Establishing *Post* Lithium Landscapes

SPATIAL TRANSFORMATIONS FOR EVOLVING CIRUCLAR ECONOMIES IN PORTUGAL

TIM VAN OORSPRONK / MASTER THESIS 2024 / TU DELFT / TRANSITIONAL TERRITORIES STUDIO

COLOFON

Master thesis report / June 2024
Title: Establishing *post* lithium landscapes
Subtitle: Spatial transformations for evolving circular economies in Portugal

MSc Architecture, Urbanism and Building Sciences / Urbanism track
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Acknowledgements

The past year have been an eventful challenging year, not only from an academic standpoint but also undoubtedly from my personal and relatives circumstances. However, I am grateful for the growth and resilience that has come from navigating through this past year and for the academic result of this thesis. For that, I would like to express my sincere gratitude to the people who helped and supported me along this journey.

Firstly, to my mentor, Nikos, for helping me structure the project, for teaching me a critical way of thinking, and for your calm, flexible, and encouraging attitude throughout the year.

Secondly, to my second mentor, Alexander, who was there to discuss the circular aspect of the project, and for your clear and invaluable feedback.

It is with the warmest gratitude that I thank my girlfriend, Cheyenne, for listening to my exhausting thoughts about extractivism and for her kindness and unwavering support during a challenging time in her life.

Further, my warmest appreciation goes to my parents for their lifelong support and for allowing me the freedom to develop myself in every possible way.

Moreover, I would like to express my gratitude to the Transitional Territories studio and their students for their collective knowledge, insights, and thoughtfulness, all of which have shaped my ideas on urbanism and beyond.

Lastly, I would like to express my gratitude to my fellow students – Kirthan, Anmol, and Rik in particular – for all of our study sessions, their sympathetic ears, their helpful criticism, and – above all – for all moments of joy we have shared throughout this final stretch of our academic careers.

Abstract

The increasing demand for critical raw materials like lithium, essential for clean energy technologies, presents both opportunities and challenges. Portugal, with Europe's largest lithium reserves, faces resistance to establishing lithium mines in the Norte region due to insufficient citizen support and concerns about socio-environmental impacts. This thesis addresses the need for a comprehensive spatial strategy that guides the region's transition from an extractivist lithium economy to a circular post-extractivist mode, while considering socio-environmental vulnerabilities and broader economic impacts.

The research involved developing a spatial strategy that integrates facilities for lithium extraction, processing, battery production, and recycling. Incorporating insights from analyzing the region's conditions, the metabolic and spatial footprint of each facility in the supply chain, and proposing strategic locations for the facilities and their supporting and infrastructural systems. The strategy is designed to support both the extractivist and post-extractivist states, ensuring sustainable long-term development.

The key findings demonstrate that the proposed strategy effectively minimizes the nuisances of the extractive operations while supporting conditions for a circular post-extractivist state. In the extractivist state, facilities are efficiently located for lithium extraction, processing, and exportation. In the post-extractivist state are infrastructures repurposed for bio-based economies and lithium recycling, while promoting circularity and reducing reliance on new raw material extraction. The strategy enhances Europe's independence in lithium supply, strengthens Portugal's role in achieving green transition goals, fosters long-term circular development in the Norte region, and supports conditions in the Alto Tamega subregion for a circular bio-based economy that helps remediate the mining landscape, while connecting to the local economy and cultural identity, as well as creating additional income for these rural areas.

The findings show the set of key interventions – including urban development for (temporary) worker accommodations, infrastructural reinforcement and development, change in cultivation patterns, water and energy infrastructure development, and industrial development – that are necessary to shape the conditions that support both states. These set of interventions could inspire other European countries to establish the necessary extractivist landscapes progressively, ensuring circular long-term development. However, the thesis recommends, that future elaboration is necessary on engaging with local communities and refining the strategy through participatory methods to ensure successful implementation.

Keywords: Clean Energy Transition, Critical Raw Minerals, Supply Chain Analysis, Extractive Landscapes, Post-extractivism, Circularity.

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Basis

This chapter starts by introducing the urgency and relevance that this project adresses, namely to establish extractive landscapes in Europe to support the ongoing energy transition. The project suggest to adress this challenge in a way that focuses beyond solely the mining sites, but considers the importance of involving the other landscapes involved in the battery supply chain to create domestic socio-economic value and shape the extractivist state in a manner that anticipates for sustainable long-term development beyond the extractivist state.

Starting point

In our pursuit of clean energy, we not only face a massive challenge in the quest for clean energy, but also a huge spatial issue that is associated with this. Not merely the deployment of clean energy technologies require space, but also the extraction of natural resources for the production of clean energy technologies involves a massive spatial dimension. The latter is a spatial issue that, with the rising demand for domestic critical raw material supplies in Europe, raises many questions. Where can we establish these mining landscapes? Are we able to adopt and get used to these landscapes? How will the European's daily life be affected by these extractive practices?

The widespread consensus is that citizen are not eager to have extractive landscapes implemented in their environment, while a lot of people do advocate the support of the clean energy transition. This classic "not in my backyard" situation elicits opposition. However, can the establishment of a mineral-based economy not also offer potential benefits and serve as catalyst for long-term post extractivst development at different scales if approached appropriately?

I felt the pressing need to unpack this challenge since the need for these extractive practices is so urgent, but the acceptance by local citizens is so low when it comes down to the implementation of extractive practices. How can something of this urgency – associated with such a large spatial dimension – be grounded in Europe and in its local context?

FIGURE 01: NOT IN MY BACKYARD
Illustration by Wes Andrews (2022)

THE ROLE OF CRITICAL MINERALS IN THE TRANSITION TO CLEAN ENERGY

With the phase out of fossil fuels and the transition to alternative forms of energy are critical raw minerals rising importance. Clean energy technologies play an important part – certainly in the first phase – in the supply of low carbon energy. Many of these technologies in turn rely on critical raw materials leading to a significant increase in demand for minerals (IEA, 2021).

Until the mid-2010s, the energy sector represented a small part of the total demand for most minerals. However, nowadays clean energy technologies are becoming the fastest growing segment of demand (IEA, 2021, p. 51). Notably, lithium, a silver-white to grey metal with a high energy density that is a vital component in the production of electric vehicles (EVs) and battery storage technologies, as well as in more everyday applications like a laptop and electric toothbrush that operate on lithium-ion batteries, is poised for exponential growth, with demand projected to surge over 40 times in alignment with the Sustainable Development scenario (IEA, 2021).

THE GEOPOLITICS OF SOURING LITHIUM

Lithium does not occur as metal in nature, but is found as in the form of inert mineral compounds in igneous rocks and as chloride in brines and seawater. The extraction of many minerals today such as lithium is highly geographical concentrated and controlled by a limited number of producers. The top three producing nations control well over 75% of global lithium output. The share of top three producing/extracting countries of lithium in 2019 are Australia (50%), Chili (25%) and China (9%) + 1% US and 4% others. Like lithium's extraction, is lithium processing capacities also highly dominated by a few countries, mainly by China (55%), Chili (27%) and Argentina (10%) + 2% US and 4% others.

This highly dominated market makes the access to critical raw materials a strategic security question for Europe's ambition to succeed the Green deal. Gaps in Europe's capacity for extraction, processing, recycling, refining and separation capacities (e.g. for lithium) reflects the lack of resilience and a high dependency from other parts of the world. Without any large-scale domestic production, the EU is heavily reliant on lithium imports. This puts its supply security and sustainability at risk for the long term.

Therefore, the European Commission pursues a diversification strategy for securing the supply chain of critical raw materials. Diversification of supply concerns reducing dependencies by diversifying access to global markets for raw materials, increasing secondary supply through resource efficiency and circularity, finding alternatives for raw materials, and establishing domestic mining potentials of primary raw materials. Establishing domestic production is an essential part of the EU becoming more resilient and developing open strategic autonomy. However, Europe is struggling to effectively initiate projects aimed at sourcing critical raw materials, even though there are significant potentials. The difficulties stem from various factors, including inadequate investment in exploration and mining, diverse and lengthy national permitting procedures, and limited public support or acceptance.

In addition, it is crucial to prioritize the development of knowledge regarding the sustainable utilization of these critical resources and enhance strategies for efficient resource management and reuse. Benjamin Specher, an industrial ecologist at TU Delft, even implies that this strategy is a better way to escape the geopolitical trap of the top producers, like China. For instance, when Russia issued a threat to cease gas supplies, it immediately had a substantial effect on our economy. When China threatens to cut off commodity supplies, it does not need to have the same consequences if we make sure to get our commodity management right in time by employing our raw materials more efficiently and reducing our reliance on them.

THE COMMON PRACTICE

Common practice is that international companies move to countries to extract the needing raw material and then leave again. This thesis suggest alternative of by exploring the possibility of introducing also the related industries of the lithium supply chain to the respective country in order to create value and stimulate circular long-term development in the country of origin.

With the growing wastestream that can be used as a secondary supply, this is particularly interesting, because the downstream part of the lithium supply chain can remain in operation and established permanently, as opposed to mining activities, which cease after the mineral has been completely extracted.

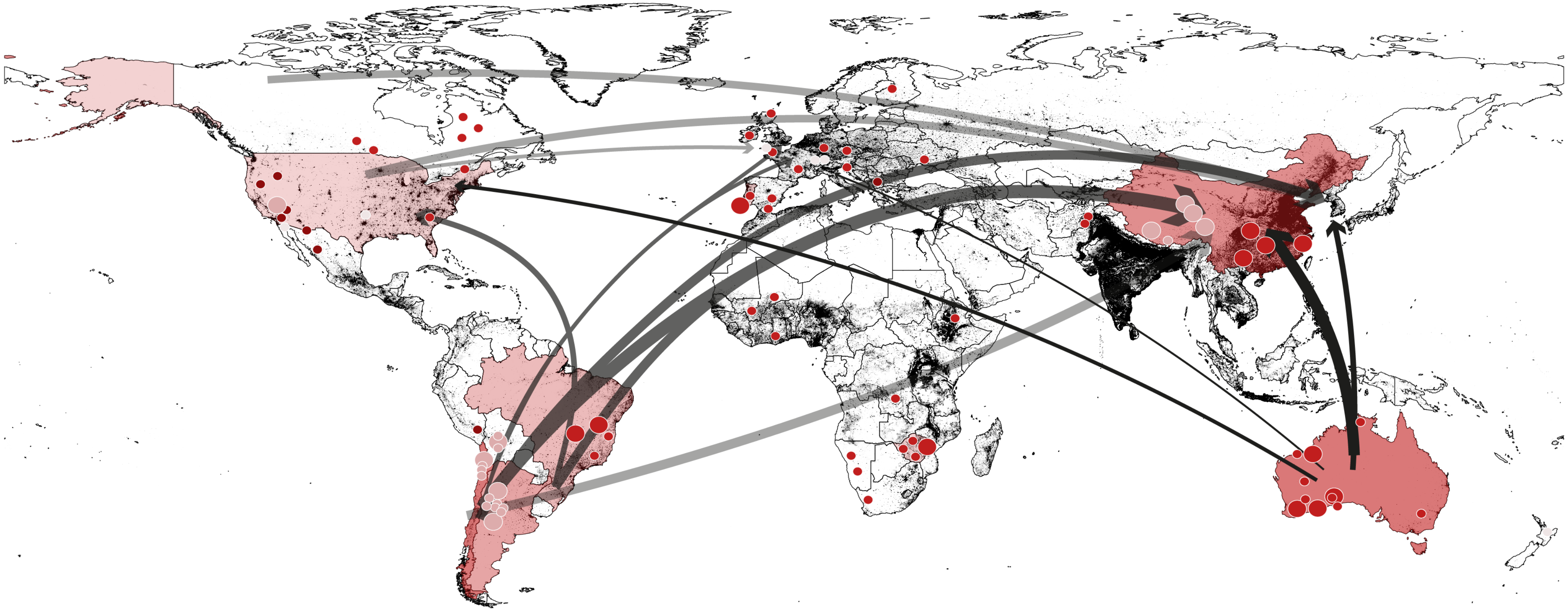


FIGURE 02: THE WORLD'S LITHIUM PRODUCTION AND TRADE (T)

- 300 - 1 000 t
- 1 000 - 3 000 t
- 3 000 - 10 000 t
- 10 000 - 30 000 t
- 30 000 - 100 000 t

- lithium deposit/occurrence
- lithium mine
- geothermal and oilfield brine
- continental brine
- pegmatite and granite
- volcano-sedimentary

- trade flow lithium hydroxides / oxides
- trade flow lithium carbonates
- trade flow spodumene concentrate

To become less independent it is important that Europe mobilizes all facilities necessary for the lithium's supply chain. Otherwise, Europe still need to outsource the commodity after mining to other continents, which leaves Europe dependent. At the same time, establishing all necessary capacities to construct a domestic lithium supply chain could significantly contribute to reduce the carbon footprint of lithium.

EUROPE'S LITHIUM OCCURRENCES

Europe has a number of lithium deposits. Exploiting some of these deposits is essential to become more resilient and secure Europe's lithium access for the long-term. The map shows where lithium occurs in Europe. Portugal has a cluster of lithium deposits that is also the largest occurrence in Europe today.

EUROPE'S LITHIUM REFINERY CAPACITIES

Europe is currently missing processing facilities that can convert raw lithium ore concentrate into battery grade lithium hydroxide or carbonate. A company that operates in Germany plans to build Europe's first lithium refinery plant in Guben. The refinery plant planned for a production capacity of 24,000 tonnes of battery-grade lithium hydroxiode per year. The company's CEO assumes that Europe by 2040 needs around 10 refineries of the size that they are building in Guben.

EUROPE'S LITHIUM-BATTERY PRODUCTION CAPACITIES

In 2022 Europe accounted around 8% of world's battery cell production capacity, while China accounted for 76% (IEA, 2023, p. 20-21). However, the number of gigafactories in Europe that produces battery cells is set to increase in the coming years due to the launched European Battery Alliance (EBA) in 2017 by the European Commission. The primary aim of this partnership was to establish a competitive value chain for manufacturing in Europe, with a focus on sustainable battery cells. The EU is offering €6.1 billion in subsidies to develop the battery production supply chain to a network of more than 600 participants from the battery value chain, aiming to build a strong and competetive European battery industy.

EUROPE'S LITHIUM RECYCLING CAPACITIES

Recycling practices for lithium are not yet on large scale established, neither in Europe. Nonetheless, with the increasing production of lithium containing products there is also an increasing emerging waste stream that could serve as secondary supply.

FIGURE 03: LITHIUM DEPOSITS TYPES IN EUROPE

National & regional context

Portugal is having Europe's largest lithium reserves, occupying the 8th position worldwide (Mineral Commodity Summaries 2021, USGS). A report, released in 2017 by a working group of the Portuguese government, concluded that Portugal has nine areas with considerable lithium deposits located in the Norte and Centro regions. In January 2018, the government approved strategic guidelines for the exploration of lithium and signed exploration contracts with an British and Portuguese company to allow the exploration in two areas in the Norte region. This concerns an area in Covas do Barroso, in the municipality of Boticas, and an area in the parish of Morgade, in the municipality of Montalegre.

In 2021, the Directorate General for Energy and Geology (DGEG) requested an Environmental Impact Assessment (EIA) for eight potential areas for lithium mining operations. In January 2022, the Lithium Research Prospecting Programme approved the right in six areas and rejected right in two areas based on the assesment. In 2022, Portugal's government set out an international public tender for lithium exploration in the six approved areas. Yet, at this moment of speak, Portugal's lithium industry is still in early stage with some small-scale operational lithium mines that feed the glass and ceramics industry (Silva & Sareen, 2023).

With the mapping of potential extraction sites, a national discourse emerged that criticized the lithium extraction plans. This is a result of Portugal's centrally-led planning and decision approach on national level and the lack of forehanded citizen participation.
Lithium mining activities carry risk of negative socio-environmental externalities such as environmental destruction, loss of biodiversity, hydrological changes and contamination and air degradation in the areas close to the mining operations. Local societies concern that they have to face the negative externalities as the results of extractivism with minimal benefits for their regional economy and negative impact on their current local economic activities like in particular agriculture and tourism (Silva & Sareen, 2023).

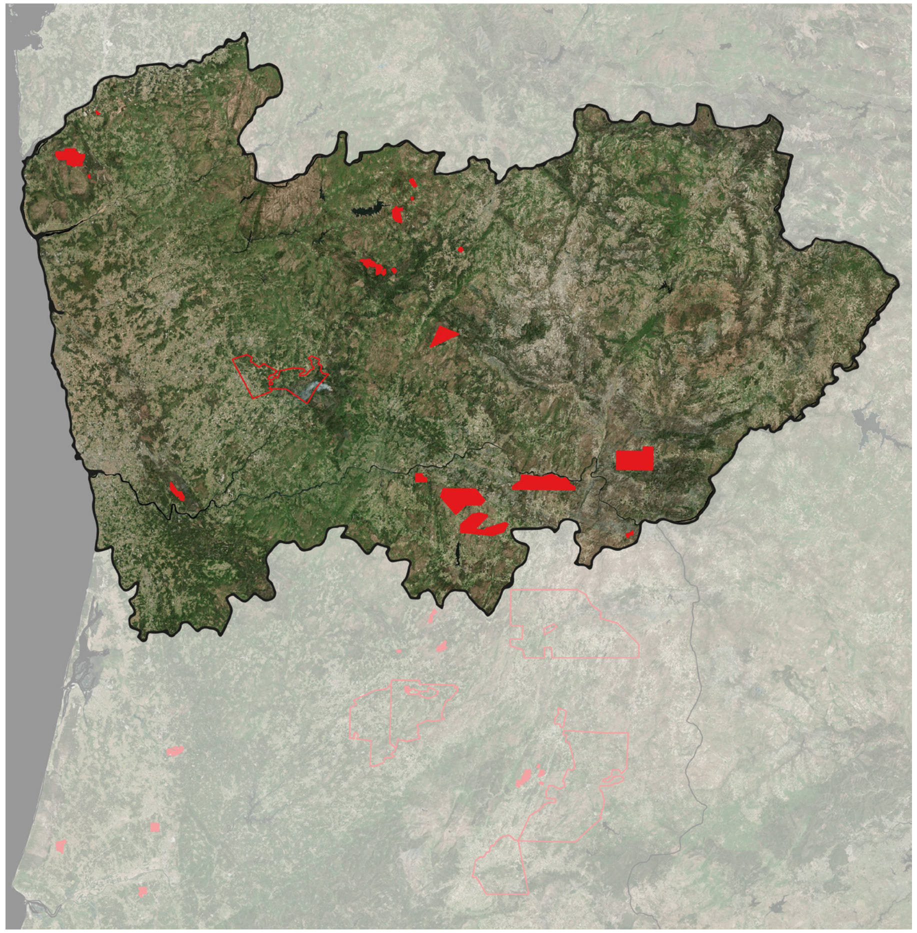


FIGURE 04: AREAS OF APPROVED LITHIUM EXPLORATION AND EXPLOITATION

■ mine concession for exploitation
□ mine concession for exploration

Problem statement

With the phase out of fossil fuels and our pursuit of clean energy raises the demand for critical raw materials like lithium. Therefore, establishing the required landscapes to set up a domestic lithium supply chain (including the mine sites where lithium is extracted out of hard rock, the refinery plants sites for the conversion of the raw ore into battery grade ore, the battery production plant sites and recycling plant sites for the recovery of lithium as secondary source) is essential to support the shift to clean energy technologies and reduce Europe's dependency on this highly dominated market.

The appropriating of Europe's lithium reserves has particularly potentials for Portugal, since Portugal is having Europe's largest lithium reserves. However, the process of establishing lithium mines in Portugal's Norte region encounters resistance. This resistance stems from insufficient citizen participation in centrally-led decision-making processes and concerns among local communities about potential negative externalities on the local society, environment, and economic activities generated by the mine operations. The current implementation process lacks a comprehensive understanding of the spatial and metabolic impact of the lithium landscapes to ensure just long-term development.

RESEARCH AIM & PROJECTED OUTCOMES

This thesis aims to develop a spatial strategy that guides the establishment of lithium landscapes in Portugal's Norte region. This strategy should not only address the challenges of the extractive phase but also envision a post-extractive state to ensure just long-term development of the evolving lithium economy in the region, while considering the local socio-environmental vulnerabilities and the broader economic impact. In this way, the strategy seeks to generate a variety of benefits across stakeholder levels.

RESEARCH QUESTIONS

[RQ] How to design a spatial strategy that guides the transformation of Portugal's Norte region through an evolving lithium economy from an extractive mode to an recycle post-extractive mode, while considering the socio-environmental and economic vulnerabilities?

ANALYTICAL SUB-RESEARCH QUESTIONS

[ASQ1] What are the spatial implications of establishing the lithium landscapes including their spatial interventions generated by the required support and transportation systems?

- **[ASQ1-1]** What are the spatial implications of lithium extraction?
- **[ASQ1-2]** What are the spatial implications of lithium refinery?
- **[ASQ1-3]** What are the spatial implications of lithium-battery production?
- **[ASQ1-4]** What are the spatial implications of lithium recycling?
- **[ASQ1-5]** Which new lithium distribution patterns emerge and what are the generated spatial implications to support these distribution patterns?

[ASQ2] What is the economic impact of mobilizing the lithium supply chain on the Norte regio's economy?

[ASQ3] What is the environmental impact of mobilizing the lithium supply chain in the Norte region?

[ASQ4] What is the social impact of mobilizing the lithium supply chain in the Norte region?

[ASQ5] What are the potential domestic mining, refining, battery-production and recycling capacities in the Norte region?

[ASQ6] When are the projective lithium landscapes and (planned) support systems in operation?

PROJECTIVE SUB-RESEARCH QUESTIONS

[PSQ1] How to plan strategically spatial interventions that support the development and operation of the lithium extractive mode while anticipating on an evolving recycle post-mining mode?

[PSQ2] Where to locate strategically the nodes of the new lithium landscapes? (meso scale)

[PSQ3] How can the spatial implications generated by the mobilization of the lithium landscapes themselves and their support and transportation systems land in the place-specific context of Portugal's Norte region? (meso- scale and micro scale)

Positioning *(critique)*

This chapter commences by introducing the methodology of the project and conceptually addresses the different scales of design. This subchapter is followed up by a theoretical and conceptual framework that discusses theory and concepts that helps forming a better understanding which parameters should be considered, in and beyond the scope of the project, to shift away from the traditional manner of extracting critical resources such as lithium.

Methodological framework

This thesis addresses the establishment of domestic lithium landscapes that could contribute to the accessibility and independency of Europe's lithium supply. The term lithium landscapes is used in this thesis to refer to all entities that are part of the lithium supply chain where the processes for the production of the lithium-ion batteries take place. The various lithium landscapes are all associated with their own spatial dimension and, in addition, generate spatial interventions to support their operation and distribution. These lithium landscapes consist of the mine sites where lithium is extracted out of hard rock, the refinery plants sites for the conversion of the raw ore into battery grade ore, the battery production plant sites and recycling plant sites for the recovery of lithium as secondary source. The spatial interventions generated by the lithium landscapes referred to in this thesis are distinguished in two types of spatial interventions inspired by Gudynas' classification (2021). Firstly, the term support systems refer to the required infrastructure to support the operations the lithium landscapes. These include, for example, dams to provide water to mining sites and hydroelectric plants that generate energy to provide the mining activities. Secondly, the term connecting systems refer to the network that is required to distribute the outputs and inputs like energy and water through roads, railways, pipelines, high-voltage electricity lines and more. The spatial interventions generated by the support systems and transportation systems can cover a larger surface than those of the lithium landscapes sites and therefore may have a greater social and environmental impact (Gudynas, 2021). Examples include, deforestation and loss of biodiversity or massive alterations in the hydrological system due to irrigation dams.

This research uses the Norte region of Portugal as a case study to showcase the archetypical spatial interventions generated by the establishment of lithium landscapes as a result of the rising demand for lithium. In addition, it aims to illustrate how these interventions can be reused and recofigured to facilitate the evolving economies in the post-extractivist state. This case study can be used to inspire the mobilization of more lithium landscapes in the hinterlands of Europe. However, for each individual project, the context-specific conditions should be considered and serve as the basis on which spatial interventions can be proposed.

The research concerns multiple levels of scale. The global, European and national scale of Portugal are used to contextualizatize the problemfield. For the actual design assignment of establishing the lithium landscapes of the lithium supply chain and their generated spatial interventions in Portugal's Norte region, the project concerns 3 scales of design.

Firstly, the meso scale, which refers in the context of this project to the scale of the emerging lithium system in Portugal's Norte region. At this scale, are the capacities per lithium landscape qualified, is the operationalization between the landscapes aligned and is the location of each lithium landscape and the infrastructural network that support the distribution of lithium and waste streams between the landscapes and exportation nodes, in both the extractive mode as the recycle-post-mining mode, proposed. The design finds it outcome in a plan and systemic section which shows the functioning of the lithium corridor.

Secondly, the meso- scale (meso minus scale), which refers in the context of the project to the scale of the lithium landscapes itself and its generated support and transportation systems. At this scale, the composition of the landscape itself and their support and transportation systems is proposed and evaluated. This scale could find it outcomes in plans, and sections.

Thirdly, the micro scale, refers in the context of the project to the scale which will evaluate on how the proposed spatial intervention interact with their adjacent surrounded elements (the actual conditions of life in place). This scale will zoom in on the transitions zones and relationships between the proposed interventions and the pre-existing elements on the scale of human level. This scale could find it outcomes in sections and collages. The figure on the right shows a conceptualization of the scales of design and the related methods that are associated on these scales. The figure on the next page shows the methods that will be used to anwser the stated subquestions.

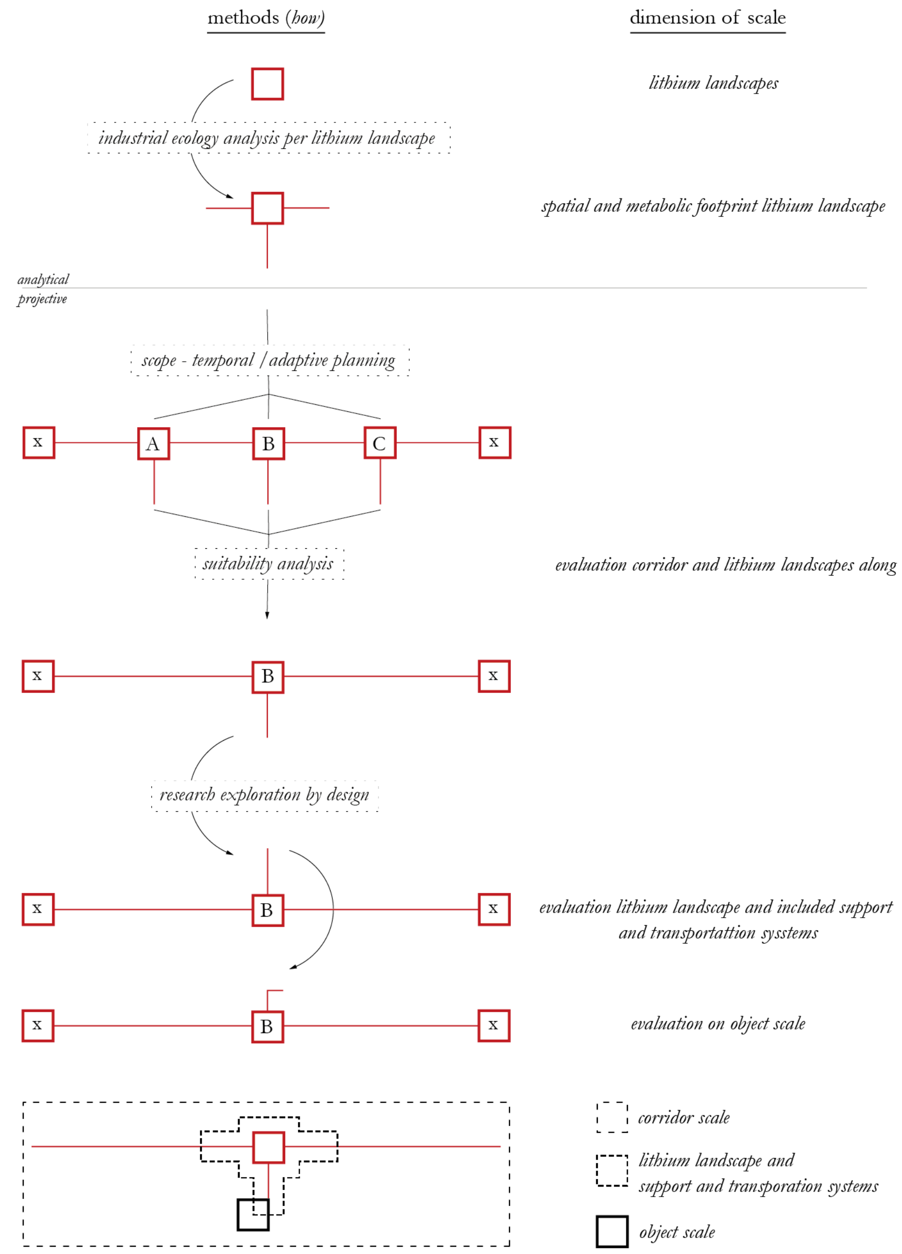


FIGURE 05: CONCEPTUALIZATION APPLIED METHODS & ASSOCIATED SCALES

Sub-question (*what*)	Aim (*why*)	Line of inquiry & scale	Methods (*how*)	Outcomes
What are the spatial implication of mobilizing the lithium landscapes including their spatial interventions generated by the required support and transportation systems?	To identify the spatial footprint of the mine, processing plant, battery-production plant and recycle plant and their associated required support and transportation systems that support lithium mining, processing, battery-production and recycle activities.	Industrial ecology *(lithium landscape metabolic ecology)* | *Abstract level*	Literature review Water/energy analysis Material Flow Analysis/ Network Flow analysis	Spatial footprint lithium landscapes, Metabolic footprintlithium landscapes
What is the *economic* impact of mobilizing the lithium supply chain on the Norte regio's economy?	To anticipate on potential conflicts with existing economic activities.	Site | *Regional and local lecel*	Identifying current economic activities and their metabolic ecology and overlay with lithium landscape ecology	Overview potential conflicts current economic activities, secion and/or mapping
What is the *environmental* impact of mobilizing the lithium supply chain in the Norte region?	To identify and anticipate on the environmental vulnerabilities driven by lithium landscape related activities that may generate local conflicts.	Site analysis, Industrial ecology *(lithium landscape metabolic ecology)* | *Abstract and local level*	Literature review, Analyse Environmental Impact Assesment, Critical mapping	Takeaways from literature and analysis, Section and/or mapping
What is the *social* impact of mobilizing the lithium supply chain in the Norte region? and how to incorporate these insight to ensure a more just outcome for human and non-human?	To anticipate on the social vulnerabilities and create benefits for local society.	Site analysis | *Abstract and local level*	Literature review on Social Warfare ((Dunlap & Riquito, 2023), Semi-structured interview locals	Takeaways from literature reviews
What are the potential domestic mining, processing, battery-production and recycling capacities in the Norte region?	To identify and qualify the lithium raw ore potentials out of the deposits, the processing, battery-production and recycle capacities.	Commodity chain *(quantification)* | *Regional*	Online desk research: company reports, industry and market reports, case reference industries	Overview quantities and capacities, Map that shows functioning lithium distribution flows
When are the projective lithium landscapes and (planned) support systems in operation?	To align and plan the operationalization of the lithium landscapes and their required supported systems.	Commodity chain *(alignment operationalization)* | *Regional*	Online desk research: company reports, industry and market reports, case reference projects	Timeline that shows phasing operationalization, Map that shows functioning lithium distrubution flows, Systemic section flows
analytical / *projective*				
How to plan strategically spatial interventions that support the development and operation of the lithium extractive mode while anticipating on an evolving recycle post-mining mode?	To plan in a efficient and flexible manner to minimze impact.	Site | *Regional*	Adaptive reuse planning and design	Map that shows spatial interventions through time temporal / adaptive planning scope
Where to locate strategically the nodes of the new lithium landscapes?	To identify and propose suitable and strategic locations for lithium processing, battery-production and recycling sites in Portugal's Norte region.	Site analysis, Commodity Chain | *Regional*	Suitability analysis	Map suitable locations
How can the spatial implications generated by the mobilization of the lithium landscapes land in the place-specific context of Portugal's Norte region?	To project and evaluate the impact of intervantions on (local) micro-scale .	Site analysis | *Local*	Research by design exploration	Projective maps, Collage

REPORT STRUCTURE

The structure of the report can be divided into three broad blocks of attitude: positioning, anticipating and projecting.

Firstly, positioning (critique) by getting involved in the discourse. In this block, the current form of extractivism is criticized and the need for an alternative form is suggested. This alternative form of extractivism goes hand in hand with an alternative economic approach that will influence the appropriation of lithium. Subsequently, this alternative form is positioned within the current policy context. From this block follows a scope that advances a more sustainable just way to appropriate lithium.

Secondly, anticipating (action) by investigation and analyzing the relationships between the different subjects in play. This block can be subdivided into three lines of inquiry: site analysis, catalogue of lithium supply chain landscapes, and material flow analysis of the commodity chain. The first line analysis the context-specific conditions of the site. The second line 'industrial ecology' identifies the spatial and metabolic footprint of the different lithium landscapes and their required support systems to support their operation and distribution on an abstract level. The commodity chain line indentifies the material flows between each lithium landscape, align their operationalization, identifies their strategic location and their required transportation system to support the distribution of lithium and waste streams between the landscapes and exportation nodes.

Thirdly, projecting (form) by speculating on a possible form of the Norte region that support the operation of lithium extraction out of primary and secondary supplies and its distribution.

Theoretical framework

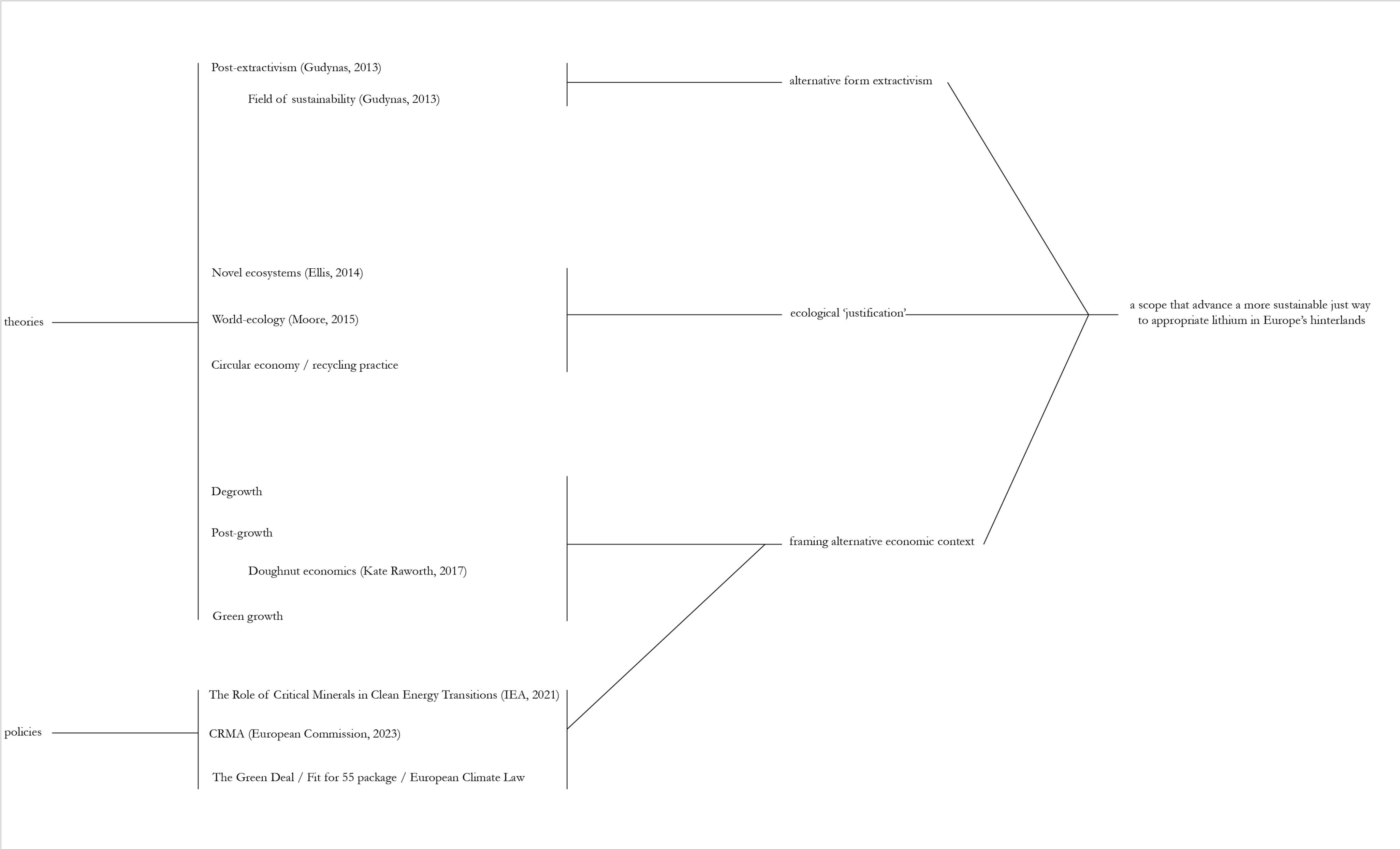


FIGURE06: THEORETICAL FRAMEWORK

THE CONCEPT OF EXTRACTIVISM

Extractivism as defined by Eduardo Gudynas (2013) is the appropriation of natural resources in large volumes through a highly intensive process where half or more of the commodity is exported to meet demand on international levels. By highly intensive and high volume does Gudynas refers to the environmental effects associated with the extraction of the commodity.

Gudynas' definition does not include the massive extraction of materials destined for national manufacturing or consumption, like coal in China. Therefore, Benjamin C. Fash (2022) argues that exports should not be considered a defining feature. He stresses that the term should emphasized on its inability to restore or care of the territories to which the natural resources belonged nor the socio-natural relations that they previously sustained. The natural resource extracted by extractivism are finite, which makes extractivism a net loss of natural heritage because in extractivism is nothing produced but extracted.

Extractivism and the environmental and social tensions it forces are always local since the removal of natural resources are geographical anchored in specific sites. This often results in local societies that must face the negative externalities as the results of extractivism with minimal benefits for their national economy or job creation. However, extractivism significance are tied in globalization due to its integration into globalized economic systems in where mine sites are the first link in international production chains.

Clearly, there is a need to find alternative ways that respects the long-term ecological limits and local well-being. Gudynas (2013) suggest a concept called 'post-extractivism' that advocates for a more balanced approach of appropriation of natural resources. According to Gudynas can these alternatives not only depend on technological reinforms or greater economic compensations, but also must consider a radical change in development of extractivism and moving away from economies that heavily depend on extraction and exploitation of raw materials.

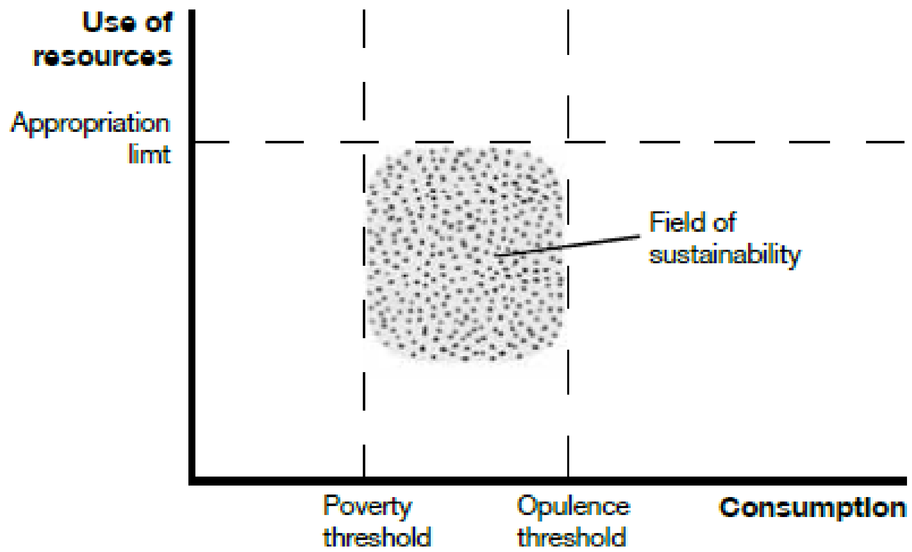


FIGURE 07: FIELD OF SUSTAINABILITY
Field of sustainability, delimited by the poverty threshold and the opulence threshold in consumption, and by a limit on the appropriation of natural resources to ensure the conservation of biodiversity and ecosystems (Gudynas , 2013)

ALTERNATIVE ECONOMIC CONCEPTS

Gudynas' suggestion for an alternative form of extractivism also tends to propose an alternative economic concept like degrowth. Degrowth is one of the concepts discussed in the debate on rethinking economic approaches since the current economic model – in which economic growth is the central objective for economic policy-making measured by the GDP indicator – has increasingly been criticized for overlooking its negative externalities for the environment and climate (Widuto et al., 2023). The main alternative directions discussed in the debate can be divided into green and inclusive growth, degrowth and post-growth.

The concept of green and inclusive growth still sees growth as central policy objective, but seeks to reconcile economic growth with ecological sustainability (Widuto et al., 2023). Key principles include the efficient use of resources and promotion of clean energy technologies. Opponents of green and inclusive growth raise concerns about the long-term sustainability of strategies proposed under green growth due to the limited regenerative capacities of the ecosystem and planetary boundaries (Widuto et al., 2023). As well Timothée Parrique (2021) – an economist strongly interwoven in the debate on alternative economic approaches – argue that green growth is not a viable strategy to achieve environmental sustainability before reaching the climate deadline we facing since achieving absolute decoupling of GDP rise and (without overshooting planetary boundaries) environmental degradation is not fast and all-encompassing enough.

The concept of degrowth challenges economic growth itself. The concepts propose a shrinking economy that downscales economic production and consumption. Examples of key strategies include stopping extraction of fossil fuels, focus on community practices and shared use of goods and reduced working time. Opponent seen the introduction of degrowth as a too radical unrealist approach since it would imply a complete reorganization of the socio-economic system and demand a radical change of people's view on consumption (Widuto et al., 2023).

Supporters of post-growth – also referred to as 'beyond growth' or 'a-growth' – state that growth of GDP does not correlate with social benefit or environmental degradation. A paper on the absence of a correlation between the growth of GDP and the status of wealth inequalities and environmental costs support this argument (Alfani and Schifano, 2021). Therefore sticking to GDP as an indicator of economic growth is not a working approach. Consequently the concept of post-growth seeks to redefine and measure growth different through incorporating non-material aspects. The approach focuses on achieving environmental and social goals, while this is accompanied by economic growth or not (Widuto et al., 2023).

It is clear that merely the commitment to the concept of green growth is not a viable strategy. Also the other models have some criticisms, but could work complementary. For instance, by remaining committed to the production of clean energy technologies to rapidly reduce the greenhouse emissions while include non-material aspects in the valuation. Simultaneously, start seeking where a local economy could shrink its production and consumption – for example, on downscaling production for individual consumption – to relieve pressure on socio-environmental factors. Both technological and non-technological actions are needed to reduce greenhouse gas emissions and reach ecological sustainability before overshooting more planetary boundaries. For that, our economy should be reshaped and be bought closer to its essence, namely satisfying societal needs and getting our society above a social minima level while remaining under an ecological maxima as Kate Raworth describes in her alternative policy framework called Doughnut Economics.

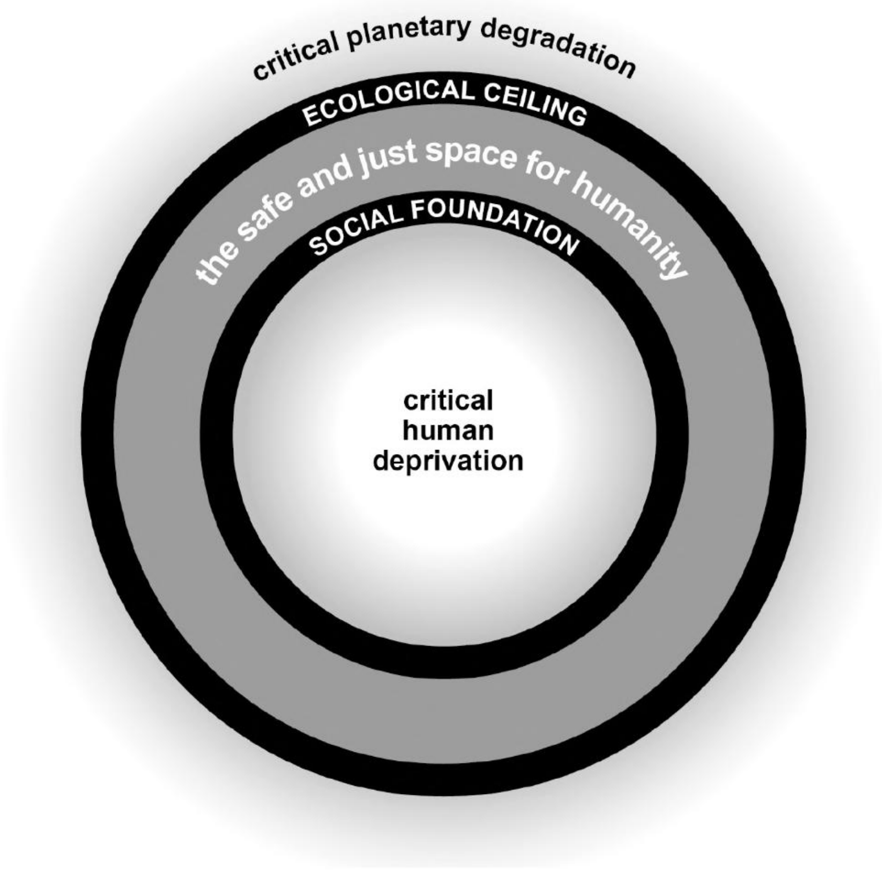


FIGURE 08: DOUGHNUT ECONOMICS
Doughnut Economics, an alternative policy framework by Kate Raworth (Raworth, 2017)

THE CHANGING NATURE OF LITHIUM FRONTIER-MAKING THROUGH AN ALTERNATIVE ECONOMIC MODEL

The current economic model is pushing the demand for natural resources and commodity frontiers further (Conde, 2017). Nevertheless, we still need the appropriation of lithium for the transition to clean energy technologies to the phase out of fossil fuels. However, an alternative economic approach – in which we combine strategic action of the discussed concepts to reduce the impact on climate change – will influence the appropriation of lithium.

In the context of this economic model will the emphasis lie on reducing extraction and consumption of lithium – especially in industrialized countries – while remaining above social minima. To cut in consumption patterns – but remain above social minima – we should rethink ownership and emphasize on 'accessibility' and 'usefulness' (Gudynas, 2013). This could be met by emphasizing on durability of products and shifting to efficient shared and public transport modes, instead of the production of electric vehicles for individual car ownership. In addition, in this context, the focus lies on circular economy principles. The primary lithium supply can be depressed by prioritizing and supporting the development and establishment of a secondary supply source through the recycling and reuse of waste streams.

On the other hand, this concept will emphasis on the importance cultural and environmental value by starting including social consideration as well-being of communities and ecosystem services in price valuation as well as restoration of degraded ecosystems / environments by extractivist processes. This will increase the prices of lithium and their by-products and will lead to the implementation of conservation and restoration of ecosystem services as part in extractivist projects. It is important that this price correlation is coordinated at European level to ensure that European lithium consuming countries not simply relocate to a cheaper exploiting country (Gudynas, 2013). Therefore, in addition, agreements should be made on where European lithium consuming countries may obtain lithium.

POLICIY CONTEXT
The introduction of the 'Fit for 55' package – a initiative under the European Green Deal – underlines the need to rapid low greenhouse gas emissions. The package includes a number of proposals to revise and update EU legislation in order to ensure that EU policies are consistent with the climate goals agreed upon by the Council and the European Parliament. The European climate law turns the political ambition of reaching the EU's climate goal of cutting emissions by at least 55% compared to 1990 levels by 2030and net-zero emission by 2050 into a legal obligation. Therefore, we need rapidly shift to clean energy and thus need critical minerals.

The World Energy Outlook (WEO) special report (2021) by the International Energy Agency (IEA) provides the most comprehensive analysis to date of the complex links between clean energy technologies and minerals and assesses the mineral requirements for the clean energy technologies – that represent the majority deployed – based on two IEA scenarios.

Firstly, the Sustainable Development Scenario (SDS) outlines a path that meets in full the world's global goals to tackle climate change in line with the Paris Agreement. Reaching net-zero emissions targets globally by relying on the deployment of clean energy technologies would mean a massive increase in the deployment of clean energy technologies and thus in mineral requirements.

However, the Energy Technology Perspectives Special Report on Clean Energy Innovation (2020) underlines that the clean energy technologies in use today are insufficient on their own to achieve the net-zero emission targets. Almost 35% of the cumulative CO_2 emissions reductions seen in the SDS by 2070 rely on technologies that currently still are at prototype phase. Another 40% rely on technologies that have not yet been commercially deployed (IEA, 2020). This indicates a major acceleration of clean energy innovation and the deployment of new technologies is needed to achieve emission targets. However, the report shows that bringing new energy technologies on the market – even successful examples as solar PV and lithium-io batteries – can take several decades. This is time we do not have, facing the climate deadline we have. This underpins the need for a scenario that not merely relies on technical solutions, but in addition non-technical solutions as proposed in the alternative economic approach.

The second scenario referred to in the report is the Stated Policies Scenario (STEPS), which charts an indication of where today's policy measures and plans might lead the energy sector without a major additional steer from policymakers. These outcomes fall far short of the world's shared sustainability goals. The report provides an overview of the mineral requirements based these two scenarios. The figure on the right shows the growth in demand for battery-related minerals in 2040 relative to 2020 levels (WEO, 2021).

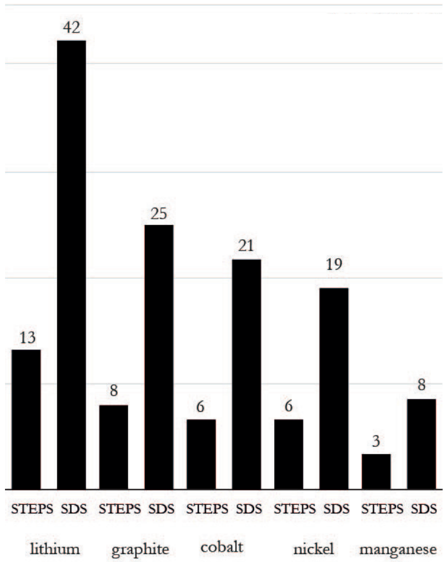


FIGURE 09: DEMAND FOR BATTERY-RELATED MINERALS IN 2040 RELATIVE TO 2020 LEVELS
By WEO (2021) and adapted by author

DEMAND DEPENDENCIES & LIMITATIONS
The mineral requirements heavily depend on the choice of deployment of the clean energy technologies types. Here lies an important role for policymakers to reduce uncertainty by being clear and consistent about their ambitions and specific policies to fulfill these ambitions. Policymakers will determine to which minerals and to what extend minerals like lithium remains an essential factor in the clean energy transition.

THE CRITICAL RAW MATERIAL ACT (CRMA)
As a result, the European Commission pursues a diversification strategy for securing the supply chain of critical raw materials. This strategy aims on diversification of supply concerns reducing dependencies by;
diversifying access to global markets for raw materials, increasing secondary supply through resource efficiency and circularity,
finding alternatives for raw materials, mobilizing domestic mining potentials of primary raw materials.

In November 2023, the EU reached a provisional agreement on a European Critical Material Act and set out the following objectives for EU domestic capacities by 2030:

- At least 10% of the EU's annual consumption for extraction,
- At least 40% of the EU's annual consumption for processing,
- At least 25% of the EU's annual consumption for recycling, (before 15%)
- Not more than 65% of the Union's annual consumption of each strategic raw material at any relevant stage of processing from a single third country.

ALIGNMENT ALTERNATIVE ECONOMIC MODEL AND CRMA OBJECTIVES
It can be argued that securing the Europe's critical raw materials is just keeping the linear growth model going. However, that is not particularly true. Firstly, it become clear that we need clean energy technologies given the urgency to rapidly shift to clean energy. For that, we need critical raw materials. Secondly, CRMA shifts away from globalized supply chains 'free' trade based which is an important step towards alternative economic model. Thirdly, the CRMA seeks to raise sustainability, as in the alternative economic context, in the material supply chains, by including local socio-environmental aspects like human rights.

The set percentages objectives for domestic capacities in the CRMA can be used in this thesis' situated /framed alternative economic context. However, the alternative approach reduces the set annual consumption of minerals since clean energy technologies in the alternative economic context are no longer the only means to reduce global emissions.

ECOLOGICAL 'JUSTIFYING' THE APPROPRIATION OF LITHIUM

According to the definition of sustainability by UN Brundtland Commission (1987) would the appropriation of minerals and metals seem unsustainable on human timescale since economically extractable mineral deposits become exhausted before replenishment by natural processes. However, the report by Jowitt et al. (2020) demonstrates that the majority of the world's metal reserves have not significantly declined over time in relation to production. This is the outcome of progressively defining recognised orebodies as mineral exploration advances, which replenishes depleted reserves. This can be seen from the generally flat mineral reserve to production ratio over the last ~60 years. In contrast, the reserve to production ratio trend of lithium and some other minor metals has been more fluctuating over the last 30 years as shown in the figure on the right. This is another reason to be reluctant in the appropriation of lithium.

ECOLOGICAL AMPUTATION

It is a fact that mining operations results in ecological disruption or so as Gudynas (year) open-pit mining describes 'ecological amputation, in sense that it is a physical removal of local ecosystems.' These ecological areas often previously sustained ecosystems and in this sense contributed to climate stabilization. The challenging issue to establish extractive landscapes is therefore a trade off between global benefits of reducing greenhouse gas emissions and the local negative impacts on environment and communities (Chaves et al., 2021, p. 9). With the introduction of an alternative economic approach, the most beneficial form of mining can be applied with minimalizes the negative externalities on socio-environmental aspects. Nevertheless, local ecological distribution is unavoidable.

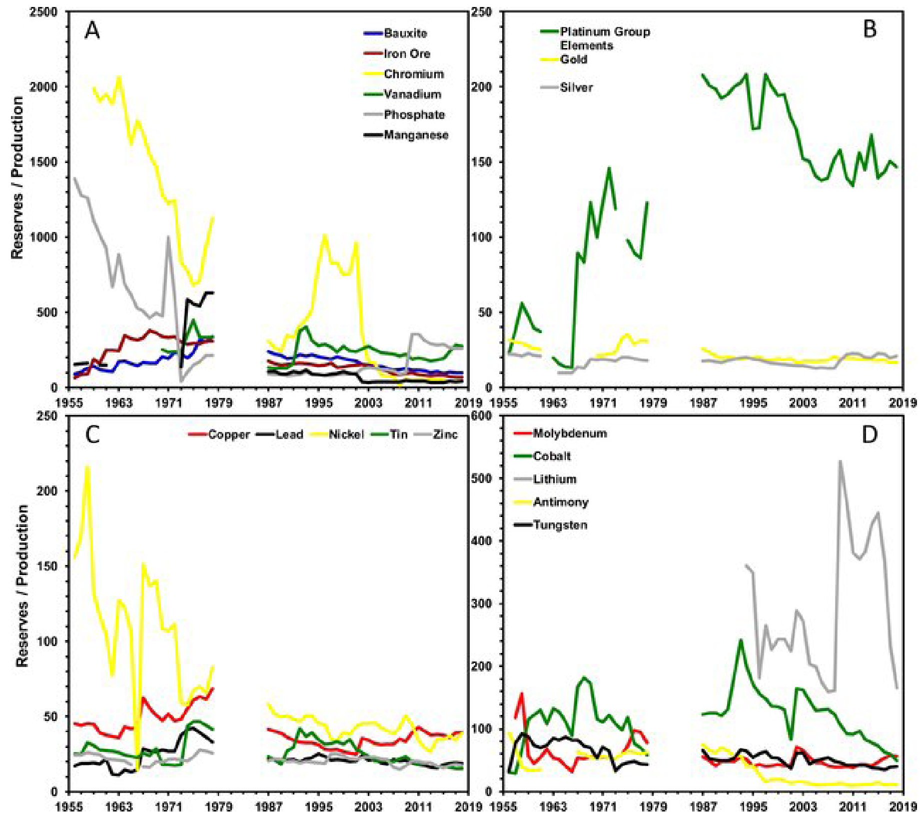


FIGURE 10: ANNUAL METAL PRODUCTION AND RESERVE DATA FOR 1956–2018
Data are shown as reserve/production ratio for selected bulk and ferrous minerals (a), precious (b), base (c) and minor (d) metals using the available USGS data. Note the data gap (1979–1986) when only "reserves base" estimates were published, which are effectively the same as resources. (Jowitt et al., 2020)

REUSE AND RECYCLING PRACTICES AS SECONDARY SUPPLY

A key difference and another argument for phasing out fossil fuels and shifting to clean energy technologies that rely on critical minerals is that to continue fossil fuel using assets, new supplies are essential. Unlike oil, minerals have a potential to be reused and recycled (IEA, 2021, p. 35).

Lithium reuse and recycling capacities could relieve the pressure on primary supply. Possible origins of recycling include tailings from processing, scrap used in manufacturing and fabrication and scrap from end-of-life products (IEA, 2021, p. 176). However, recycling practices are not yet established on large scale, but with the increasing production of lithium containing products there also emerge an increasing waste stream. The amount of spent EV batteries reaching at the end of their first life is expected to surge exponentially after 2030, reaching 1.3 TWh by 2040 in the SDS (IEA, 2021, p. 35). According to the report by the IEA (2021) would recycling not eliminate the need for continued investment in new lithium mines, but the IEA estimate that by 2040, the recycled quantities for lithium (and nickel, copper and cobalt) from spent batteries could reduce combined primary supply requirements for these minerals up to 12%. A study by the World Bank suggests that new investment in primary supply will still be needed even in the case that end-of-life recycling rates were to reach 100% by 2050. (World Bank, 2020).

The alternative framed economic context suggested in the previous subchapters will influence the quantities of the emerging waste streams. By a reduced lithium consumption and thus a lower production of lithium-containing products is the waste stream that will emerge lower than in the SDS. However, since also the demand for lithium in this context is lower, the ratio demand and potential secondary supply out product waste streams remain more or less the same. In other words, this is not limiting the development of the secondary supply.

Price competition from primary supply on the other hand, is often challenging the further development of secondary supply markets. However, by including non-materials aspects and negative environmental externalities in the price valuation of lithium's primary supplies, further investment in secondary markets will be encouraged (Nicolli et al, 2012; Söderholm, 2020).

Policy-support can play an important role in scaling up recycling efforts by stimulating recycling for products reaching the end of their operating life, simulating and facilitating efficient sorting and collection facilities and funding innovation in recycling practices (IEA, 2021, p. 169).

According to recent studies and articles becomes the recovering of lithium (and other materials) out of lithium batteries more and more developed. Partly for this reason, the provisional agreement (CRMA) by the European Commission (2023) has increased the benchmark for domestic recycling from 15 % to at least 25% of EU's annual consumption of raw materials.

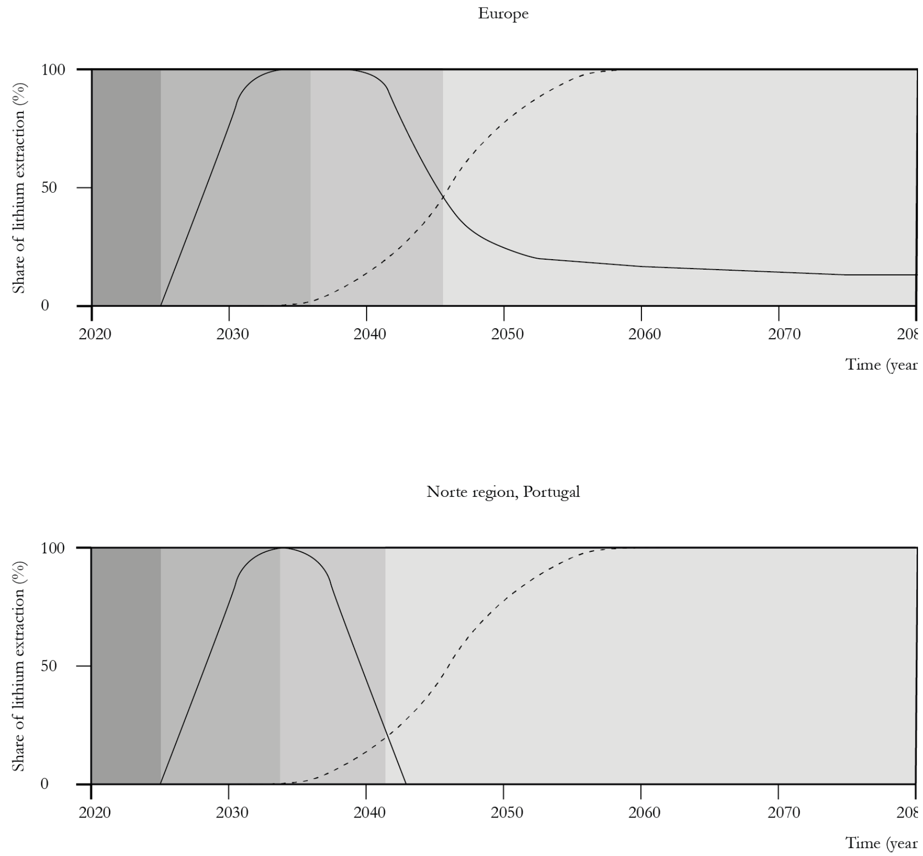


FIGURE 11: PHASING PERSPECTIVE FOR EUROPEAN CONTEXT AND FOR THE NORTE REGION OF PORTUGAL

- preperation phase
- primary extractive phase
- transition phase
- recycle-centric phase
- extraction out of primary supply
- extraction out of secondary supply

E-WASTE GENERATED IN EUROPE

As discussed can e-waste play a vital role as secondary source of supply to feed the lithium industry. This is particular intresting since e-waste is the fasted growing waste category in the world. Based on data released by the United Nations Institute for Training and Research (2024), Norway produced the highest amount of electronic waste per person in Europe in 2022, with an estimated 26.8 kilogrammes per person. The United Kingdom, with about 24.5 kilogrammes produced per person, came in close second. Russia produced the most e-waste in that year, with 1.6 million metric tonnes, while Norway generated 139,000 metric tonnes overall. Europe was the third-largest producer of electronic trash in the world in 2022, after the Americas and Asia, with an estimated 13 million metric tonnes produced.

FIGURE 12: E-WASTE POTENTIALS UNUSED IN EUROPE

Conceptual framework

The conceptual framework proposed ways to achieve the aim of a just evolving lithium economy from an extractive mode to a re-cycle mode represented in the inner circle of the framework. The red cubes indicate on which scale the main conflicts have and will occur when establishing the evolving lithium economy in Portugal's Norte region if following the common manner of practice. These conflicts include lack of citizen involvement, lack of community engagement, lack of considering the existing local economic activities and environmental degradation. The external circle is using the concept of post-extractivism to provide the broader outline to achieve a more just form of extractivism than the traditional form, which necessary to achieve the context-specific project aim in the inner circle. This concept has evolved though academic research on natural resource extraction and has been discussed by experts in the field of political ecology, environmental studies and social theory. Eduardo Gudynas, an economist and researcher, have contributed significantly to the conceptualization of post-extractivism form the context of Latin America. The concept, in essence, critiques the traditional model of relying on natural resource extraction that is accompanied a range of negative local socio-environmental impacts and forcing pressure on existing economic activities. Therefore, the concept advocates for a shift to more sustainable practice. This concept of post-extractivism, destruct itself along four disciplines by a set of action and positions of care per discipline in order to be functional in the case of the Norte region.

Firstly, when considering the mobilization of an evolving lithium economy in the Portugal's Norte region from a post-extractivism perspective governance should involve local society and their concerns. This is essential to achieve a transparent informal decision-making process.

Secondly, the concepts advocates for diversifying the economy beyond the reliant on the appropriation on lithium out of natural resources by using circular principles (reuse and recycling) and support and invest in the development of lithium-ion batteries recycle practices to transition to a recycle mode.

Lastly, total avoidance of environmental degradation is not feasible in a context in which society remain dependent on the appropriation of lithium. However, by approaching the alteration of the existing ecosystems due to extractive activities as new totality. We could be more sensible and careful in the consideration and evaluation of the environmental impact of extractive, processing and other lithium related activities and considering the way of disposal.

Below explanations of keywords that can be found in the framework:
By procedural and social justice, this project refers to a transparent informal decision-making process with involvement of local communities and including the consideration of social values of communities.

By economic justice, the project refers to an equal distribution of economic opportunities and benefits within the regional society.

Lastly, by environmental justice the project refers to an approach in which environmental and non-material values are included as well as the implementation of conservation and restoration activities as part in extractivist projects.

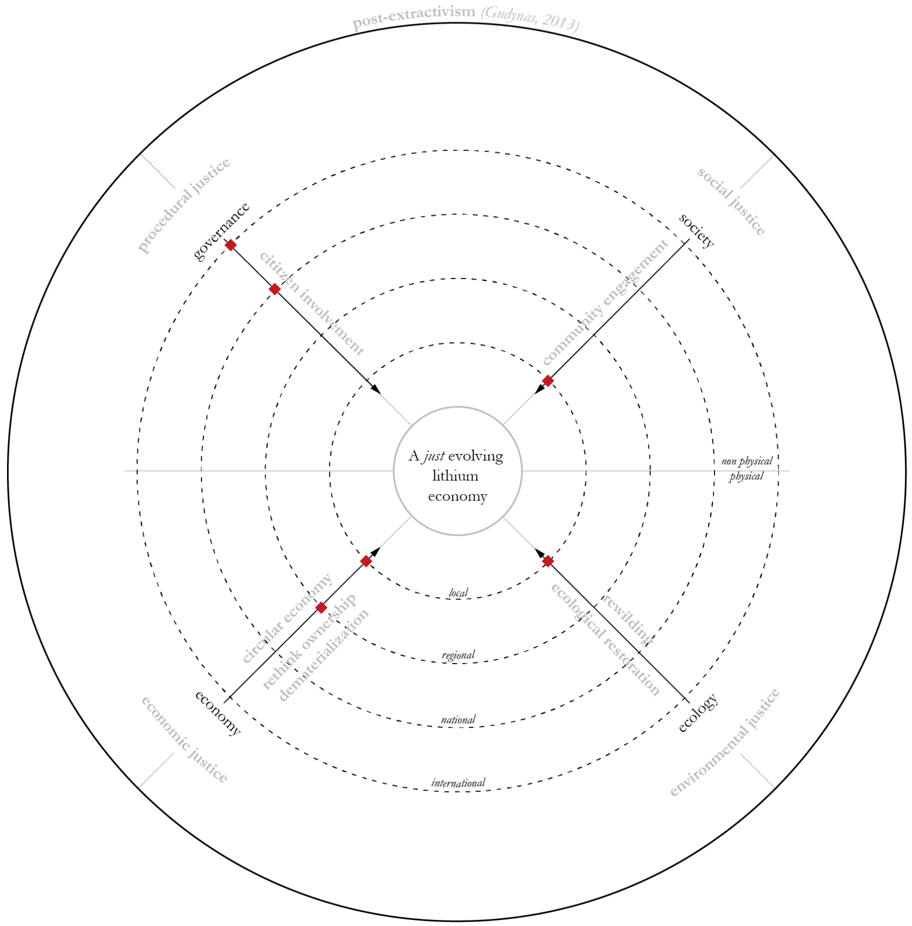


FIGURE 13: CONCEPTUAL FRAMEWORK

Investigating & Anticipating *(action)*

This chapter is built up of three lines of inquiry. The first line analyses the context-specific conditions of the Norte region. The catalogue of lithium supply chain landscapes identifies the key characteristics of each node in the chain and their metabolic footprints and anticipates their input requirements. The third section identifies the material flow between each landscape, gives a sense of the quantities, and aligns their strategic operationalization. The insights from these sections help inform the design assignment addressed in chapter o4, in which the thesis elaborates on spatially organizing the support systems that will fulfil the requirements to let each landscape operate.


NÃO À MINA
SIM À VIDA
BARROSO PATRIMÓNIO AGRÍCOLA MUNDIAL
UNIDOS PARA
DEFENDER
O QUE É
NOSSO!
FUTURO
MINADO?
NÃO!
OBRIGADO
É ISTO QUE QUERES PARA A TUA TERRA?
RO DA MINERAÇÃO !
PASSARÃO


msc


MAERSK
SEALAND
MAERSK
CMA CGM

REGIONAL LAND USE PATTERNS

Portugal's Norte region is characterized by a varierty of land uses, as illustrated in the map on the right, which categorizes the land into agricultural, urbanized, and natural land uses. These land uses reflects the regionals economic actvities.

Agricultural land dominates much of the region's landscape, particularly noted for its intensive viticulture. The vineyards in region are renowned for producing the famous Port wine, a pivotal economic contributor that also shapes the cultural heritage and landscape of the region. This agricultural activity is central not only to the economy but also plays a role in maintaining rural traditions and land use practices.

Urban land use is another crucial component, prominently in the coastal area and especially Porto, the region's largest city, which acts as a commercial and industrial hub. This urbanization supports a range of economic activities, including manufacturing and service industries,

Lastly, the natural land within the Norte region is characterized by expansive forested areas utilized for both wood production and environmental conservation. These forests are vital for biodiversity, offering essential ecological services like carbon sequestration and water regulation. The natural coastal zones play a dual role in supporting fisheries and tourism.

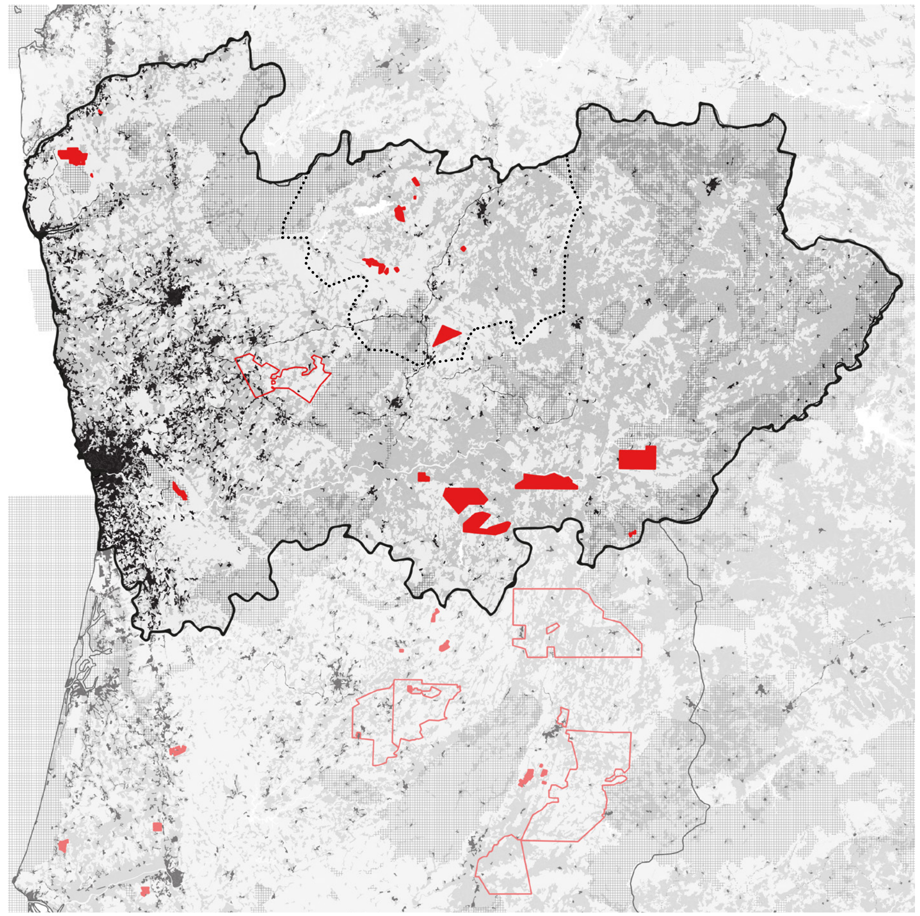


FIGURE 14: LITHIUM CONCESSIONS IN RELATION TO LAND USE PORTUGAL'S NORTE REGION

- mine concession for exploitation
- mine concession for exploration
- urbanized
- agriculture
- nature
- water
- Alto Tamega region

Site

REGIONAL POPULATION PATTERNS

Portugal's Norte region is one of the most densely populated regions in the country, particularly along the coastal areas, with a total population of approximately 3.6 million people as of 2021. The metropolitan area of Porto stands out as a high-density area, attracting a significant portion of the population due to its economic and social opportunities. This rapid urbanization in the coastal areas places considerable pressure on existing infrastructure and housing development.

Conversely, within the region, there are notable variations in population density. The Alto Tâmega subregion, known for its rural and mountainous terrain, is less densely populated. Certainly, the areas directly surrounding both mines consist of sparsely populated regions spread across small hamlets, with communities not larger than a hundred people. The region, where the mine concessions are located, faces distinct challenges compared to its urban counterparts, including depopulation and an aging demographic. These trends in rural areas may lead to a decline in conservation of local economies, especially in traditional sectors such as agriculture.

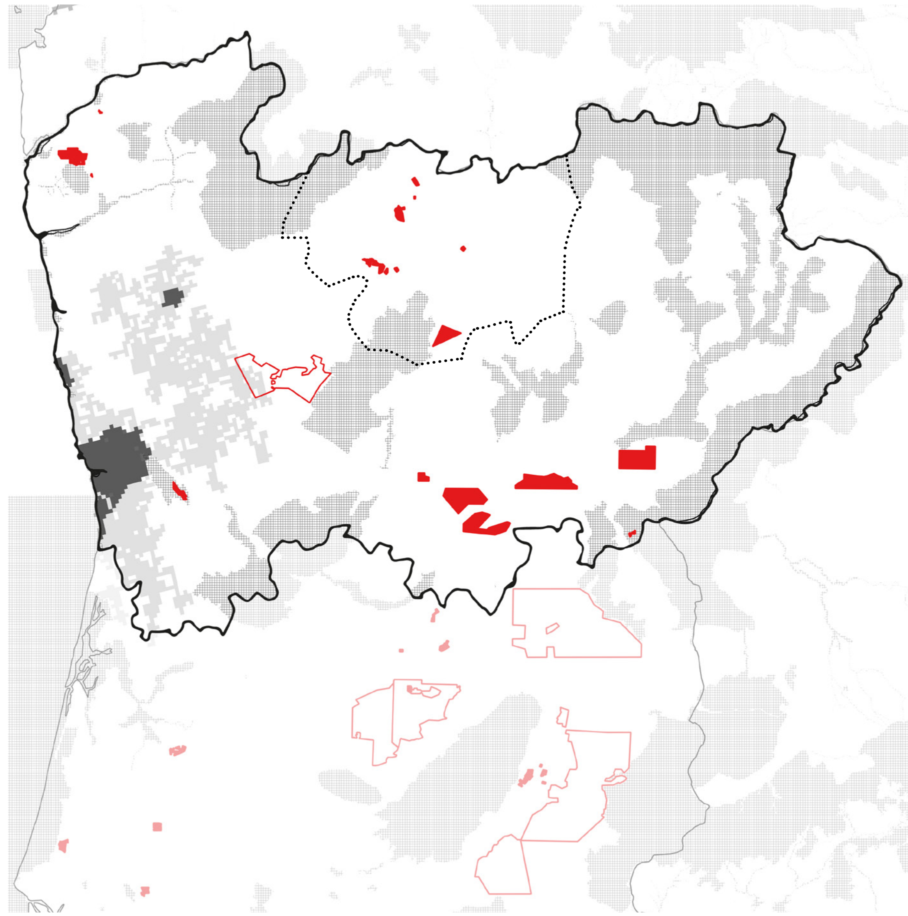


FIGURE 15: URBAN DENSITY PORTUGAL'S NORTE REGION

- mine concession for exploitation
- mine concession for exploration
- density >1 500 inh/km
- density >300 inh/km
- density <300 inh/km
- nature 2000 areas
- Alto Tamega region

Site

REGIONAL TOPOGRAPHICAL CONDITIONS

The topography of Portugal's Norte region, characterized by its varied landscape from rugged mountains in the interior to gentler coastal plains, is a defining feature that shapes the region's economies along with the culture and population distributions. This will also have its impact in shaping the evovling lithium economy. The mountainous areas, particularly around the Alto Tâmega subregion, are significant due to their geological formations, which contains many mineral deposits and thus host several mining concessions. This terrain impacts the accessibility of these areas which is an important factor to consider while establishing the lithium battery chain.

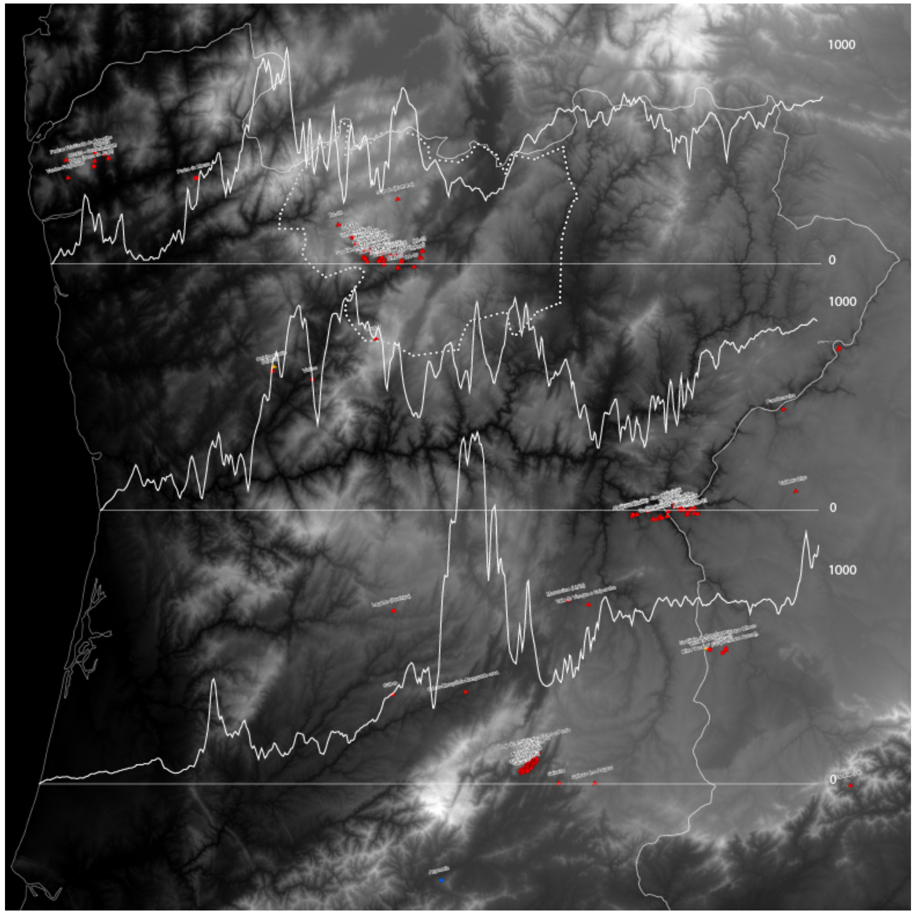


FIGURE 16: LITHIUM CONCESSIONS IN RELATION TO LAND USE

lithium occurrence
highest topographic point
lowest topographic point

Site

PORTUGAL'S NORTE REGION'S PROFILE

In Portugal's Norte region, the agricultural sector plays a crucial role in the local economy. Particularly in the three inland located subregions which includes the Alto Tâmega subregion that houses both the mines of intrest. Here, employment in agriculture is not only a key source of income for many families but also an essential component of the area's cultural heritage. The Alto Tâmega is noted for its specialized farming practices, which are well-adapted to the region's unique terrain and climate. This specialization includes the cultivation of rye, potatoes, and corn, alongside viticulture that is tailored to produce distinctive local wines. These agricultural activities support a significant proportion of the local workforce, providing both employment and sustaining traditional farming techniques that have been passed down through generations. As such, agriculture in the Alto Tâmega is part of the regions identity and key driver of its economy.

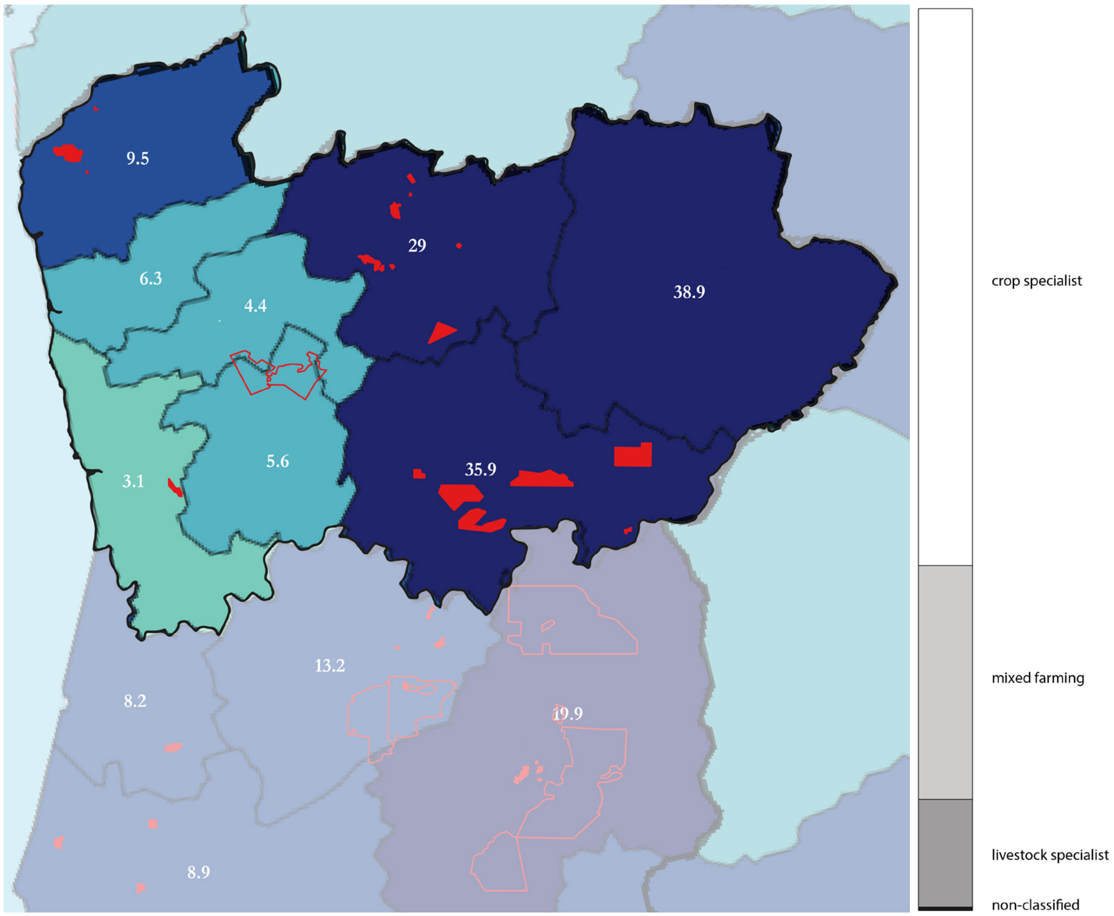


FIGURE 17: EMPLOYMENT IN AGRICULTURE, FISHING AND FORESTRY PORTUGAL'S NORTE REGION
Data recieved from Eurostat (2020)

- mine concession for exploitation
- mine concession for exploration
- lowest employment rate in primary sector
- highest employment rate in primary sector

LITHIUM LANDSCAPE PROFILE:
MINE BARROSO

[Overview industry]	
Name:	Mina do Barroso by Savannah Resources
Location:	Covas do Barroso, Boticas, Portugal
Form	open-pit mining
[Key features]	
Deposit type:	hard rock/pegmatite-aplite
Deposit capacity:	27 Mt pegmatite
Extraction capacity:	1,500,000 t spodumene concentrate
Spatial dimension:	542 ha
[Operationalization]	
Start construction:	2025
Start mining operation:	end 2026
End mining operation:	2038
[Employment impact]	
Direct jobs:	300 construction phase, 215 extractivist state
[Input]	
Material:	spodumene ore
Energy:	electricity to power equipment, machinery, and buildings
Water:	water for mining operations
[Output]	
Material:	spodumene concentrate 1,500,000 t/y
Water:	wastewater
Byproducts:	quartz and feldspar (input for ceramic and glass industry), waste rock and tailings

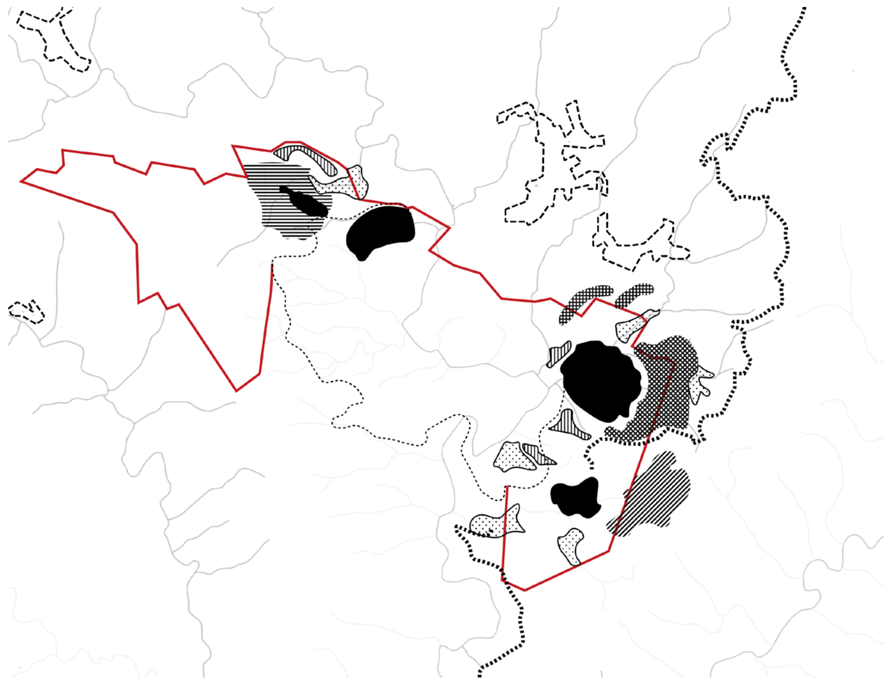


FIGURE 18: SPATIAL FOOTPRINT INCLUDING SUPPORT SYSTEMS BARROSO MINE

LITHIUM LANDSCAPE PROFILE:
MINE ROMANO

[Overview industry]	
Name:	Mina do Romano by Lusorecursos
Location:	Morgade, Montalegre, Portugal
Form	open-pit mining and underground mining including refinery plant
[Key features]	
Deposit type:	hard rock/pegmatite-aplite
Deposit capacity:	15 Mt pegmatite
Extraction capacity:	1,500,000 t spodumene concentrate
Spatial dimension:	268 ha
[Operationalization]	
Start construction:	2025
Start mining operation:	2027
End mining operation:	2040
[Employment impact]	
Direct jobs:	300 construction phase, 390 extractivist state
[Input]	
Material:	pegmatite-aplite/spodumene ore
Energy:	electricity to power equipment, machinery, and buildings
Water:	drinking water max. 200 m3/day, grey water
[Output]	
Material:	lithium carbonate 17,000 t/y
Water:	wastewater
Byproducts:	quartz and feldspar 60,000 t/y (input for ceramic and glass industry), waste rock and tailings

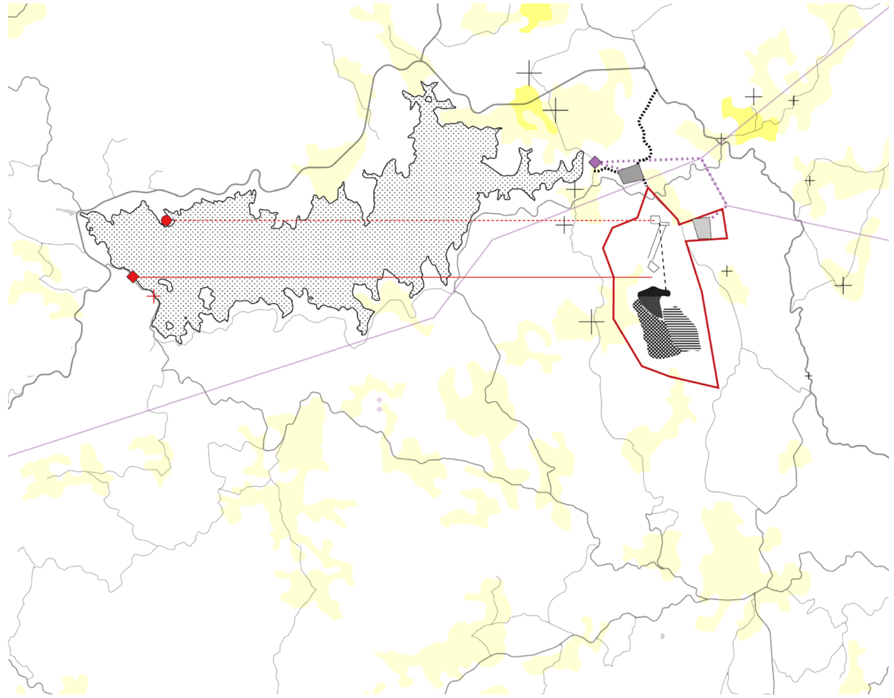


FIGURE 19: SPATIAL FOOTPRINT INCLUDING SUPPORT SYSTEMS ROMANO MINE

LITHIUM LANDSCAPE PROFILE:
REFERENCE / CATHODE MATERIAL AND LITHIUM-ION BATTERY CELL MANUFACTURING

[Overview industry]	
Name:	Northvolt Ett
Location:	Skellefteå, Sweden
Function:	cathode materials and lithium-ion battery cell manufacturing
[Key features]	
Classification of industry:	heavy industry (chemical processing)
Capacity:	60 GWH/y
Spatial dimension:	50 ha (equal to 71 football fields)
[Employment impact]	
Direct jobs:	2000 - 4000
[Input]	
Material:	lithium carbonate, nickel, manganese, and cobalt
Energy:	electricity to power equipement
Water:	water for cooling processes
[Output]	
Material:	lithium-ion battery cells
Byproducts:	production scrap

FIGURE 20: NORTHVOLT ETT, CATHODE AND BATTERY CELL MANUFACTURER

LITHIUM LANDSCAPE PROFILE:
REFERENCE / LITHIUM-ION BATTERY PACK MANUFACTURING

[Overview industry]	
Name:	Northvolt Dwa
Location:	Gdańsk, Sweden
Function:	lithium-ion battery modules and pack manufacturing
[Key features]	
Classification of industry:	light industry (assembly and distribution facility)
Capacity:	5 GWH/y
Spatial dimension:	5,2 ha (equal to 119 basketball courts)
[Employment impact]	
Direct jobs:	250 - 500
[Input]	
Material:	lithium-ion battery cells
Energy:	electricity to power equipement
Water:	water for cooling processes
[Output]	
Material:	lithium-ion battery packs
Byproducts:	production scrap

FIGURE 21: NORTHVOLT DWA, BATTERY MODULES AND PACK MANUFACTURER

LITHIUM LANDSCAPE PROFILE:
REFERENCE / COLLECTION AND PREPROSSESSING RECYCLING PLANT (SPOKE)

[Overview industry]	
Name:	Li-Cycle Germany Spoke
Location:	Sülzetal, Germany
Function:	shredding e-waste (end-of-life batteries)
[Key features]	
Classification of industry:	light industry (shredding, crushing and warehouse facilities)
Capacity:	10 000 (up to 30 000 t/y battery material)
Spatial dimension:	3 ha (equal to 4 football fields)
[Employment impact]	
Direct jobs:	50-60 (for 1 operational line)
[Input]	
Material:	end-of-life lithium-ion batteries collected from e-waste
Energy:	electricity to power equipement
Water:	water for cooling processes
[Output]	
Material:	black mass
Byproducts:	production scrap

FIGURE 23: LI-CYCLE GERMANY SPOKE, LITHIUM-ION BATTERY RECYCLING PLANT

LITHIUM LANDSCAPE PROFILE:
REFERENCE / RECYCLING PLANT (HUB)

[Overview industry]	
Name:	Li-Cycle Rochester Hub
Location:	Rochester, New York, USA
Function:	coverting black mass into battery grade materials
[Key features]	
Classification of industry:	heavy industry (chemical processing)
Capacity:	35,000 t/y black mass (equal to 90,000 lithium-ion batteries)
Spatial dimension:	25 ha
[Employment impact]	
Direct jobs:	270
[Input]	
Material:	black mass
Energy:	electricity to power equipement
Water:	water for cooling processes
[Output]	
Material:	battery grade materials; lithium carbona-te, nickel sulphat, and cobalt sulphate
Byproducts:	production scrap

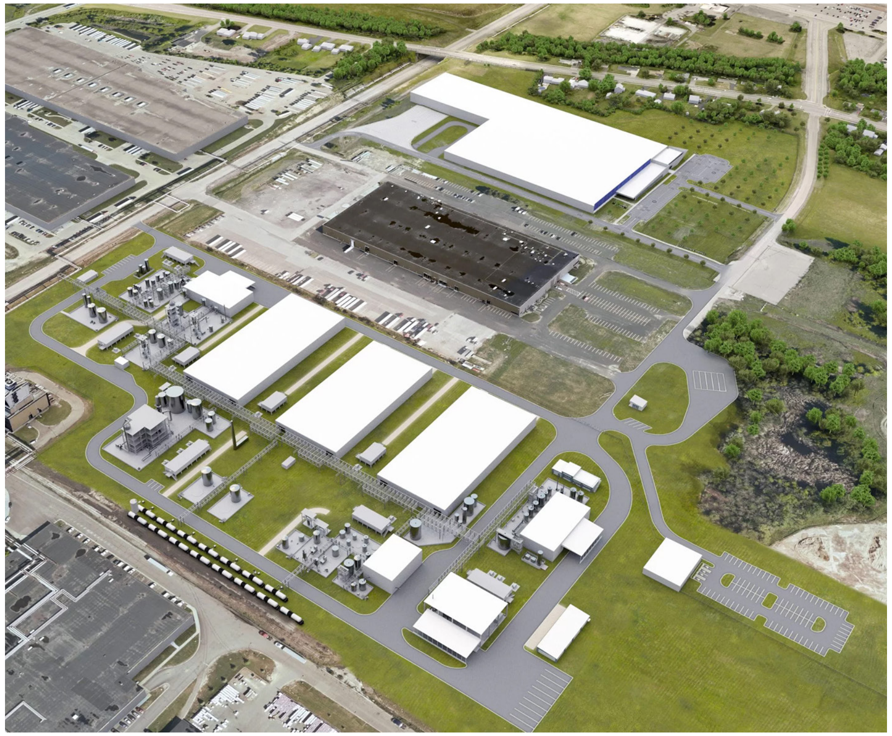


FIGURE 24: LI-CYCLE ROCHESTER HUB, LITHIUM-ION BATTERY RECYCLING PLANT

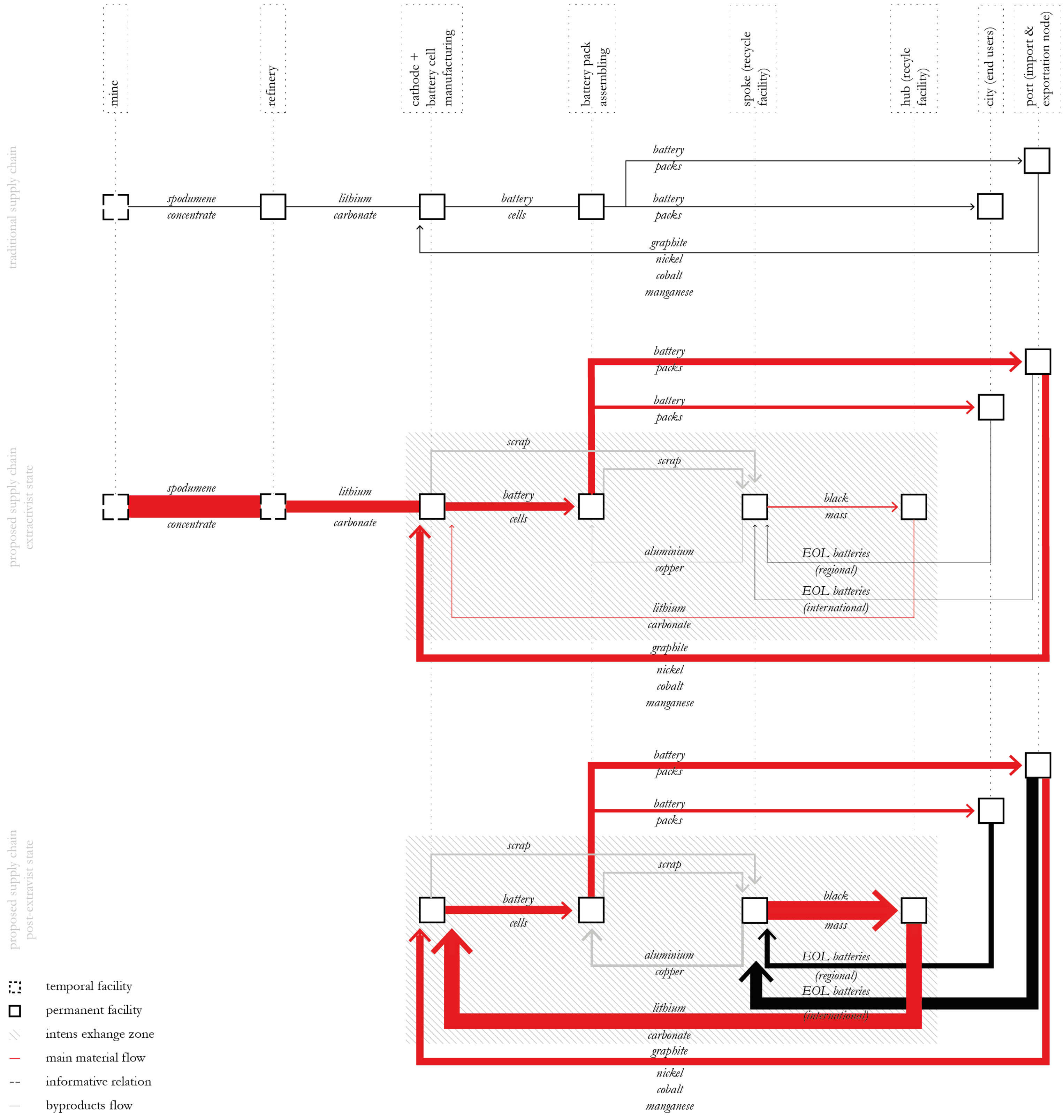
Supply/commodity chain

CIRCULARITY IN THE COMMODITY CHAIN

The transition from the traditional supply chain to a more circular one includes the integration of recycling industries that feed the lithium-ion battery cell manufacturing. Initially, the supply from recycle industries is relatively low, as it primarily relies on the production scraps from the battery cell and battery pack industries. However, in the transition towards the post-extractivist state decouples the mining sites and refining operations, thereby also cuts of its reliance on natural resource extraction. In this transtion, the main source of supply shifts to the emerging e-waste that will supply the system.

Strategically locating the facilities of the supply chain, can play an important role in supporting an efficient circular supply chain. In traditional lithium chains are facilities often spread thousends of kilometers apart. However, as shown in the diagram, the recycling facilities have substantial exchange flows of their main export commodity, as well as production scrap that can be used as input in the other facility. Strategic clustering these facilities that engage in reverse exchanges, not only enhances operational efficiency but also minimizes transportation distances. In addition to the distances between facilities, their geographic location may also play a crucial role. For mid-downstream facilities, locating near cities where e-waste accumulates or in areas that allow for efficient importation of e-waste streams from regional, national, and international collection points is beneficial. Conversely, situating refineries close to mining sites minimizes the frequency and volume of heavy freight to battery manufacturers.

As noted in previous chapters, a commitment to proper management and reuse of raw materials once obtained can significantly reduce the demand for natural resources. This not only addresses environmental concerns but also enhances geopolitical and economic security by reducing dependencies. This underscores the crucial role of knowledge institutions and R&D centers in pioneering research in the field. Strategic positioning of recycling facilities near these institutions or where R&D centers can be established may fosters collaboration and innovation in the field.



Takeaways

PLANNING FOR BOTH STATES

- Understanding the regional population patterns and trends can help strategically locate the industries and stimulate development.

- Recognizing the role of the agriculture sector in shaping the cultural and physical landscape of the Alto Tâmega region is crucial for envisioning a post-extractive future that respects and integrates in the local context and identity, ensuring a strategy that is widely accepted. The existing agricultural foundation in the region may provide a robust base for transitioning to a post-mining biobased economy.

- Understanding of the key features of each industry helps to plan and facilitate for the requirements of each landscape, mainly workforce, energy and water demand.

- Strategically situating and clustering the industries in the battery supply chain can significantly enhance operational efficiencies, exchange of materials and encourage collaboration with the quaternary sector to support innovation in the field.

Projecting *(form)*

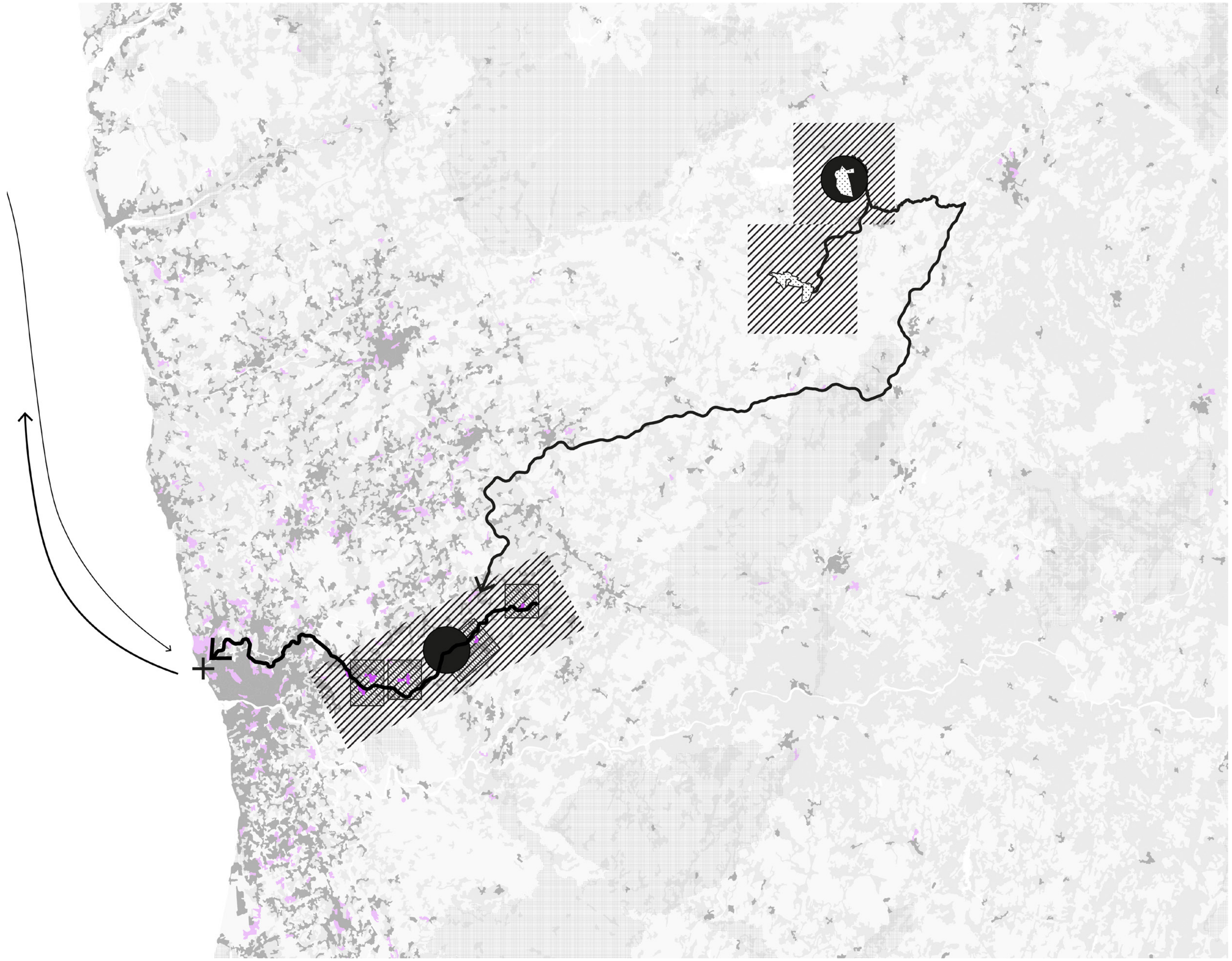
This chapter discusses the regional vision that shapes the conditions to establish the evolving economies in the Norte region in both the extractivist state and post-extractivist state. Both states require (different) elements of spatial organization. The elements of spatial organization introduced in the extractivist state will be reused and/or reconfigured to launch the economic activities in the post extractivist state. The strategic vision indentifies the key spatial interventions that support the operationalization of each state.

Vision *(extractivist state)*

The vision proposes the way of functioning of the lithium battery economy for both states. Following the abstract logic of how the different landscapes in the region act and function, the vision identifies areas of extraction, processing/production, areas of circulation and areas of investment and development of support and transportation systems to support the operation of each landscape and the distribution of their inputs and outputs.

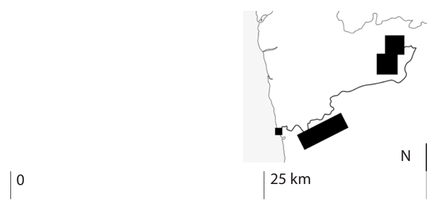
In the extractivist state is the area of extraction geographical fixed, namely the area of both mine sites. Both mines will have pre-processing facilities that takes care of the beneficiation process of the raw ore that reduces the raw ore into spodumene concentrate. The more northern mine sites includes a refinery facility that can process the spodumene concentrate to lithium carbonate. To support the operationalization of the mining activities, facilities on site and the distribution of exports between the mining site further south to the one more north and to the next lithium landscape in the supply chain, there will be invested in support and transportation systems. This includes the investment and development of an energy supplier, electricity grid, water supplier, water treatment plant, an area that facilitates the accommodations for the workers involved in the both mines, internal road network and external road network.

The battery supply chain's facilities will be situated along the railway to facilitate efficient international and national exports and imports, particularly in post-extractivist import-oriented state. Moreover, this cluster of facilities will be located near the edge of Porto to meet the workforce demand in the downstream part of the chain and encourage exchange with related sectors in Porto. The strategic location of these facilities is important, as they will operate in both states.



dotted : area of input (extraction/cultivation)
solid : area of processing/production
line : infrastructural element
arrow : flow of circulation
hatched: area of investment in support systems (workforce, energy, water)

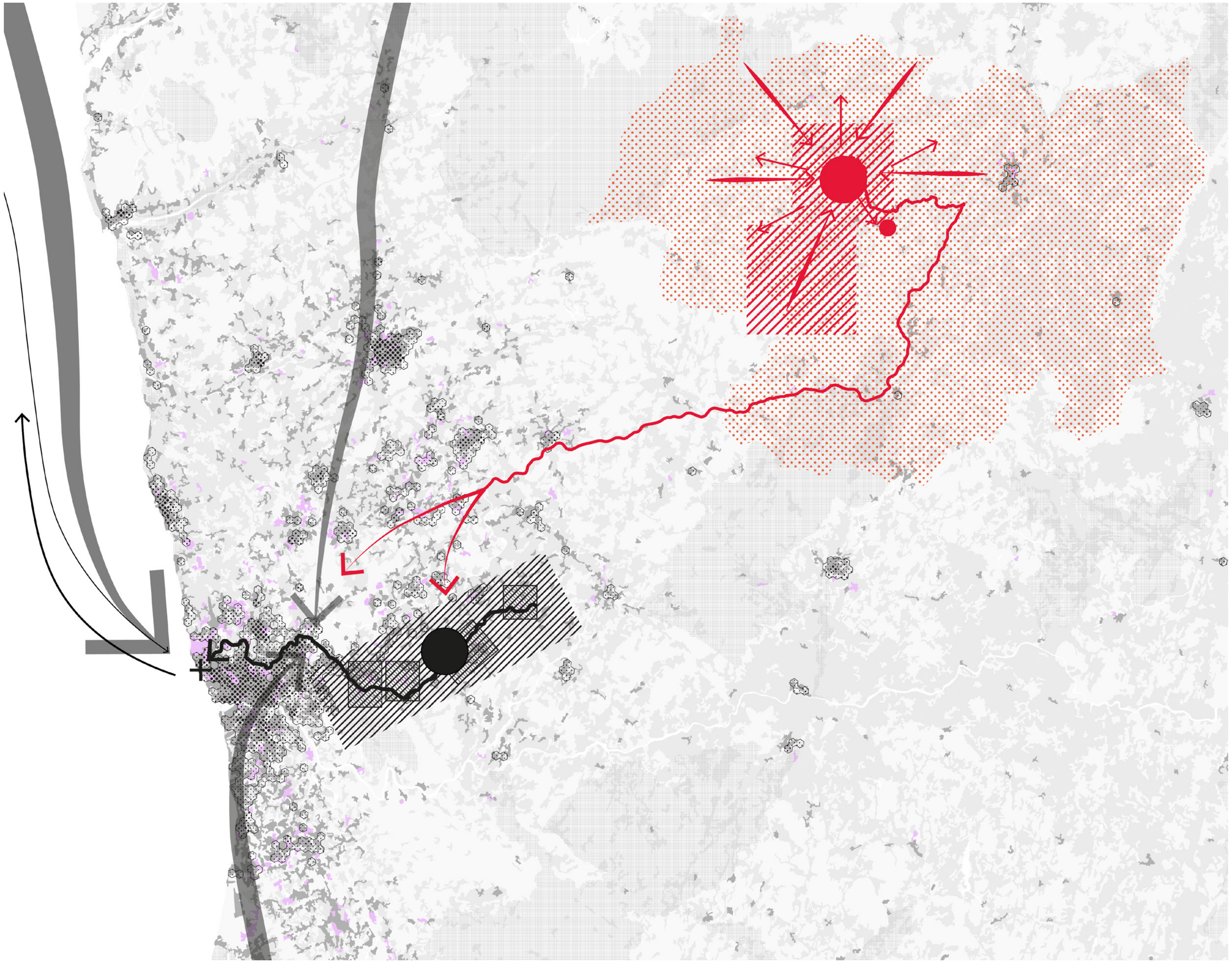
industrial areas
lithium economy related



Vision *(post-extractivist state)*

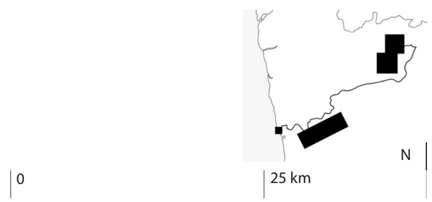
In contrast to the extractivist state that reflects a more export-oriented economy, reflects the post-extractivist lithium economy a more circular and import-oriented economy. In this state both mine sites that extracted lithium out of natural resources – the areas of extraction – decouples. However, the production facilities downstream the battery chain remain operational, sourcing their inputs from secondary supplies at international, national, and regional levels. The support areas – of investments in support and transportation systems – in and around the mining sites, that previously facilitated these operations can be repurposed to launch and facilitate the post-mining economy.

The vision proposes a bio-based economy in post-mining areas which offers a holistic revitalization of the landscape, economy, society, and environment. By rehabilitating degraded lands with biomass cultivation, the visual and ecological aspects of the landscape are improved, enhancing local biodiversity, promotes carbon sequestration, and improves air and water quality. Economically, this transition diversifies the existing cultivation economy towards sustainable sectors like bio-energy and structural biomass production. Socially, it allows to involve farmers in the region to turn their waste stream into energy, which creates an additional income. On the other hand, it allows for new job opportunities and enhances community engagement through education and training in emerging green technologies. Overall, this integrated approach not only mitigates the ecological disturbances caused by the mining activities but also envisions a sustainable, resilient post-mining future, aligning an additional revenue for rural economies with environmental stewardship.



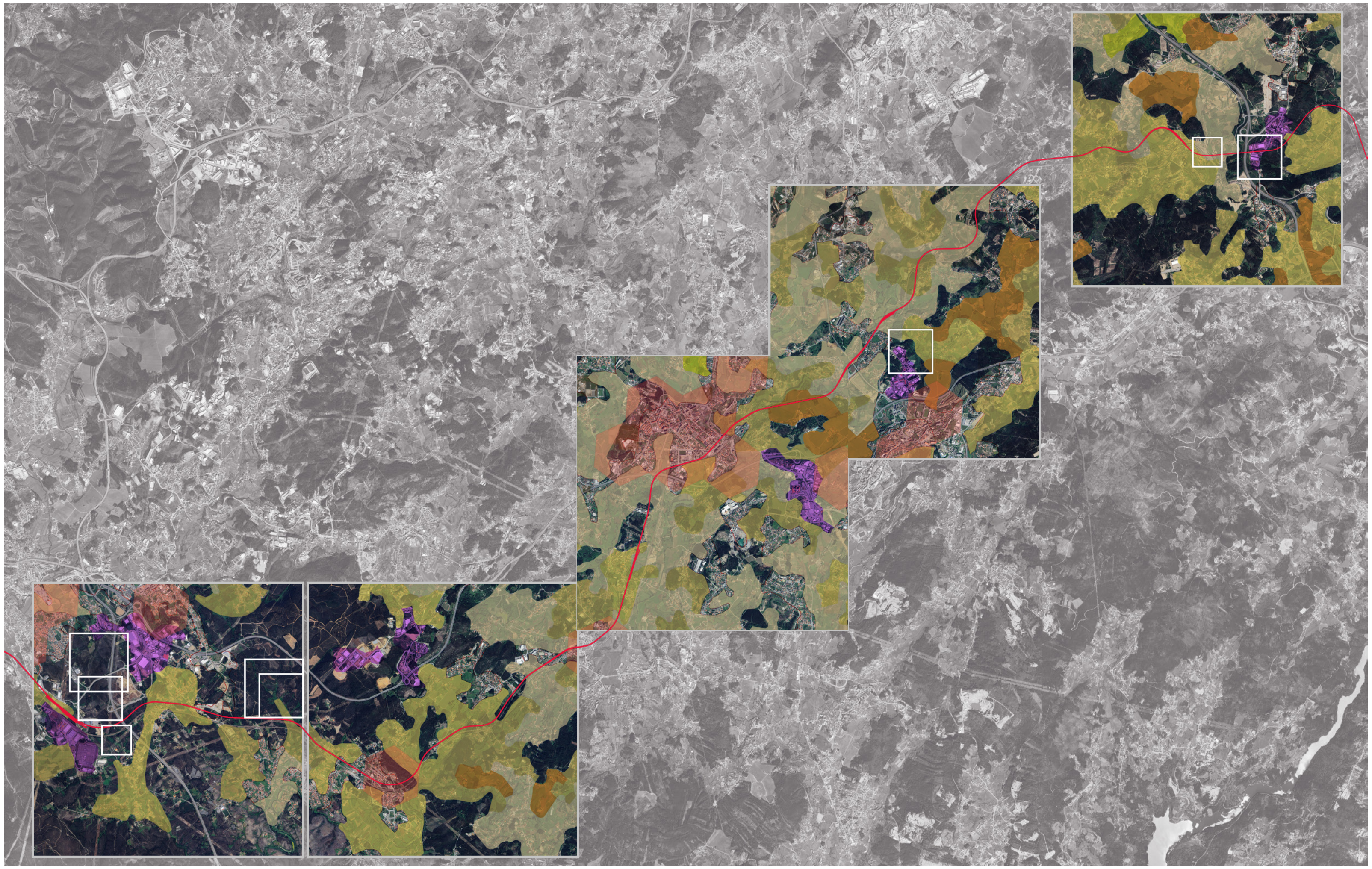
dotted : area of input (extraction/cultivation)
solid : area of processing/production
line : infrastructural element
arrow : flow of circulation
hatched: area of investment in support systems (workforce, energy, water)

industrial areas
lithium economy related
biobased economy related



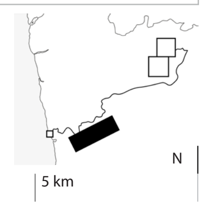
LOCATION DETERMINATION INDUSTRY CLUSTER

The strategic selection of a location for the cluster of mid-downstream facilities in the battery chain involves a comprehensive approach that aligns with the broader vision of the project while balancing operational efficiency, economic benefits, environmental considerations, and social impacts. To avoid unnecessary land use changes, it is preferable to situate the facilities near existing industrial areas. This approach leverages and enhances current infrastructural connections and clusters economic activities with existing ones. Strategic considerations begin with evaluating the availability of space for establishing facilities based on reference industries in the supply chain landscape catalogue. Ensuring access to major transportation networks, proximity to a (skilled) workforce, and access to energy resources crucial for industry operations are also key factors. Additionally, the local topography must be conducive to the establishment of these facilities. By adhering to these preconditions, the chosen location – left on map – for the industry cluster is strategically considered.



Acces to ... / Availability of ...	Space	Motorway	Railway	Labour	Energy	Landscape form
Area 01	++	++	++	+	+	+
Area 02	+	0	++	-	-	-
Area 03	-	+	0	0	0	0
Area 04	0	++	--	--	--	--

urban agglomeration >1 000 inh.
agriculture
industrial area
railway
25/50/100 ha



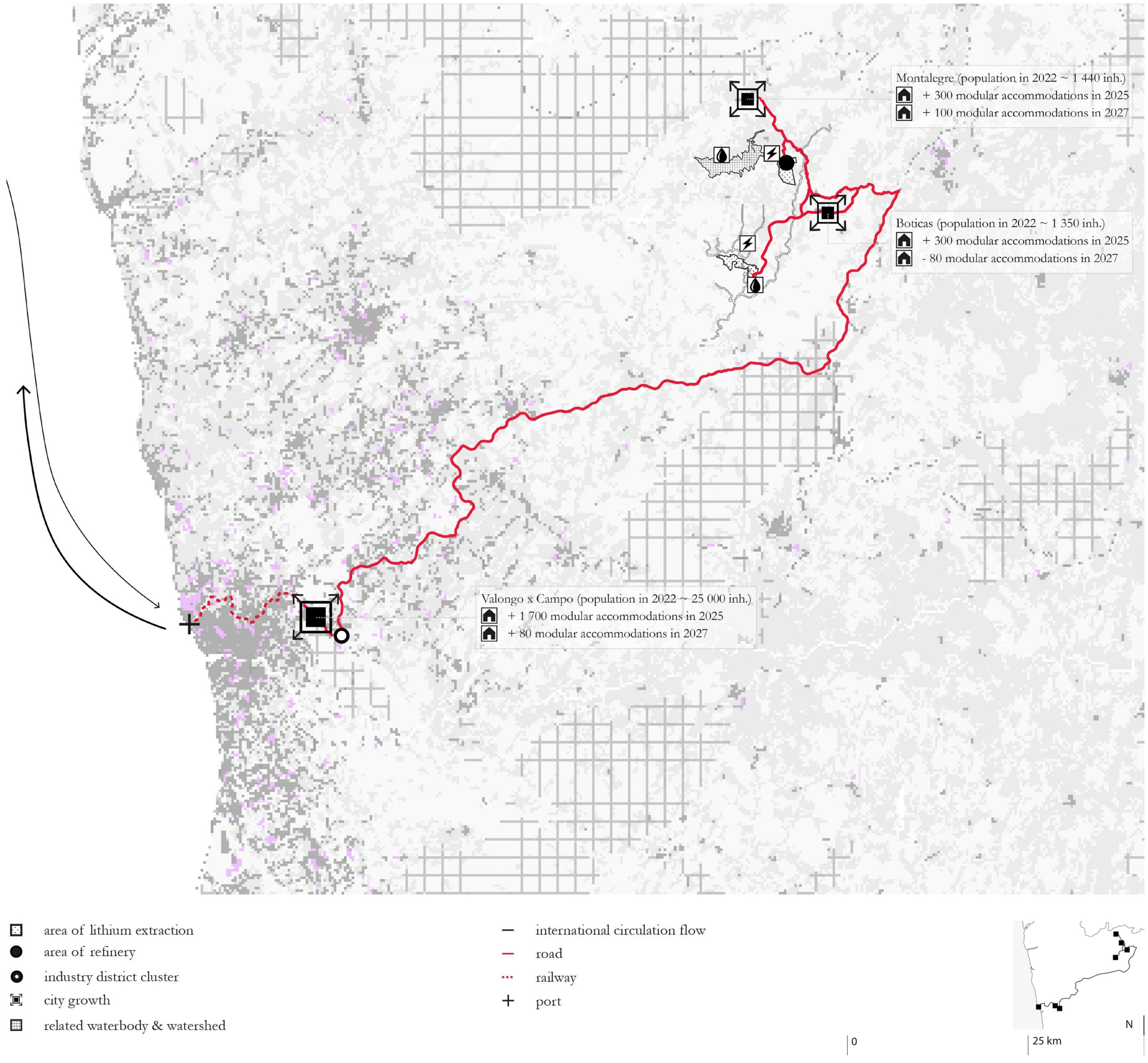
Strategy *(extractivist state)*

ACT OF FUNCTION

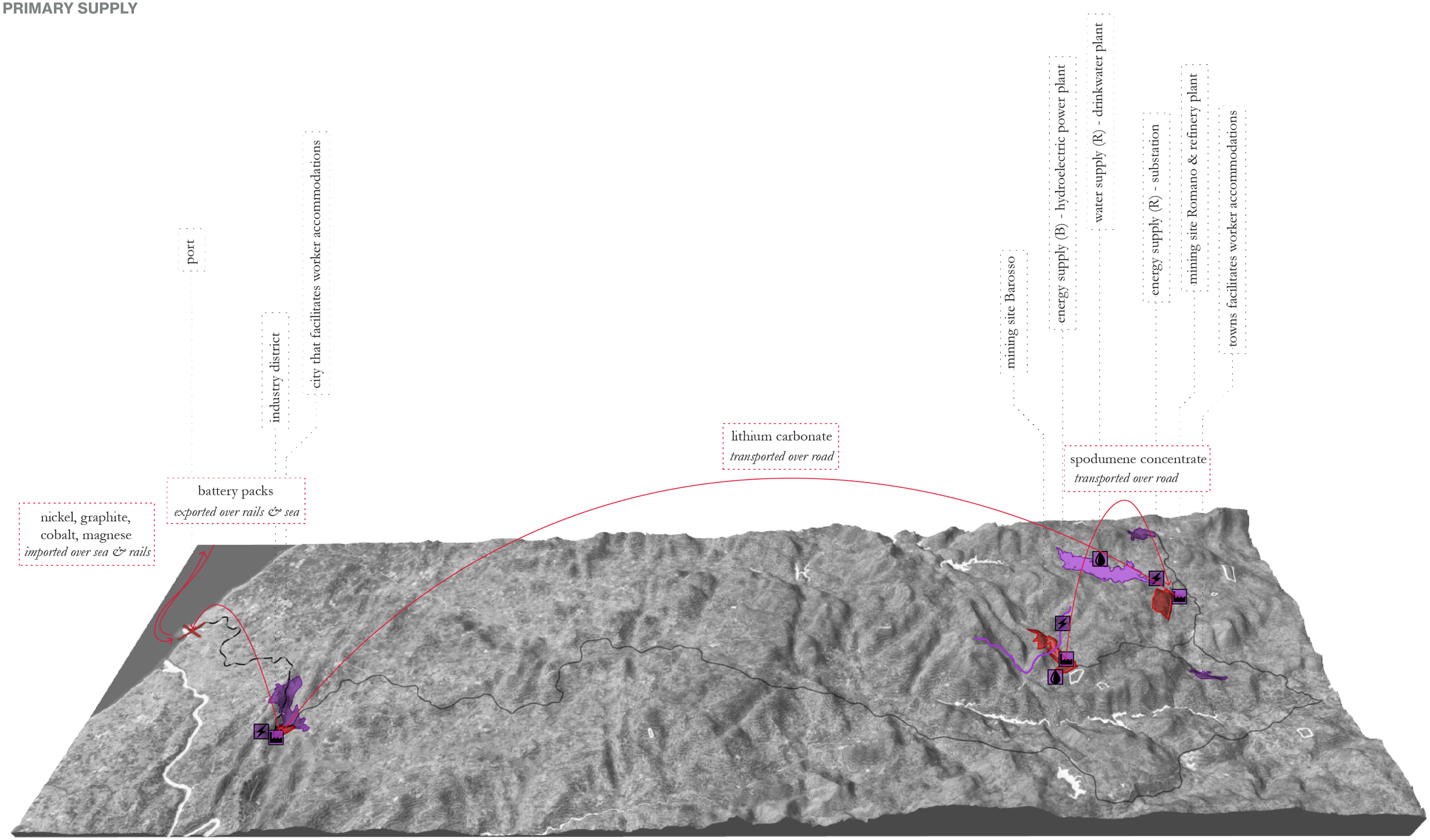
The strategic vision identifies the spatial interventions and key projects that are needed. These involve actions of urban development for (temporal) worker accommodations, infrastructural reinforcement and development, change in cultivation patterns, water and energy infrastructure development and industrial development. These interventions will be explored on the scales of action.

In order to facilitate the demands of temporary workers during both the construction and operational phases of the mines, the Alto Tamenga region must provide temporary housing accommodations. The catalogue of lithium landscapes in the previous chapter indicates the number of workers that work in each landscape. Downstream the supply chain, where most facilities are located, is the demand for around 1500 workers in the extractivist state, which will add up to approximately 2000 workers in the post-extractivist circular state. The workforce demand upstream the chain is roughly 200 to 400 workers per mine for around 12 years.

To facilitate these workers, the strategy suggests temporarily constructing modular timber assembly houses in two towns roughly 13 kilometres away from these towns. Both towns – Montalegre and Boticas – have developed infrastructure and contain essential services such as health care, education, stores, and areas for recreation. The capacity of both towns allows them to accommodate the number of temporary workers. Locating and clustering the workers in these villages will allow for a bus connection to facilitate the commuting of workers between the mines and towns and avoid congestion of traffic flows in the narrow roads of the hamlets. Clustering the accommodations in the villages will prevent further fragmentation of the rural landscape of which the hamlets are a part. This has a proven positive effect on biodiversity and thus contributes to preserving the ecology of the area (EEA, 2011).



LITHIUM ECONOMY BASED ON PRIMARY SUPPLY



- lithium economy related
- support areas/systems
- railway
- roads

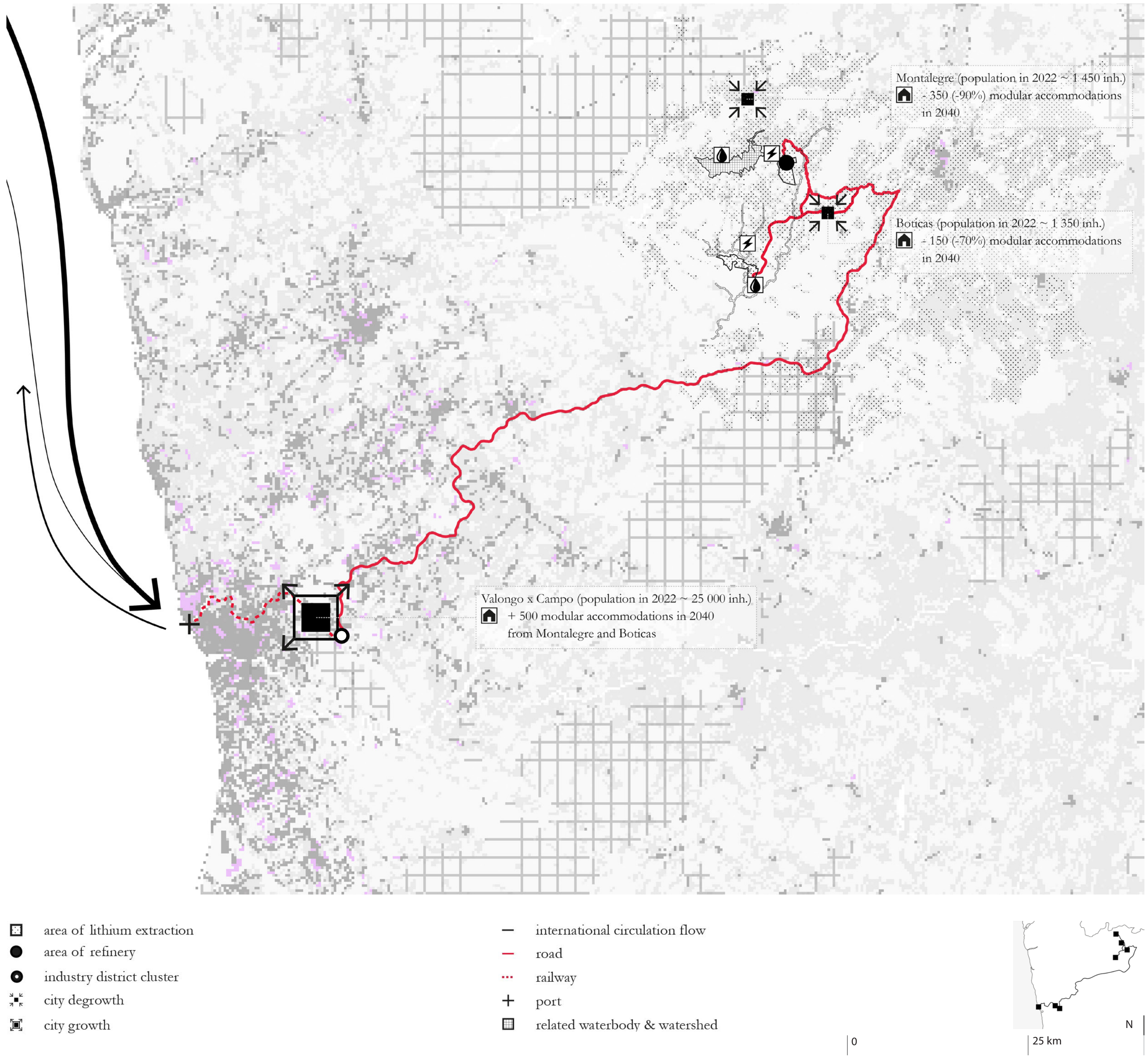
0 — 25 km

N

POST-MINING ECONOMIES

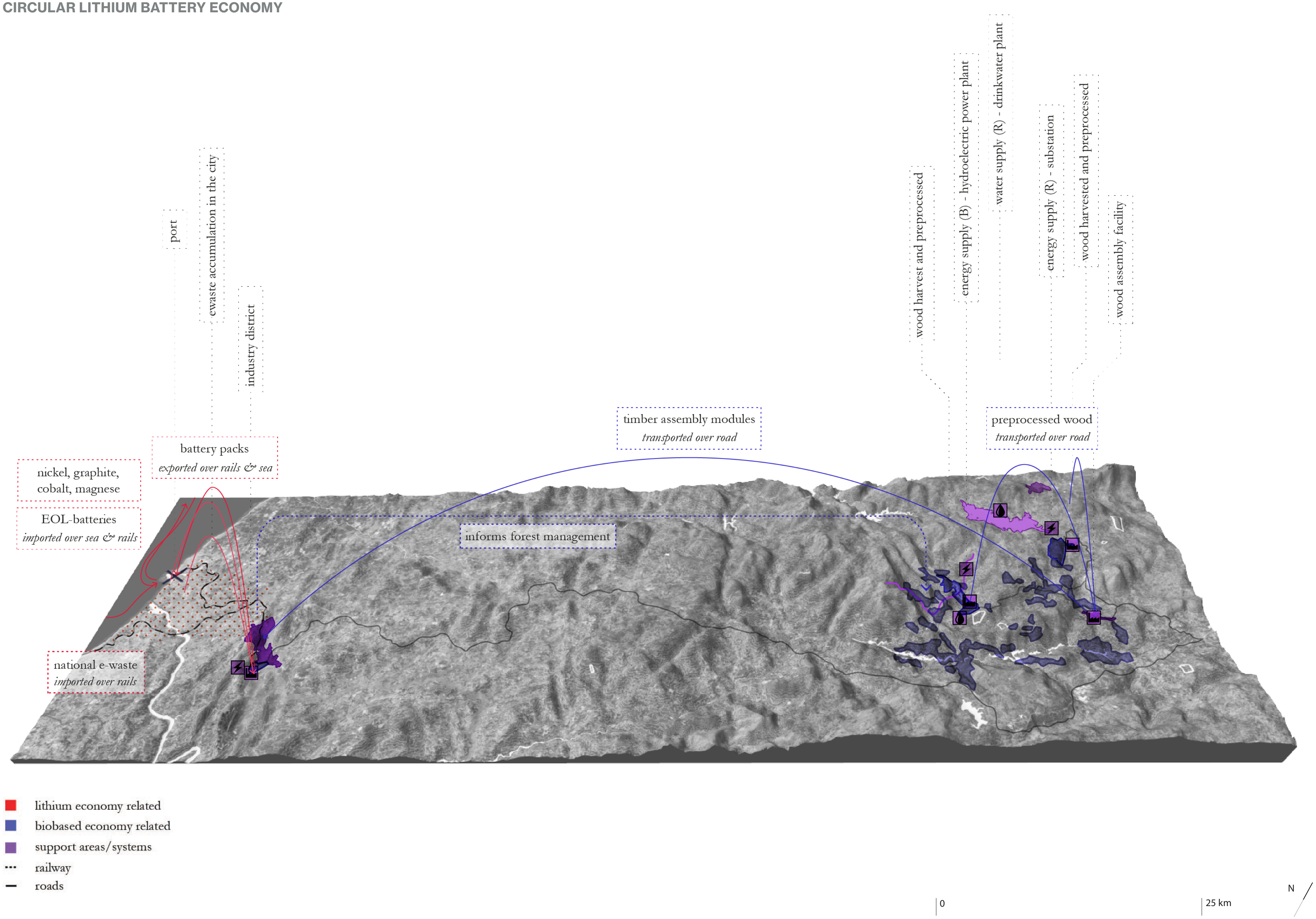
In the post-extractivist state, when both towns will shrink due to the closure of the mining operations, can the modular houses be disassembled and reassembled in the city of Valongo to facilitate the growing demand for housing in the post-extractivist state. It is likely in this state, that the majority of the mine workers will move somewhere else to work. The strategy presumes that roughly 90 percent of the workers will move out of Montalegre and 70 percent of the workers will move out of Boticas. The percentage of disassembled modular houses is lower in this latter town since the strategy proposes to use this town to host the a timber assembly facility that requires a workforce in the post-extractivist state.

The activites related to the biomass economy emerge on two scales, both function on a regional level, both one has its output on the territorial level and the other on the local level.In the following the subchapters will elaborate on both economies.



Strategy *(post-extractivist state)*

STRUCTURAL BIOMASS ECONOMY AND CIRCULAR LITHIUM BATTERY ECONOMY



Strategy *(post-extractivist state)*

THE INTRODUCTION OF A BIOBASED ECONOMY

The figure on the right shows what the two chains of the biomass economy consist of. Both will be fed by the newly introduced cultivation pattern on the post-mining land. In addition, both subeconomies could be fueled by the connection of existing cultivation practices and the use of their outputs and/or waste streams.

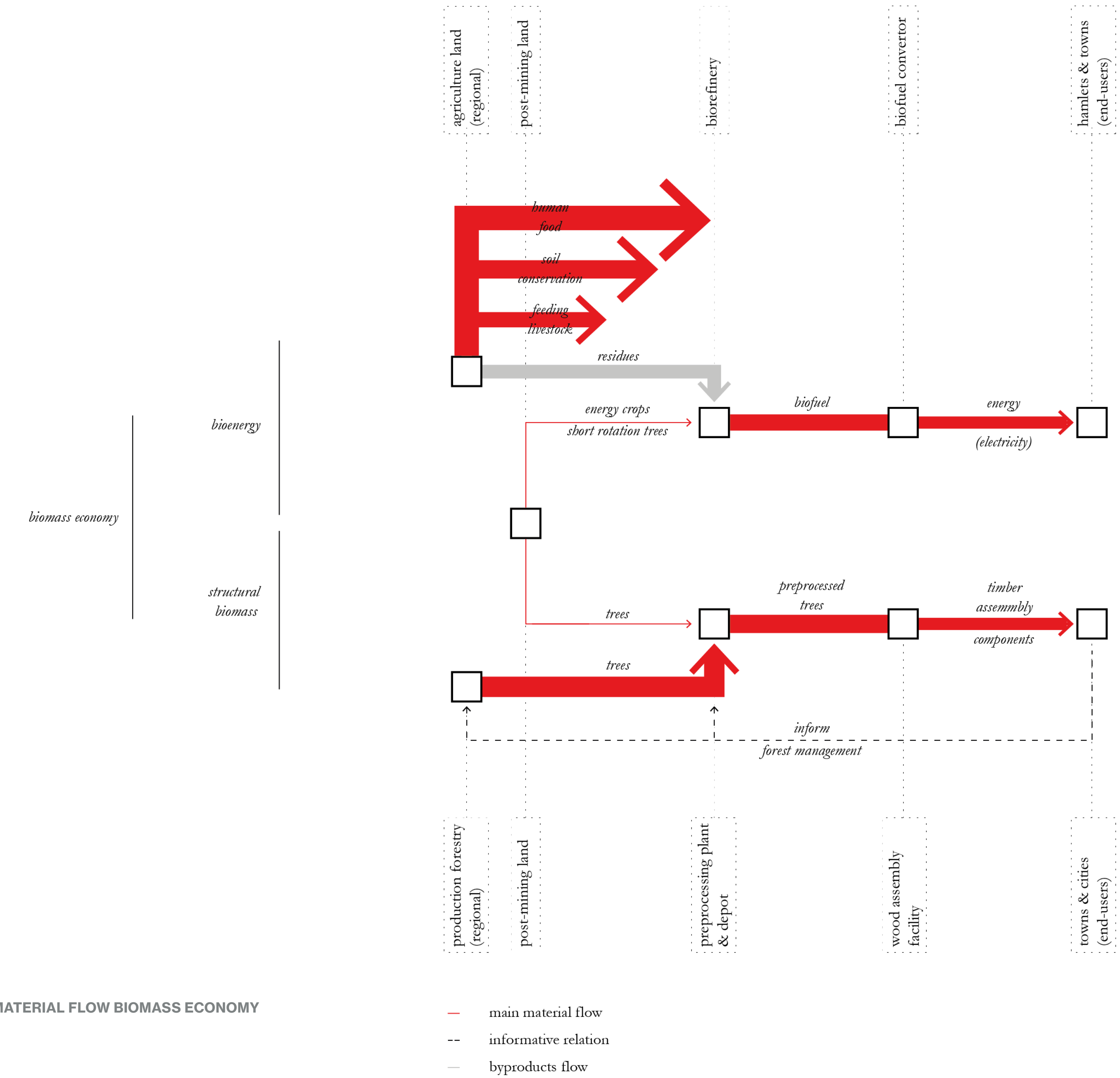


FIGURE 25: MATERIAL FLOW BIOMASS ECONOMY

BIO-ENERGY ECONOMY BASED ON AGRICULTURAL WASTE STREAMS AND ENERGY CROPS

Biomass resources obtained from the land can serve other purposes apart from cultivating food for humans, such as producing bio-plastics, textiles, biochemicals, or bioenergy. Unlike food, energy can be generated directly from renewable sources such as the sun, wind, or running water. However, biomass is necessary for people to meet their nutritional needs (De Boer & Van Ittersum, 2018). However, it is not desirable to grow crops for food consumption on the post-mining land. Therefore, we could use this land to cultivate energy crops like Miscanthus and Switchgrass and short rotation trees for bioenergy while remediating the soil and restoring biodiversity.

Furthermore, can the bio-energy economy be significantly enhanced by utilising the by-products of the food-agriculture system, such as production, processing, and consumption residues, which are not used for soil improvement or conservation nor for feeding livestock to produce food from animal sources. This helps create additional income for farmers in the region from their existing waste streams.

The table on the right shows the byproducts that can be used as resources and received from their associated land cover, their potential related uses, their associated required facilities, their harvest seasonality, and their harvest frequency.

biomass resources	associated landcover	asssociated facility	seasonallity (winter, spring, summer, autumn)	harvest frequency
short rotation trees	post-mining area	thermochemical		every 2-4 years
energy crops	post-mining area	thermochemical		
miscanthus				annually
switchgrass				annually
crop residues	non-irrigated land / annual crops associated permanent crops	thermochemical, biochemical		annually (depends on crop type)
orchard prunnings / vineyard prunnings	vineyards / land coverd by agriculture and significant areas of natural vegetation	thermochemical		1-2 times per year
forestry residues / logging residues	forestry	thermochemical		every 1-2 years (depends on forestry management plans)
livestock manure	pastures	anaerobic		year-round
food waste	residential areas	anaerobic		year-round

FIGURE 26: FORMS OF (POTENTIAL) BIOMASS RESOURCES IN THE ALTO TAMEGA REGION

BIOMASS FOR HEAT/ELECTRICITY PURPOSES

The map on the right shows for the Alte Tamega subregion the geographical location of the areas that can feed the bioenergy economy by utilizing their associated byproducts. A cooperative of farmers initially directed at the level of both municipalities can be highly efficient in managing the supply and collection of agricultural waste streams. At a later stage, this cooperation can grow to be directed at the level of the Alto Tamega subregion in order to make full use of the waste streams in this agriculturally rich subregion.

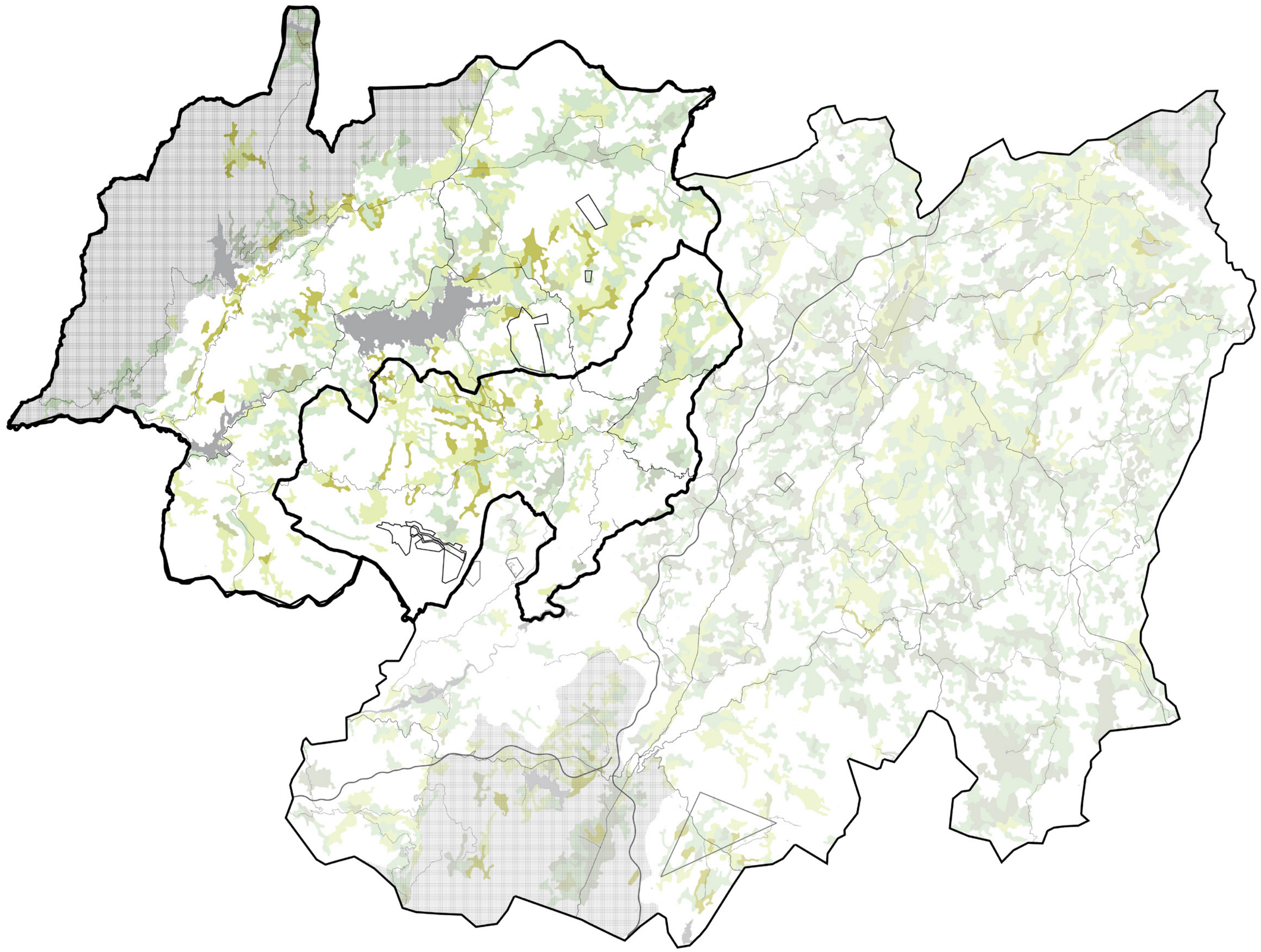


FIGURE 27: (POTENTIAL) HARVESTING AREA TO FUEL THE BIOENERGY ECONOMY IN THE ALTO TAMEGA

- mine concession area
- vineyards/orchard prunings
- live stock manure
- crop residues (from irrgated land)
- crop residues from (non irrigated land)
- nature 2000 areas

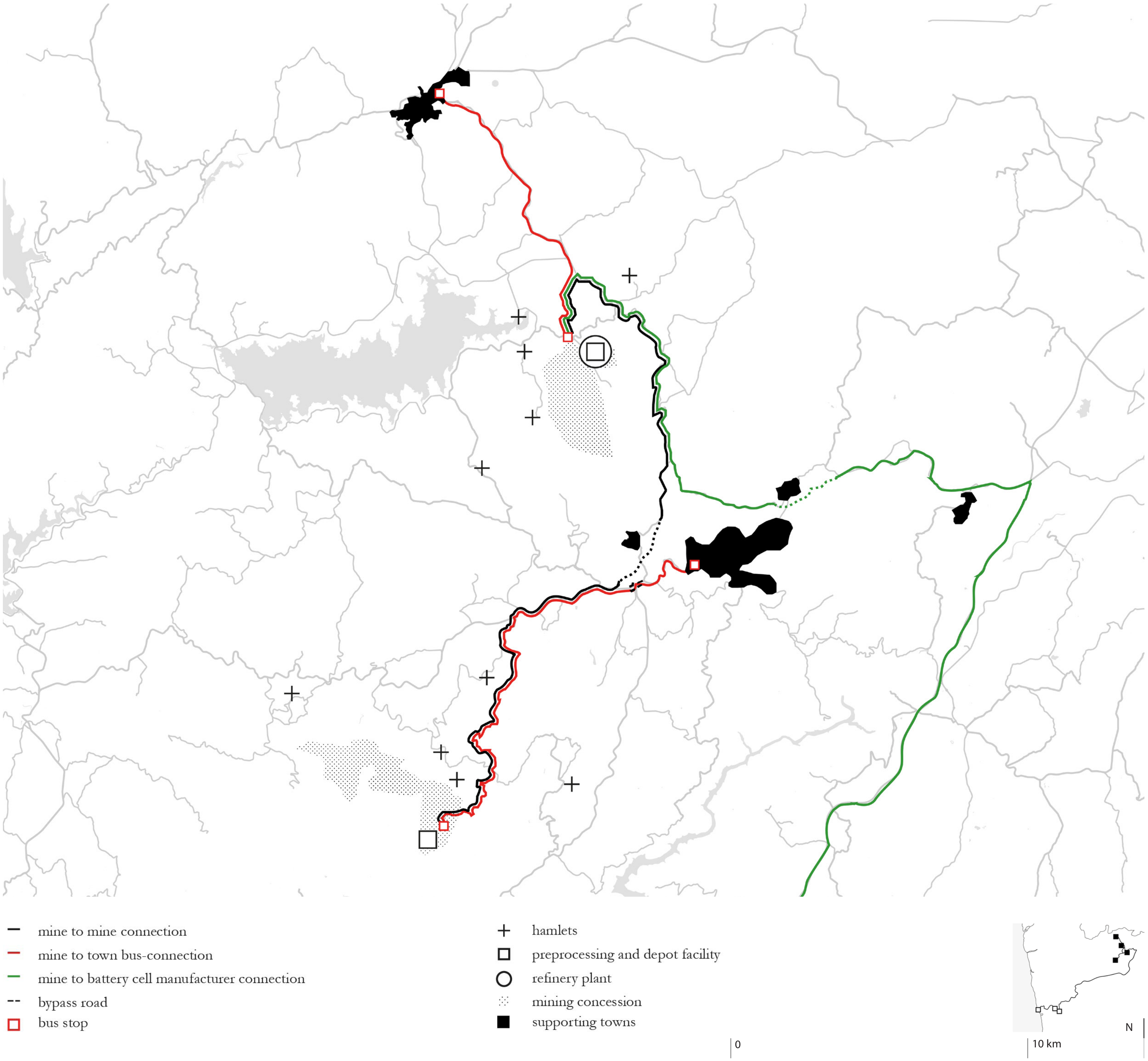
INFRASTRUCTURAL REINFORCEMENT AND DEVELOPMENT

To facilitate the distribution of commodities, the strategy develops and reinforces some infrastructural connections. The strategy distinguishes three types of infrastructural connections based on type of traffic and duration of operationalization related to the lithium economy or post-mining economy; (1) permanent connection facilitating heavy transport, (2) temporal connections facilitating light traffic, and (3) temporal connection facilitating medium heavy traffic.

Firstly, Mina do Barosso is connected to Mina Romano to bring the spodumene concentrate to the refinery facility. This connection is permanent because also operational for the distribution of materials is the post-extractivist state. This connection facilitates heavy traffic and passes through two villages. To reduce interaction between heavy traffic (trucks) and local light traffic in and around the villages, there will be bypass roads.

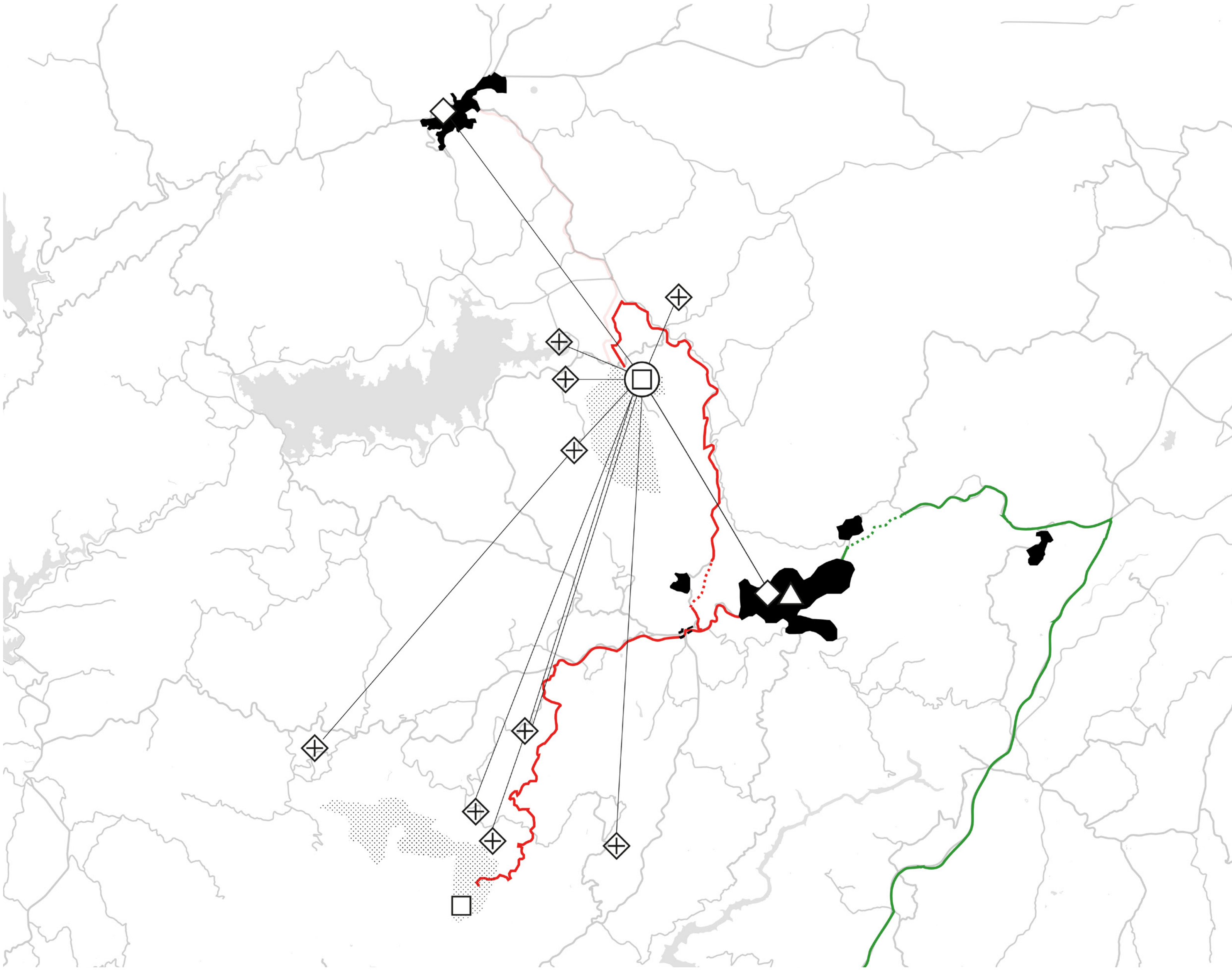
Secondly, both mine sites are connected to a nearby village through an existing infrastructural connection. This connection facilitates a bus service between the villages and the mine sites to facilitate the employees of the mine sites who are housed in these villages. Since the connection is temporary for the time the mines will be operational and facilitates light traffic, no modifications are necessary.

The connection is the one over which the refined ore - lithium carbonate - is distributed to the cathode and cell manufacturer on the industry cluster downstream. Most of this connection includes the A24 which is very suitable for freight traffic. The part up to the motorway will be widened and partly relocated to avoid inconvenience in the villages where freight traffic would otherwise have to pass.

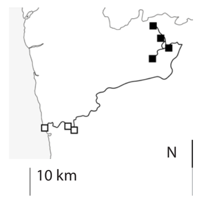


CENTRALIZED REFINERY FOR LOCAL BIOENERGY

In considering the establishment of a bioenergy economy, two distinct alternatives present themselves. The first alternative involves a centralized refining system where biomass is collected regionally by the cooperative, refined into biofuel at the northern post-mining area, and then distributed to each hamlet where the biofuel is converted by small scale reactors. This alternative potentially is lower in production costs since it can produce on large scale while making use of support and transportation network in the extractivist state. This alternative allows for better control over biofuel quality. However, it could incur high transportation costs and emissions, and the central dependency could disrupt supply if operational failures occur.

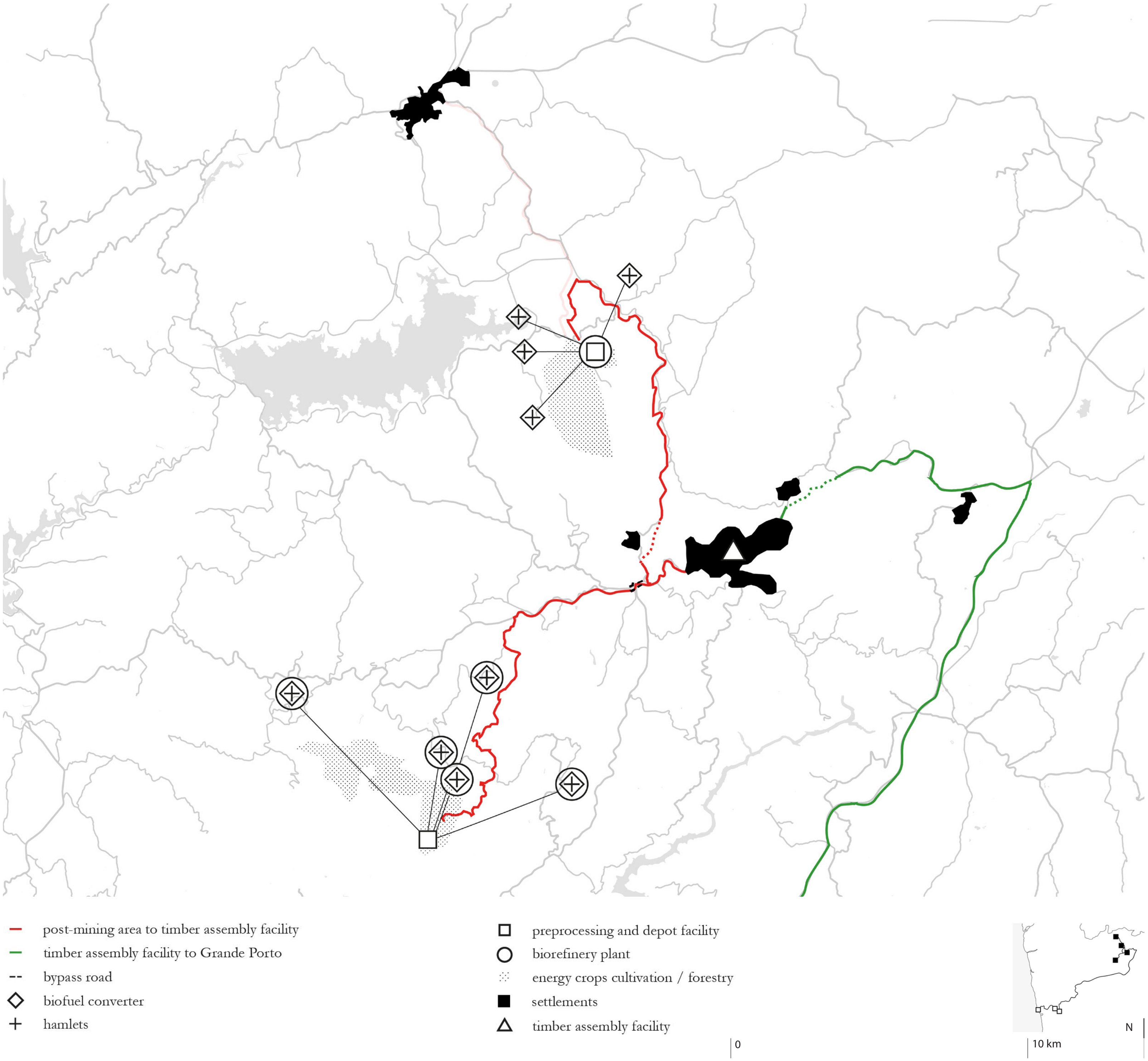


- post-mining area to timber assembly facility
- timber assembly facility to Grande Porto
- bypass road
- biofuel converter
- hamlets
- preprocessing and depot facility
- biorefinery plant
- energy crops cultivation / forestry
- settlements
- timber assembly facility



LOCAL REFINERY FOR LOCAL BIOENERGY

The second alternative proposes local refining within each hamlet, where biomass is both harvested and converted to biofuel locally, then converted locally into electricity for usage in the hamlets. This principle of functioning on decentralized scale is shown in the map on the right and can be projected over hamlets in the subregion. This decentralized approach supports local employment and community building, reduces transportation requirements, and enhances community resilience by making each hamlet energy-independent. On the downside, this alternative might face higher production costs per unit since alternative have spatial foundations to set up these small-scale operations. At the same time may managing these multiple small-scale operations be more complex, but involves more local empowerment. Both alternatives offer distinct advantages and challenges, weighing operational efficiency and scale against local empowerment and environmental impacts.



STRUCTURAL BIOMASS ECONOMY

The structural biomass economy is supplied by production forests and the extraction of wood through forest management practices. The harvested wood is pre-processed in the selected forest area and transported to the wood assembly plant in Boticas. Here, the wood is prefabricated into wood assemblies that are transported to the construction site in Valongo and other areas.

By establishing a structural biomass economy, the emphasis can be placed on revitalizing the often-overlooked connections between extraction, production, and circulation areas, as highlighted in the book Wood Urbanism by Ibañez et al. (2019). Restoring these linkages could integrate architects and constructors more actively into the transformation of forestry landscapes. This integration influences the choices in timber assembly, dictating specific tree species selection for planting and harvesting based on material requirements. The graphic on the right illustrates these metabolic interlinkages by demonstrating how harvesting specific trees in the Norte region is linked to the production of certain timber components to construct the frame assembly of choice. This approach not only streamlines the use of natural resources but also fosters a cohesive interaction between urban development and forestry management. The urban development strategy for accommodation temporal modular houses suggests building mid-rise assemblies and mass-timer assemblies in Valongo. Based on this knowledge, we can select a forest, harvest trees, and replant the trees we plan to need to meet future demands.

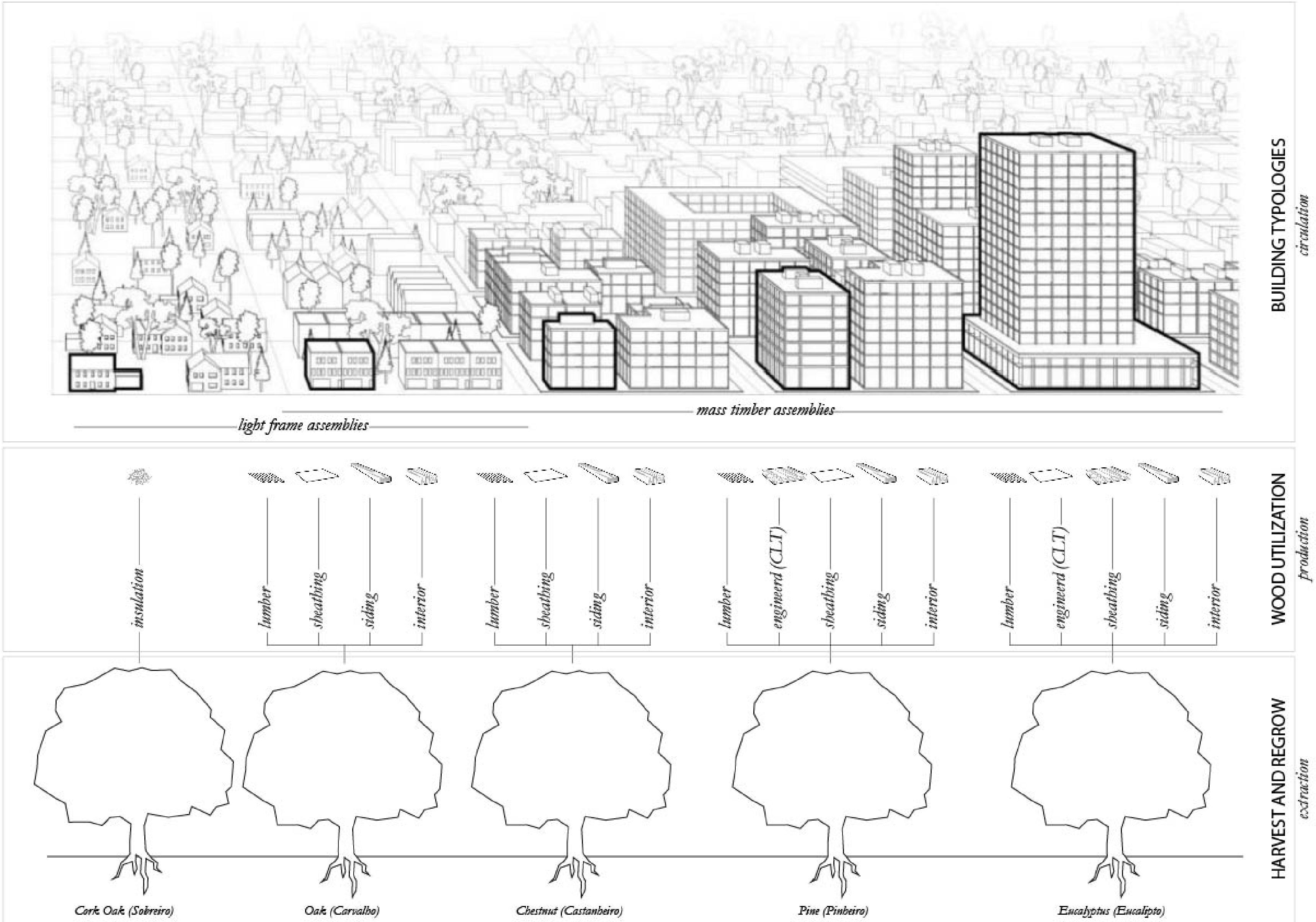


FIGURE 28: METABOLIC INTERDEPENDENCIES TREE HARVESTING AND TIMBER ASSEMBLIES
Illustration inspired by the book Wood Urbanism (Ibañez et al., 2019, p. 125) and adapted by author

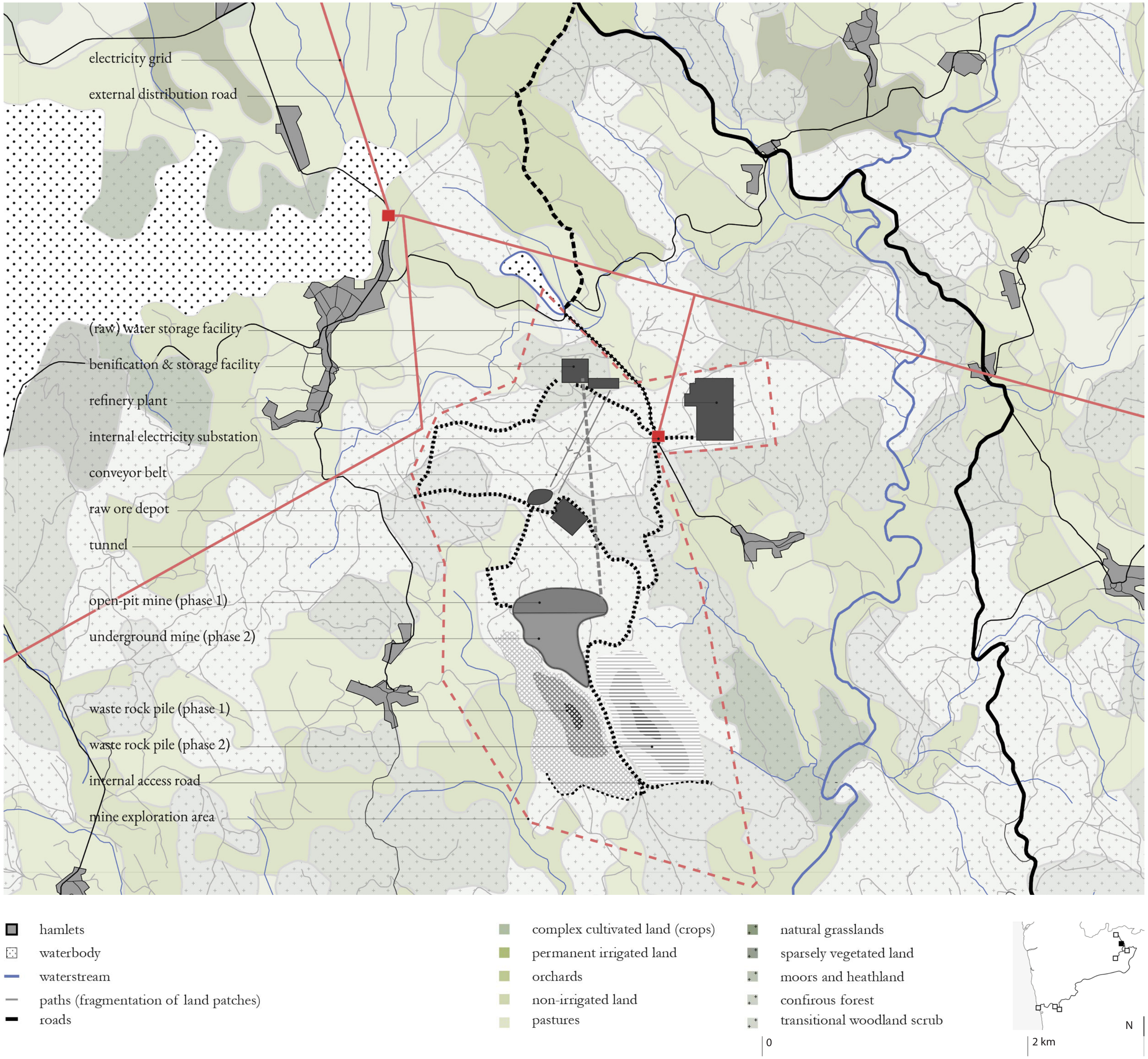
EXTRACTION AND REFINING OPERATIONS ROMANO MINE

The Romano concession consists bodies of apelite-pegmatite LCT form of swarms of dykes. The extraction of the ore out of these bodies will occur in two stages, that both are accompanied by different exploitation methods. During the initial stage, open-pit mining will occur by cutting into the surface to a depth of about 40 meters (920 meters elevation). In the second stage, exploration methods will shift to underground mining techniques.

The mine site includes facilities that extract the concentration of lithium out the raw ore using several specific methods in the beneficiation process (e.g., crushing and milling, granulometric separation, optical sorting, magnetic and gravity separation and foam flotation processes, among others). Subsequently, the refinery plant coverts the output of the beneficiation plant into lithium carbonate, the component that will be used in battery cells.

The operation of the projects involves the use of electricity to power the equipment, machinery and buildings on site. The project will fulfills the energy demand by introducing a new substation on site that connects to the regional grid that is linked with windmills park in the area.

All drinking water consumed in the social facilities on site will have origin in the Águas do Norte, S.A. drinking water pipeline, which is produced from of water collected in Albufeira do Alto Rabagão and treated at the Water Treatment Station Rabagão Water. The pipeline will runs north of the mining area and is available to supply the mine the maximum amount of drinking water required (200 m3/day). The supply of and use of water for all concession activities will fundamentally be the recycling of all the water in the industrial complex, whether domestic sewage or process water, as well as water from used in mining activity. The mining area will have a raw water reservoir that will have its supply form rainwater, treated by the internal wastewater plant and from the mining activities.

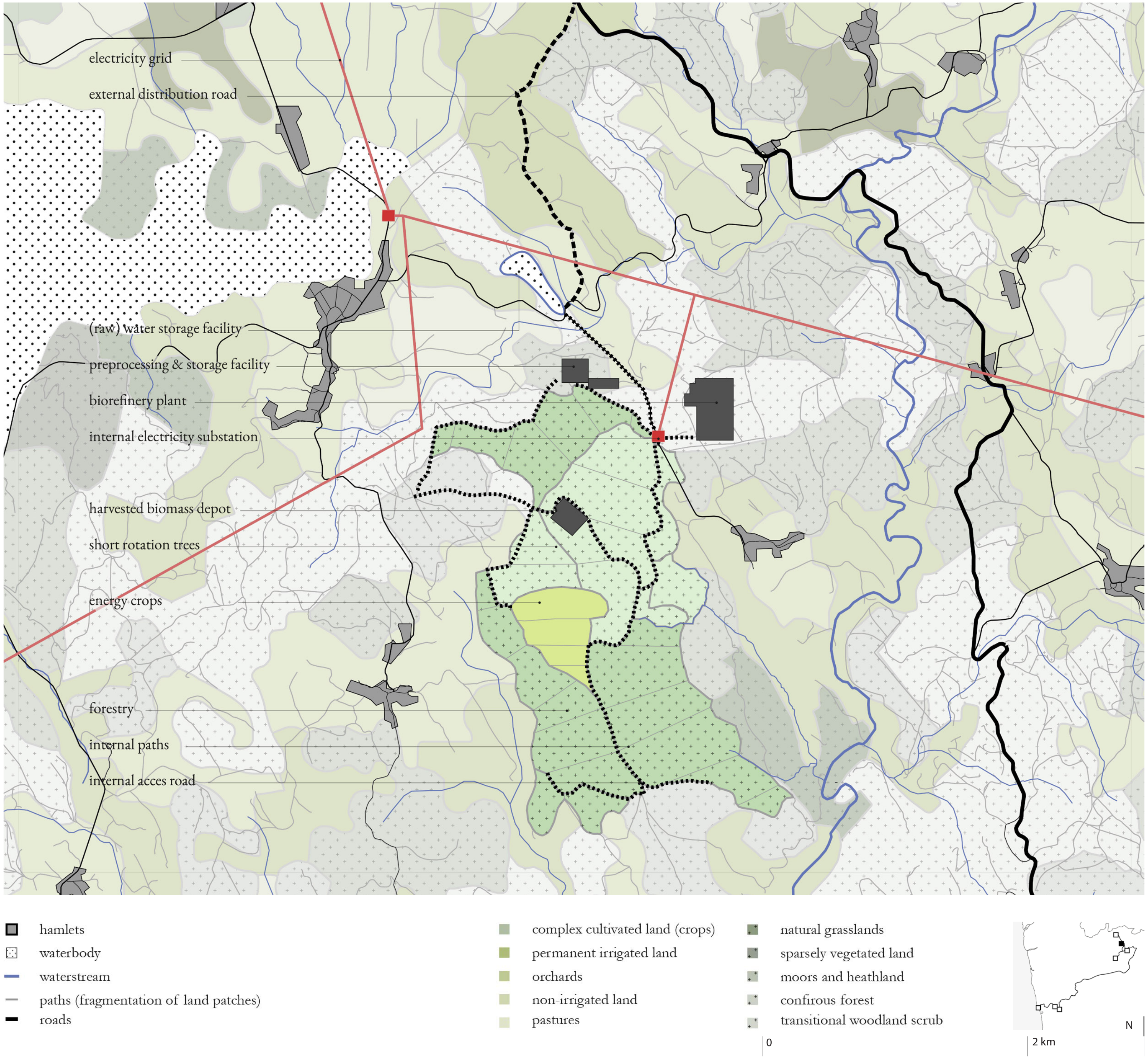


CLOSURE AND LAUNCH OF POST-EXTRACTIVIST STATE ECONOMY

The mining activities will produce waste in form of waste rock and tailings. The host rock that does not contain ore is considered as waste rock. The waste resulting from the beneficiation and refinery process is called tailings. A mixture of these residues will be used to stabilize and fill the underground concavities of rock extraction.

The landscape will be rehabilitated by regenerative crops. Long-term remediation process start during the mining operations and evolves further after closure. By using biomass resources proposes the strategy a viable remediation strategy. By cultivating native plants that also can be used as biomass resources the soil can be revitalized. The strategy proposes to cultivate three types of biomass resources: energy crops like miscanthus and switchgrass, short rotation coppice (SRC) trees such as willow and poplar, and forestry on the post-mining area. The location determination of the cultivation patterns for each biomass source depends on its ability to remediate the soil and its water requirements. Based on this logic, the strategy proposes the cultivation patterns visible in the map.

The introduced connection to the energy grid can be reused to power the biomass facilities in the first stage. Later the biomass refinery on site could provides for its own energy demand. The internal road network introduced by the mining operations can be reused to harvest the biomass resources in the post-mining area. The external road network can be used to distribute the export of the biomass economy (biofuel to the hamlets and structural biomass to the wood assembly facility). The strategy identifies some of the facilities and buildings introduced by the mining operation that can be adapted for alternative use to support the biomass harvesting, storage, and preprocessing activities on site. Probably the refinery itself is too complex to transform into a biomass refinery, but the site can be reused to set up the biorefinery. Some other smaller facilities could be adapted to support the biomass operations. For instance, the raw ore storage facility on sit can serve as feedstock depot for the harvested biomass, the crushing shredding facilities can be reused to preprocess (shredding and cutting) the biomass feedstock, and the water retention basins to store rainwater in periods of drought.



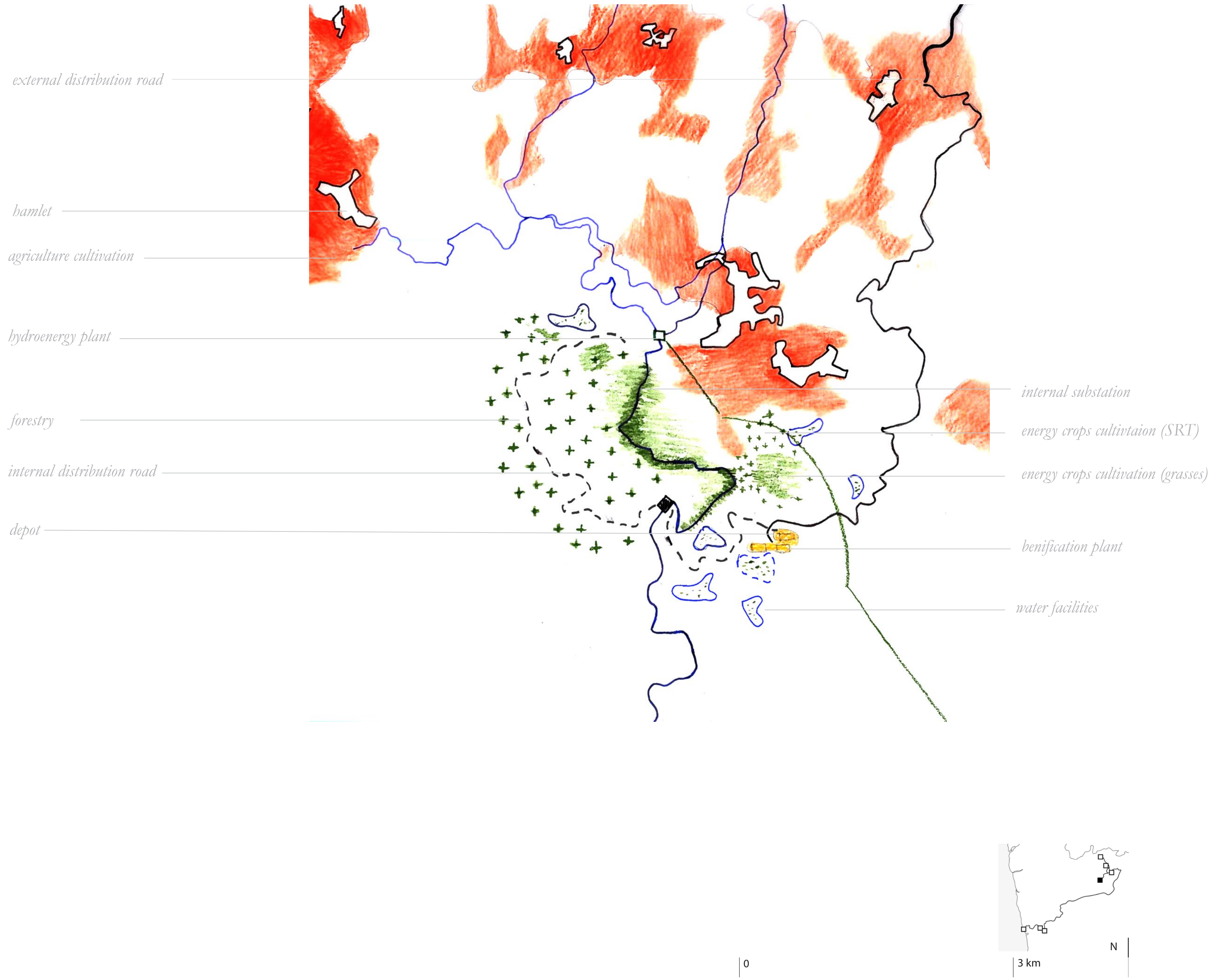
MINING AREA *(extractivist state)*

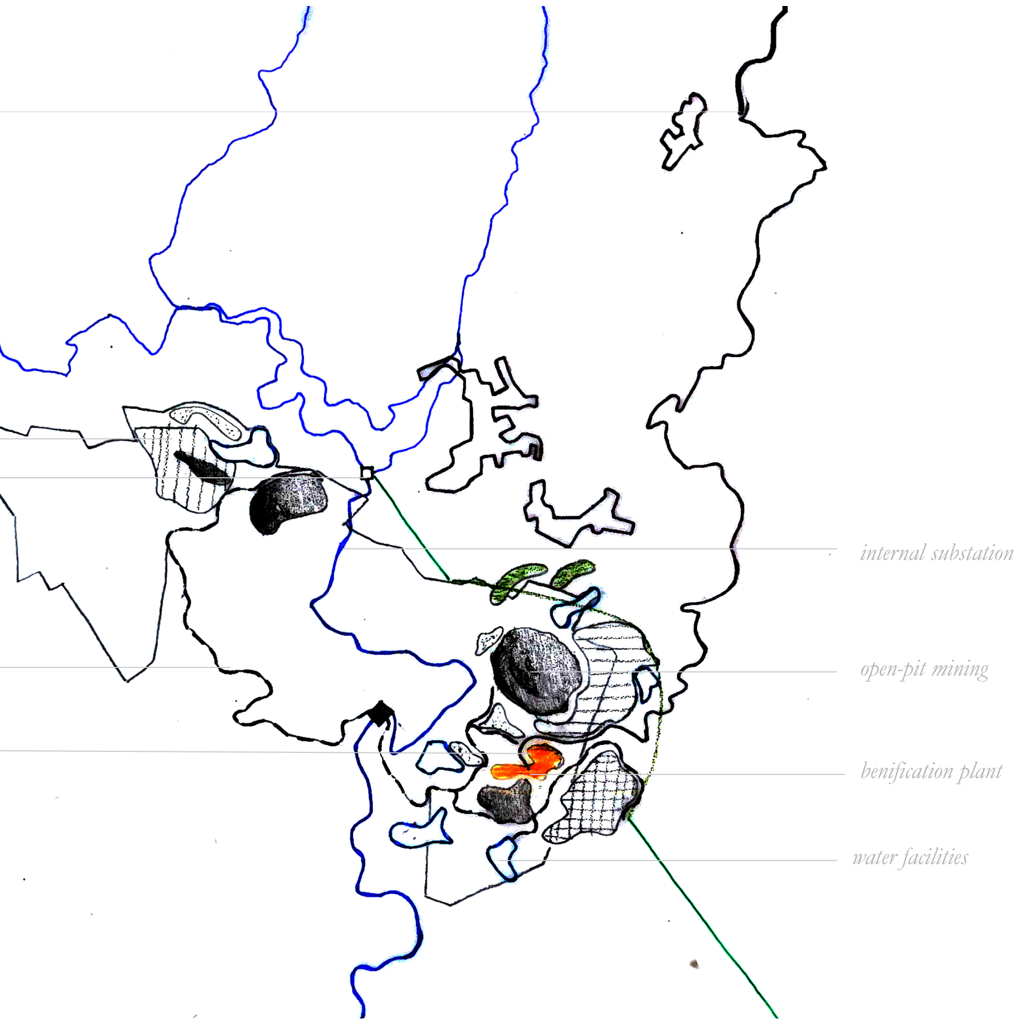
POST-MINING AREA *(post-extractivist state)*

Strategy *(extractivist state)*

EXTRACTION AND BENIFICATION OPERATIONS BARROSO MINE

The sketch on the right shows the elements that support the extractive and beneficiation activities during the extractivist state.





Strategy *(post-extractivist state)*

CLOSURE AND LAUNCH OF POST-EXTRACTIVIST STATE ECONOMY

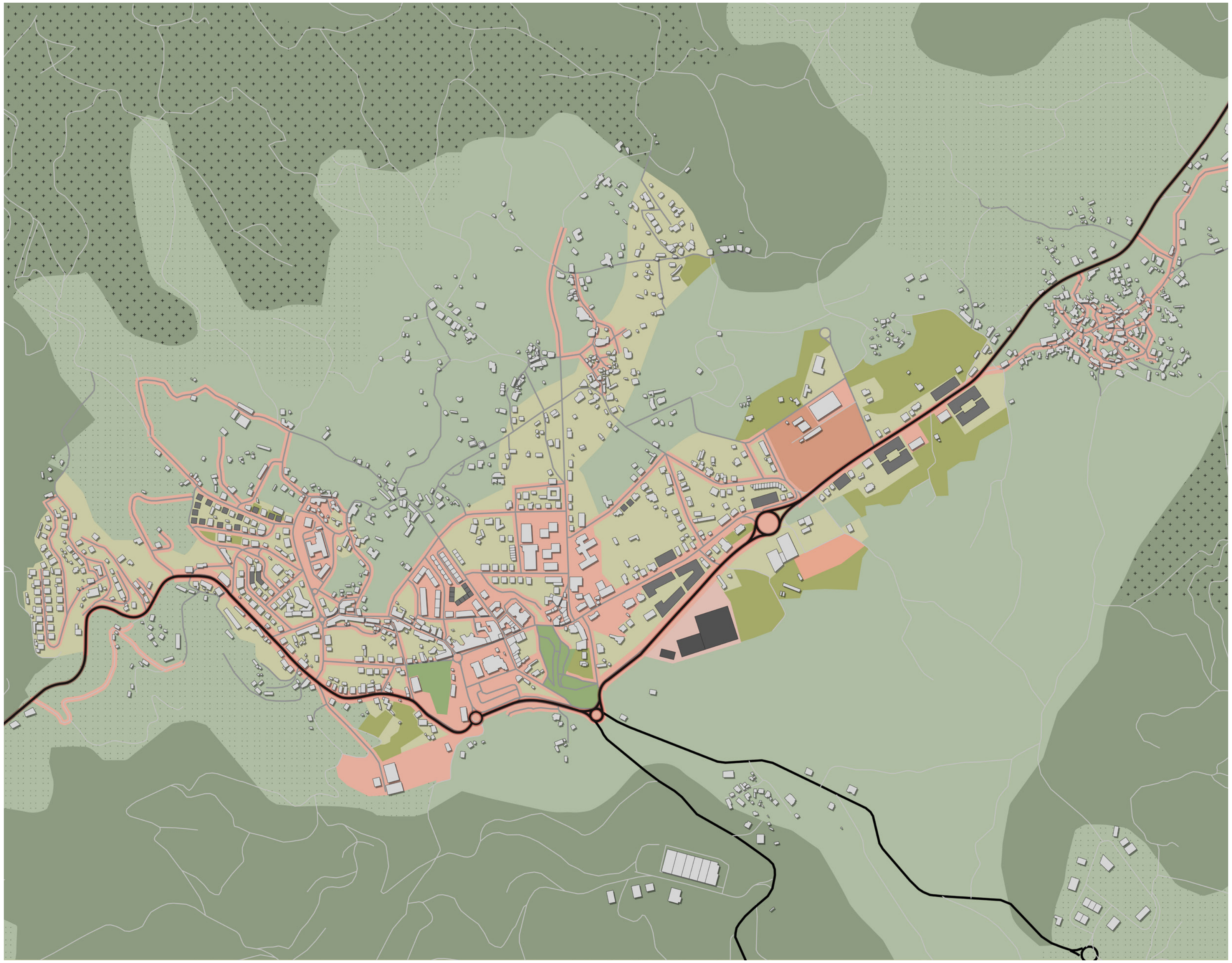
The sketch on the right shows which elements introduced in the extractivist state will be reused to support biomass cultivation in the post-mining area. The principles beyond the design are similar to the Romano mine.

Strategy *(extractivist state)*

BOTICAS ACCOMMODATION STRATEGY

The housing strategy for accommodating the mine-workers is guided by two typologies and logics, based on accommodations with a temporarily and permanent character. This approach caters to the distinct needs of three groups of people: those who will leave after the mine closes, those who stay and find a job in an other sector like the biobase economy, and those who imigrate to Boticas to work in the timber assembly plant.

The location selection for the temporary housing that will be disassembled in the post-extractivist state is tailored for those who will relocate after the extractivist state. These accommodations will primarily consist of modular mid-rise buildings strategically placed along major transportation axes. This placement facilitates easy access to transit, ensures efficient use of space and allows for assembling and disassembling without significant disruption. The disammbeled assemblies are designed to be reassembled in Valongo. The mid-rise typology aligns with the urban typology of Valongo and supporting a dynamic, adaptable housing strategy that can respond to shifting population patterns and housing demands.



- existing buildings
- additional modular timber buildings
- additional timber assembly & storage facility
- residential roads
- major transportation road / development axes
- public open space
- cemetery
- sports
- small/community scale agri-cultivation
- vegetated/developble land
- park
- coniferous forest
- crop residues
- complex cultivation patterns
- vineyards
- transitional woodland scrub
- coniferous forest

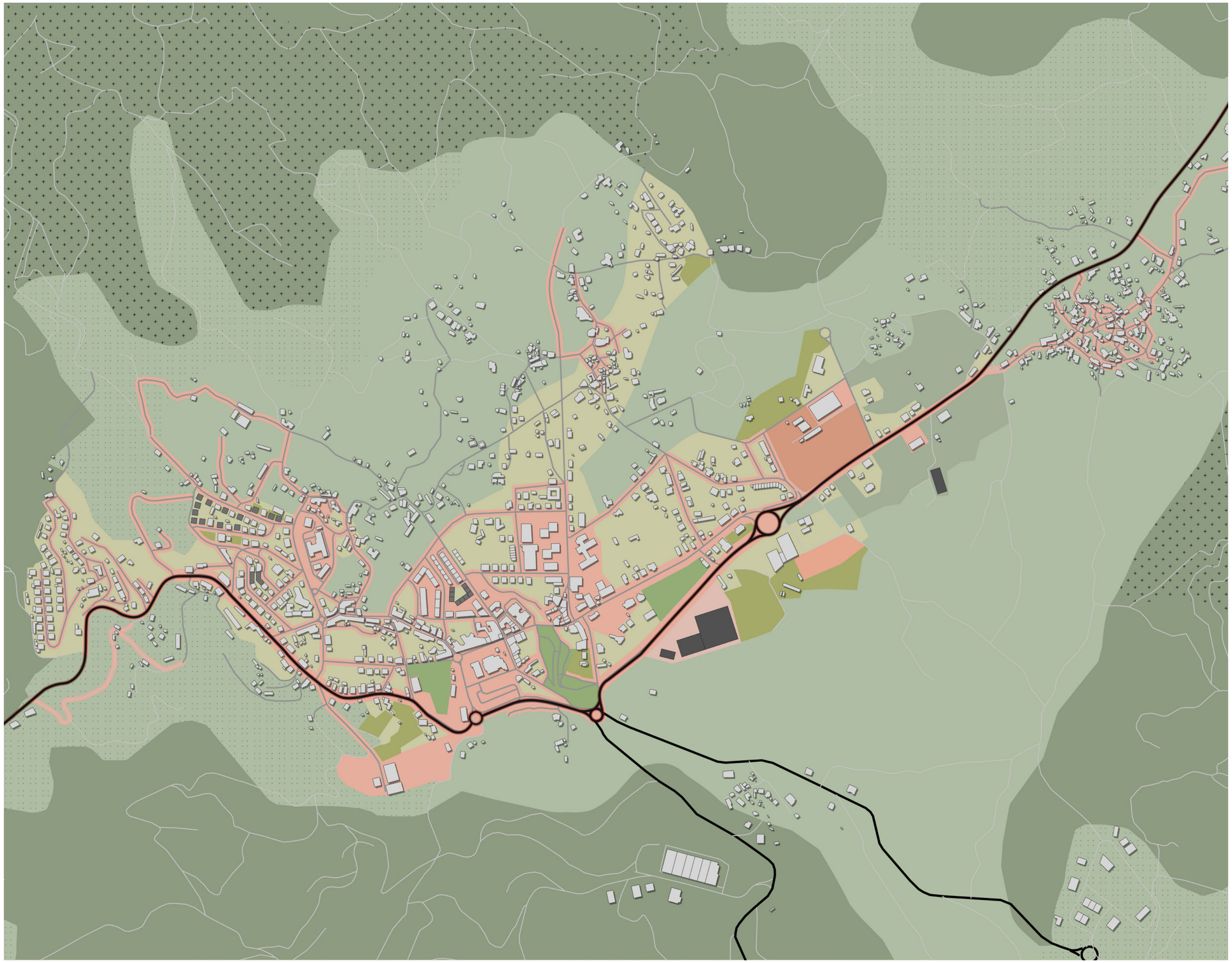
0

1 km

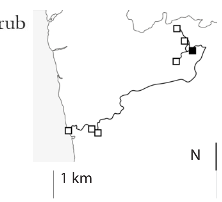
Strategy *(post-extractivist state)*

BOTICAS ACCOMMODATION STRATEGY

The location selection for the permanent housing which remain in the post-extractivist state is following the principle of infill development, integrating new family homes into the existing urban fabric near to Boticas' historical core. This method of densification helps preserve the morphology and character of the town while providing long-term housing solutions for permanent residents.



- existing buildings
- additional modular timber buildings
- additional timber assembly & storage facility
- residential roads
- major transportation road / development axes
- public open space
- cemetery
- sports
- small/community scale agri-cultivation
- vegetated/developble land
- park
- coniferous forest
- crop residues
- complex cultivation patterns
- vineyards
- transitional woodland scrub
- coniferous forest



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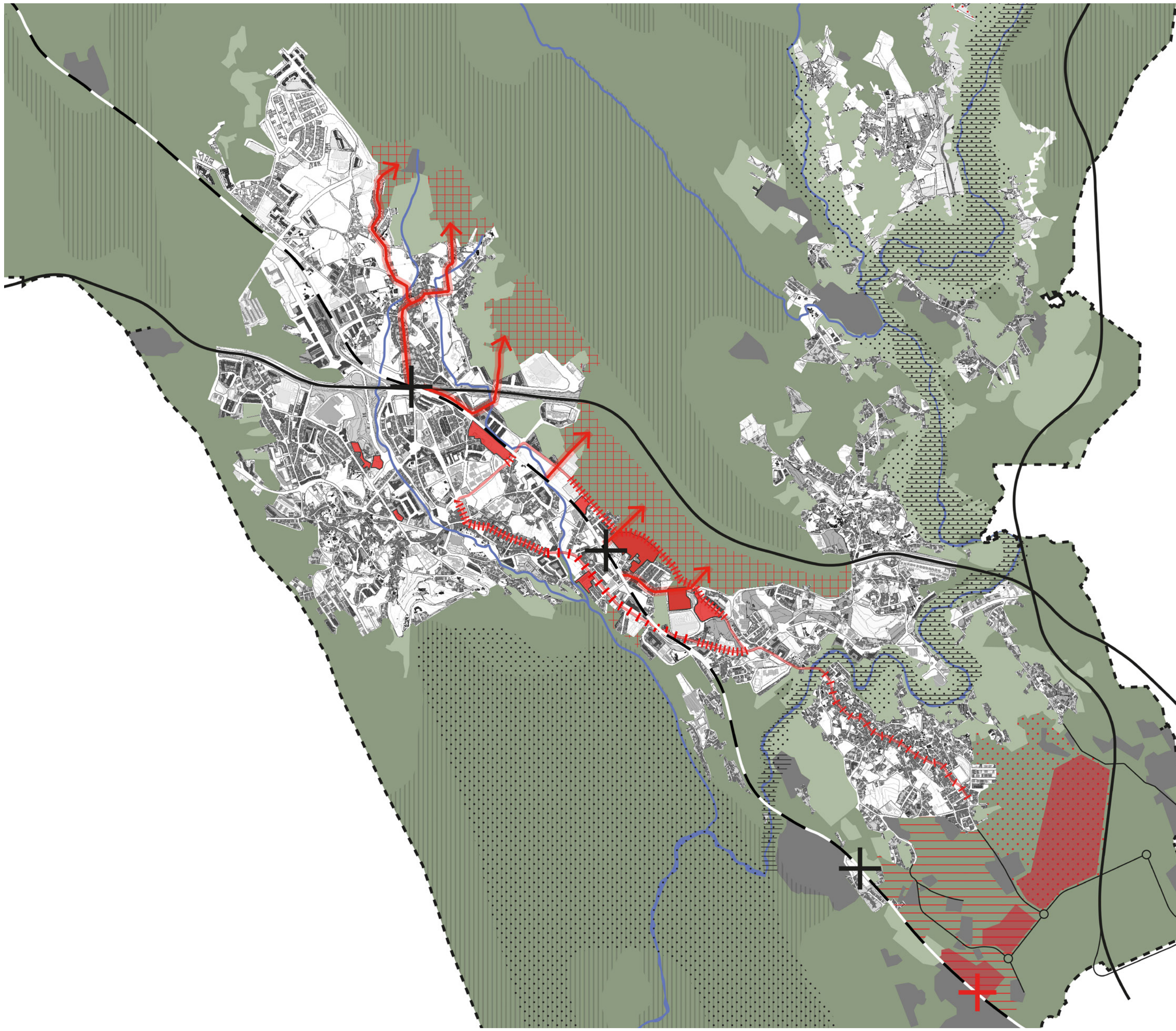
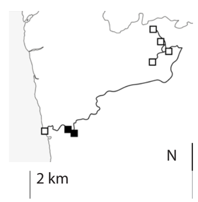
URBAN DEVELOPMENT STRATEGY VALONGO X CAMPO

The urban densification strategy for Valongo x Campo follows the logic of selection of areas that have a high accesibility to the train stations to encourage commute by public and shared transport to the industrial district, but also through rest of the metropolitan region. Therefore the strategy commits first on fill-in densification within an area of 15-min walk to the stations. Secondly, fill-in densification outside the area of 15-min walk to reduce urban sprawl and support compact city development. Simultaneously, support revitalization of existing urban fabric and infrastructure. In addition, urban infill development integrates additional housing through the existing fabric, and helps to mix different kind of people. Thirdly, develop by extending the existing urban fabric within the constrains of urban developable land. Constraining factors are areas of erosion risk, flood threatened areas and agricultural lands that remain operational.

The strategy suggest to connect the existing urban fabric and areas of development with the introduced industrial park district. This urban development axes will have public services in the plinth to activate circulation on this axes. Firstly, connect to existing streets with active plinths, secondly activate the plinths in the connected existing streets to revitalize these streets and lastly, the creation of public active plinths in the introduced extended urban fabric. This urban axes function on the city scale of Valongo x Campo.



- fill-in densification
- development by extending urban fabric
- mix of existing and new light industries
- (heavy) industry park district
- projection industrial plots
- administrative boundary municipality
- forestry
- agriculture
- urban fabric
- industrial fabric
- water course
- areas of maximum infiltration
- areas of risk erosion
- flood threatened areas
- motorway
- railway
- trainstation
- new trainstation
- development axes (with public functions)



INDUSTRIAL DEVELOPMENT

The development of the industrial district distinguishes two types of zones as shown in the map on the previous page. Firstly, a zone with a mixture of existing light industries, introduced light industries from the battery supply chain and services out of the quaternary sector like R&D centres and education and training centres in cooperation with knowledge institutions. This zone is located along the railway and is highly accessible by the newly introduced train station as shown in the zoom-in design on the next page.

The second zone integrates the heavy industries – cathode material and lithium-ion battery cell production and the chemical recycling (hub) facility – into a park landscape. This park landscape functions as a buffer between heavy industries, which in the ever-faster development of the industrial application becomes cleaner and quieter, and residential areas while also functioning as a recreational zone that allows visitors to walk over the industry landscape since the buildings will be nestled into the landscape. The current landscape of this zone is forested and has slopes from the edges to the center. In the current state is this landscape barely connected to the neighbourhoods in Valongo. There are opportunities here to make this a recreational zone for the neighbourhood and city, following the concept of the park-industrial landscape inspired by the reference project Indu Zero Landscape by Buro de Haan. This project had a similar scale that exceeds the scale of architecture. Therefore, the buildings are conceived as a landscape that is widely accessible to the public while at the same time fundamentally reducing the ecological impact.

ZOOM-IN VALONGO TRAIN STATION

(current state)

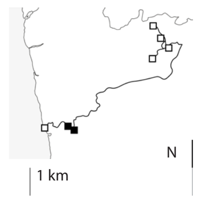
The maps shows the development of the non-integrated industrial / park area into a vital industrial hub that is highly accessible by the introduced trainstation.

- introduced trainstation
- innovation square (R&D/education)
- logistic hub
- additional light industries/services
- additional heavy industries
- administrative boundary municipality
- forestry
- agriculture
- existing buildings/fabric
- additional residential buildings

ZOOM-IN VALONGO TRAIN STATION

(extractivist & post-extractivist state)

- wadi/water collection pond
- development axes/connection to park
- pedestrian/bicycle path
- building part under landscape



REFERENCE INDUSTRY-PARK

The reference project shows the process of integrating the industry fabric into the landscape to create industry park landscape. The impressions on the right give a sense the spatial quality in which this results.

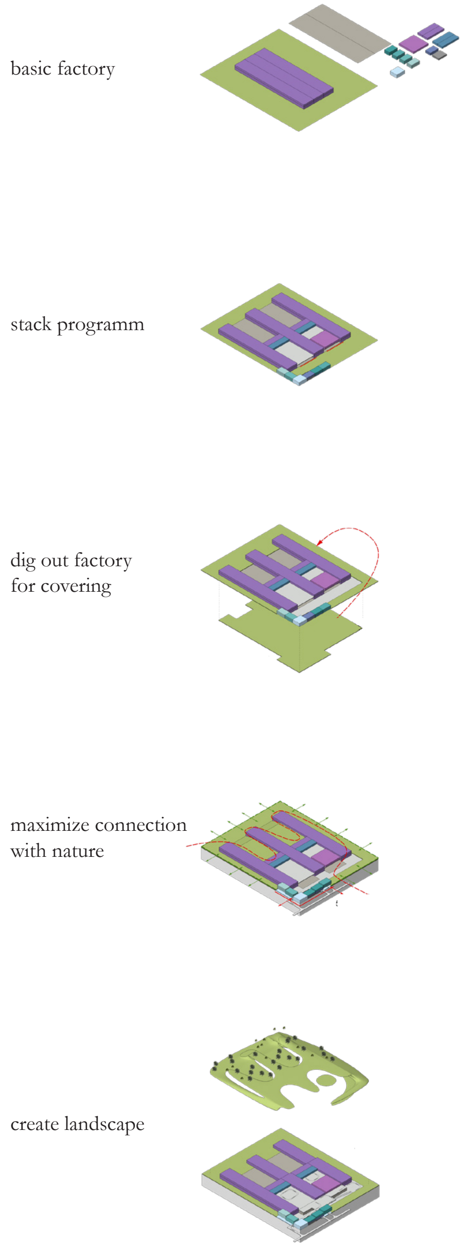


FIGURE 29: REFERENCE PROJECT, INDU ZERO LANDSCAPE
The illustration shows the process of integrating the industry fabric into the landscape by Buro de Haan (2021)

FIGURE 30: REFERENCE PROJECT, INDU ZERO LANDSCAPE
Impressions of the industry-park landscape by Buro de Haan (2021)

ZOOM-IN VALONGO TRAIN STATION

(current state)

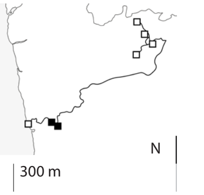
The maps showcase the urban densification around the existing train station and its connection to the introduced development axes that guides the further urban extentions northeast.

- train station
- railway
- existing roads
- additional roads
- development axes
- vegetated/developable land
- small/community scale agri-cultivation
- public space around public functions
- existing buildings
- additional modular timber buildings

ZOOM-IN VALONGO TRAIN STATION

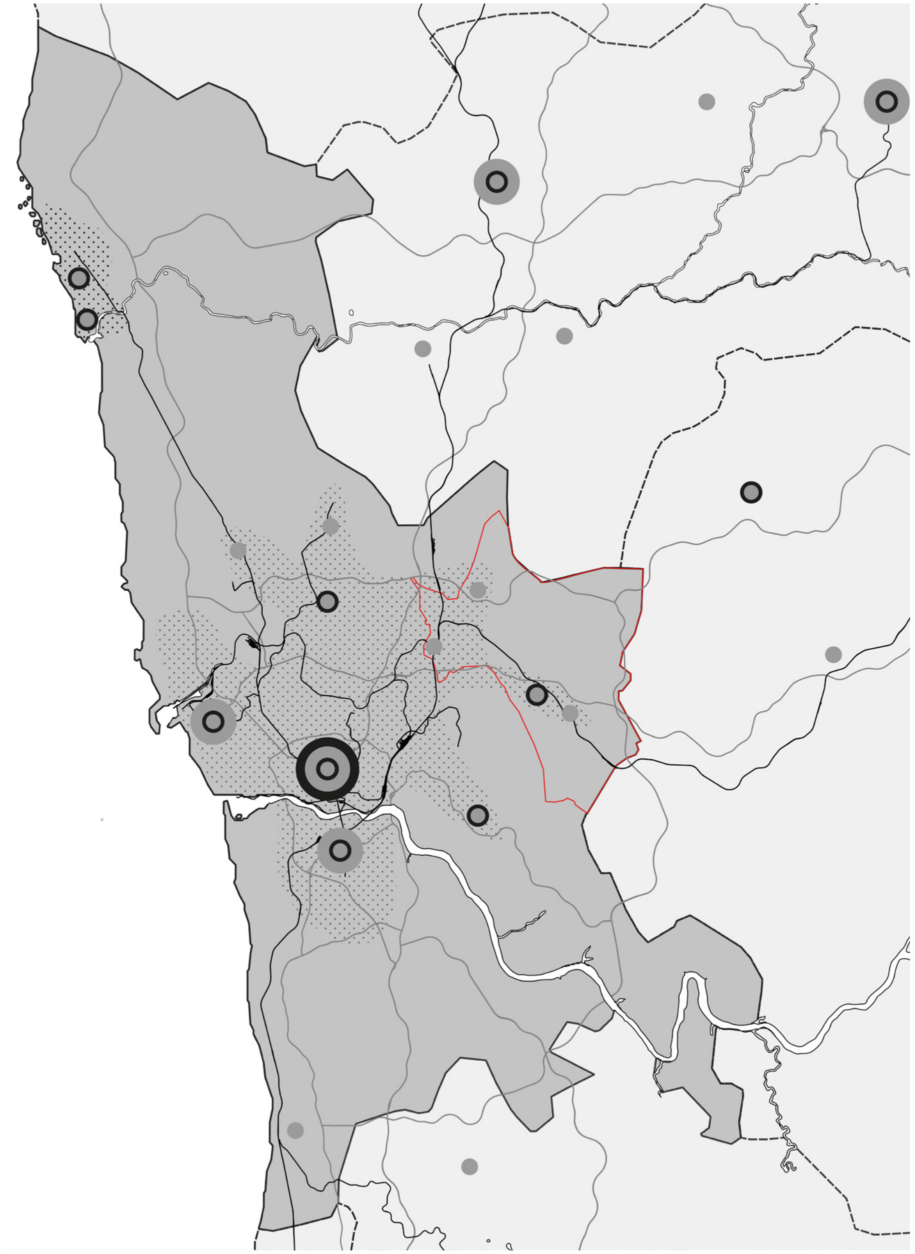
(extractivist & post-extractivist state)

- park



THE CURRENT ROLE OF THE MUNICIPALITY OF VALONGO

Traditionally, Valongo has functioned as a residential and commuter town, providing housing and community services for those employed in the more urbanized and industrialized areas of Porto. It benefits from its proximity to Porto by offering a suburban lifestyle while maintaining strong transport links that facilitate easy access to the metropolitan center. Valongo's economy has been primarily driven by local commerce, small-scale industries, and agriculture, contributing to the overall diversity of the region's economic base. The municipality also plays a role in preserving cultural and natural heritage, with its scenic landscapes and historical sites attracting local tourism. This complementary relationship with Porto helps to balance urban-rural dynamics, offering a quieter, less congested living environment that supports the metropolitan area's workforce and enhances the socio-economic fabric of the region.



national urban center of international significance
urban center of national significance
urban center of regional significance
urban center of municipal significance

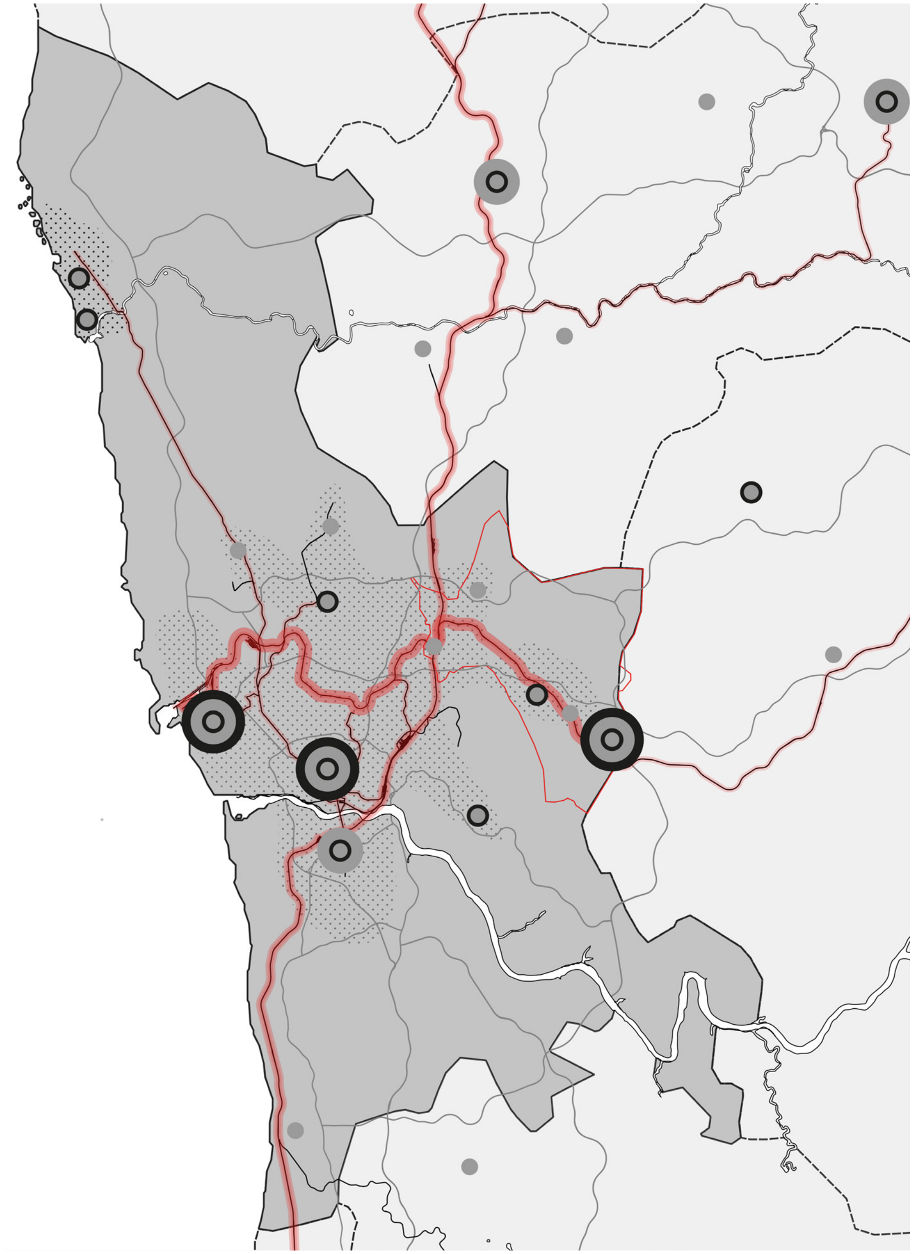
wider urban area
infrastructural road network
infrastructural railway network
administrative boundary municipality Valongo
metropolitan area Grande Porto (NUTS3)

regional/national significance
national/international significance
international significance

0 20 km N

THE EVOLVING ROLE OF THE MUNICIPALITY OF VALONGO

The introduction of the industry district centered around the lithium battery supply chain will significantly transform the role of the municipality of Valongo within the metropolitan region of Porto. This development will elevate Valongo from a primarily residential and commuter town to a vital industrial hub, integrating high-tech manufacturing and recycling industries. The clustering of the battery cell manufacturing, battery pack industry, and recycling facilities will attract approximately 2000 workers, necessitating the development of new housing and associated infrastructure. This influx will stimulate local economic growth, diversifying Valongo's economic base beyond local commerce and small-scale industries. Enhanced transport links, including the use of the port of Porto for exporting products and importing e-waste, will further integrate Valongo into the regional economic network. The municipality will evolve into a key player in the sustainable energy sector, contributing to regional innovation and economic resilience. This transformation will also foster job creation in construction, retail, and services, driving a broader socio-economic uplift and establishing Valongo as a dynamic and integral component of the metropolitan region of Porto.



- national urban center of international significance
- urban center of national significance
- urban center of regional significance
- urban center of municipal significance

- wider urban area
- infrastructural road network
- infrastructural railway network
- administrative boundary municipality Valongo
- metropolitan area Grande Porto (NUTS3)

- regional/national significance
- national/international significance
- international significance

N

0 20 km

Evaluating *(reflect)*

Conclusion

CONCLUSION STATEMENT

The research aimed to develop a spatial strategy that could guide the transformation of Portugal's Norte region through an evolving lithium economy, through an extractivist mode to an circular post-extractivist mode, while considering the socio-environmental vulnerabilities and broader economic impact. The proposed vision and strategy illustrates how the spatial interventions designed for the extractivist state, can be repurposed to transitioning to a circular post-extractivist state while generating long-term benefits.

At the European level, the proposed strategy fosters greater independence in lithium supply. Nationally, it enhances Portugal's position as a key contributor to achieving European green transition goals. Regionally, the strategy promotes long-term economic circular development by using extractivist facilities to establish a circular battery economy and stimulate the integration of circular material flows. Locally, the strategy minimizes the nuisances of extractive operations while enabling ongoing activities in the Alto Tamega region. In the post-extractivist state, the strategy support conditions for a circular bio-based economy that helps remediate the mining landscape, while connecting to the local economy and cultural identity, as well as creating additional income for these rural areas.

The vision encompasses two states. The first, the extractivist state, locates facilities in the downstream part of the supply chain, fed by the Barroso and Romano mines, functioning for extraction, processing, and exportation of lithium battery packs. In the post-extractivist state, the system decouples from the mines, becoming circular and import-oriented, fed by lithium extracted from e-waste. The spatial organization that supported the upstream part of the chain is transformed in the post-extractivist state to support a biomass economy. This bio-based economy operates on two dimensions: producing biofuel from agricultural residues and energy crops, and producing bio-based structural construction materials for timber assemblies used to meet the urban development in the metropolitan region of Porto downstream.

The set of key interventions – including urban development for (temporal) worker accommodations, infrastructural reinforcement and development, change in cultivation patterns, water and energy infrastructure development and industrial development – identified in the thesis are necessary to shape both states. This set of interventions could inspire other European countries to establish the necessary extractivist landscapes progressively, ensuring circular long-term development. However, before implementing the strategy, decision-makers and planners should consider engaging with local communities to test and refine the strategy.

RESULTS IN RELATION TO THEORETICAL FRAMEWORK

The thesis shows that there is such thing as just or green mining. Extractivist practices will always results in local ecological disruption. Nevertheless, the thesis still advocates for the need for critical minerals for the production of green energy technologies following an alternative form of extractivism based on economies that not heavily rely on extraction of natural resources but rather prioritize extraction out of waste streams based on circular principles. In addition the thesis suggest an alternative economic model, that suggest that clean energy technologies should not be the only mean to reduce greenhouse gas emissions, but also reducing the demand for critical minerals like lithium.

PROJECT LIMITATIONS

This thesis is based on the idea that Europe is committed to electrification and battery storage as key technologies of the clean energy transition to combat climate change. The demand for lithium (landscapes) is highly dependent on the deployment of certain types of clean energy technologies. Ultimately, policymakers will determine whether lithium remains an essential factor in the clean energy transition. Additionally, the demand of lithium is depending on the product design industry. Alternative battery designs could reduce or eliminate the appropriation of lithium.

AVENUES FOR FUTURE RESEARCH

A potential directions of the project could be opening up the project and co-design the post-extractivist economy in collaboration with the local stakeholders and examinate the proposal for biomass economy on the two levels – biofuel and structural biomass. Moreover, investigate further on how the proposed co-operative of farmers in the subregion Alto Tamenga could be established and function This could be enhanced by the creating of policy and regulatory frameworks for better stakeholder involvement and emphasize more on making the strategy more socially just. Furthermore, the design could elaborate on the aspects of repair of the mining landscape.

RELATION BETWEEN TOPIC AND TRANSITIONAL TERRITORIES STUDIO

The topic of this thesis, landscapes of extractivism, is related to the topic of the studio 'altered nature'. As extraction landscapes create critical environments, socially, ecologically and economically. The thesis proposes a systemic approach for spatial transformations and their associated methodologies and representations that integrates industrial activities with local ecological and social systems. This approach reflects a broader understanding of how landscapes can be transformed to both recover from mining degradation and prepare for long-term circular development. By doing so, the research contributes to the discourse on how critical environments can allow for design conditions that manage and enhance their resilience and functionality in the face of ongoing environmental challenges.

RELATION BETWEEN TOPIC AND THE PROFESSION URBANISM

The supply of critical raw materials like lithium in Europe from natural resources (extractive landscapes), but also from secondary supplies (e-waste) is, as described in the thesis, accompanied by a spatial organization on different scales. To establish ambitions like the establishment of domestic lithium extractive landscapes, there is a role for urban planners to explore the spatial interventions generated by this ambition and fit them into the local context while ensuring social, environmental and economic long-term sustainable development.

RELATION BETWEEN TOPIC AND MSC PROGRAMME AUBS

Traditional architectural and urban design isolates itself to the design of the object scale. However, it is becoming increasingly clear that in order to address the timely social, environmental and economic issues as discussed in the master program, research into the social and metabolic interdependencies of the object is necessary. Choices made on object scale will reflect in the social, environmental and economic dimension as is shown in the thesis.

ON RESEARCH AND DESIGN

The research integrating analysis across the spatio-temporal dimensions. The socio-economic analysis of the regions helped understanding the regional population dynamics, identity of the Alto Tamenga region shaped by the agriculture sector and landscape and landscape characteristics. The catalogue of supply chain landscapes that identifies the key features of each industry helps to plan and facilitate for the requirements of each landscape, mainly workforce, energy and water demand. The analysis of the materials flows helped to argument for strategically situating and clustering the industries in the battery supply chain can significantly enhance operational efficiencies, exchange of materials and encourage collaboration with the quaternary sector to support innovation in the field. In this way these insight have strongly informed the design of the strategy, ensuring that the strategy would be appropriate for the region of implementation and its long-term sustainable development.

On the other hand, the design of the lithium supply chain system in the extractivist state operated as a whole, by decoupling downstream and upstream, the strategy proposes a better social integrated and circular local economy. This allowed for further research on the biobased economy and its feasibilities by repurposing the introduced spatial elements from the extractivist state.

ON PROCESS AND METHODS

The thesis addresses the topic by analyzing the each facility of the lithium-ion battery chain and its metabolic and spatial footprint in the form of a catalogue. Subsequently, the thesis examined a suitability analysis to determine the strategic location of the facilities downstream considering both the extraction and circular post-extractivist state. Then, the landscape and its generated support and transportation systems is designed and evaluated on the local scale. For example, by looking at how the temporal houses could best be integrated into the existing urban fabric of the supporting town, but also the design of the industrial-park landscape and its connection development axes is an example of this.

I chose the method because I expected that the industries downstream would not necessarily be clustered and therefore the design of the system would consist of multiple nodes. However, the material flow analysis showed that it was better to cluster the downstream facilities and proved a location that suited to establish this clustering of industry. The methodology addresses transformation at multiple scales, allowing the impact of the strategy to be evaluated at different scales. However, the scale of the project makes it difficult to evaluate each spatial element at the human scale. This gives a chance of conceptual reduction helped to design the chain, but at the same time can lead to uncontrolled interactions that make the proposed strategy unpleasant. This is particularly a risk of oversimplification for infrastructural elements over which goods will be transported. In reflection, the methodology lacks a form of co-design with local communities. As a result, the proposed strategy is to some extent based on the analysis and my interpretation of what the local community would want and be involved in, without exclusive evaluation of support from the local population.

SOCIAL RELEVANCE

It is clear that the availability and access of critical raw materials such as lithium have a huge impact on the functioning of the world we live in. It strongly affects the success of a decarbonizing energy system and is thus an important factor in combating climate change. Secondly, it affects the availability and

development of all the battery-containing products humanity uses on a daily basis.
However, implementing mines raises resistance and has limited public acceptance, especially on a local scale. This is understandable because the implementation of mining involves large-scale land use change. It is therefore the research investigates how the implementation of the extractivist state provide benefits in form of spatial organization that is useful to launch a circular post-extractivist state. Therefore the thesis address the transformative impacts of the lithium economy on local communities in the hamlets, mining supporting towns and industry supporting city. By strategizing the shift from an extractivist to a circular post-extractivist, the research directly engages with crucial social issues, including job creation, socio-economic stability, and community well-being. This transition is not merely an industrial change but a socio-economic evolution that considers the livelihoods and cultural fabric of local populations. The research emphasis on integrating community and ensuring the economic benefits. Furthermore, the research highlights the importance of sustainable practices that safeguard the long-term sustainable development, emphasizing not just economic but also environmental stewardship as integral to social well-being .

SCIENTIFIC & ROFESSIONAL RELEVANCE

In our pursuit of clean energy, we not only face a massive challenge in the quest for clean energy, but also a huge spatial issue that is associated with this. Not merely the deployment of clean energy technologies require space, but also the extraction of natural resources for the production of clean energy technologies involves a massive spatial dimension. The latter is a spatial issue that, with the rising demand for domestic critical raw material supplies in Europe, raises many questions. Where can we mobilize these mining landscapes? Are we able to adopt and get used to these landscapes? How will the European's daily life be affected by these extractive practices? I believe it is the task of our profession to contribute to provide a better understanding of the spatial impact (and the spillover effects of that) through the scales of implementing transitions like this, which in this case is the need for domestic critical materials capacities in Europe to support the clean energy transition. By proposing a spatial strategy, the project demonstrates how urban planning can play a pivotal role in facilitating sustainable economic transitions. The casestudy can be used to inspire the mobilization of more lithium landscapes in the hinterlands of Europe. However, for each individual project, the context-specific conditions should be considered and serve as the basis on which spatial interventions can be proposed.

Apart from the contribution in the field of spatial planning, this thesis tries to provide scope that advance a more sustainable just way to appropriate lithium in Europe's hinterlands. This scope could contribute to the broader understanding and discourse of just resource management and circular economy principles.

PROJECT TRANSFERABILITY

With the rising demand for critical raw materials will the need to establish extractivist landscapes and recycle-base practices grow. The occurrence of the materials is geographically anchored and quite limited to some areas where a significant amount exist. Establishing extractive economies can be extra interesting in areas that demand an economic stimulus, since as shown in the strategy the investment in spatial organization elements for these temporal landscapes can be used to launch more persistent landscapes associated with a circular post-mining economy. The thesis uses the emerging lithium extractivist landscapes in the Norte region of Portugal to showcase the archetypical spatial interventions generated by the establishment of extractivist landscapes. These interventions give a idea which spatial transformations are associated with such transition. The set of spatial interventions can be copied, since they probably will be similar to establish extractivist landscapes elsewhere. However, to ground each typology of interventions the local physical as social dimension should be considered. Furthermore, the strategy can also be transferred to post-industrial landscapes in imagining the spatial implications of certain economic investments which stimulate urban development around it. At the conceptual level, it can also help in understanding any form of productive/ operational landscape which is technically intensive and demand capital accumulation.

ON CIRCULARITY

The thesis critically reflect on circularity by illustrating the transition from an extractivist to a post-extractivist state within the lithium economy, emphasizing principles central to a circular economy. Initially, in the extractivist state, the strategy focuses on efficient resource extraction and processing, aiming to minimize waste and optimize resource use. The shift to a circular post-extractivist state is marked by strategically repurposing existing infrastructure for recycling lithium from e-waste, thus extending the material lifecycle and reducing dependency on new raw material extraction.

The thesis underscores the necessity of community involvement and fair distribution of benefits, ensuring that circular practices are inclusive and socially equitable. A key aspect of circularity proposed in the strategy integration of agricultural residues and energy crops into a bio-based economy. This approach transforms waste products into valuable resources, such as bioenergy and bio-based construction materials, showcasing waste minimization. The thesis emphasis the economic benefits of circular practices, including job creation and local economic resilience, while addressing environmental sustainability through reduced extraction pressures and lower carbon emissions.

ON GREEN TRANSITION

Establishing extractivist landscapes to meet the demand of critical minerals is justified through the name of green transition. However, extractive landscapes always are local environmentally disruptive and results in a physical displacement of local environments that previously sustained ecosystems that contributed to climate stabilization. That is why anti-mining movements question if mining is the right solution considering its local impact, as long as there is no green mining. In this manner does European environmental policies generate climate reductionism, narrowly focusing on reducing greenhouse gas emissions, while resulting in local socio-ecological catastrophes, as in Norte region case. In this context, often the term green grabbing is used to refer to land acquisition to 'serve green ends' using environmental agendas to justify capital accumulation (Dunlap and Riquito, 2023). However, the thesis suggest that mining critical raw minerals is necessary to support the green transition and reduce global greenhouse gases. The thesis brings forward a possible way to approach extractive landscape through circular thinking and discussed the need for an alternative economic model as discussed in chapter 02. Nevertheless extracting minerals required for clean energy transition will always be a trade off between reducing greenhouse gas emissions for global benefits and local environmental disruption (Chaves et al., 2021, p. 9).

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List of figures

All the figures in this thesis are drawn by the author unless stated otherwise, and included in the reference list below.

FIGURE 01: NOT IN MY BACKYARD
Illustration by Wes Andrews (2022)

FIGURE 07: FIELD OF SUSTAINABILITY
Field of sustainability (By E. Gudynas). (2013). Transitions to Post-extractivism: Directions, Options, Areas of Action. https://gudynas.com/wp-content/uploads/GudynasTransitionsPostExtractivismDirectionsOptionsAction.pdf

FIGURE 08: DOUGHNUT ECONOMICS
Raworth, K. (2017). *The essence of the doughnut. Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist.* https://www.google.com/url?sa=i&url=https%3A%2F%2Ffenix.tecnico.ulisboa.pt%2FdownloadFile%2F845043405579281%2FRa

FIGURE 10: ANNUAL METAL PRODUCTION AND RESERVE DATA FOR 1956–2018
Jowitt, S.M., Mudd, G.M. & Thompson, J.F.H. Future availability of non-renewable metal resources and the influence of environmental, social, and governance conflicts on metal production. *Commun Earth Environ 1*, 13 (2020). https://doi.org/10.1038/s43247-020-0011-0

FIGURE 20: NORTHVOLT ETT, CATHODE AND BATTERY CELL MANUFACTURING
Source by Northvolt

FIGURE 21: NORTHVOLT DWA, BATTERY MODULES AND PACK MANUFACTURER
Source by Northvolt

FIGURE 22: LI-CYCLE GERMANY SPOKE, LITHIUM-ION BATTERY RECYCLE PLANT
Source by LI-CYCLE

FIGURE 23: LI-CYCLE ROCHESTER HUB, LITHIUM-ION BATTERY RECYCLE PLANT
Source by LI-CYCLE

FIGURE 28: METABOLIC INTERDEPENDENCIES TREE HARVESTING AND TIMBER ASSEMBLIES
Illustration inspired by the book Wood Urbanism (Ibañez et al., 2019, p. 125) and adapted by author

FIGURE 29/30: REFERENCE PROJECT, INDU ZERO LANDSCAPE
Source by Buro de Haan (2021)