level of depth, a number of horizontal tunnels are bored.

Then hundreds of thin, angled shafts are drilled up from these horizontal tunnels in all directions. These small, angled shafts cover completely the volume of the iron ore body above the particular level. These smaller shafts are packed with explosive, the level is evacuated, and the charges are detonated. As the ceiling caves in, the iron ore within flows down into the tunnel, where it can be easily excavated. This ore is then carried to the surface for refinement. This process allows for more complete coverage of the volume of a mine. No regions are left untouched to serve a support for the levels above. [24]

As volumes of rock are removed from the mine, the ground above is liable to cave in proportionally. In Kiruna, the Kiirunavaara iron ore body slopes, at an angle, beneath the town. Sublevel caving has created a sinkhole, which originates at the mine and extends outwards towards the town. The ground seeps and falters, and will eventually cause the town to crumble into a pit of waste rock. (See Figure 2.1.)

This process is slow but somewhat inevitable. If mining operations ceased today, the surface would destabilize within a few decades. As mining operations continue, the sinkhole expands even further. LKAB estimates the town will be unlivable within a century.

As of 2015, those neighborhoods closest have already been evacuated and dismantled. The relocated citizens have moved further out into town, towards what will become the city centre of New Kiruna. As this process repeats for each neighborhood in now-old Kiruna, some buildings will be carefully dismantled and rebuilt at new locations. The Kiruna church is one such lucky building. (See Figure 2.2.) Others, like Town Hall, will be town down and rebuilt anew in their new locations.[17]

This relocation is a massive, expensive, and disruptive undertaking. LKAB, taking complete responsibility, has offered to oversee and fund the operation. Thus New Kiruna is also being built on LKAB dime.

The choice of location for the new Kiruna was a joint decision between town hall and LKAB. The new location balances the desire to protect natural reserves with the desire to avoid further proximity to current or future mining operations. After the location was chosen, the town hall held a city planning competition. LKAB approved the winning submission, designed by White, a Swedish architecture firm. Thus, even in the new Kiruna, community depends on industry for sustenance. Buildings, roads, and infrastructure in new Kiruna are to be supplied by LKAB, just like old Kiruna. Thus the administrative role LKAb holds in the relocation project serves to further strengthen their political and social influence.

The bulk of the relocation has yet to occur. Local government and LKAB alike are still in the planning stages. There is much work to be done before individual families are relocated. We can examine one potential outcome, written in the histories of Gällivare and Malmberget.

2.3.2 The Slow Malmberget Disaster and Relocation to Gällivare

Gällivare (pop. 15,000) is a mid-sized town in Norrbotten. It lies five kilometers from Malmberget (pop. 6000), a small mining community. *LKAB Gällivare* operates the Malmberget mine, and exerts similar political power over Malmberget and Gällivare as in Kiruna.

Apart from size, the major difference between LKAB Kiruna and LKAB Malmberget is a distinction in mining practice. While the mine at Kiruna is deep below the Kiirunavaara mountain, the mine at Malmberget is open-pit. The town of Kiruna is at the

Figure 2.1: The effects of sublevel caving in Kiruna.

Figure 2.2: The Kiruna Church, which will be dismantled and reconstructed in New Kiruna.

foot of the mountain, but the town of Malmberget encircles the pit. The large pit lies atop an ore body which extends deep below the surface of the town.

In the 1950s, the pit, nicknamed *Kaptensgropen*[1], began to expand of its own accord. LKAB evacuated nearby buildings, moved some structures and abandoned others entirely. The ever-growing pit divided the town of Malmberget in two. Houses and neighborhoods were swallowed by the dangerous sinkhole. Between the risk of rockfalls and the threat of relocation, the town of Malmberget began to dissolve socially and economically. Mining ceased, and a majority of residents moved to the neighboring Gällivare.

Malmberget is currently a sad and surreal sight. Now with population 6000, it was once a much larger community, and the city plan reflects that. Most houses and streets are empty. The pit only becomes obvious when driving through town, with many roads closed and blocked off. Peering through a fence, tilted houses and crumbling roads can be seen, leading deeper into the expanding pit in the center of town.

LKAB completed a mapping of the entire Malmberget ore body in 2010, and announced an intent to resume mining. With nearly the entire town already evacuated, mining could be safely resumed, at no risk to a vacant community. The town of Gällivare, still reliant upon the mining industry, agreed. The remaining residents of Malmberget will migrate to Gällivare, and mining is expected to resume as of 2015.

2.3.3 The Relative Tranquility of Aitik

Aitik, another large mine in Norrbotten, is a 7000 hectacre open-pit mine just south of Gällivare. (See Figure 2.4.) It measures three by one kilometres in area, and is 320 metres deep. It produces 3.2 million tonnes of ore annually, the largest in Europe and one of the largest of the world. Aitik began production in 1968 and is expected to remain safe and profitable stable for at least another 25 years.

Because Aitik began operations in the 1960s, modern automotive technology meant that its workers could simply live in the nearby town of Gällivare. There was no need for a hyper-local mining community, as in Kiruna and Malmberget. There are no community issues, no cost of human impact, and no evacuations. When the mine begins to crumble into instability in the coming decades, it can simply be abandoned. With the precautions of modern mining technology, yearly tests for groundwater pollution are reassuringly negative. While there are other environmental impacts, Aitik has the smallest social footprint of any major industrial mine in Norrbotten.

2.4 Megasystemic Repercussions of the Norrbotten Megasystem

2.4.1 Disease and Mortality amongst the Mining Community

Mining is a dangerous profession by its nature. Mining communities and their residents are prone to statistically high rates of cancer, respiratory disease, and other forms of heightened mortality. The mining industry of Norrbotten is no exception. One study from 2009 observes nearly twice the incidence of lung cancer in Swedish iron ore miners, and attributes it to exposure to the crystalline silica, a carcinogen, and radon/quartz exposure. [4] Another study from 1974 places the mining community in Kiruna at nearly

[1] the Captain's Pit

Figure 2.3: The *Kaptensgropen* at Malmberget

Figure 2.4: The open-pit mine at Aitik.

thrice the risk of pulmonary disease compared to the rest of Norrbotten. [33] A third study from 1979 showed heightened risk for mental symptoms, joint/muscle pain, and cardiopulmonary symptoms, and correlates them with negative changes in socioeconomic group amongst Swedish miners. [10]

2.4.2 Indigenous Peoples in Norrbotten

The Norrbotten megasystem requires numerous environmental changes, such as the construction of roads and railways, the damming of rivers to build hydropower plants, and the pollution of fields and mountains for the mining industry. These changes are of economic concern to the Samí, as they disrupt the annual migration path of their herds and can often drown or poison the animals. Numbering 20,000 in Sweden alone, the Samí definition of territory and land ownership is more subtle and complex than that of the Swedish state. [16] Thus the infringement of the Norrbotten technological megasystem upon traditional Samí land is a symptom of larger megasystemic repercussions in Norrbotten, and is often perceived as representative of a common industry-first attitude.

2.4.3 Mining Jobs in Norrbotten

One major repercussion of the Norrbotten megasystem on the surrounding community is that of economic reliance. When an industrial town is founded adjacent to some natural resource, the community that grows up around it tends to be predominantly employed in that specific industry. Kiruna, Malmberget, Gällivare, and the majority of the small industrial towns in Norrbotten are no different. When the majority of the residents of a town are employed either directly in one central industry, the health of that industry tends to parallel the health of the town. [11] By the same mechanism, the health of the Norrbotten industrial megasystem, and all the myriad industries it contains, tend to parallel the financial and social well-being of those living in the region.

Thus a specific company or industry, tends to gain special influence in the politics of the region. The relocation of Kiruna is to be funded by LKAB, designed by LKAB in association with the town hall, will eventually be approved by LKAB, and finally executed by LKAB. In a similar mechanism, the environmental concerns of the region tend to be weighed against the health of the industry, which is given preference in nearly all cases.

The modern reliance on industry in Norrbotten only becomes more exacerbated as we delve deeper into history. At the inception of Kiruna, the only transport mechanisms available to citizens were the railroad built for transporting iron ore, the local roads built for the transport buses LKAB provided, and the company tram used to transport workers.

2.4.4 Conclusions on Megasystemic Repercussions

Norrbotten has a well-documented economic reliance on its megasystem. Yet consistent health issues, an oppressed indigenous community, and a restriction on autonomy have all led to many forms of community resistance in Norrbotten. We will examine a history of past and current environmental and labor protests in the region.

Figure 2.5: A small hydropower plant along the *lilla luleälven* near Jokkmokk, decorated with Samí art.

2.5 Industrial Resistance to the Norrbotten Megasystem

2.5.1 Environmental protests

There is a long and storied history of Swedish environmental protest. However, unlike the famous 1972 Almbråket protests, which were indicative of a larger socioeconomic discontent, the recent series of environmental protests in Norrbotten are specifically tied to individual cases of industrial prospecting. [2] August 2013 saw protesters near Jokkmokk opposing the recently announced development of the region by Jokkmokk Iron Mines AB. In July 2013, local Samí protested to the test drilling by Beowulf Mining (owned by Jokkmokk Iron Mines AB) at the Kallak mine in Kvikkjokk, Norrbotten. Consistent protests indicate an underlying discontent within the community regarding the ever-increasing industrialization of Norrbotten.

Not all residents of Norrbotten protest so strongly. The older generation or retired miners may have come to accept things like the relocations of Kiruna and Malmberget as difficult but necessary. One man, our tour guide in Malmberget, spoke on what it was like to lose chunks of the town to the pit:

> "The school's not there. You are a stranger in your own town... The world is changing all the time. You must accept it."

A local arts initiative to document all the houses in Malmberget, past and present, is similarly indicative of the Norrbotten mindset. In a mining community, history is literally, not metaphorically, fleeting. The city will crumble anyway. Why not continue mining in Malmberget? The maximum amount of damage has already been done.

2.5.2 Unionization in Norrbotten

Sweden has an exceptionally high unionization rate of 67%. [27] The Swedish labor movement, which began in the 1870s in Sundsvall, Västernorrland, has grown into one of the strongest in the world. The history of worker's rights strikes in Sweden began with the Sundsvall strikes in Västernorrland in the 1870s. These strikes begat a successful and eventually near-ubiquitous coalition of specific labor unions. These specific labor unions eventually united under the Swedish Trade Union Confederation (LO). [14] The history of the labor movement in Sweden is similarly tied to its mining towns, which often featured some of the most dangerous working conditions of any industry. Famously, the *stora gruvstrejken*[2] of 1969 saw thousands of miners in the Norrbotten region protesting low wages and long hours, and led to the *skogsarbetarstrejken*[3] in 1975. Consistent strikes, a strong labor movement, and the rise of unionization in Norrbotten specifically can be seen as a part of the larger pattern of community resistance to the Norrbotten megasystem.

2.5.3 Diversification of Industry in Kiruna

The strongest indicator of Kiruna's desire to unbind itself from the economic monopoly of the Kiruna mine is that of its push for space research. Established in the 1960s, the

[2] LKAB conflict
[3] forest worker's strike

Esrange Space Center paved the way for an onslaught of aeronautical technology institutes, such as Luleå University's Department of Space Science and the Institute of Space Physics. The location is prime because of its latitude and geography. Observatories located above the Arctic circle receive longer, clearer nights in the winter, and rocket launches from so high on the globe have a political and physical advantage due to their geometry. Observational studies on the magnetic field, sunspots, and the Aurora Borealis are similarly better positioned due to the latitude. Virgin Galactic, a spaceliner (commercial space-flight) corporation, struck a deal in 2009 to become Europe's first commercial spaceport.

Kiruna's strong interest in space research is represented in town iconography The futurist spire atop town hall, and the murals on the walls of a Kiruna high school testify to this. Among a younger generation of Kiruna residents, space research may be seen as an alternative form of resistance: apolitical, without protest. This diversification should be seen as representative of Kiruna's desire to unbind itself from the monopoly of the Norrbotten mining industry.

Chapter 3

Environment

3.1 Luleå harbour

It was vital to have a working harbour from which to load iron ore onto the ships that would transport them to Europe. The English companies placed the harbour on the isle of Svartön, outsie Luleå. Luleåharbour saw its first loading in 1887, and has been in use since then. In 1965, the decision was made to rebuild and expand the shallow harbour, adding a new waterway and increasing shipping potential.[12]

Luleå harbour now has a capacity of 9,000,000 tonnes, compared to an old capacity of 4,300,000 tonnes. Ten kilometers were dredged, and a rocky shore was blasted away during construction. Seeking still greater capacity, LKAB decided in 1994 to built a new harbour at Sandskär. Construction was completed in fall 1996. [34]

The report *Inventering av djuphamnarna i Norrbottens län enligt MIFO-modellen*[1], released in 2001, studies the risk of chemical exposure at Svartö. *Inventering* posits that the risk of exposure to both humans and nature is small, due to the location's isolation and high fences. The local soil conditions are not conducive to toxin seep. Thus the biggest issue in the area is the pollution of a variety of petroleum products due to a nearby tank station. [12]

The new harbour at Sandskär is pictured in Figure 3.1. Today Sandskär is owned by Luleå Hamn AB, and has a silo capacity of more than 4,000,000 tonnes of iron ore, with an additional outdoor storage capacity of 50,000 tonnes. LKAB may apply to increase the amount of outdoor storage if necessary. [22]

Swedish law compels LKAB to compile an annual risk analysis report for Sanskär. The *Naturvårdsverket*[2] handbook requires the report to include analysis on both environmental impact and risk to human health. The report discusses the impact of iron ore loading, unloading and storage. The report finds that the main impacts to the environment is that of waste rock dust and high noise ouput. As of 2014, the noise output has yet to exceed the legal requirement.

In 2014, dust emissions have gone down from previous years (2012-2013), but is still double its output in 2011. The Sanskär harbour contains four dust emission measuring stations. As seen in Figure 3.2, two of them have exceeded the legal requirements as of 2014. The legal maximum amount of dust emission is 10 mg/m^3.

Luleå Hamn AB plans to deepen its waterways, and built a new harbour, which will be connected to the nearby railroad. These efforts, together called *Projekt Malmporten*,

[1]Inventory of deep harbours of Norrbotten according to the MIFO model

[2]Swedish Environmental Protection Agency

Figure 3.1: Sandskär. [22]

Mätpunkt	mg/m^3 Ntg	Mätdatum
LST 10 (Lossningsstation)	5.9	2014-06-19
	1.5	2014-10-01
LST 11 (Sikstation)	27.5	2014-06-01
	19.8	2014-06-19
	5.7	2014-11-21
LST 12 (Silotopp)	4.3	2014-06-01
	3.4	2014-10-02
LST 13 (Siloutlastning)	7.7	2014-06-01
	68.2	2014-10-02
	0.7	2014-10-16

Figure 3.2: Dust emissions at Luleå harbour in 2014. [35]

are expected to complete in 2020. *Projekt Malmporten* arose from a desire for higher security, and higher iron ore capacity, both influenced by an increasing global need for iron ore. Current mineral transport railroads are congested, and the Swedish state has passed new restrictions on sulphur and nitrogen emissions. [23]

3.2 Porjus

At the end of the 19th century, more energy was needed to run mining operations in Norrbotten. The answer was hydropower. In 1910, the Swedish state commissioned a hydropower plant at Porjus, on the Lule river. Porjus would be the largest hydropower station in Scandinavia, and produced a then-record breaking 50 MW upon completion in 1915. Today it produces 480 MW, making it the 4th largest in the world. The largest, Harsprånget, lies further north along the Lule river. [18]

Nearly half of Sweden's energy demand is met by hydropower. The Lule river is the largest source of hydropower in Sweden, and all fifteen hydropower plants along it are run by the state-owned *Vattenfall AB*. See Figure 3.3 [36]

Many of the Lule river hydropower plants were built during periods of lesser environmental regulation. Therefore many of them manage minimum draught at suboptimal levels or at the wrong time. Similarly, many of them were built without consideration for biodiversity in the area, and can harm aquatic life along the Lule river. Despite this, hydropower is still an environmentally friendly energy source, due to a limited waste byproduct.

The European Union has instructed its members to review all hydropower plants and evaluate their environmental impact. Thus the Swedish state has required all prioritised water-related industries to re-apply for a new environmental permit, supplied by the Swedish Environmental Code. Early applicants will be rewarded by financial compensation, and all industries will be required to submit timely applications. [9]

To be certified environmentally friendly, the Swedish state requires the following criteria to be met:

1. No new hydropower plants may be built in virgin waters.
2. All hydropower plants must have working fauna passages, in the interest of fish and water conservation.
3. Flow regulation must be adjusted to favour fauna.
4. Hydropower stations which supply less electricity than is justifiable considering their environmental impact must be dismantled.
5. All hydropower plants must have a permit under the Environmental Code. [26]

In a 2013 environmental report, *Vattenfall Vattenkraft AB* claims that the new state regulations on hydropower will cost 20% energy production. In resistance, *Vattenfall* has instituted a new program: *Our work towards biodiversity and hydropower*. This program identifies outlet rivers and obstacles for fauna, and cleans up outlet areas and tributary flows along the Lule river. *Vattenfall* focuses on five areas: 1. biodiversity, 2. waste, 3. pollution of air, 4. environmental hazards, and 5. education. [13]

The *Swedish Hydropower Association* agrees with *Vattenfall* in believing that these state regulations are too harsh. They claim that small business owners will go bankrupt

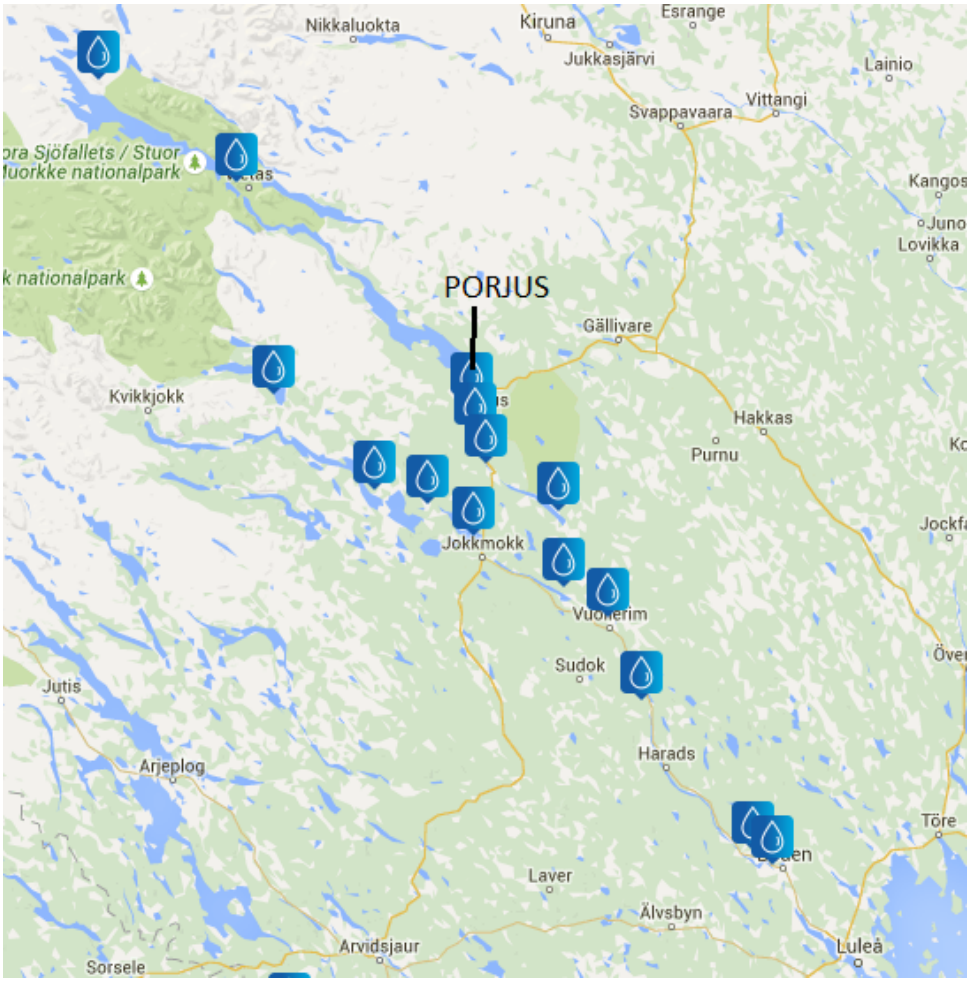

Figure 3.3: Hydropower plants along the Lule river. [36]

Figure 3.4: The hydropower plant at Porjus, from above. [39]

due to high costs, which goes against the original *EU* intention to identify and reinstate old hydropower plants.[3]

In his 2015 article *USA slår Sverige på punkt efter punkt*[3] in *Svenska Dagbladet*, Peter Rudberg compares hydropower plants in the USA with Swedish hydropower plants. He concludes that Sweden lags in environmental development, because the American hydropower certification expires after 30-50 years. This short turnaround demands renovation and innovation from industry.

The Government of Energy and *The Government of Sea and Water* have estimated that Swedish hydropower production under these new regulations would decrease 2.3% [29]

These government investigations recommend the following strategy:

> Suggested strategy for the Lule River is the river basin is not supplied more hydropower or more regulations of the river basins, but that increased efficiency can be implemented in hydropower plants in the Lule River's mainstream. The River regulation may need to be increased in the future to cope with uncontrollable renewable energy from other energy sources. Environmental measures should essentially be located at those tributaries of the Lule River which are not included in the control system. [28]

3.3 Malmberget - Kiirunavaara - LKAB

LKAB mainly extracts iron ore from the Norrbotten region. Most of the iron ore in Norrbotten is located in the mountains Kiirunavaara and Malmberget. In Kiirunavaara, the iron ore body is one massive sheet 80 metres by 4 kilometres, sloping down at an angle at least 2 kilometres into the earth. This is the largest underground mine in Sweden. More then a billion tonnes of magentite have been extracted since the mine opened. The iron ore body at Malmberget the second largest underground mine in Sweden, is more fragmented. Malmberget has around ten different extraction points at different elevations. Malmberget contains both magnetite and hematite, in varying locations. [20]

Iron ore is excavated by sub-level caving, which creates tunnels through the body. The ore is then fragmented by drilling and blasting. (See Figure 3.5.) When the ore reaches the surface, it is processed in three steps: dressing, concentrating, and pelletising. In the dressing stage, the ore is sifted, crushed, and separated from the gangue. The ore is then enriched in concentrators, via grinding and magnetic separation with water. After the concentration process, the product is a fine iron ore concentrate. The ore is then pelletised. Depending on which pellet product is wanted, different dope and binders are added to the concentrated iron ore, which is then rolled into marbles. The marbles are then sifted, dried, preheated, sintered, and cooled, before being loaded onto a railroad. (See Figure 3.6.) It is finally transported to either of the nearby harbours of Luleå or Narvik. [35]

3.4 Aitik - Boliden

Aitik is Sweden's largest sulphide mine, and is 3 kilometres by 1 kilometre, extending 450 metres deep. It is an open-pit mine located south of Gällivare. (See Figure 2.4.) The

[3]The US beats Sweden on point after point

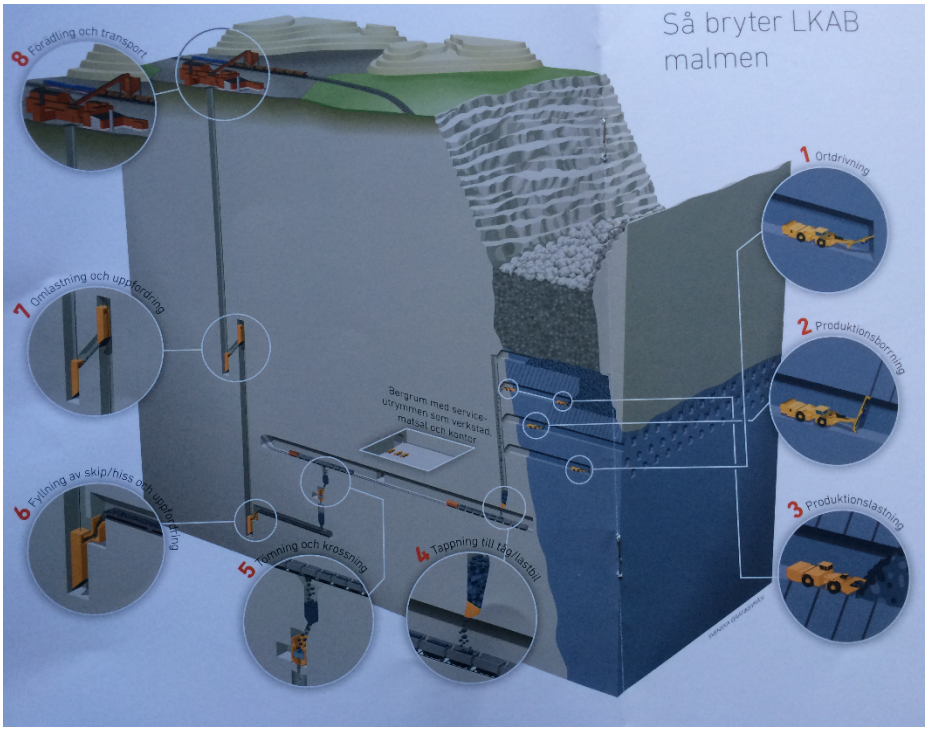

Figure 3.5: LKAB's excavation of the iron ore. [20]

metals extracted from Aitik include copper, gold, and silver. In 2014, Aitik produced 36 million tonnes of ore, and over 480 million tonnes of waste rock. Much of the waste rock is used as ballast in concrete and in road construction. [37]

In Aitik, ore is excavated by drilling vertical holes, which are then loaded with explosive and blasted. The blasted rock is then loaded onto trucks, and taken to a crushing station. There, conveyors connect the station with ore storage. After storage, the ore enters a nearby mill, where it is ground and water is added. When the ore reaches the correct water fraction, approaching a slur, it is transported to a mixer. There, regents will be aded, allowing flotation of the mineral chalcopyrite. The leftover sediment is transported to the tailing pond. The foam of minerals is gathered, dewatered, and sifted. The final products are zinc concentrate, with 50% zinc or copper concentrate and 25% copper. These are transported via railroad to the Rönnskär smelter. (See Figure 3.7.) [5]

3.5 The environmental aspect of mining from different parties

3.5.1 Geological Survey of Sweden

The *Sveriges geologiska undersökning*[4] says that the environmental impact of the mines has been reduced in the last few decades. Yet the environmental impact is still substantial, and can be seen in the form of noises and dust, as well as pollution of air and water. Running a mine takes a lot of energy, and metal and mineral extraction produces a lot of waste. In 2010, the sum total of all waste from all Swedish mines summed to 89 million

[4]Geological Survey of Sweden

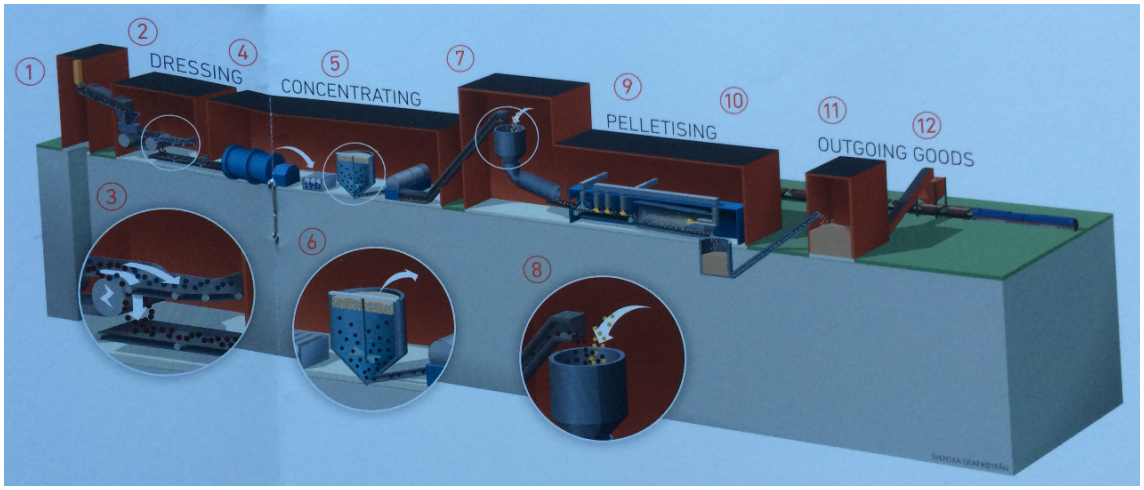

Figure 3.6: LKAB's processing of the iron ore. [21]

tonnes. This waste is mostly gangue and tailing. The gangue is stockpiled, and can be later used in road construction or concrete ballast. The tailing, which comes from the separation of minerals and metals in the waste concentrator, is dumped into tailing ponds and left to sediment.

Swedish ore is either oxidic or sulphidic. Most environmental issues in mining tend to be caused by sulphidic ores, like pyrite and pyrrhotite. If iron sulfide lies unprotected, it can oxidize in weather and wind. Weathering creates acidic leachate water rich in metal, often termed *acid mine drainage*, or *AMD*. To prevent this reaction, iron sulfide tends to be stored in tailing ponds, where water cover prevents access to oxygen. Thus the AMD process tends to occur in old and closed mines, where waste lies uncovered. [31]

3.5.2 LKAB

In a 2014 environmental report, LKAB finds the production of iron ore to release airborne carbon dioxide, sulphur dioxide, flouride, chloride, nitric oxide, and other dusts. Mining also consumes high amounts of energy and water, and processing produces large amounts of waste rock. The tailing ponds tend to have very high pH levels, high levels of nitrogen, and a high concentration of soluble inorganic irons. These ponds, which can neighbor communities, often flood over into the recipient tributaries *Metta Rakkurijärvi* and the Kalix river. In a similar process, the Malmberget mine flooded its processed water over into the recipient river Lina. [35]

In 2014, the Kiruna mine was found to have a dust concentration above environmental standards, which has since been adjusted with new filters. Länstyrelsen has since reported similar high concentrations of dust to the authorities. Dust and other toxins, often suspended solids floating in the processed tailing pond water, can leak out into the adjacent mire.

Although the impact on the environment is somewhat limited by location, there are no further means to fix the problem. Overflooding of tailing ponds has been curtailed to some degree, and these events have been reported to Länsstyrelsen by LKAB. Similarly, high levels of noise have been compensated by a lower railroad speed and better dampers on mine fans.

Every fourth year, LKAB investigates its surrounding environmental systems. The

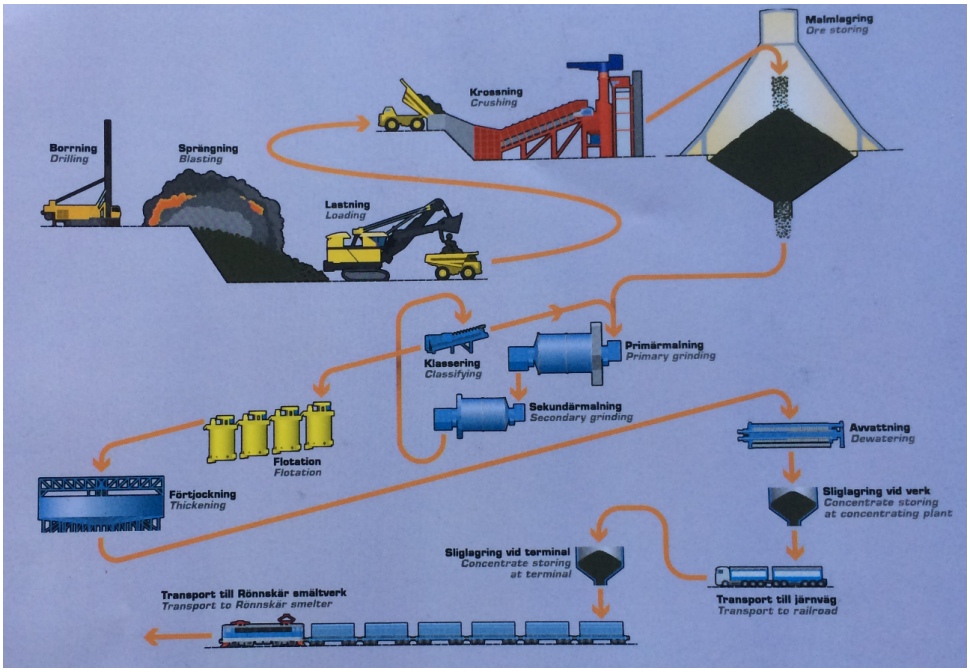

Figure 3.7: Boliden's excavation and extraction of metals from the ore. [5]

latest investigation, in 2012, included analysis of water chemistry, benthos, periphyton, and higher aquatic fauna and sediments. All values were shown to be within legal requirements. [35]

In 2014, the mine at Malmberget had a similar problem with dust, which was fixed by cleaning and replacing over three hundred filters. To compensate for elevated values of suspended solids in tailing pond water, LKAB has excavated the clearing pond and plans to lead the processed water from the clearing pond to the tailing pond instead. [35]

3.5.3 Boliden

Boliden's self-stated environmental goals are to:

1. Decrease the spill of metals in water by 25% by 2018.
2. Decrease the spill of metals in air by 10% by 2018.
3. Decrease the spill of sulphur dioxide in air by 10% by 2018.
4. Stabilise the carbon dioxide intensity to within 0.77 tonnes CO^2 produceed metal by 2018.
5. Aim for zero environmental accidents per month.

However, there have been thirteen environmental accidents during 2014, nine of which exceeded legal requirements. There has also been recorded leakage of polluted water due to heavy rainfall. No effects on nature have been yet recorded. Most of the metal pollution is from smelters, and most of the nitrogen pollution is from blasting. The handling of water runoff is the most critical part, as ponds are most sensitive during heavy rainfall. [6]

The *Swedish Environmental Protection Agency* has appealed the *Swedish Environmental Court*'s verdict, which would give Boliden permission to expand the Aitik mine. They similarly believe that the mine has a high hazard risk towards the surrounding environment. They also believe that the mine is not financially suitable to expand. [15]

3.5.4 Swedish Society for Nature Conservation

The Swedish Society for Nature Conservation has published a rather negative report on the mines in Sweden and the regulations that exist for the mining industry. The environmental issues that they states is:

1. Leakage of metals to the surroundings and acidify the lakes and rivers.
2. Breakage of the dams could lead to seriously accidents downstream.
3. High energy consumption and long way transportations.
4. Closed down mines is a big issue considering leakage of polluted substance.
5. Violation on treasured nature areas.
6. Dust from the mines affects the inhabitants nearby.

In 2013 the Swedish government published a report on a sustainable mineral strategy. There were 5 areas that was pointed out:

1. A mining and mineral nutrition in tune with the environment, culture and other sectors: This area mentioned among other assignments to the SGU to identify the potential for increased recycling of metals. Norrbotten County Administrative Board will produce guidance for consultation and communication between reindeer- and the mining industry.
2. Dialogue and collaboration that fosters innovation and growth: A national minerals forum will be established, and led by the Minister of Enterprise and Energy, to follow up the mineral strategy. Companies, authorities and organizations will participate. The *Tillväxtverket*[5] shall develop and operate a national support program when planning large investments from the business sector and produce a handbook for municipalities that faces big mining establishments together with the Environmental Protection Agency.
3. Framework conditions and infrastructure for competitiveness and growth: Environmental assessment must be made more effective and take less time, but no new measures mentioned do not really except that the government intends to work for simplified rules on environmental impact assessment in parallel with the negotiations in the EU on a new directives. It mentions also extensive new investments (already proposed by the government) in infrastructure, including increased capacity on the Ore Railway, the railway between Pajala and Svappavaara and possible investments in Bergslagen. The *Tillväxtanalys*[6] should compare Swedish licensing processes in the mining sector with foreign.

[5]Growth Board
[6]Agency for Growth Policy Analysis

4. An innovative mining and mineral nutrients with an excellent knowledge base: SGU shall start a project on the geology's role in society.

5. An internationally well known, active and attractive mineral nutrition: Business Sweden is to investigate a Web portal that exposes mining projects for foreign interests. SIDA and the SGU will jointly submit proposals on how Sweden and Swedish companies can contribute to the development of a sustainable mining industry in developing countries. [1]

The report also points to instances of Swedish law benefiting mining corporations, and attracting foreign companies to the Swedish mining market.

This legislation allows mining companies to prospect and begin excavation on private land without the landowner's consent. Mines in Sweden are often considered so important that protection agencies allow large emissions of heavy metals and other contaminants, sometimes beyond what would be tolerated in other industries. The mining industry's so-called national interest similarly trumps other national interests, such as environmental protection, outdoor tourism, and the reindeer herding industry.

The tax rules are similarly generous in many ways. The mining industry is exempt from the landfill tax, has a lessened energy tax compared to other forms of industry, and only pays the *mineral charge* on 0.2% of the excavated value of its minerals. [30]

Chapter 4

Conclusions

4.1 The Community Impact of the Norrbotten Megasystem

A community adapts to a megasystem by becoming a part of it. Specifically, Kiruna and its now-migrant communities have adapted to Norrbotten's industrial megasystem by giving up much of their their autonomy to LKAB, and relying upon it to handle the migration process for them. Thus Kiruna and its citizens become an asset for the company, to be handled, protected, and weighed alongside all its other assets. Environmental and labor protests, though indicative of unhappiness with the situation, have not changed it. LKAB and other mining companies remain the predominant power in Norrbotten, and all other major industries around Kiruna, Gällivare, Malmberget, Aitik, and Jokkmokk remain tied indelibly to it.

Yet LKAB and the mining community is *composed* of the residents of Kiruna, who depend upon it nearly completely for their livelihood. To separate the company from the town is misleading. The company is the town.

There is, as of yet, no alternative industry in Kiruna. Were LKAB to cease mining, the surface might stabilize: but the economy would crash and the town would bust, like so many mining communities do when the natural resource is finally depleted. Thus community is both actor and victim, and the town itself is ultimately responsible for the pit which is eating it alive.

While Kiruna, Gällivare/Malmberget, and Aitik all have slightly different spins on the common company-town cycle, the nature of industry in Norrbotten remains the same: inescapable, megalithic, and massive. Every aspect of life in the north is affected by it, between the layout and placement of a city, the town politics, and the community's raison d'etre. Resistance or no, the social, political and economic leverage Norrbotten megasystem exerts over the region is absolute.

The future of the region could play out in a number of ways. First, the Kiruna space industry could boom as a function of increased interest and economic investment in space travel. Second, environmental restrictions on the region could be lessened, allowing for mining of undeveloped and unpopulated ore bodies without the risk to community well-being. Third, mining could cease entirely, as a result of either natural resource depletion, economic failure, or increased environmental restrictions. After the migration of Kiruna is complete, it is estimated to remain safe at its new location for approximately a century before another complete migration must be initiated. Thus the future of Norrbotten will be perpetually in flux: both community and industry alike.

4.2 The Environmental Impact of the Norrbotten Megasystem

4.2.1 Mining

The mining industry is one of the world's largest, and Sweden is an important European participant in it. The steel industry is a large part of the Swedish export economy, and provides a foundation for Sweden's financial health.

Of the many environmental issues surrounding mining, the largest is the handling of the waste and dust that occur during production. Mines in Norrbotten have a tendency to swallow their surrounding towns. Improved regulations for the reuse and recycling of metals and minerals are critical to benefit the mining industry, and should be enacted before the industry builds any more new mines. Furthermore, mines should be banned from nature reserves. Additionally, the Swedish mining industry enjoys tax relief unlike that available to any other industry.

Often mining companies which go bankrupt abandon their mines altogether, leaving the physical structures in a dangerous and pollutant state. Abandoned mines are often bought by the Swedish state at great expense. To avoid this, there ought to be regulations ensuring that a company is financially stable before being granted a mining permit. Unregulated and abandoned mines are a common pollutant in Sweden's ecosystem. There has been no recent comprehensive environmental survey of all closed and abandoned mines.

4.2.2 Luleå

Luleå Hamn AB is responsible for the environmental problems in the Luleå harbour. They are responsible for ensuring that the harbour runs smoothly and follows environmental regulations. But the companies that work in and use the harbour are also responsible, and should be held financially accountable for their pollution and contamination. However, the harbour is home to many companies in close concentration, which leads to confusion over whose fault a given contamination event is. Thus lots of environmental problems fall between the lines. Although the Swedish government has hardened some of the regulations for mining, the harbour remains vital for the Swedish economy and trade with Europe. So fiscal stability is often valued above environmental issues in state legislature regarding the harbour.

4.2.3 Hydropower

Hydropower is the backbone of the Swedish energy supply. This is true because of the amount of energy it supplies, but also for its role as stabilizer in the Swedish electrical grid. Hydropower is easy to regulate throughout a day, to compensate for fluctuations in energy consumption.

Hydropower has many environmental problems, the largest of which is damage to aquatic life and ecosystems. Additionally, the environment surrounding many power plants undergoes drastic changes, where rivers are drained and flooded. The hydropower industry knows its' vital role in the Swedish energy market, and works hard against state regulation. This makes the state a very weak regulator.

4.2.4 Analysis

In every part of the Norrbotten Technological Megasystem, economic profit and financial stability take precedence over the environment. Mines give out the most pollution, and have the worst track record for cleaning up after themselves. But the true culprit is the Swedish state, which allows companies in Norrbotten to avoid responsibility for their environmental impact. The government lets companies pit *miljoöbalken* [1] against each other when applying for permits. This lets industry set the different government agencies responsible against each other. Finally, all industry permits should have expiration dates. Companies today still use permits from half a century ago. This stifles innovation and environmental law.

4.3 The Total Impact of the Norrbotten Technological Megasystem

In both community affairs and environmental considerations, industry in Norrbotten tends receive special treatment. This often leads to destructive tendencies, unnatural byproducts of mining, hydropower, and transportation. Towns are crushed and rebuilt. Environments are destroyed. Regulatory limits are surpassed. All this, in the name of industry.

Yet Sweden's very financial health depends upon the Norrbotten Megasystem. This is not reason to abandon regulation altogether. If the Megasystem can grow and prosper, benefitting itself and Sweden alike, it must do so in harmony with the citizens and land around it. Like a tragedy of the commons, an unchecked industrial megasystem can consume everything in its' path. The Swedish state must continue to impose and maintain strict regulations on behavior and consumption for Norrbotten's industrial megasystem. Northern industry works tirelessly to benefit the citizens of Norrbotten, and make the country of Sweden strong. Yet without regulation, there may be no Norrbotten left to work for.

Industry tears the ground out from under communities, literally and figuratively. Now more than ever, environmental regulation is critical in Norrbotten. Community health must be understood and protected in the interest of Norrbotten.

Norrbotten will only industrialize in coming decades. We are now entering an era of human development when metals, minerals, and energy will be more important than ever. Protecting Sweden's resources and ensuring its' position as a viable supplier of these essentials of trade is critical for Sweden's present and future. Yet without proper legislature, regulation, and oversight, the Norrbotten Technological Megasystem may have no future at all.

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