Which Landscape? Material Traces of an Integrated Design and Research Approach in Kiruna

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In 2015, during the first workshop organized within the "Green/Blue Infrastructure for Sustainable, Attractive Cities" European-funded project, participants were given a series of images from the approved masterplan for the development of new Kiruna. The three visual excerpts from the masterplan had been selected because they acknowledged "Kiruna's ambitious vision of becoming a leader and role model of sustainability" and to "focus the participants' mindset during the workshop,"[1] as a starting point for discussion. The "shape of the city" envisioned by the new masterplan was one of a series of "external challenges/drivers for change" that Kiruna's water systems would have to respond to: others were "mining activity," "climate changes," "increasing environmental regulations," "natural conditions."[2]

This paper looks at the different narratives around the concept of landscape in the context of the relocation of a large part of the city of Kiruna, in northern Sweden, where a collectively constructed notion of landscape is at the core of current political debate, one that includes and intertwines the subarctic landscape that precedes and surrounds the town, the urban landscape that is currently undergoing a radical and arguably unique change, and the technical landscape that results from the activities of the extraction industry. How do these three components participate in the narratives that sit within decision-making processes, how do they precipitate on the ground, and how can design tools and competences enter the discussion?

The paper attempts to define a collectively constructed notion of landscape as a sociotechnical imaginary, by setting it in the context of two projects that had been intended to intertwine (the masterplan Kiruna 4-Ever and the European-funded project "Green and Blue Infrastructure"), and will then articulate three narratives that express three alternative directions in which the debate might progress, by foregrounding their material dimension and their physical effects: a *landscape of sacrifice*, where the social and political factors yield to the economic interests of the extraction activity; a *mono-functional landscape*, where the mine and its related infrastructures, terraformed grounds, logistical systems is understood as a world in itself; and a *multi-functional landscape*, where the attempt at balancing the different identities of the town and the sustainability of socio-ecological quality and civic value is at the center of public discourse.

Landscape as Socio-Technical Device

Antoine Picon uses the term "anxious"[3] to define contemporary urban landscapes, wondering why we seem to be so disturbed by the spans of cranes, cement, containers, refineries and

1 Günther Leonhardt et al., "Relocating a city, challenges and opportunities for the transition of water infrastructure in Kiruna," UDM2015, 10th International Urban Drainage Modelling Conference, Mont-Sainte-Anne (Canada), Sept. 20-23, 2015.

2 Ibid.

3 Antoine Picon, "Anxious Landscapes: From the Ruin to Rust," *Grey Room* 1 (2000): 64-83.

factories that surround contemporary cities: "[the response to this question] requires, in my opinion, the definition of a notion of technological landscape that distinguishes itself from that of traditional landscape on several points."[4]

Picon is reflecting on the aesthetic presence of technological systems as disturbers of a previous, clearer order of things, one in which human artifacts were *in* the landscape, and proposing that they *are* now *the* landscape. Picon's position looks back to a legacy of disciplinary critical debate that attempted to make sense of the complex relationship between so-called artificial and natural environments – from André Corboz's notion of landscape as a "palimpsest,"[5] a stratified but non-disposable object, one that is by necessity continuously rewritten on, erased, modified by human and non-human actors alike; to concepts such as Emilio Ambasz's "post-technological environments"[6] adopted to propose a different way to teach and learn the design disciplines; or "techno-utopian"[7] systems, in which a definite - almost guilty - fascination with the human-made blends in with an array of projective stances that justify the attempts made by architect authors to have a say in the matter.

The notion of landscape can be understood as stemming from a "cultural construct of *artialization*,"[8] whereby it exists as a result of a double endeavor, one that happens *in situ* – the technical construction / tracing / projection of artifacts on the ground – and *in visu* – their interpretation through and within varying forms of art; in this perspective, landscape cannot exist without human intervention onto "nature," and it is equally "impossible without representation."[9]

Among a number of attempts at defining that which falls outside of established genres of interpretation, the aesthetic category of technological sublime[10] is an attempt to domesticize the fascination we feel towards the material presence of large technological feats: dams, mines, terraforming, etc. The notion of the Anthropocene, which was ultimately rejected as a geological epoch[11] but remains pervasive as an aesthetic category, is equally representative of such fascination. At its core is a "relation to an 'interior landscape' of cognitive disorientation,"[12] in a progression that is at once linear with and divergent from traditional subjectivistic notions of landscapes.[13]

The modernity of cities can, arguably, be measured by the degree of invisibility of their infrastructure:[14] early modern European cities proudly displayed the infrastructural appendages of technological networks such as water towers, dams and plants; conversely, late modern European cities conceal their infrastructural networks underground, or distribute them neatly into orderly bundles of cables; then again, in the fast-growing cities of the Global South, infrastructural networks are laid bare, and become an integral and visible part of the urban landscape.[15]

4 Ibid., 66.

5 André Corboz, "Le territoire comme palimpseste," Diogène 121 (1983): 12-31.

6 Emilio Ambasz, "Institutions and artifacts for a post-technological society," *Casabella* 35 (359-360) (1971): 87-99.

7 Felicity B. Scott, *Architecture or Techno-Utopia: Politics After Modernism* (Boston: The MIT Press, 2010).

8 Alain Roger, *Court traité du paysage* (Paris: Gallimard, 1997).

9 Ibid.

10 For instance, for an overview of the category of the technological sublime and its relationship with landscape literature, see Angela Harutyunyan, "Landscape and its double: the technological sublime," *ARTMargins* 10 (1) (2021): 66-76.

11 The Anthropocene Working Group was instituted as part of the Subcommission on Quaternary Stratigraphy to discuss the definition of the new geological epoch following Paul Crutzen and Eugene Stoermer's proposal in 2000 (see for instance http://quaternary.stratigraphy.org/working-groups/anthropocene/).

12 Matthew Gandy, "Marginalia: Aesthetics, Ecology and Urban Wastelands," *Annals of the Association of American Geographers* vol. 103, 6 (2013): 1301-16.

13 Michael Jakob, *Le origini tecnologiche del paesaggio* (Siracusa: LetteraVentidue, 2022).

14 Maria Kaika, Eirk Swyngedoux, "Fetishizing the modern city: the phantasmagoria of urban technological networks," *International Journal of Urban and Regional Research* 24 (2000): 120-38.

15 Matthew Gandy, *The Fabric of Space: Water, Modernity, and the Urban Imagination* (Boston: MIT Press, 2017).

The move from a critical, or cognitive, understanding of landscape to a "technological" one relies on "precise historical devices that literally shaped landscape throughout the centuries"[16] and calls for a definition of different categories of understanding: different frameworks, we add, that can help to cross the subjective and cultural construction of the notion of landscape with the technological and social processes that shape it.

The field of Science and Technology Studies offers a specific cognitive tool that allows one to focus on the promise value of collectively held imaginaries, together with the technological and socio-political features that underwrite them. In this way, the shortages are overcome of both previous STS literature – which only focuses on the measurable aspects of the relationship between scientific development and context – as well as critical readings of technological landscape, which focus on conceptual categories that are more helpful in operations of generalization rather than in measuring material effects of specific actions.

> "Unlike mere ideas and fashions, sociotechnical imaginaries are collective, durable, and capable of being performed; yet, they are also temporally situated and culturally particular. Moreover, as captured by the adjective 'sociotechnical,' these imaginaries are at once products and instruments of the co-production of science, technology, and society in modernity."[17]

In particular, where the field of STS focuses on the agency of very diverse sets of actors and actants, as well as the contingency that technological processes develop in, the concept of sociotechnical imaginaries allows to factor in the strength of collectively constructed promises, and the subjective values they express. Sociotechnical imaginaries are by definition "communicable"[18] schemata that represent "future objectives" and express "the means by which these objectives will be realized,"[19] thus producing a "sense of belonging to a specific collective."[20] The collective of sociotechnical imaginaries was initially intended by its proponents to be a large collective – one that exerts its agency at the national scale, the scale of legislative frameworks – but was then reframed as a collective that could vary significantly: from the very local and regional to the transnational.[21]

The concept of sociotechnical imaginaries was born within Science and Technology Studies, which is by definition a transversal field of studies: it is therefore employed to look at a very diverse array of sociotechnical constructs, not necessarily spatial ones, and not necessarily related to the concept of landscape. Specifically, the concept of sociotechnical imaginaries has been increasingly employed in the analysis of energy-related futures: from the initial comparative study of nuclear power technology in the United States (US) and South Korea[22] to China's offshore wind power,[23] to Austria's atomic future.[24] Nonetheless, we think that this concept can be quite helpful in understanding the entanglement of aesthetic, political, social and economic tensions, interests and perspectives that pull decision-making processes with varying strength, and towards different directions. In the case of Kiruna, the construct of landscape, and its changing interpretation, sits at the core of a complex urban process in which the technological entwines with the social, and relies on and in turn builds a specific – though articulate – promise of the future.

16 Jakob, *Le origini tecnologiche del paesaggio*.

17 Sheila Jasanoff, S.H. Kim, *Dreamscapes of modernity: sociotechnical imaginaries and the fabrication of power* (London: University of Chicago Press, 2015): 19.

18 Frans Berkhout, "Normative expectations in systems innovation," *Technology Analysis and Strategic Management* 18(3/4) (2006): 302.

19 Ibid.

20 Sheila Jasanoff, H.R. Simmet, "Renewing the future: excluded imaginaries in the global energy transition," *Energy Research & Social Science* 80 (2021).

21 Ibid.

22 Sheila Jasanoff, S.-H. Kim, "Containing the atom: sociotechnical imaginaries and nuclear power in the United States and South Korea," *Minerva* 47 (2) (2009): 119-46.

23 Marius Korsnes, "Ambition and ambiguity: expectations and imaginaries developing offshore wind in China," *Technological Forecasting and Social Change* 107 (2016): 50-58.

24 Florian Bayer, U. Felt, "Embracing the 'atomic future' in Post-world war II Austria," *Technology and Culture* 60 (1) (2019): 165-91.

By looking at two specific documents – the 2014 "Kiruna 4-Ever" masterplan and the 2014-2016 "Green/Blue Infrastructure for Sustainable, Attractive Cities" project – and attempting to trace their effects on the ground, we try to analyze the implications of a specific idea of landscape onto normative as well as narrative and analytical, projections of collective life.

Kiruna: A Landscape of Narratives

The 2023 Netflix production "Abyss" is acclaimed as the most effective Swedish disaster-movie to date. A high-ranking employee of the mining company managing Kiruna's iron ore mine is in charge when the ground above the excavation subsides after a series of earthquakes, and large portions of the city collapse underneath. When asked why she lives in a "place like this," the protagonist answers that "she likes it," her gaze fixed intensely over the expanse of the mine, as if looking over a landscape of pastoral qualities.

In a much more sober and analytical picture of the town's move, director Greta Stocklassová[25] paints a thick description of the narratives, the interests, the aspirations, as well as the volatility of certainties and convictions, that govern daily life in Kiruna, portraying a range of different perspectives around the event of the move, and the new landscape that is associated with it.

The necessity to move a significant portion of the town, and more broadly its defining cohabitation with invasive extraction activities, has forced Kiruna to deal with its notion of landscape in political terms: in terms of economics and of heritage, through an incremental definition of a shared – though far from conflict-free – cultural construct that is narrated as national interest.

In 1984, a Preservation Plan was approved, which aimed at protecting the built environment of Kiruna,[26] but as early as 1990 the Swedish National Heritage Board designated the whole town a Heritage site, on the basis that it represented an "early 20th-century town setting and industrial *landscape*, where a vision of a model society was realized in an unprecedented manner in previously unexploited mountain scenery."[27]

The extraction landscape is collectively acknowledged as an integral part of the fabric of the town. When asked what makes Kiruna stand out and what they would choose to preserve, secondary school students pointed to the mine itself, alongside recognized historical landmarks of the town.[28] Within the current process, parts of the city are turning into extraction landscape: this is quite explicit in the policy tool of "Mine City Parks"[29] through which the administration and the mining company manage the transition from urban area, through temporary park area, and finally to the mining area of those portions of land that become part of the system of extraction. In turn, the arctic landscape allowing for the livelihood and reproduction of Sami traditional herding practices gives way to the new expansion of the town: the symbiotic relationship between the technological landscape of extraction, the urban landscape of the town, and the encompassing arctic landscape, is key in the peculiar process that the town is undergoing: in this particular "palimpsest," the boundaries of reindeer herding land are being continuously scraped and moved, just as the roads and urban blocks of old Kiruna are being demolished and retraced a few kilometer's distance, and the fences of the extraction site are being pushed increasingly to the east.

25 Greta Stocklassová, "Kiruna - A Brand New World" (2019).

26 The town features, or in some cases featured, noteworthy projects by architects such as Gustaf Wickman (who also drafted the original town plan in 1900), Artur Von Schamlensee, and Ralph Erskine; see for instance Andrea Luciani and E. Poma, "Sub-Arctic architecture in detail. Erskine's disappearing architectural and constructional legacy in Kiruna," *Journal of Architectural Conservation* 29/3 (2023): 275-300.

27 Jennie Sjöholm, "A photograph is not always enough," in *Kiruna Forever*, Daniel Golling, Carlos Minguez Carrasco (eds.) (Architektur Förlag, Arkdes, 2020), 203.

28 Survey managed by Norrbottens Museum, referenced in Ibid.

29 Mine City Parks were established in the February 21, 2011 City Council meeting. https://samhallsomvandling.lkab.com/en/about-the-urban-transformation/kiruna/mine-city-parks/.

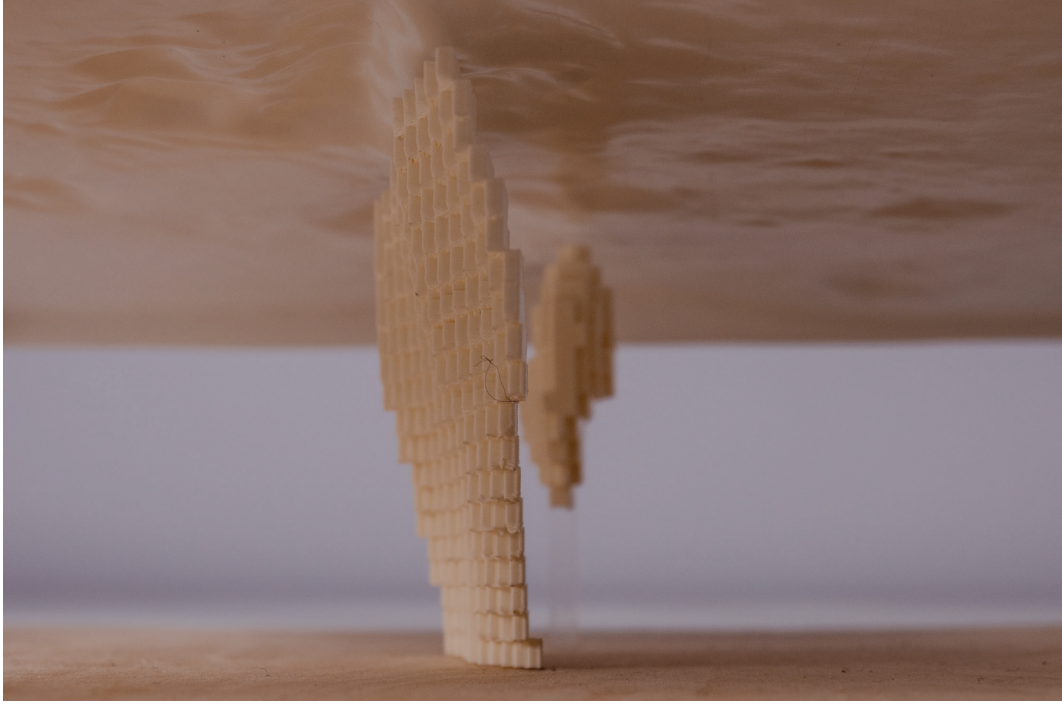

Fig.1: Subterranean model of the Kirunavaara ore body showing the oblique occurrence of the deposit

In March 2004, state-owned mining company LKAB (Luossavaara – Kiirunavaara Aktiebolag) informed the Municipality of Kiruna that underground extraction of iron ore at 60-degree angle from the ground plane would be continuing below the central districts of Kiruna, and that a portion of the town had to be demolished to prevent damages due to the subsidence of the ground.[30] (Fig. 1) This specific letter is often referred to as the starting point of a process that arguably makes Kiruna a unique case,[31] but at the same time reveals how deeply embedded it is within a wider technological system that spans the whole region and affects other towns, mines and infrastructures:[32] it is a process that carries the weight of nation-wide economic interests, and makes explicit the way they precipitate onto the very material, and spatially defined, space of a town.

Soon after the 2004 announcement by LKAB, the administration began to work on a new and deeper comprehensive plan for the center of Kiruna, to safeguard the city's development and turn the challenge of the decommission and new construction into potential for enhancing the city's attractiveness as an all-round urban environment, rather than a predominantly mining town. A number of alternative locations for the new city center were investigated, all of which would involve the urbanization of varying extensions of land employed by the Sami communities for reindeer husbandry.[33] On September 19, 2011 the Municipal Council held a meeting in which it resolved in favor of building the new city center to the east – partly onto rural land and partly onto industrial land – as well as in favor of an architecture competition for the drafting of the new masterplan. (Fig. 1)

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30 Alisa Maria López, "Transforming Kiruna. Producing Space, Society, and Legacies of Inequality in the Swedish Ore Fields," *Uppsala Studies in Cultural Anthropology* 62 (2021).

31 Although of course it is possible to contextualize it in wider frames of reference dealing with the relationship between mobility and environmental issues: see for instance Giovanna Borasi (ed.), *Journeys: how travelling fruit, ideas and buildings rearrange our environment* (Barcelona: Actar, 2010).

32 On the Norrbotten Technological System; see for instance Agatino Rizzo, Jennie Sjöholm and Andrea Luciani "Smart(en)ing the Arctic city? The cases of Kiruna and Malmberget in Sweden," *European Planning Studies* 32:1 (2024): 59-77.

33 All of Kiruna sits onto land traditionally used for winter pasturing by the Sami people, before the development of the railroad had made it possible to fully exploit the iron mine. The Reindeer Husbandry Act of 1886 is the most widely referred political tool employed to regulate the misalignment between new settlers' farming (and extraction) activities and the Sami husbandry practices. See for instance Eivind Torp, "The legal basis of Sami reindeer herding rights in Sweden," *Arctic Review on Law and Politics* vol. 4, 1 (2013): 43-61.

The Masterplan Kiruna 4-Ever

In June 2012, the Municipality of Kiruna in partnership with the Swedish Association of Architects arranged a competition concerning the vision, strategy and design of a city center for a new Kiruna,[34] to which ten teams of architects were invited. In early 2013, the Jury proclaimed as winner the project Kiruna 4-Ever, submitted by the team of White Arkitekter, together with Ghilardi + Hellsten Arkitekter, Spacescape AB, Vectura Consulting AB. The jurors' assessment stated:

> "The landscape in and around Kiruna makes a very important difference to its identity. The landscape has been created both by natural processes and anthropogenically, and it will go on being subjected to this influence. The natural processes which most conspicuously created the place were played out 10,000 years ago, when the ice cap melted and released the Arctic bedrock. That is when both the undulating mountain landscape and the low-lying water landscape were created. Later on, human beings arrived and began cultivating and using the landscape, which they have been doing ever since. When mining came here at the end of the 19th century, the town of Kiruna was also created. Since then, the mining industry, the development of the town/city and its infrastructure have wrought big changes in the landscape."[35]

It is worth noting that the competition entry which most tried to focus onto the changing concept of landscape, by proposing to design the new Kiruna onto terraformed ground, was considered interesting but was rated second to last by the jury:

> "The starting point of the entry is the modelling of a new landscape, using spoil from the mine. [...] This suggests that the mining industry can make more extensive use of its residual products and assume responsibility for the vulnerable landscape of our time."[36]

Arguably, the idea that the extraction industry could "assume responsibility" was deemed unrealistic by the jury; but more generally, the role that the extraction industry took in this proposal was too dominant — visually and materially — and would push the local imaginary of landscape towards one direction, rather than exploiting the possibilities offered by its nuanced and incremental cultural construction. On the other hand, another entry which made the symbiotic relationship between built fabric and the natural features of the landscape its main point of focus also did not meet the jury's favor. In this proposal, clusters of settlements, each defined by a specific dominant program, were dispersed into the landscape, in a manner that would allow incremental expansion, but was deemed excessively "unplanned" by the jury.

The winning entry, Kiruna 4-Ever, was considered effective in interpreting the complexity of Kiruna and its landscape: particularly as it introduced – although the competition brief did not explicitly ask for it – a longer-term scenario of development, in the hypothesis that extraction activities would continue and the town would have to continue "moving" to the east, giving form to "the permanent uncertainty which will forever be one of Kiruna's planning ingredients" and making explicit the "possibility of repairing the deformed landscape in a long-term perspective." Also, the proposal would give residents and visitors "close access to nature" by increasing the density of the urban fabric rather than spreading it around.

Following the masterplan, in 2014 the Municipality adopted a Comprehensive Plan,[37] which adapted the main logics of the winning entry to both the jury's suggestions: these mainly regarded the location of several road infrastructures, as well as practical issues — particularly, coming to terms with economic matters. This plan also delves carefully in different aspects of the relationship between urban and rural landscape, and the drivers that affect it: key concepts

34 "A New City Centre for Kiruna. Jury pronouncement, March 2013," https://www.arkitekt.se/app/uploads/2014/06/T%C3%A4vlingar-2013-Ny-stadsk%C3%A4rna-i-Kiruna-Jury-Pronouncement.pdf, accessed March 2024.

35 Ibid.

36 Ibid.

37 Kiruna Kommun, "Detailed Comprehensive Plan" (March 2014).

frequently employed towards a definition of the attractiveness of New Kiruna are, among others, "proximity to nature," "proximity to wilderness," "outdoor qualities," "nature and city in interaction." Planning consideration for the "natural landscape" include reflections on the orientation of buildings and their clustering: for instance, "heights and slopes are preferable to the sinks and valleys where cold air mass in winter" and "Sydsydvästsluttningar receives more solar radiation compared to the east-northeast slopes."[38]

The Green and Blue Infrastructure Project

As the city adopted the Comprehensive Plan and as the first instances of construction and demolition work started, a partnership of European universities obtained funding to carry out a research project that would support the City of Kiruna in the design of its "Green and Blue Infrastructure (GBI)" system.[39] The aim of the project as applied in Kiruna was to implement, within the overarching vision offered by the Kiruna 4-Ever masterplan and the subsequent Comprehensive Plan, a series of guidelines to improve the water and vegetation system in the new section of the city.

> "The Kiruna case is strategically well-positioned for the transition to a sustainable urban water system through ambitious planning and a conducive political climate. The momentum for this transition is the anticipated expansion of Kiruna's iron ore mine. The prospect of a new business and residential core of the town presents the opportunity for redesigning the way Kiruna manages its water management. But with this opportunity come a number of uncertainties."[40]

The uncertainties include, among others, the specificities of the subarctic climate, which may prove challenging in the application of shared protocols regarding green and blue infrastructure systems; policy settings, which will have to adopt future European requirements on carbon emissions; and demographic trends, which may or may not see an increase of residents' population in Kiruna. All these factors are recognized as having an impact on the application of a specific component of urban design. The layout of the proposed infrastructural system must be able to respond to the

> "ongoing and future (programmed) transformation of the city landscape, enabling the continuity of cultural identity (heritage) and the harvesting of new values provided by ecosystem services of GBI."

The research was conducted through a continuous interaction with the Kiruna Municipal Technical Office, which was a formal partner in the project, and through a series of co-creation workshops (Living Labs) during which participants expressed doubts, uncertainties and preferences regarding the different solutions for GBI.

The main result of this part of the project and research work was an advanced decision-making framework that would allow selection among different physical models of GBI depending on wider socio-political developments. For instance, it would allow the "exploration of different spatial structures according to socio-economic and climatic variables", or to factor in the flexibility of "actual municipal investments." (Fig. 2)

For the extra-modern town of Kiruna, where the technical landscape is one with the urban and rural landscape, this was intended to be a way to make visible the infrastructural network, its material components and its being closely intertwined with the space of the city. Very diverse

38 Ibid.

39 The JPI Urban Europe project "Green Blue Cities -– Green/Blue Infrastructure for Sustainable, Attractive Cities" was conducted by Luleå University of Technology (Sweden), Leopold Franzens University Innsbruck (Austria) and Delft University of Technology (The Netherlands). Duration: 2013-2016; Budget: 1,600,000 EUR. Test cases and living labs: Kiruna, Sweden; Zwolle, Netherlands; Innsbruck, Austria. One of the authors of this paper was involved in the project.

40 "Green Blue Cities – Green/Blue Infrastructure for Sustainable, Attractive Cities" project report.

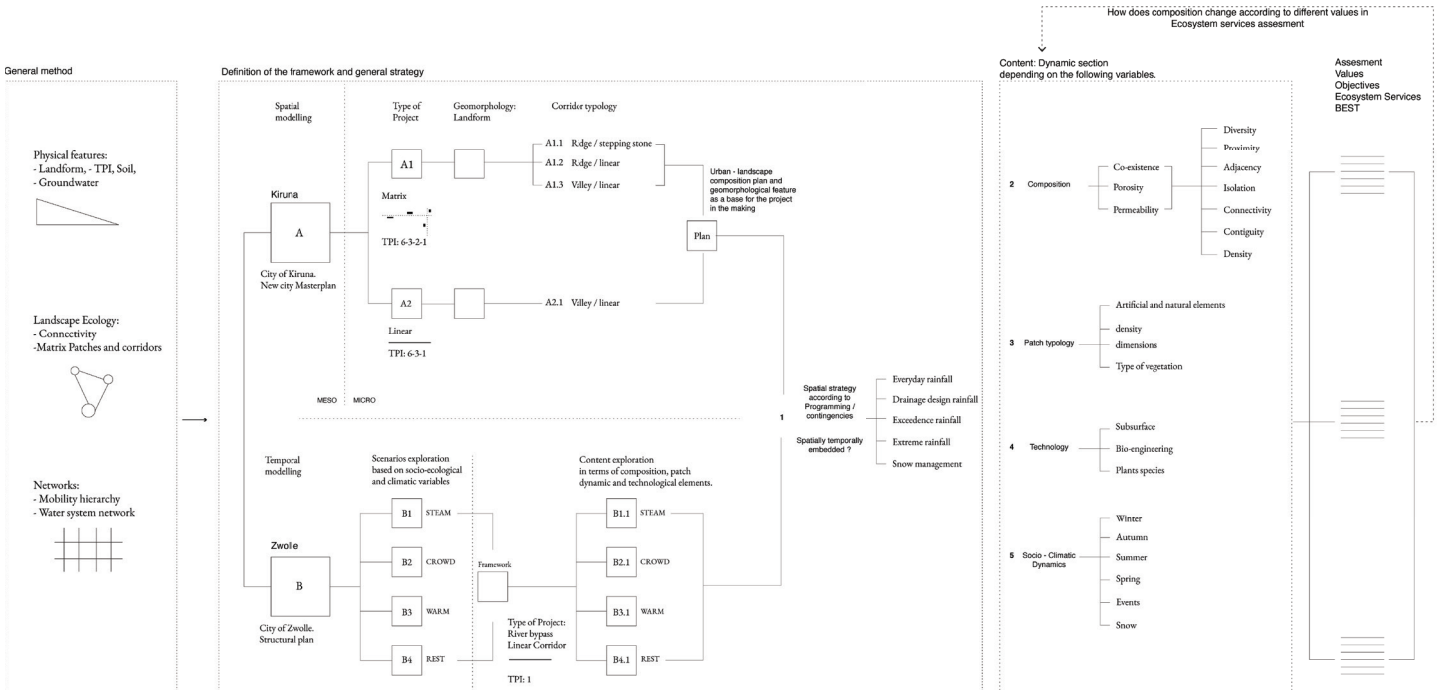


Fig. 2: JPI Urban Europe - Green/Blue Infrastructure for Sustainable, Attractive Cities Research Project. Authors: Taneha Kuzniecow Bacchin and Filippo La Fleur

scenarios for the future of Kiruna and of the region are being envisioned and discussed through different disciplines, and in different venues,[41] weighing in different factors and their future impact on the society as a whole: a (welcome) increase in the decision-making power of Sami communities, for instance, might tip the balance of future development one way or another, as might the influx of new waves of migration or, conversely, the full automation of extraction activities.[42] Such scenarios address the social and technical structures of Kiruna and its surrounding region, but in order to understand their scope, we think that it is necessary to first understand the material traces that they leave, in the form of the landscape – as the GBI project was intended to do. (Fig. 2)

On-the-Ground: Material Traces

Let us briefly look at a still frame from Kiruna, from August 2024: demolition is ongoing in the western sector, around the wooden red building of the fire station, soon to be moved across the city to its new location. A long blue fence is separating this area from the area that will be demolished a few months later, where two stores are still open: one of them sells handmade, high-quality Sami products and will relocate to a specific building in New Kiruna soon; the other, a Red Cross second-hand store, will likely close when the building is demolished.

Just a little to the south, another fence was raised two months prior around the Church of Kiruna, which will also be moved to New Kiruna the following year: to this end, roads connecting the two sites are being made wider to accommodate its 40 x 40 x 40m frame. A little to the west, a Gruvstadsparken – "Mine City Park" – occupies an already demolished area of the city that is now open to residents and visitors as a public park, working as a buffer zone between the westernmost portion of the city that is still inhabited, and the part of town that was demolished first and that is now part of the extraction zone. A plate and the steel entrance frame of the old building mark the site of the former City Hall, designed by Arthur Von Schmalensee in 1963 and razed in 2019.

Landscape of sacrifice

While on the surface buildings are being demolished, disassembled or transported while creating the mine city parks, simultaneously, at 1,365m below the mine reference level every night at 1:00 AM, ten large detonations can be felt and heard to extract the iron ore. Residents of Kiruna are accustomed to the sounds and tremors of detonations, which always happen at night to allow time for ventilation of explosive gases for several hours before people are allowed back in.

Data from the Swedish Pollutant Release and Transfer Register (S-PRTR) suggest that the mining and processing in Kiruna result in large environmental degradation that pollutes the natural air, water, and soil systems with greenhouse gasses, halogens, nitrogen and phosphorus, heavy metals, and dioxins, most of which are uncontained, resulting in toxic environments for both environmental and human health.[43] One of the pronounced effects of the mining activities is the contamination of the groundwater. The use of explosives and heavy machinery increases the concentration of nitrates and sulphates which impact the local water quality.[44]

41 See for instance Anna Zachrisson and Karin Beland Lindahl, "Political opportunity and mobilization: The evolution of a Swedish mining-sceptical movement," *Resources Policy* 64 (2019); Linda Stihl, "Challenging the set mining path: Agency and diversification in the case of Kiruna", *The Extractive Industry and Society* 11 (2022); and Bo Nilsson, "Ideology, Environment and Forced Relocation: Kiruna - a Town on the Move," *European Urban and Regional Studies* 17 (4) (2010): 433-42.

42 Annika E. Nilsson and Simo Sarkki, "Scenarios and Surprises. When Change Is the Only Given," in Sverker Sörlin, *Resource Extraction and Arctic Communities: the new extractivist paradigm* (Cambridge: Cambridge University Press, 2022).

43 See records of LKAB Kirunagruvan on Swedish Environmental Agency, Swedish-Pollutant Release and Transfer Register (2023).

44 See E. Videll, "Survey of sulphates in process water of LKAB-Kiruna operation" (2019).

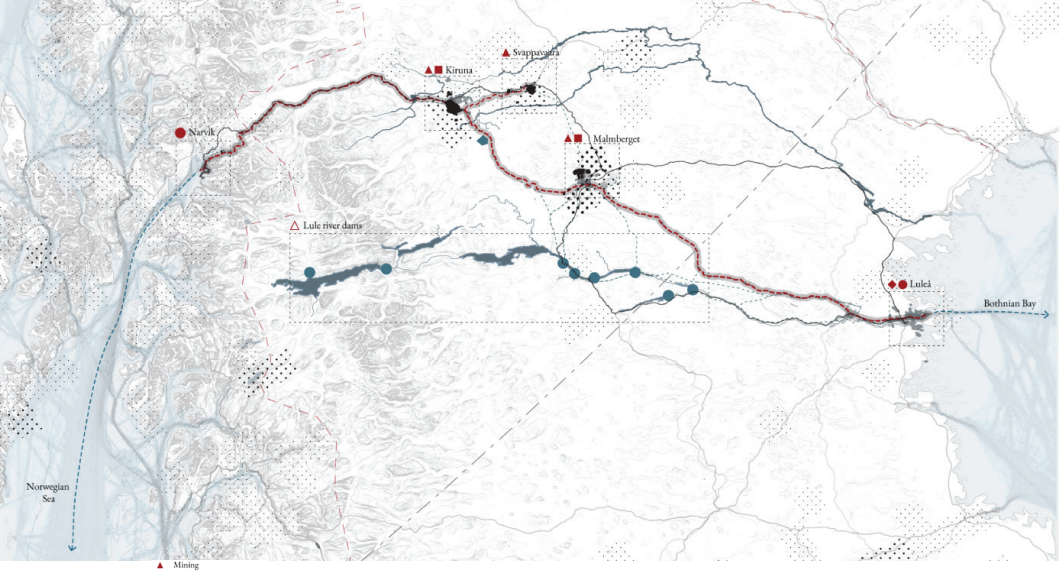
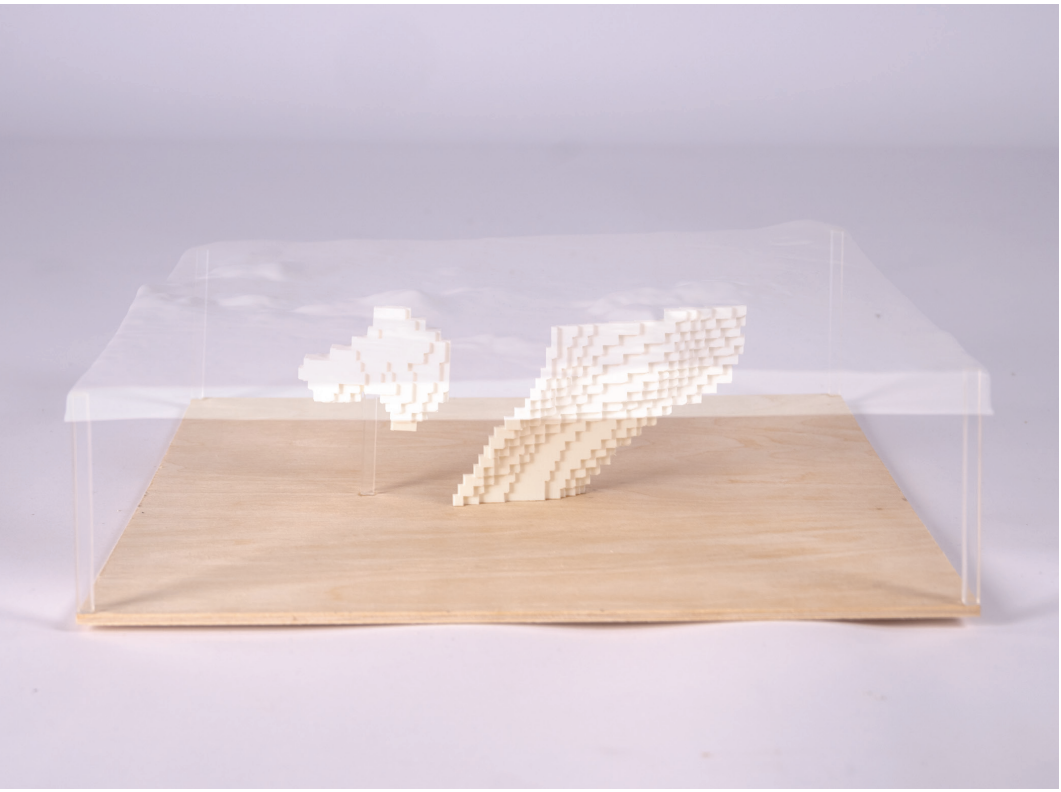


Fig. 3: Map illustrating the territorial composition of Norrbotten Technological Megasystem (based on Sotoca and Esteve's The NTM and its components)

Fig. 4: Model of the terrain of Kiruna and the underground ore bodies showing the Per Geijer and Kirunavaara deposits



These instances of normalization of sacrifice create grounds for increased tolerance towards the exploitative nature of extractivism towards the reproduction of natural and cultural dependencies.

Skorsad[45] points out that, historically, mining has been seen as an act of national sacrifice, because of its socio-economic characteristics – power and interests, distribution of goods and burdens, activism and social movements and environmental impact.

If we accept that the Kiruna landscape is a sociotechnical imaginary, then it can be intended to be socially constructed by the definitions of scarcities and resources. While the industrial revolution and the demand for iron constitutes the socio-economic basis of resources, the socio-technical basis for these resources was backed by the technological development to enable extraction in the landscape. Kiruna is a part of the Norrbotten Technological Megasystem (NTM), which is a corridor developed since the late nineteenth century to exploit the iron-ore resources of the region.[46] (Fig. 3) In the NTM, Malmberget in Gallivare was the first mine where iron was extracted and transported to Luleå.[47] But in 1902, railways connected the deposits in Kiruna to Malmberget and were extended to the Norwegian coast through the Malmbanan Iron Rail. While the Malmbanan set the ground for the technical appropriation of the territory and the operationalization of extraction, the construction of the dams on the Lule River allowed power extraction activities. The construction of these dams were detrimental to the indigenous land practices of the Sami who have been living in this area since the last ice age,[48] as they interrupted reindeer migration corridors, fragmented the landscapes and claimed the grazing area.[49] Since the Sami are partly a nomadic community, land and water were managed by abstract concepts of property and nature conservation through a system of commons; the Swedish crown used the principles of ownership of property to signify territorial claim: the water – rivers and lakes belonged to the state, and principles of nature conservation were defined to restrict Sami land practices through the formation of nature reserves.[50] The very cultural landscape of the indigenous community is altered, as they consider the natural elements like sun, wind, earth and water to have spirits and are dependent on the ecology of the territory for daily life. On the other hand, not only reindeer but all living systems, plants, animals, microbial life, as well as non-living matter such as geological materials are equally affected by the significant alteration of the landscape. (Fig. 3, 4)

Mining in Norrbotten accounts for the majority of European iron production: the demand for these resources changes over time and creates dynamic conditions of scarcity — economic crises and mining booms which in turn is concentrated in the mining areas in Norrbotten managed by LKAB.

The mining boom in 2018 led to increasing the mining depth in Kiruna from 1,045m to 1,365m below ground level, and the current main level of 1,365m is estimated to yield up to 2048.[51] Exploration at increased depth led to the discovery that the ore body was smaller

45 Berit Skorstad, "Sacrifice Zones: A Conceptual Framework for Arctic Justice Studies?" in *Arctic Justice*, eds. Corine Wood-Donnelly and Johanna Ohlsson (Bristol, UK: Bristol University Press, 2023), 96-108.

46 Staffan Hansson, "Malm, räls och elektricitet: skapandet av ett teknologiskt megasystem i Norrbotten 1880-1920," in *Den konstruerade världen: tekniska system i historiskt perspektiv*, 1998, in Jennie Sjöholm, Andrea Luciani, "Norrbotten's Technological Megasystem as a heritage discourse: paradoxes and controversies," *AMPS Proceedings Series* 2, 15 (2019): 292-300.

47 Adolf Sotoca, "More Than One City: Kiruna and the Technological Megasystem of Sweden's North," in *Kiruna Forever*, eds. Daniel Golling and Carlos Minguez Carrasco (Architektur Förlag, Arkdes, 2020), 65-81.

48 Swedish Sami Parliament, "Minerals and mines in Sapmi: The viewpoint of the Swedish Sami Parliament" (2014).

49 Carl Österlin, Hannu I. Heikkinen, Christian Fohringer, Élise Lépy, and Gunhild Rosqvist, "Cumulative Effects on Environment and People," in Sverker Sörlin, *Resource Extraction and Arctic Communities* (Cambridge: Cambridge University Press, 2022), 109-24.

50 Berta Flaquer, "Urbanization as Socionatures' Reproduction: from Territories of Extraction," PhD dissertation, Luleå University of Technology, Luleå, 2023, 153-292.

51 LKAB. "A Summary Technical Report on the MIneral Resources and Mineral Reserved of LKAB - Kiruna


Fig. 5: Caving deformations (left) Dumping of tailing piles (right)

and the mining was unprofitable.[52] This opened up the feasibility search for newer deposits for exploitation in the surroundings of Kiruna. The material estimation in the new Per Geijer deposits located to the north of the city proved for profitable returns.[53] (Fig. 4) The precise technological ability to estimate the chemical composition of the resources proved the higher concentration of Rare-Earth Elements (REE) and Phosphorus in the deposits, both of which are deemed Critical Raw Materials by the EU Critical Raw Material Act.[54]

The recent geopolitical crisis with Russia creates pressure on the supply of phosphorus because the phosphorus to Europe used to be supplied by Russia,[55] while the global REE market is currently monopolized by China,[56] making the deposits relevant to cut European dependency. At the same time, continuing extraction activities in this area might intensify local socio-environmental conflicts as the deposits would claim the winter pastures of the Gabna village currently designated as national interest for reindeer husbandry with reindeer herding routes and rest areas,[57] aside from housing cultural-historical remains and recreational functions like ski-routes etc. The deposit consists of wetlands and forests and is surrounded by protected nature: ground deformations would, again, require relocation of these functions with subsequent loss of historical and cultural landmarks in the area. The mining activity could also exacerbate the soil and water contamination as rare earth deposits may contain radioactive by-products[58] the impacts of which are yet uncertain. On the other hand, the Rare-Earth industry might attract further immigration due to the novel technologies employed and partly diversify demand.

The change in terrain, in the very form of the landscape, is the most evident instance of environmental impact in Kiruna. Matter from underground is extracted causing a 4km long deformation cavity and is piled up in the mountains of waste tailing piles which are of comparable scale to the existing mountains. (Fig. 5 and 6) While these landscapes are characterized by the continuous formation and reformation, extraction activities engender an alteration of the memory of the landscape that occurs at rapid pace, and with it, of the human and more-than-human associations with the territory, geographically and culturally.

Mine - December 2023" (2024), 28.

52 Sverker Sörlin, *Resource extraction and arctic communities: the new extractivist paradigm.* (Oxford: Cambridge University Press, 2023), 235.

53 Ibid.

54 European Critical Raw Materials Act, Pub. L. No. IP/23/1661 (2023).

55 LKAB, "Europe's largest deposit of rare earth metals is located in the Kiruna area," LKAB Press Release (January 12, 2023).

56 Ibid.

57 See Environmental and Social Governance and Permitting LKAB, "A Summary Technical Report on the Mineral Resources and Mineral Reserves of LKAB - Per Geijer Iron oxide-Apatite Deposit - December 2023" (2024): 67-70.

58 J. Bai, X. Xu, Y. Duan, G. Zhang, Z. Wang, L. Wang, and C. Zheng, "Evaluation of resource and environmental carrying capacity in rare earth mining areas in China," *Scientific Reports* 12 (2022), and A.C. García, A. C., M. Latifi, A. Amini, and J. Chaouki, "Separation of Radioactive Elements from Rare Earth Element-Bearing Minerals," *Metals* 10 (11) (2020).

Fig. 6: Terrain model of the Kiruna showing surface deformations: tailing piles in the left and the caving deformations in the right.

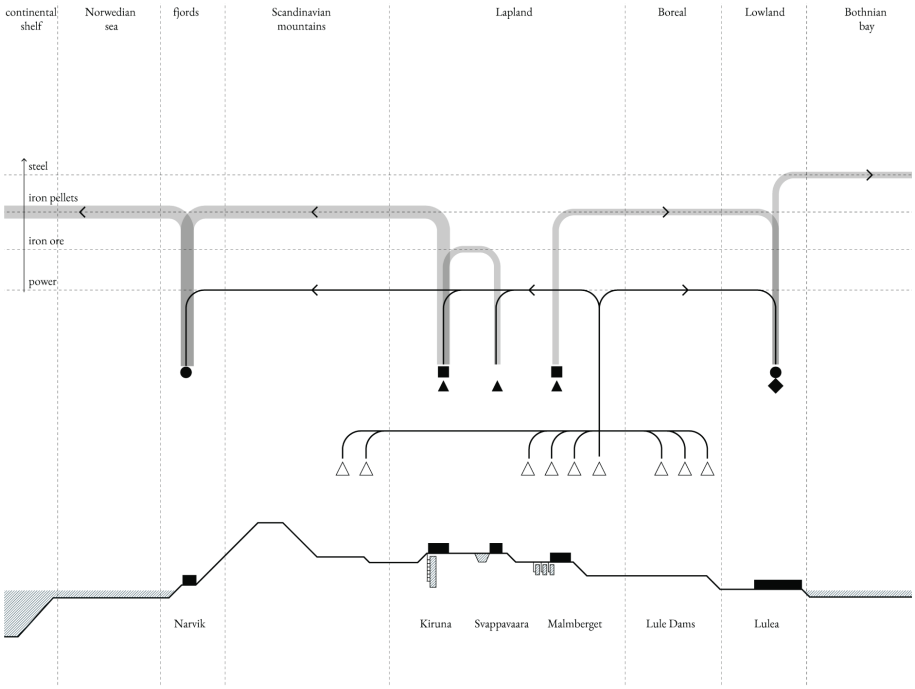


Fig. 7: Schematic section illustrating the territorial configuration of the Norrbotten Technological Megasystem and the movement of matter in the territory

Fig. 8: Schematic Maps highlighting the Elements of (i) extraction, (ii) processing and (iii) logistics in Kiruna mine

Mono-functional landscape

Kiruna offers a very apt example of what Peter Gallison terms "Technical Landscapes," i.e. sites where global knowledge practices have converged to transform the physical geography of the land.[59] Extractive landscapes as technical lands rely on *performative parameters*, in this case the ability to survey the geographical location, to identify the geological composition of the resources and to extract the resources.

Extractive landscapes are characterized by generation of different types of spatial interventions.[60] In the case of Norrbotten Technological Megasystem, these are (i) the extraction enclaves – Kiruna, Svappavaara and Malmberget, (ii) the support areas — hydropower dams of Lulea river and (iii) connecting networks – railway and energy infrastructure with the exportation nodes of Lulea and Narvik. At the scale of the Norrbotten Technological Megasystem, where the territory is configured to extract and process the iron from the inland thanks to the hydropower infrastructure of the Lule river, and export it through the ports of Narvik and Lulea, the functional role of Kiruna is to extract the iron from the deposits and process them. (Fig. 7) Kiruna as a mono-functional landscape can be observed in the extraction enclave and the spatial elements of mining, processing and logistics that operationalize extraction of iron. (Fig. 8)

The core of the mine features a complex network of tunnels, called drifts, excavated using periodic explosions to access and extract the 80m thick iron ore deposit. Currently at the depth of 1,365m below the ground, the main level collects the ore and transports it to the surface. Stephen Graham's conception of Skyscrapers as *inverted minescapes* critically conveys that the ability of the mines to go deeper enabled the buildings to soar higher and touch the sky.[61] Employed intensive mining methods have considerable ecological repercussions that are, in a way, exemplary of the "antivisual" characteristics of technical lands where the operations are heavily monitored and technologically advanced, but the environmental degradation and the impacts on the local communities are made secondary in public discourse. One instance is the management of water materials in Kiruna: the mine produces large quantities of reactive and non-reactive waste rocks of about 5 megatons every year, which are stored in the enormous tailing piles (Waste Rock Storage).[62] These piles resemble the snowy mountains in subarctic winters but are really artificial constructs that significantly alter the landscape.

The iron-ore processing facility processes the extracted magnetite ore into pellets and powder. This process emits a range of pollutants including heavy metals, greenhouse gases, dioxins and particulate matter contributing to air quality degradation and posing health risks to the surrounding communities.[63] These emissions are part of a debate over the hidden costs of the industrial activities in the technical lands, where the economic justification of resources appear prioritized over environmental health. The processing of iron also necessitates the use of large amounts of water, which after use is deposited into tailing ponds and recirculated. The presence of tailing ponds highlights the extensive spatial claim covering the inland wetlands in the areas which has a high impact on the natural biodiversity of the place. The water pollutants increase the concentrations of halogens, nitrogen and phosphorus, potentially contributing to larger ecological imbalances.[64]

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59 Jeffrey S. Nesbit and Charles Waldheim, *Technical Lands: A Critical Primer* (Berlin: Jovis, 2022), 29.

60 Eduardo Gudynas. "Nature, Space and Territories," in *Extractivisms: Politics, Economy and Ecology* (Practical Action Publishing, 2021), 65-78.

61 See Stephen Graham, "Vertical Imperialism: The Technical Lands of Mining Extraction," in Jeffrey S. Nesbit and Charles Waldheim, *Technical Lands: A Critical Primer* (Berlin: Jovis, 2022), 158-61.

62 LKAB, "A Summary Technical Report on the Mineral Resources and Mineral Reserved of LKAB - Kiruna Mine - December 2023," 45.

63 See records of LKAB Kirunagruvan on Swedish Environmental Agency, Swedish-Pollutant Release and Transfer Register (2023).

64 Ibid.

The logistical area supports the iron ore mining and processing operations and is characterized by an expansive network of railway tracks specifically designed for the operational needs of the mine, including maintenance and transportation of various forms of iron. A network of conveyor belts facilitates the movement of processed iron from the processing plant onto the train with a series of wagons bound to Narvik, at the beginning of its journey towards international markets. The logistical area also includes arrays of warehouses and control buildings. These structures are dedicated to planning and managing the mining operations, and their layout is designed to maximize the level of coordination and control. All these instances portray Kiruna as a mono-functional landscape and an instance of extended urbanization,[65] in that the operationalization of landscapes are situated far-beyond dense population centers forming the hinterlands. Brenner and Katsikis[66] argue that operational landscapes, being the hinterlands of the Capitalocene, have become much more industrially intense, infrastructurally dense and more specialized. In the case of Kiruna, they are not the hinterland of a city but rather form a larger network of hinterlands enmeshed within the capital-intensive structures of highly infrastructuralized landscapes and material movements. The mono-functional network of the iron movement does not stop in Kiruna or the Norrbotten Technological Megasystem, but it extends to the global commodity chain and the markets fueling the extraction, to "larger circles"[67] intensifying the definition of technical lands.

One of the questions Brenner and Katskis ask is "if the massive sociotechnical capacities could be harnessed to support forms of collective existence which are much more just, democratic, non-violent, culturally vibrant and ecologically sane."[68] The mono functionality of the extractive landscape provides politics and engineering an agency in the spatialization of extraction. This question encourages us to critically rethink the agency of spatial design in programming landscapes beyond the technocratic approach to extractive landscapes.

Multi-functional landscape

The two projects Kiruna 4-Ever (and subsequent Comprehensive Plan) and Green and Blue Infrastructure both represent attempts at reorganizing the landscapes of Kiruna in a way that overwrites its technical infrastructure (mono-functional landscape) as well as counters the predominance of its impacts in the narrative onto other aspects of its identity (landscape of sacrifice). The extreme subarctic climate, in addition to the gradual relocation of the city's fabric, questioned how to design urban infrastructure that can accommodate continuous change while sustaining urban quality and civic value. The Green and Blue Infrastructure design aimed to transition existing urban water infrastructure, renew biophysical processes, and provide ecosystem services while protecting landscape cultural identity.

Since the approval of the Comprehensive Plan in 2014, things have moved forward. Large sections of the western part of the city have been demolished,[69] and sections of the new center have been built to the east. Construction companies are developing individual plots and buildings,[70] new infrastructures,[71] some historical buildings have been moved through a photogenic process

65 Neil Brenner and Christian Schmid, "Towards a New Epistemology of the Urban?" *City* 19, 2-3 (2015): 151-182.

66 Neil Brenner and N. Katsikis, "Operational Landscapes: Hinterlands of the Capitalocene," *Architectural Design* 90 (1) (2020): 22-31.

67 Peter Galison, "What are Technical Lands?" in Jeffrey S. Nesbit and Charles Waldheim, *Technical Lands: A Critical Primer* (Berlin: Jovis, 2022), 18-27.

68 Brenner and Katsikis, "Operational Landscapes."

69 Including, among others, the Kiruna City Hall designed by Artur von Schmalensee, and the Kvarteret Ortdrivaren designed by Ralph Erskine.

70 See for instance https://group.skanska.com/projects/262841/Borsen-H1%2C-Kiruna, accessed March 2024.

71 See for instance https://nyabgroup.com/en/nyab-wins-two-contracts-in-kiruna-municipality-infrastructure-projects-for-infranord/ and https://constructions.lt/project-kiruna/, accessed March 2024.

that was widely mediatized,[72] while others will be in the near future.[73] The wider perception of the move appears to have shifted a little: the initial enthusiasm that pervaded public discourse around what was, arguably, a collective imaginary, has trickled into practical considerations over some of its effects, such as historical businesses shutting down,[74] or the fact that the denser fabric of New Kiruna, which had been one of the points in favor of the winning masterplan proposal, is "really quite dense"[75] and the central square, which had been anticipated as a welcome addition to a town that had never had a square, is "really quite large,"[76] as well as very technical issues - as for instance the fact that some of the new apartment buildings are already experiencing roof leakages.[77]

Nilsson[78] argues that the urban transformation process was biased by a strong "ideological phantasy" created by LKAB and Kiruna Council to claim public support for the relocation of the town. Even the most innovative initiatives such as the Kiruna Sustainability Center (KSC)[79] are being analyzed in this perspective:

> "despite using and representing the green, smart and sustainable discourse, [initiative such as the KSC] become rather functional and embedded to ensure the continuation of mining operations and extractive activities and their territorialization."[80]

The dominant point of discussion is still, nonetheless, the attractiveness of Kiruna as a town that can offer more than mining jobs. As this paper is being written, Kiruna is deep in the run for 2029 European Capital of Culture, competing with the city of Uppsala for the title. The proposal, which was submitted January 2024, is built around a concept of movement, for obvious reasons: "Below Ground, on Earth, in Space."[81]

ECOC funding, plus the budget that would be added by the Swedish Government, would be employed to enhance the vitality of Kiruna:

> "[the town] currently has international recognition thanks to our unique industries, climate, cultures and our urban transformation. However, the municipality is struggling to attract residents and today there are 1,000 vacant jobs in the municipality. In order to reach the goal of 25,000 residents by 2030, the municipality needs to both motivate Kiruna residents to stay and get new people to move here. In order to ensure [an] increased supply of skills and attractiveness in the municipality and the region, Kiruna needs the culture."

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72 One example among many: https://www.forbes.com/sites/davidnikel/2021/03/23/kiruna-a-mining-town-on-the-move-in-northern-sweden/, accessed March 2024.

73 The projected move of the church is certainly the most representative case. The church was voted Sweden's most popular building in 2001. The site initially chosen for its relocation is now under revision due to the closeness to the airfield and the height of the church https://northswedenbusiness.com/news/2023/april/veidekke-designs-the-relocation-of-kiruna-s-church/.

74 https://www.huffpost.com/entry/kiruna-sweden-city-move-mine-lkab_n_5c02ff0ee4b04fb21168a25b, accessed April 15, 2024.

75 Conversation with local residents, January 2024.

76 Ibid.

77 Ibid.

78 Nilsson, "Ideology, Environment and Forced Relocation."

79 Kiruna was together with five other Swedish towns an innovation platform for sustainable and smart cities and a testbed to test smart urban innovations that included the following sub-projects: sustainable buildings; waste management; urban farming; energy systems; IT and IoT; flexible traffic; and system integrated planning. The project was led by the Kiruna Council in cooperation with nearby university and research centres, among which Lulea University.

80 Agatino Rizzo et al., "Smart(en)ing the Arctic city? The cases of Kiruna and Malmberget in Sweden," *European Planning Studies* 32, 1 (2024): 72.

81 https://kiruna.se/download/18.70537e5518d2a9c921fd1c/1705935220679/ECoC%20Kiruna%20Bidbook.pdf, accessed March 20, 2024. The "In Space" section refers to the space program established by the European Space Agency 38Km east of Kiruna. Results of the application will be made public in December 2024.

Guidelines for ECOC applicants cities give some pointers as to what is usually rewarded by the jury: reduce focus on tourism as the main driver of development, avoid only replicating and systematizing existing activities, and, notably, suggest challenging the city's past, when needed: "an ECOC is an opportunity to explore openly and critically a city's history, including its darker side."[82] In the case of Kiruna, this might mean the overcoming of both narratives that we termed "landscape of sacrifice" and "mono-functional landscape" as narratives that, even when recognizing that the technical landscape of Kiruna is one with its other landscapes, tend to subordinate the latter ones to the former. Linda Stihl's[83] recent analysis of the potential and criticalities for diversification in Kiruna, and the agency of different sets of actors in the process, reveals the continued dominance of the mine, which is continuously short-staffed and offering wages that are hard to compete with in other sectors; LKAB is sometimes vividly referred to "as a vacuum cleaner, cleaning Kiruna of all labor."[84]

Conclusion

This paper attempts to give an articulated overview of the different ways in which the concept of "landscape" enters public discourse in Kiruna: as a sociotechnical imaginary, such a concept can be analyzed and situated within trajectories of change that are complex, involve a number of very diverse actors with very diverse agencies and perspectives, and have different effects on the ground. This "landscape of narratives" is relevant in that it allows to trace some relationships between the physical form of the landscape and landscape as discursive practice: these relationships are not yet clear, and it is especially not yet clear how they will develop. Actions such as the 2014 Kiruna 4-Ever Masterplan and the Green and Blue Infrastructure (GBI) are relevant in showing the traces that documents leave on the ground: the Kiruna palimpsest is not only made of grass, earth, iron, building elements and asphalt, but also of documents gathering collective intentions and narratives, and precipitating effects on the physical landscape. Several important variables such as the future extraction of Rare Earth Elements, or the appointing of Kiruna as European Capital of Culture, might tip the scale in one of many possible directions. Clearly, the role of the extraction industry is and will be dominant, but some space might be found for increased diversification. In this context, a continuous tracing of the process, its actors and the way it precipitates on the ground is needed, in order to find spaces for agency and, where possible, to inform future developments.

82 https://www.kulturradet.se/nyheter/2022/svenska-stader-kan-ansoka-om-att-bli-europeisk-kulturhuvudstad-2029/, accessed March 18, 2024.

83 Stihl, "Challenging the set mining path."

84 Ibid., 8.

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