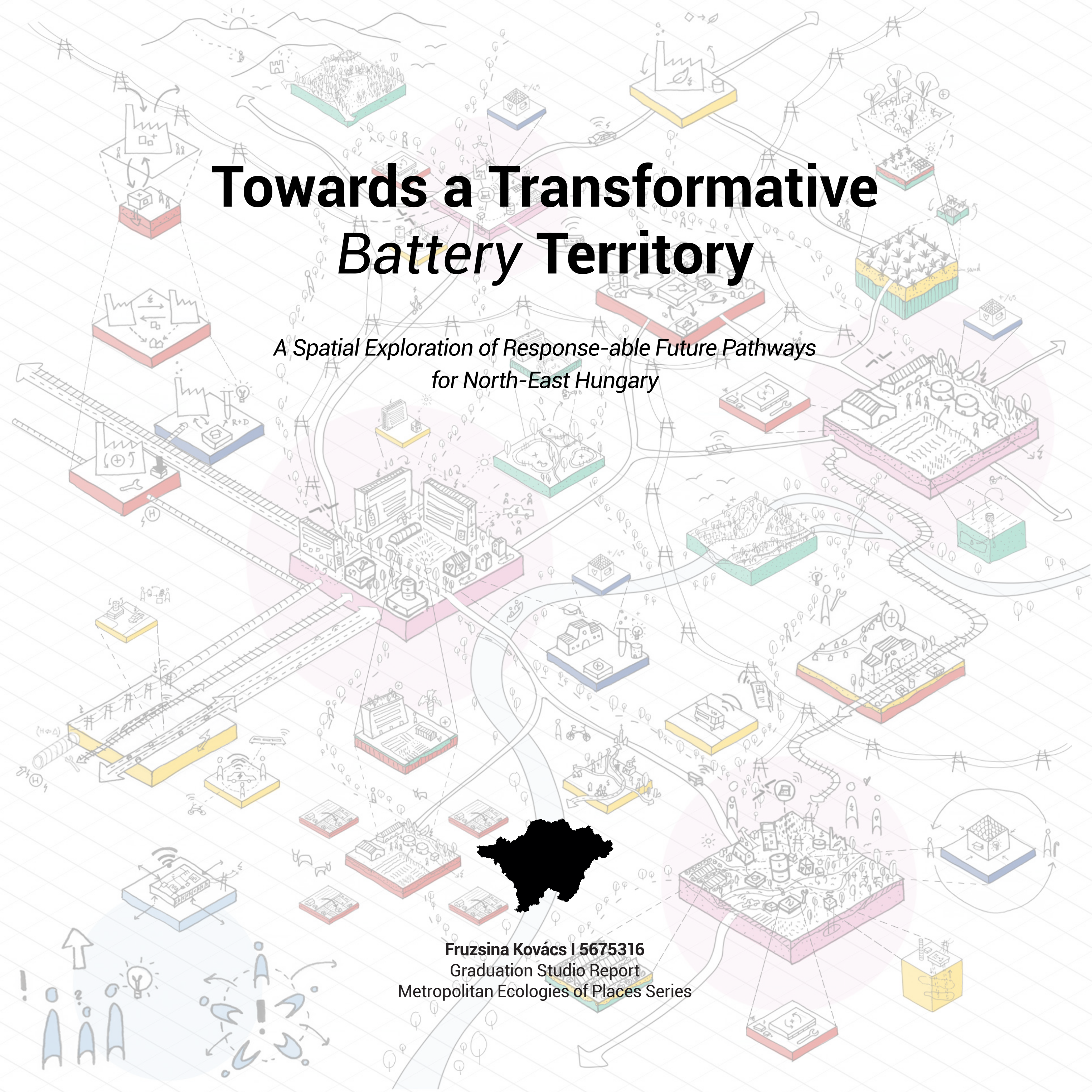

Towards a Transformative *Battery* Territory

A Spatial Exploration of Response-able Future Pathways for North-East Hungary

Fruzsina Kovács I 5675316
Graduation Studio Report
Metropolitan Ecologies of Places Series

Master Thesis P5 Report

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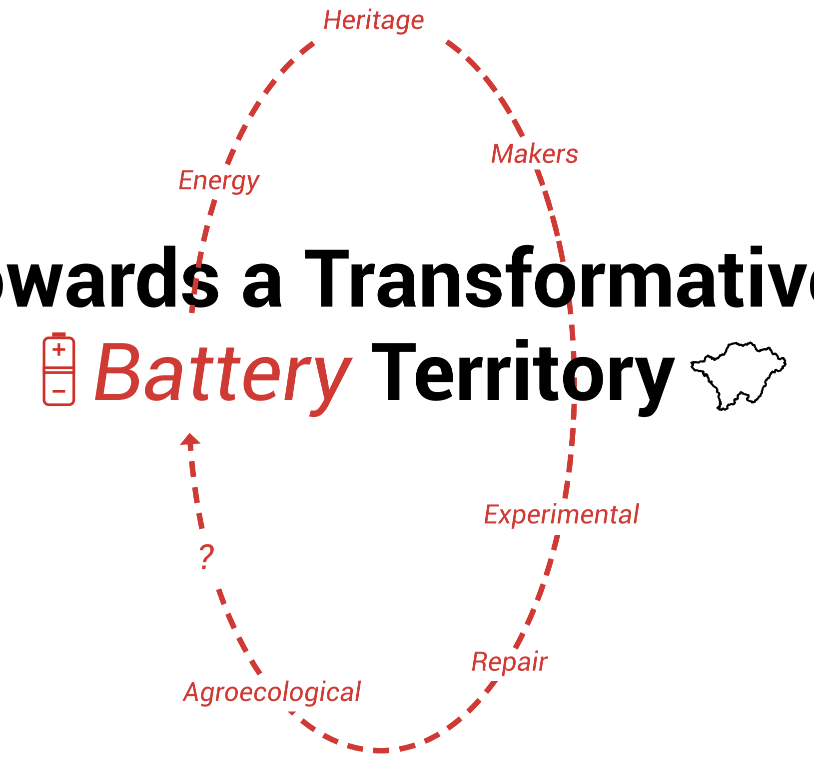

Fruzsina Kovács I 5675316

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Acknowledgements

ENG

Although there is only one author stated, this thesis represents the contribution of multiple wonderful people, without whom it would have been immensely more difficult to navigate this graduation year. For this, I owe them a sincere thank you.

Firstly, I would like to thank Alex and Francesca, my two mentors, for their unwavering guidance and support throughout this 10-month journey. I deeply appreciate the time and effort you devoted to our discussions, navigating multiple meter-long sketches, and allowing me to dwell in the complexity of the project. I would also like to express my gratitude to the teachers of the MEP studio, for organising lectures, workshops and excursions throughout the year.

Secondly, the Hungarian experts who took the time to listen to my proposal and provided me with invaluable insights and enthusiasm. Initially, I did not expect that conducting interviews would have such a significant impact on the thesis, but thanks to this experience, I could grasp the importance of doing a project that deals with crucial problems in my home country.

I cannot pass by my 'teammates' - Alina, Max and Sanne - who went through this process alongside me. Thank you for engaging in interesting discussions, giving feedback and listening. I am grateful for the little 'support-group' we formed through Alex.

Working during graduation is not an easy feat, but having an office that supported me and provided the necessary flexibility made it much easier. I would like to thank everyone at VOIDS for their patience and insight at the early stages of the project.

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HUN

Bár a dolgozatnak csak egy szerzője van feltüntetve, valójában sok csodálatos ember hozzájárulását tükrözi, akik nélkül ez a diplomaév jóval nehezebben lett volna teljesíthető.

Először is szeretném megköszönni Alexnek és Francescának, a két mentoromnak, hogy a tíz hónapon át tartó munka során kitartóan támogattak és irányítottak. Hálás vagyok az időért és energiáért, amit a diskurzusokba, és a több méter hosszú skiccek átbeszélésébe fektettetek, valamint hogy hagytátok, hogy elmélyedjek a projekt összetettségében. Ezen felül köszönettel tartozom a MEP stúdió tanárainak is, akik az év során előadásokat, workshopokat és tanulmányutakat szerveztek nekünk.

Másodszor szeretném megköszönni a magyar szakértőknek, akik időt szántak arra, hogy meghallgassák az elképzeléseimet, amiket értékes meglátásaikkal és lelkesedésükkel gazdagítottak. Kezdetben nem gondoltam, hogy az interjúk ekkora hatással lesznek a diplomamunkámra, de ennek a tapasztalatnak a hatására megértettem, hogy milyen fontos egy olyan projekten dolgozni, ami kortárs magyar (téri) problémákkal foglalkozik.

Nem mehetek el szó nélkül a „csapattársaim" – Alina, Max és Sanne – mellett sem, akik velem együtt járták végig ezt az utat. Köszönöm a tartalmas beszélgetéseket, a visszajelzéseket és a figyelmet. Hálás vagyok ezért a támogató közegért, amely Alex révén jött létre.

Diplomamunka mellett dolgozni nem könnyű feladat, de sokat segített, hogy ezt egy támogató irodában tettem, ahol elegendő rugalmasságot biztosítottak a számomra. Köszönöm a VOIDS minden tagjának a türelmet és az értékes meglátásokat a projekt kezdeti fázisában.

Végül de nem utolsó sorban szeretném kifejezni hálámat barátaimnak és családomnak a bíztatásért és támogatásért, gondtalan és stresszes időszakokban egyaránt. Elsősorban Sjoerdnak, aki rengeteg szeretetet és megértést tanúsított, végig mellettem állt ezen az úton, lektorálta a szövegeket és prezentációt gyakorolt velem; valamint Anyának, Apának, Barninak és Mamának, akik távolról is támogattak, és segítettek a bejárások során. Köszönöm Nektek!

Köszönetnyilvánítás

Abstract

Currently, Hungary is undergoing a rapid (re)industrialisation process, manifesting in the rise of lithium-ion battery manufacturing driven by the economic vision of the government. While framed as an important cornerstone of the energy transition towards decarbonisation, in reality this process deepens resource dependencies and results in spatially and socially uncontextual, unsustainable development - triggering what can be described as a battery manufacturing-induced crisis. The project focuses on North-East Hungary, which has become a key region in this phenomenon, bearing the disproportionate costs of a transition from which it gains minimal long-term benefits.

Therefore this thesis proposes a paradigm shift from transition to transformation, by addressing the research question: 'How could the current battery crisis be leveraged to enable long-term spatial, transformative change in North-East Hungary?' Grounded in theories of change and resilience-thinking, the research aims to offer a long-term vision for the region that allows for transformability in moments of crisis, at the same time responding to the short-term impacts of unsustainable battery development patterns.

Using a multi-scalar lens, the study combines a territorial capital and a frequency of change analysis to identify static and dynamic regional elements and their transformative potential. Two future scenarios - based on the opposing transformability principles of efficiency and redundancy - are constructed and assessed through a value-based evaluation system. These inform a balanced, flexible long-term spatial framework and a set of transformation pathways that bridge immediate decisions regarding the battery industry with broader transformation goals. By proposing an engagement strategy and a new, landscape-based governance system as well, the project aims to call for action and serve as a catalyst for spatial imagination.

Ultimately, the thesis attempts to provide a future direction to an otherwise disadvantaged region, shifting the narrative of an unsustainable transition towards a flexible, circular, socially just and spatially integrated territorial transformation in North-East Hungary.

Key words: Battery Industry, Transformative Resilience, Frequency of Change, Territorial Capital, Adaptation Pathways, North-East Hungary

'Yet what is any ocean, but a multitude of drops?'
- Mitchell, D. (2004). Cloud Atlas. Sceptre.

source: own image

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source: UVATERV / Fortepan

INTRODUCTION

A Dual Transition - *Unsustainable Development or Transformative Opportunity?*

Since 2022, articles have been published almost weekly in Hungarian newspapers about a polarising topic: battery manufacturing and its consequences. This rapidly evolving industry is currently reshaping the country, profoundly influencing its economy, society, environment and spatial development.

Independent media outlets raise questions, investigate risks and express scepticism about the phenomenon, while government-affiliated media frames it as a cornerstone of future transition, promising economic growth and prosperity for Hungary. This duality can be identified not only in the media, but also in the nature of the transition driving battery development: industrial electrification, a branch of the broader energy transition. Even though the main goals are decarbonisation and reaching Net Zero Emissions (CO_2) until 2050 (IEA, 2022), as well as industries based on green energy and electricity instead of fossil-fuels based sources (ISPT, 2024), the degree of sustainability of the Hungarian processes are questionable.

Over the past eight years, more than 40 battery manufacturing plants and related facilities have been established, predominantly operated by East-Asian companies (China, Japan, South-Korea). This integration into the global Lithium-ion battery supply chain has prioritised economic gains, often at the expense of considering the broader local implications (Czirfusz, 2022). The absence of spatial strategies at the regional scale has enabled battery development to proceed without adequate spatial or social context, leaving local communities and ecosystems vulnerable to the potentially harmful effects of the factories, deepening inequalities and risking the deterioration of public health, all under the banner of a sustainability transition.

This thesis therefore explores how to shift the paradigm from the current locally unsustainable trajectory towards deeper, sustainable change. Focusing on the territorial scale, it employs the concept of transformability – an ability of a system to 'bounce forward' after a crisis event and use it as an opportunity to step into a new systemic state (Folke et al., 2010; Folke, 2016) - as a core theory. Consequently, the aim of the project is to offer flexible, adaptive, and 'response-able' development pathways for North-East Hungary - one of the country's most vulnerable regions and among the most affected by the ongoing battery-centred economic shift.

Fig. 1.1: Independent newspaper articles connected to battery manufacturing and its effects.

source (articles and images): Telex

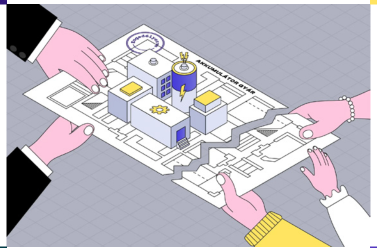
Fig. 1.2: 'Hungary will soon have two capital cities' - opinion of the government

source: Origo

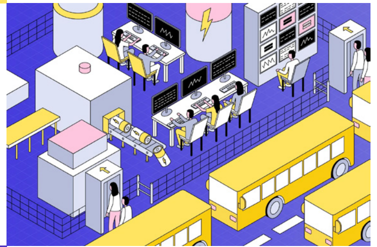
'Why is it so important to Orbán and his associates that we **become a country of battery factories?**'
(Előd, 2023a)

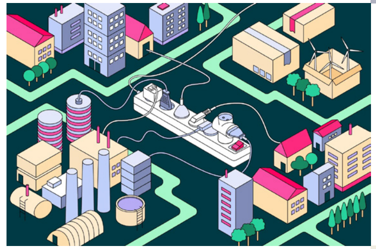
'Should we be afraid that battery factories are **poisoning** us?'
(Előd, 2023b)

'Battery manufacturing: the industry where **laws are being removed to clear the way**'
(Weiler, 2023a)

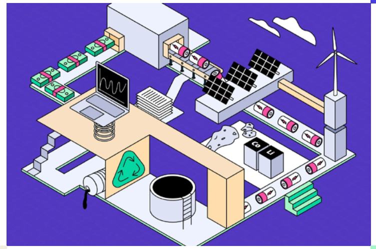


'I just watch the conveyor belt **like a robot in the battery factory**, but I earn twice my previous salary'
(Weiler, 2023b)



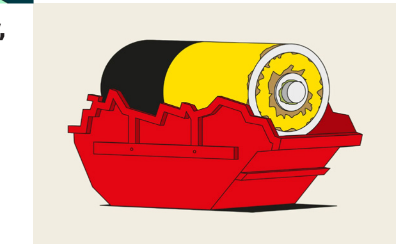


'A battery factory consumes as much electricity as one and a half counties. But **who will generate this power?**'
(Weiler, 2023c)

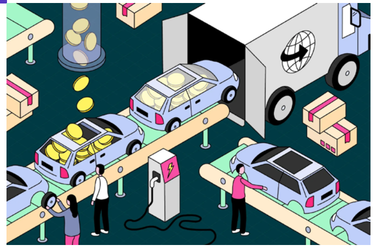


'The question isn't how many batteries are produced in the country, but **what Hungarians contribute to this**.'
(Előd & Weiler, 2024b)

'**You shouldn't be anti-battery, but pro-Hungarian**'
(Vigh, 2024)



'Factories are being built in Hungary like never before, **but what is this all good for**?'
(Előd & Weiler, 2024a)



VS

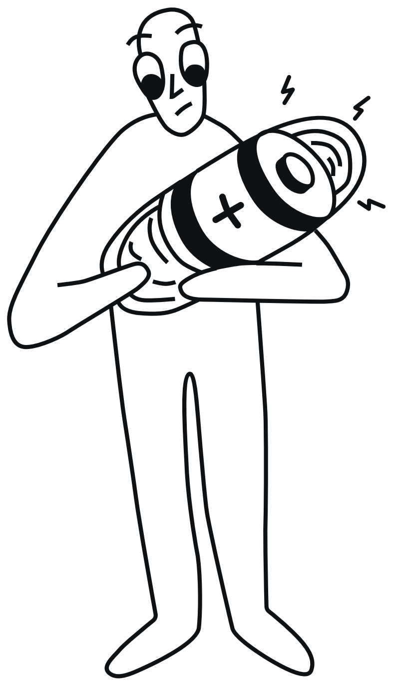
2023. 09. 08. Debrecen

'Hungary will soon have two capital cities'

'In the upcoming years Debrecen could become the leading city of Central-Eastern Europe and the second centre of Hungary.'

CONTEXTUALISATION

The Industrial Electrification Transition
The Hungarian ‘Battery Boom’



The Industrial Electrification Transition

'Electrification of industrial processes refers to the **systematic transition** from conventional fossil fuel-based energy sources (such as oil, gas, and coal) **to the utilization of electricity or green energy sources** (such as renewable electricity, green molecules or hydrogen) to power various stages of manufacturing, production, heating and other industrial operations.' (ISPT, 2024).

The industrial electrification is a key component of a broader **sustainability transition: the energy transition**. In response to the harmful effects of climate change driven by human activities during the Anthropocene, numerous strategies have been developed over the past two decades to reduce global CO_2 emissions and **achieve carbon neutrality**. The graph on the right (Fig. 2.2) illustrates the primary milestones, trends, and projections up to 2050, relative to the values of 1900, based on the Net Zero by 2050: A Roadmap for the Global Energy Sector report, updated by the IEA in 2022. Decoupling GDP growth from carbon emissions and transitioning to clean energy represent some of the most significant challenges of the next 25 years, with industrial electrification playing a critical role in achieving the net-zero emissions target.

However, electrification and the shift from traditional fossil-fuel-based energy production to renewable energy systems come with new resource demands. These include critical raw materials, such as lithium and cobalt, as well as new products derived from them, such as batteries and electrolysers. This shift introduces a new cycle of resource extraction and global competition, highlighting the interconnected challenges of sustainability and resource dependency.

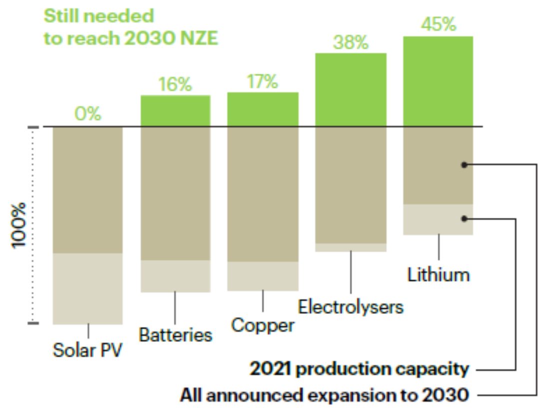
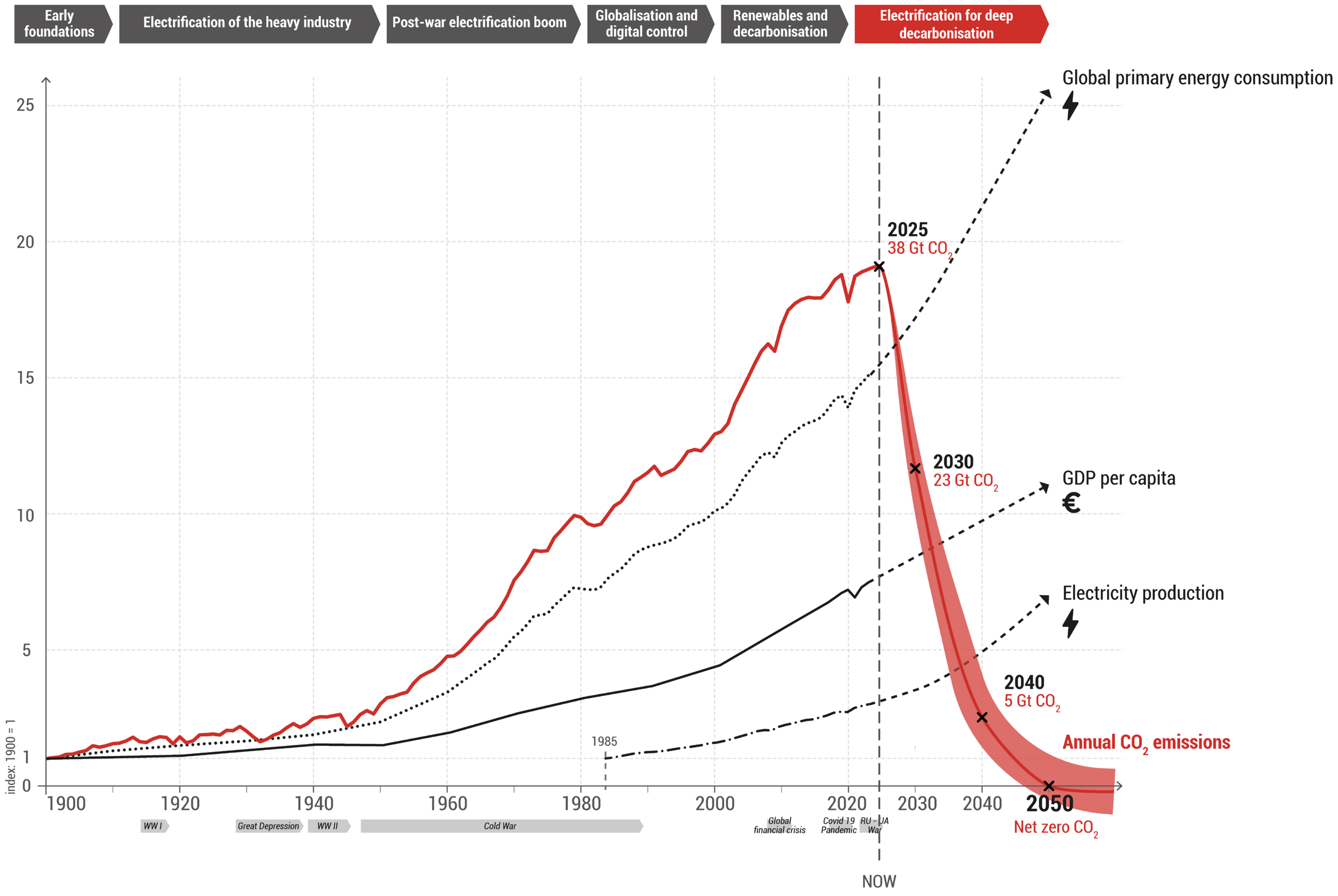


Fig. 2.1 (left): Scaling up production capacity - Critical Raw Materials

source: IEA, 2022b

Fig. 2.2 (right): The decarbonisation challenge: global trends and estimations

source: author



The Hungarian 'Battery Boom'

In Hungary, the industrial electrification transition is primarily characterized by the **rapid construction of lithium-ion battery manufacturing facilities**. Although battery manufacturing is an important aspect of electrification in supporting electricity security and facilitating clean energy transitions (IEA, n.d.-b), this phenomenon is significantly reshaping the economy and industrial sector of the country. Since 2017, more than 40 facilities - including battery manufacturing plants and related facilities, as well as electric vehicle assembly factories - have been built or are under construction (Czirfusz, 2022), resulting in a 'Battery Boom'.

The graph on the right (Fig. 2.4) illustrates Hungarian trends in comparison to global ones, highlighting key electrification milestones (e.g. the construction of the Paks nuclear power plant), and providing historical context. During the communist era, the economic vision of the leadership was to make Hungary the 'country of iron and steel', even though the natural characteristics were not ideal for this purpose (Így épült a vas és acél országa, 2013). Similarly, with the current government's focus on battery development, history appears to be repeating itself, as **the nation is once again pursuing ambitious industrial goals of becoming a middle power as the 'land of battery manufacturing', without adequately considering its natural and spatial context** (Czirfusz, 2022; Kaiser, 2023).

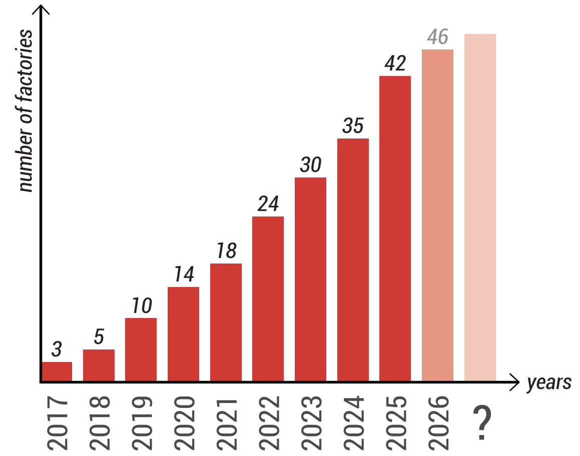
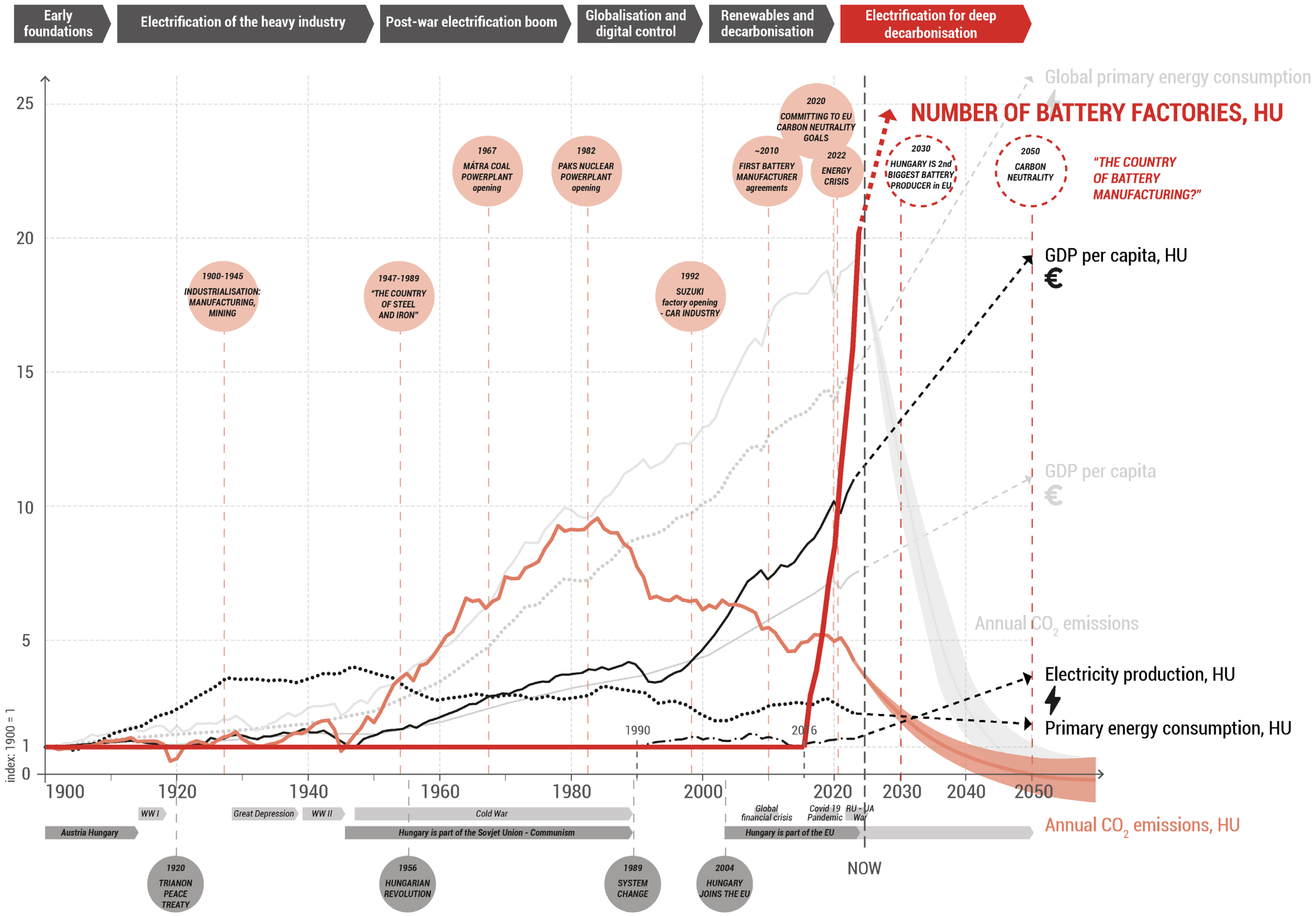


Fig. 2.3 (left): Growing number of battery-related manufacturing factories in Hungary

source: author

Fig. 2.4 (right): The 'alternative' timeline of Hungary towards battery manufacturing

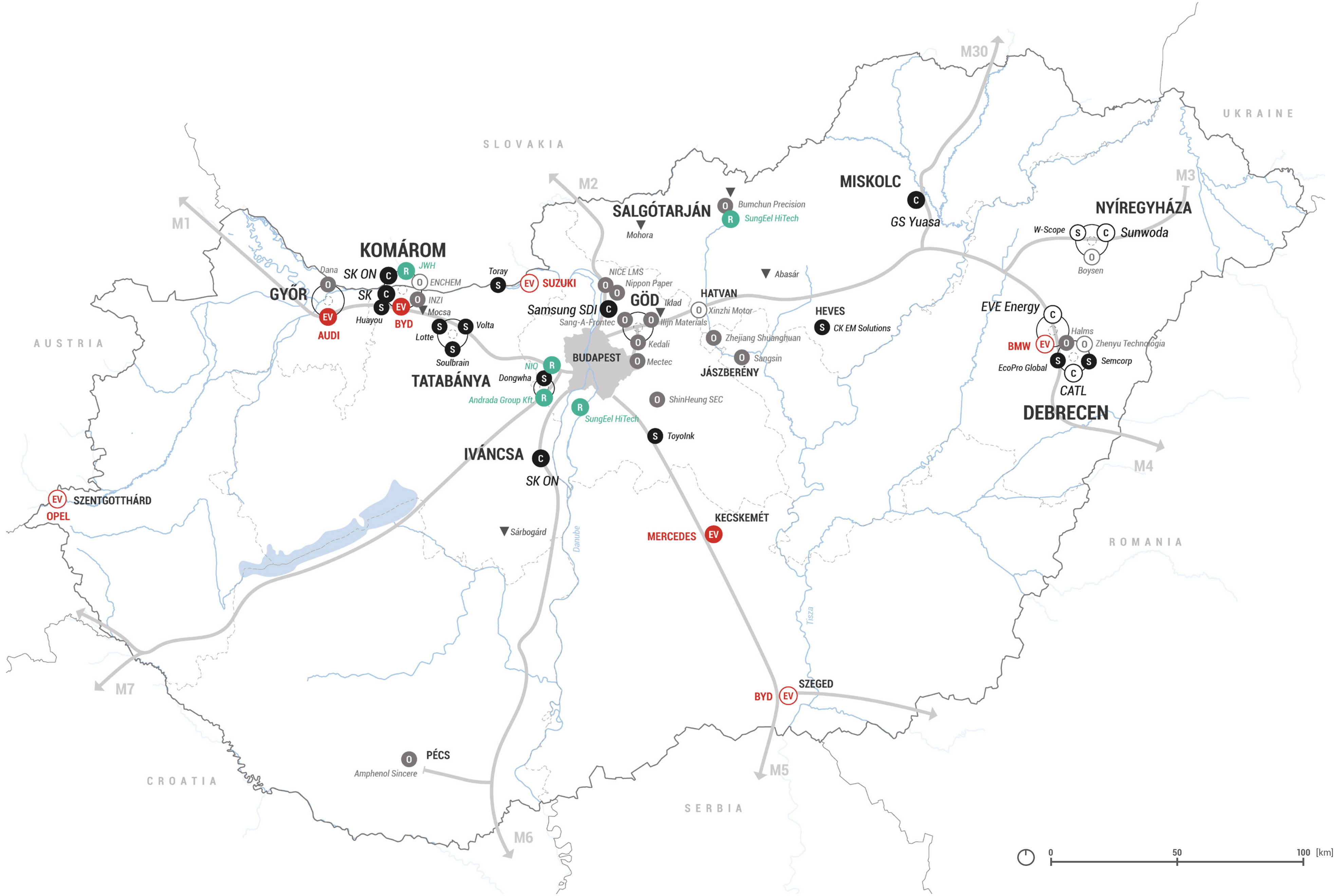
source: author



The Hungarian 'Battery Boom'

At the same time, the data suggests (Fig. 2.4) that Hungary has already managed to decouple its economic growth from CO2 emissions, despite the historical correlation between the two values (Ritchie, 2021). The country also committed to the carbon neutrality goals of the European Union in 2020, and subsequently created a National Clean Development Strategy (IEA, 2022a).

To achieve the net-zero goals, electricity production is predicted to increase, gradually replacing fossil-fuel based plants with nuclear energy and renewables. The national energy consumption is projected to stabilise at approximately 210 TWh, while addressing the energy-trilemma of the country is crucial: 'balancing access and affordability, environmental targets, and security' (Gulyás, Palkovics, & Gondola, 2024).



BATTERY INDUSTRY IN HUNGARY

● active / ○ planned or being built

- EV Electric vehicles
- C Cell manufacturers
- S Sub-component manufacturers
- O Other components
- R Recycling companies
- ▼ Illegal battery-waste dumpsites
- Highways
- Waterways
- Waterbodies
- NUTS2 region borders

Fig. 2.5 (right): Battery industry-related facilities in Hungary

source: author

The Hungarian ‘Battery Boom’

Currently the world’s fourth-largest battery manufacturer, Hungary aims to become Europe’s second-largest battery producer by 2030, with a projected annual capacity of 216 GWh (Bonnefous & Chastand, 2024; PEM, 2024).

Most battery manufacturing-related factories are closed off, grey boxes in the landscape, either standing in an industrial cluster, or in-between agricultural areas and the city or village. One of the most interesting areas to observe regarding this transition is the North-East Hungarian region, with cities like Debrecen (the second biggest city of Hungary), where one of the largest Chinese battery manufacturing companies, CATL, is building its megafactory at the moment.

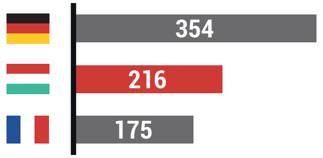


Fig. 2.6: Top 3 battery production countries in the EU (Gwh) *(based on PEM, 2024)*

source: author

Fig. 2.7: The cathode material manufacturing factory of EcoPro Global Hungary Zrt. in Debrecen

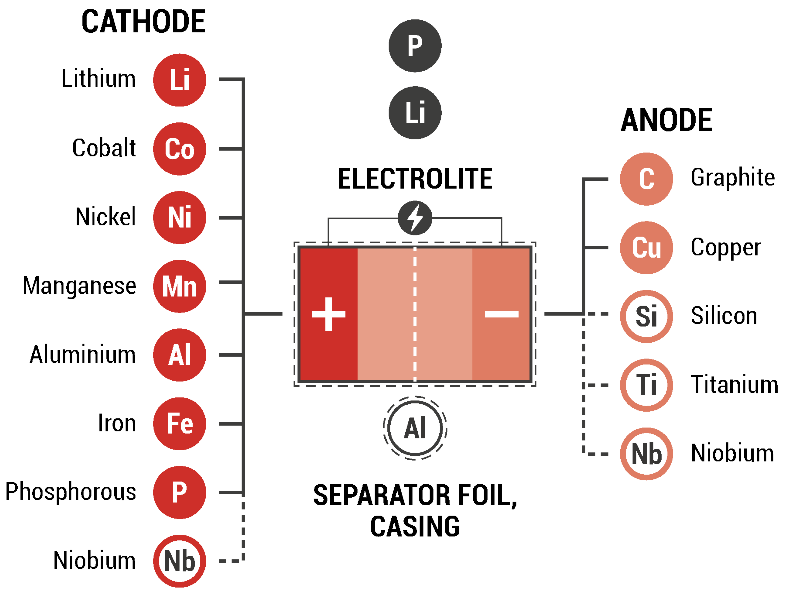
source: author’s own photo

Fig. 2.8: The already operational battery assembly factory of Göd – Samsung SDI

source: @Bődey János / Telex (in the article of Előd, 2023)

Fig. 2.9: Buildup of a Lithium-ion battery cell, with the required critical raw materials, based on the JRC Foresightstudy (Carrara et al., 2023)

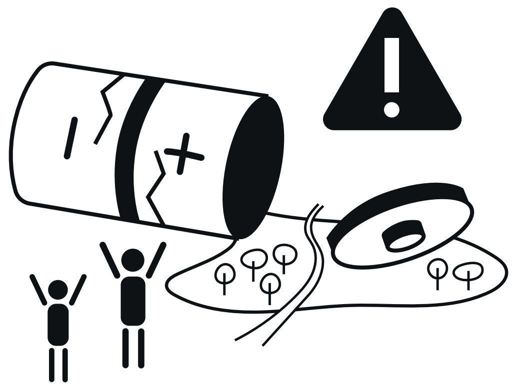
source: author



How does a battery look like?

A Lithium-ion battery cell is built up from an anode, a cathode, an electrolyte, a separator foil and casing material, which all require significant amounts of critical raw materials. It is used by the energy storage, electric mobility, ICT, and aerospace and defence sectors among others (Carrara et al., 2023). The technology is dynamic and rapidly changing, new resource materials (e.g. silicon or niobium) are being tested in order to reduce the cell size and maximise capacities. The manufacturing process requires the handling of hazardous materials (OSHA, n.d.).

PROBLEM FIELD



Multiscalar Disparities and Dependencies

The Problem Field chapter summarises the main problems of industrial electrification and the Lithium-ion battery supply chain. The spatial aspect of the transition raises questions and induces problems on multiple scales, leading to various dependencies and disparities between them. The global system influences the regional level almost to the same degree as the national scale does, while both Europe and Hungary depend on the global value chain, as well as regional characteristics and processes. Understanding these global interrelations is crucial for the local scale, and vice versa.

Disparities often have social and spatial dimensions, rooting in the desire towards economic gain and power as the new race for critical raw materials unfolds. In order to propose future change, one first needs to understand the existing system of the ongoing transition and its issues.

A global process with local consequences.

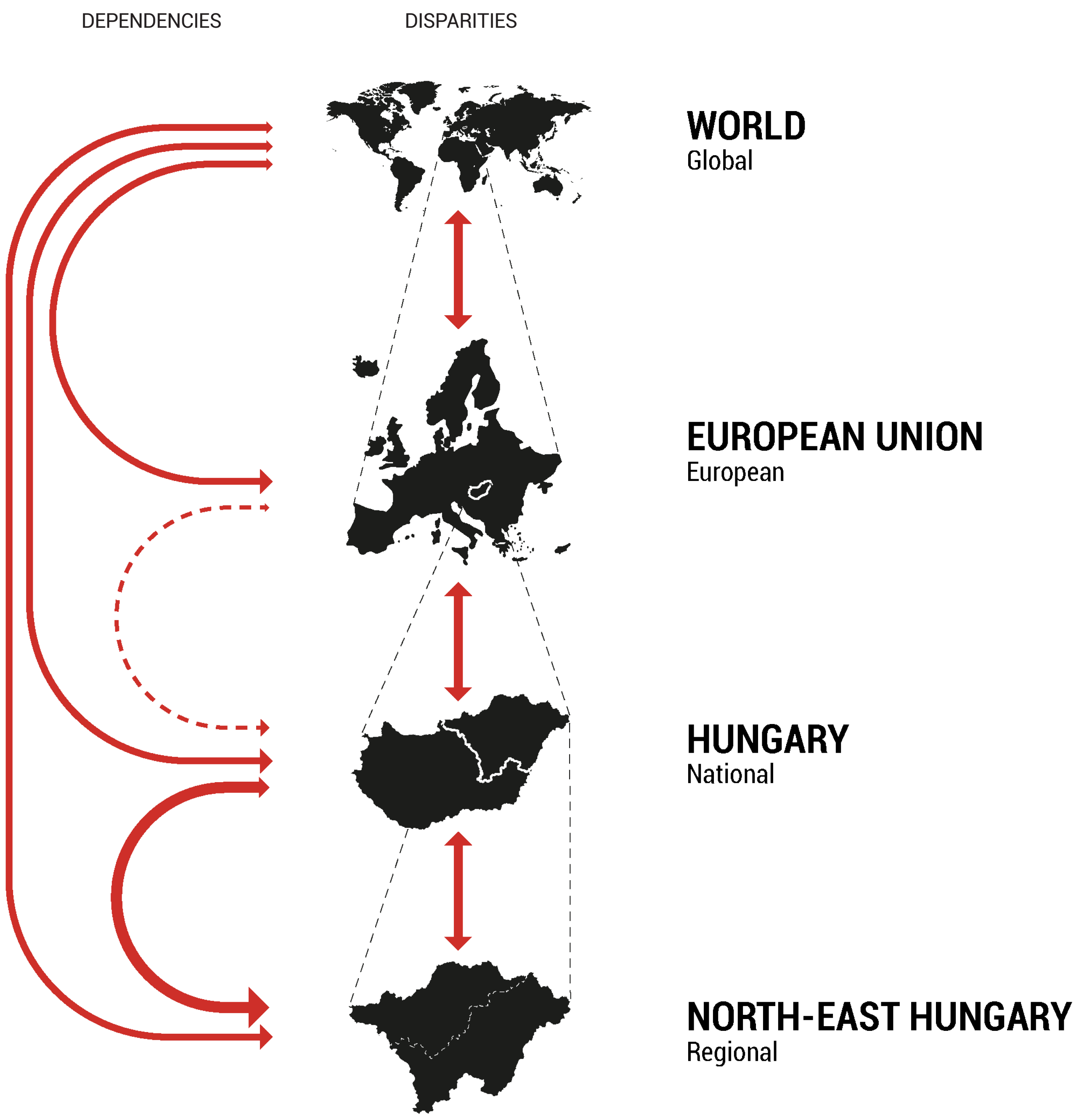


Fig. 3.1: The summary of the problem field: multiscalar disparities and dependencies

source: author

[World]
A Two-faced Global System

From the mining of raw materials to the manufacturing and end-of-life phases of the current global lithium-ion battery supply chain, significant disparities can be observed.

The distribution of the raw materials essential for lithium-ion batteries lead to inequalities and supply-demand imbalances. Many critical resources are concentrated in a limited number of locations, giving certain countries invaluable strategic advantages. However, this dominance often comes at a cost: exploitative mining conditions and threats to the local ecosystems.

The next phase of the supply chain, battery manufacturing, is concentrated in China, Japan, South-Korea, Eastern-Europe and the USA. Locations with loose environmental regulations, low labour costs and proximity to the end-use markets are particularly favoured. If these factors are paired with non-liberal governance and the lack of transparency, that leads to further local disadvantages.

China holds a dominant position in the global lithium-ion battery supply chain, controlling a majority of critical raw materials, processed materials, and battery production. The country also leads in recycling facilities, showing its influence across all stages of the supply chain (U.S. Department of Energy, 2022; Carrara et al., 2023).

Recycling
Manufacturing (size: ~Gwh)
Processing
Mining (size: ~amounts on graph)
Flows of raw materials

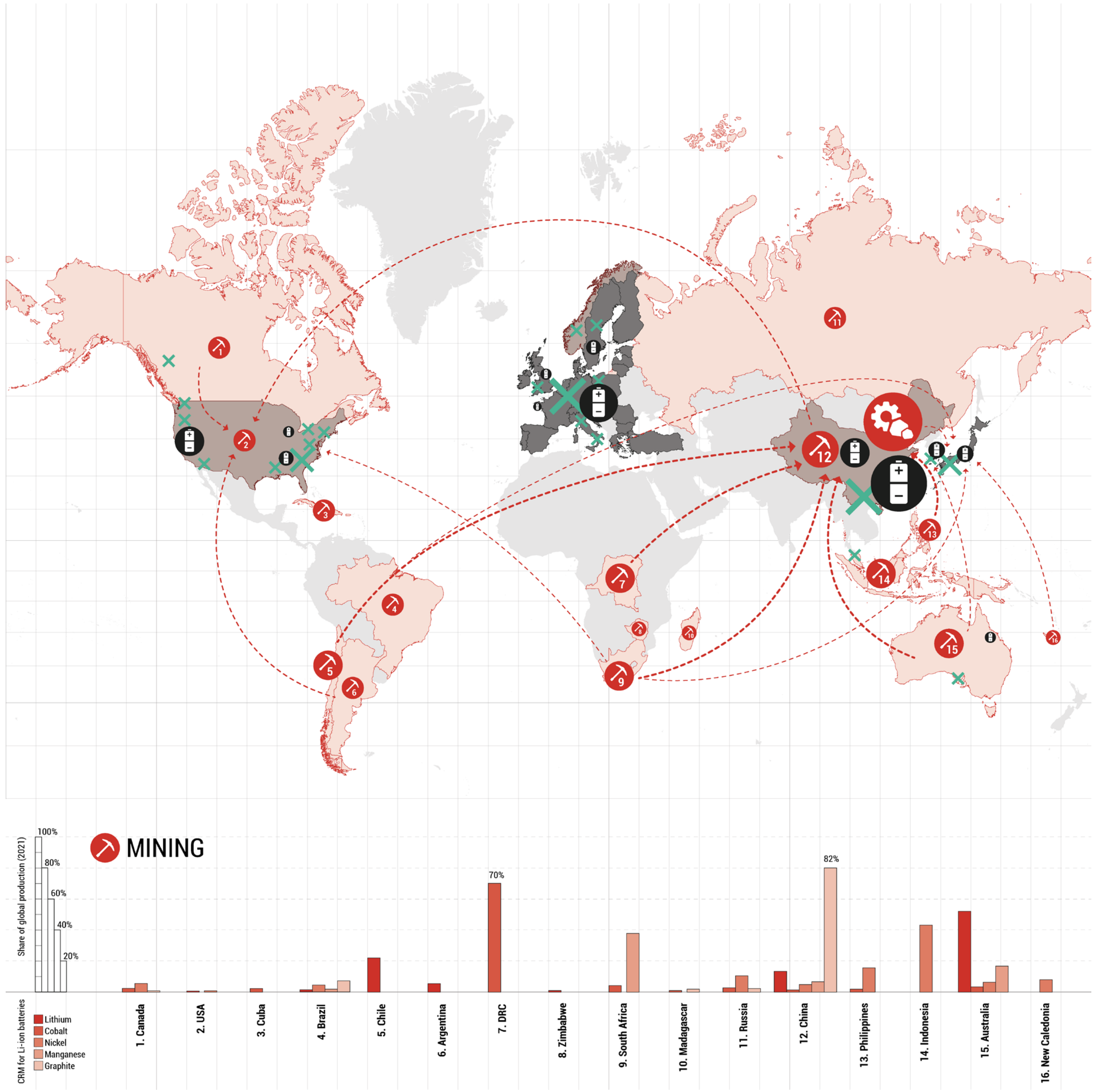


Fig. 3.2: Geographical distribution of global processes of the Li-ion battery supply chain: mining, manufacturing and recycling

source: author

[World]
A Two-faced Global System

The current Lithium-ion battery supply chain is depicted on the right (Fig. 3.3). Currently there are five types of end-of-life activities being done around the world: repairing, remanufacturing, refurbishing, repurposing and recycling (5 Rs). The first three are not truly end-of-life solutions, as the batteries are being reused for the same purposes. Repurposing means that the battery is given a ‘second life’. One example of this is V2G batteries, when the battery previously used for an electric vehicle (V) is repurposed for stationary grid storage (G). During recycling the battery is broken apart, and the components are rebuilt into a different item, using the techniques of pyrometallurgy, hydrometallurgy or direct recycling (U.S. Department of Energy, 2022).

Despite the successful efforts towards a circular supply-chain, recycling is not always worth it. In recent years, several studies have revealed that **recycling companies have moved to ‘pollution havens’, typically developing countries or regions with weak environmental regulations. This relocation has led to significant environmental and health damage**, including adverse effects on students’ academic performance. This highlights that promoting polluting industrial activities is detrimental even for poorer nations, as it erodes their human capital and hampers their potential for economic growth (Mészáros, 2024). As an example, at the moment there are more hazardous materials produced than the recycling and neutralising capacity of Hungary, while failing to provide transparent information about where this material surplus gets deposited (Vigh, 2024).

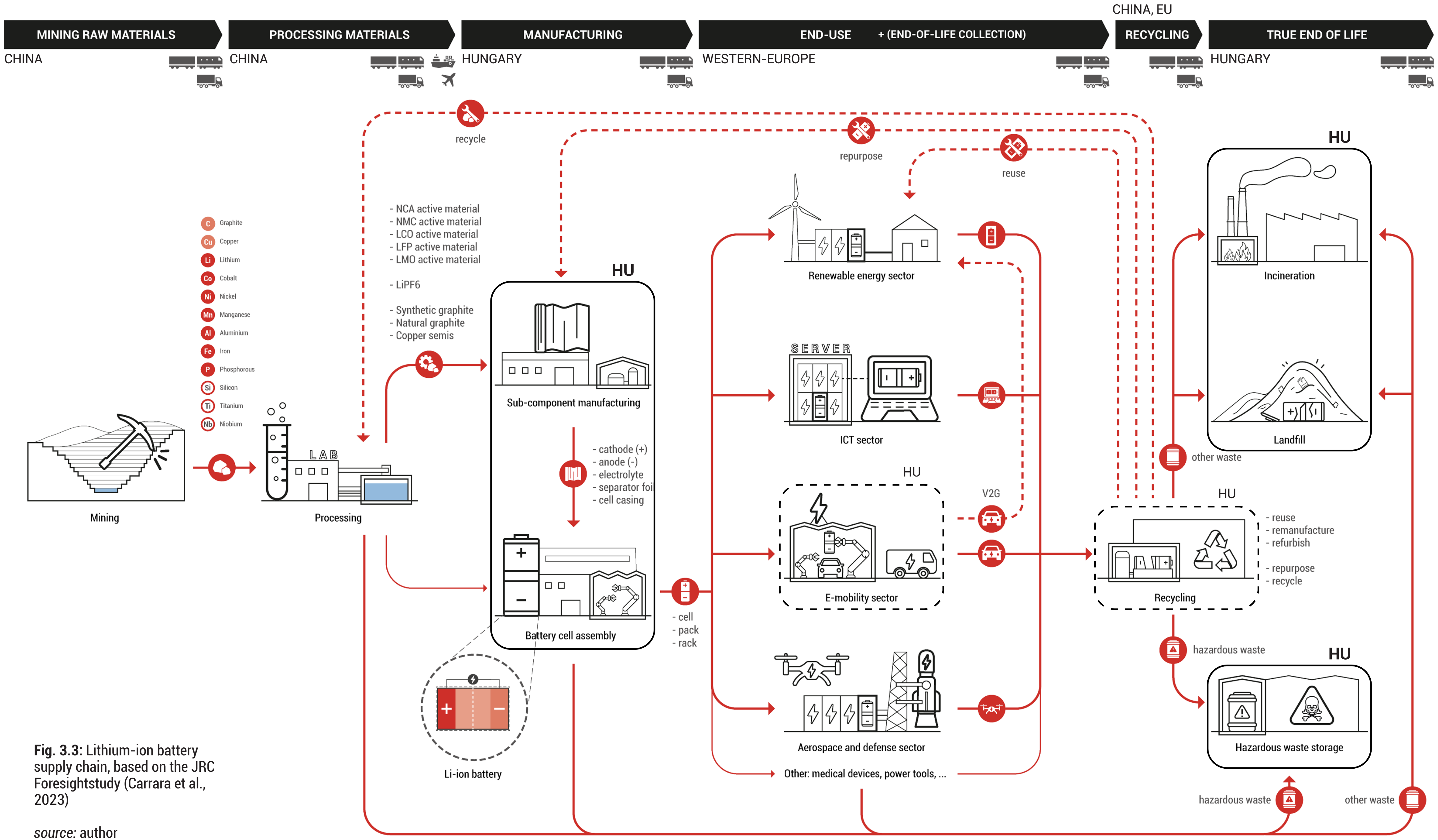


Fig. 3.3: Lithium-ion battery supply chain, based on the JRC Foresightstudy (Carrara et al., 2023)

source: author

[Europe]

Losing Competitiveness

The European Union (EU) aims to enter the China-dominated, critical raw materials-based development path, as its productivity growth has weakened in recent years, threatening its global competitiveness. In response, the EU formulated the ***European Critical Raw Materials Act*** to establish independent, resilient, and sustainable value chains for critical raw materials (European Commission, 2023). This act sets **priorities and benchmarks** for 2030 regarding domestic extraction, processing and recycling:

- 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
- no more than 65% of the EU's annual consumption from a single third country

In addition to legislative measures, strategic recommendations have been outlined to address Europe's competitive challenges. **Mario Draghi**, in his September 2024 report titled ***The Future of European Competitiveness,*** identifies the fading of three critical externalities that previously supported European growth: trade, energy, and defence. **The crisis of the multilateral trade order, dependency on Russian gas, and shifting geopolitical dynamics** have exposed the EU to vulnerabilities and global dependencies. Draghi emphasizes three key transformations necessary for the EU to maintain its competitiveness:

1. Knowledge and skills: accelerating innovation and finding new growth engines

2. Sectoral and industrial focus: reducing energy prices while decarbonising and shifting to circular economy

3. Security: lowering global dependencies and strengthening defence investments

Furthermore, Draghi proposes a new industrial strategy for Europe, emphasising the importance of a just transition that preserves social inclusion while addressing these challenges.

EU 100 km grid
EU 27
Major cities

CRM dependency:
Major EU suppliers of CRM
Battery manufacturing

Russian gas dependency:
Gas pipelines:
Main
General
LNG terminals
Natural gas extraction
Natural gas pipeline import
Gas- and oil plants
size ~ no. elements in the cluster

Geopolitical conflicts:
Ongoing conflicts
Countries in conflict

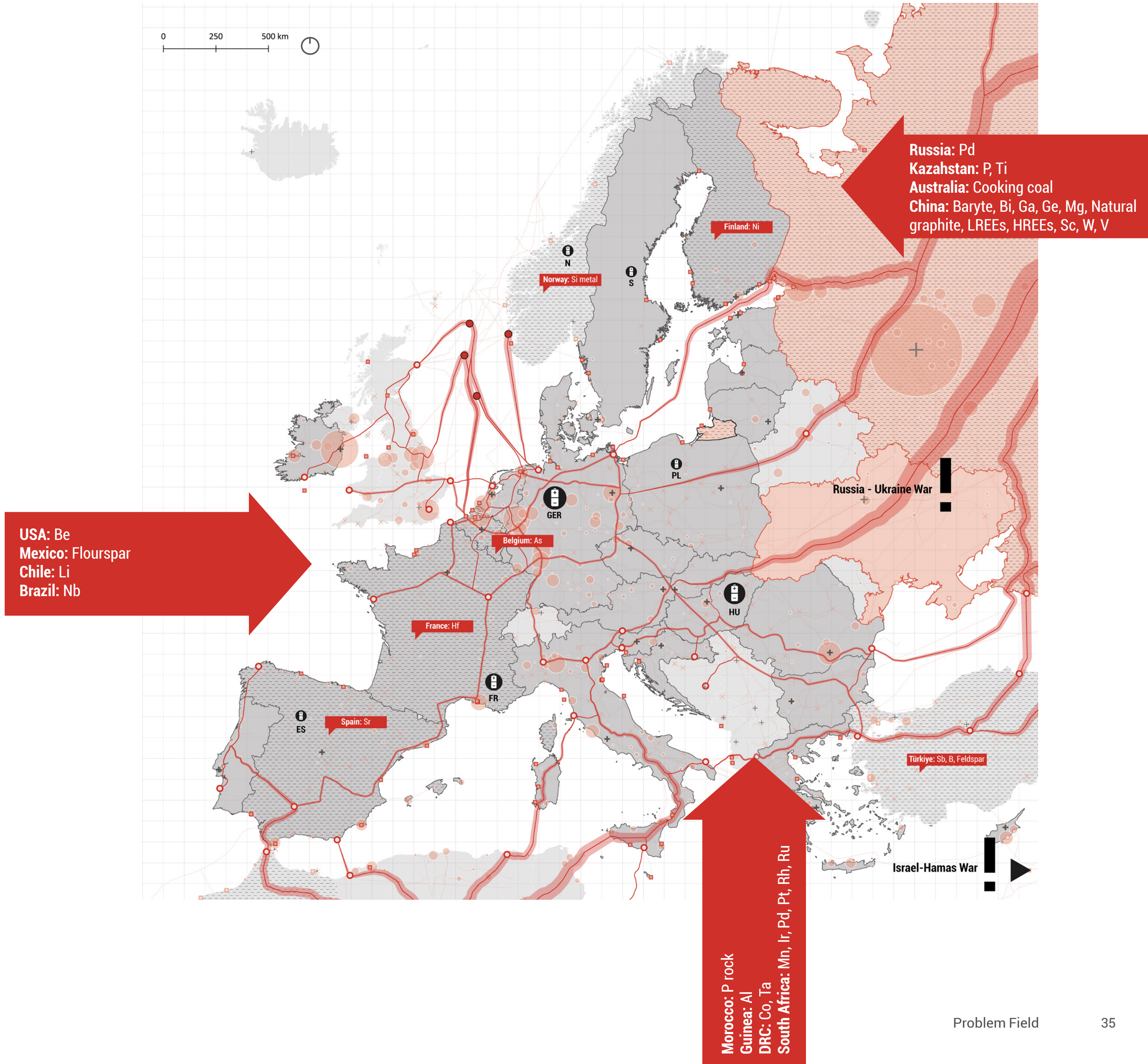


Fig. 3.4: The map of European dependencies: import of critical raw materials, energy dependency and geopolitical conflicts

source: author

[Hungary]
The System of Friend Shoring

Based on the government's vision, Hungary is undergoing an economic shift toward lithium-ion battery production and sector electrification, building on its existing automotive industry, as detailed in 'The Hungarian Battery Boom' sub-chapter. **Contrary to European goals, Hungary is building more global dependencies than reducing them, as the operating manufacturing companies are predominantly from East-Asian countries** (China, Japan, South-Korea). Hungary's centralised, illiberal government structure, coupled with loose environmental regulations, subsidises and allows these facilities to be constructed without public participation or significant legal barriers, in close proximity to the European end-market. This phenomenon is called **'friend-shoring'** (The Economist, 2024). Mario Draghi critiques this parallel development path, arguing that the EU must prevent its value chain from being overtaken by 'state-subsidised foreign producers' (Draghi, 2024).

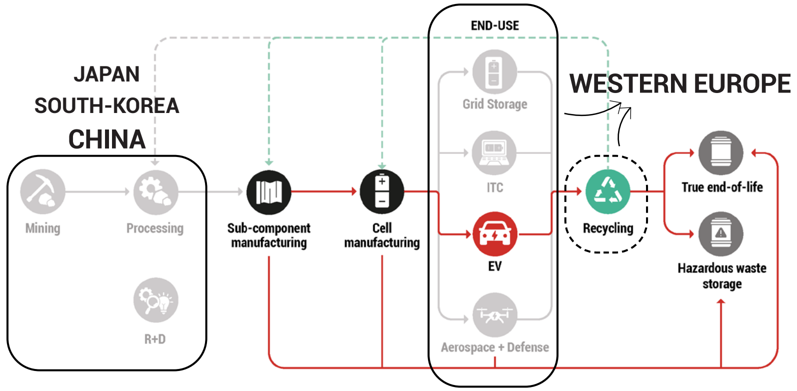
Beyond manufacturing and true end-of-life functions, Hungary lacks significant recycling facilities and ongoing research and development in the battery sector. The lithium-ion batteries produced are purchased by German car manufacturers with assembly plants in Hungary, and the resulting electric vehicles are primarily sold in Western Europe. **This makes Hungary a stepping stone between Asian battery manufacturers and German carmakers, providing little economic benefits while generating substantial volumes of pollution and hazardous waste** (Czirfusz, 2022).

The future of Hungary's integration into the European battery value chain remains uncertain, as the government might opt for avoiding Western-European dependencies and continue its reliance on non-European actors (Czirfusz, 2022).

'In the short term, the **main objective for the sector should be to avoid** a radical delocalisation of production away from the EU or **the rapid takeover of EU plants and companies by state-subsidised foreign producers**, while continuing decarbonisation.' (Draghi, 2024).

Fig. 3.5: The simplified lithium-ion battery supply chain highlighting the Hungarian processes

source: author



● active / ○ planned

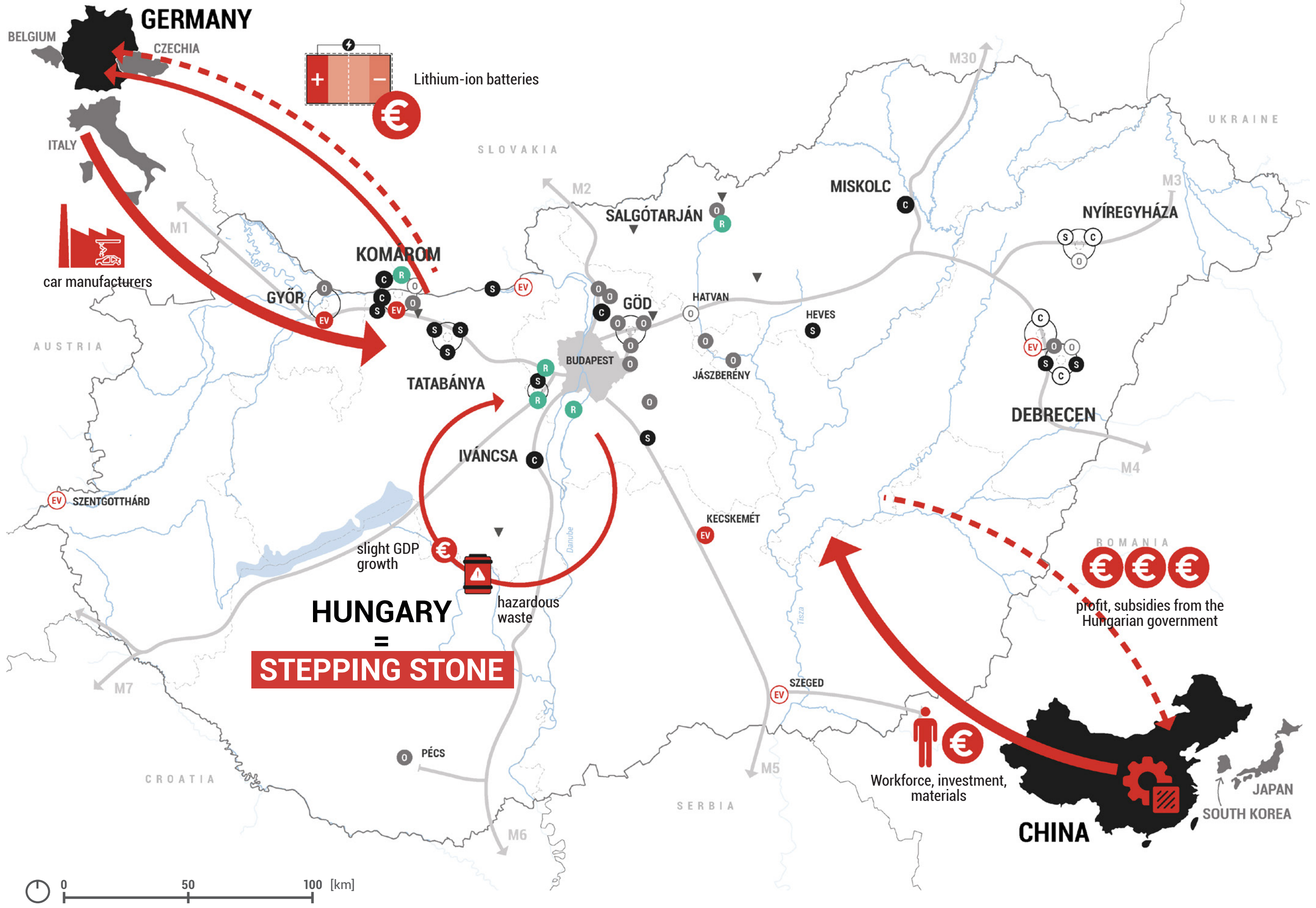
- EV Electric vehicles
- C Cell manufacturers
- S Sub-component manufacturers
- O Other components
- R Recycling companies
- ▼ Illegal battery-waste dumpsites
- Highways
- Waterways
- Waterbodies

Fig. 3.6 (right): The system of friend-shoring, a parallel development path.

source: author

Fig. 3.7 (left): The critique of Mario Draghi

source: Admin, 2024; Draghi, 2024



[Hungary]

Resource Dependency and Environmental Pollution

Battery manufacturing is a resource-heavy sector. Apart from the critical raw materials and processed materials used for the battery cells, **the procedure requires significant amounts of energy and water** (Fig. 3.8). This demands a 10-15% increase in energy production, a capacity that Hungary does not have at the moment, and further disadvantages areas prone to drought (Weiler, 2023c).

The presence of these factories also boosted the NMP (N-methyl-2-pyrrolidone), lithium and heavy metal emissions in the country, affecting the soil, water and air. If the environmental regulations do not become stricter, it poses the risk of Hungary becoming a ‘pollution-haven’ in the future (Mészáros, 2024).

> **‘They meet the CO_2 emission standards, and we will end up suffocating.’**
> *- A concerned citizen (Telex.hu., 2023)*

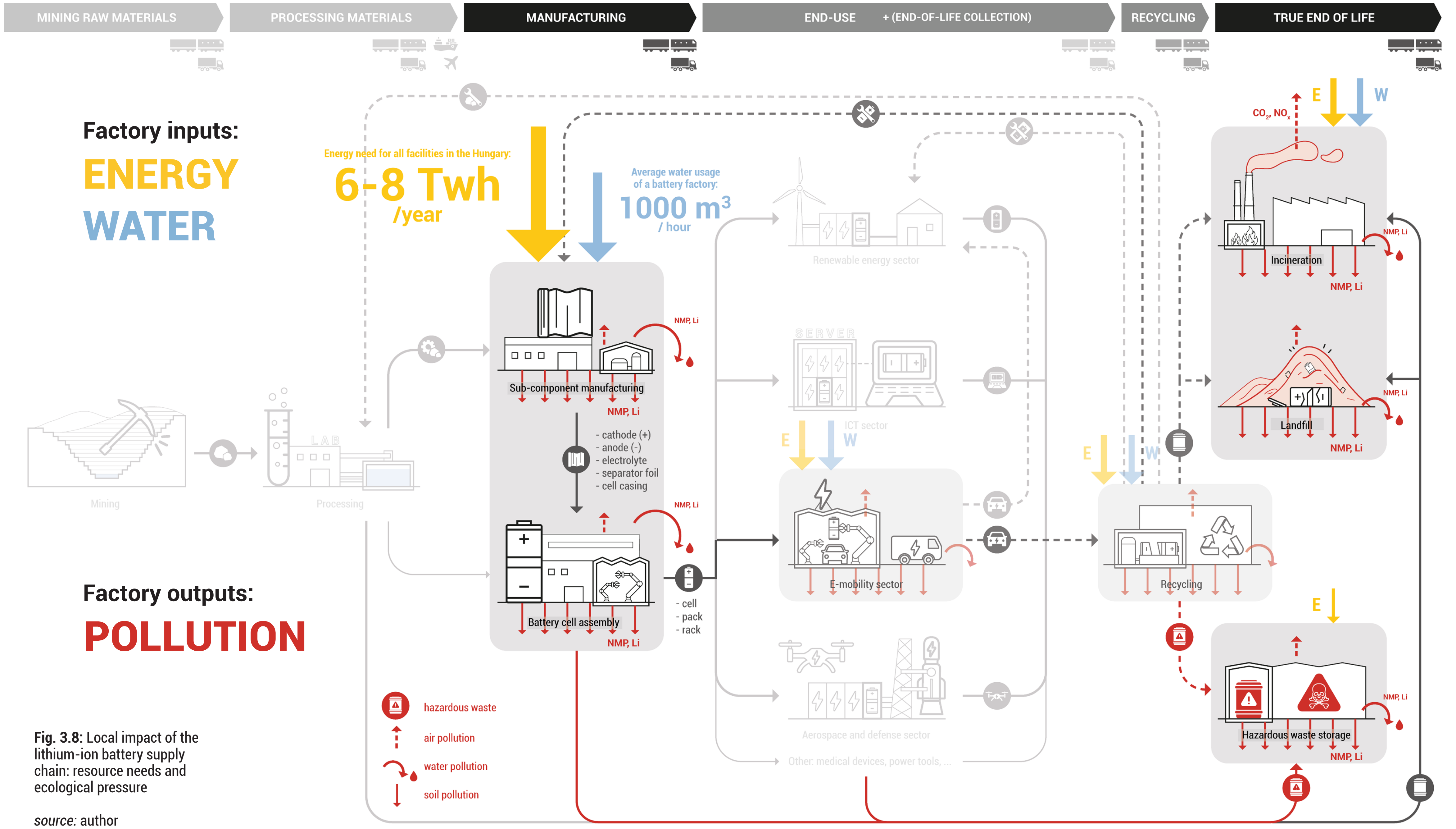


Fig. 3.8: Local impact of the lithium-ion battery supply chain: resource needs and ecological pressure

source: author

[Hungary]
Uncontextual Battery Development - Socially and Spatially

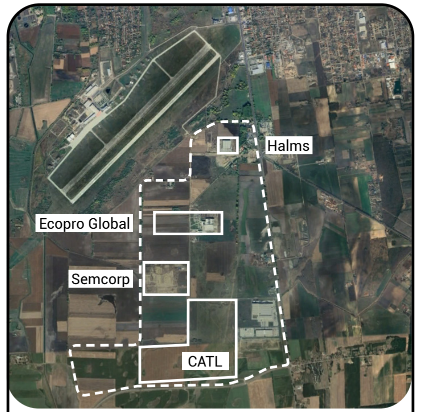
'In managing battery industry investments, HIPA (Hungarian Investment Promotion Agency) essentially **views Hungary as a homogeneous country**; considerations related to **regional development or local characteristics do not appear to play a role in site selection** for these investments (with the exception of clustering within the value chain).' (Czirfusz, 2022)

Megafactories next to villages

SK, Iváncsa - next to a village of 3000 inhabitants, without participatory planning, polluting the soil, water and air.

Greenfield developments

W-Scope, Nyíregyháza - it is being built at the moment on one of the best agricultural soils in the country.



Away from resource availability

Southern Industrial Park, Debrecen - no water available nearby, they need to build a pipe system to provide for the factories.

Battery-related development in Hungary is happening uncontextually, disregarding local characteristics. The three main spatial trends are megafactories next to small villages, greenfield developments on high-value agricultural soils, and battery development at areas without enough water or energy resources.

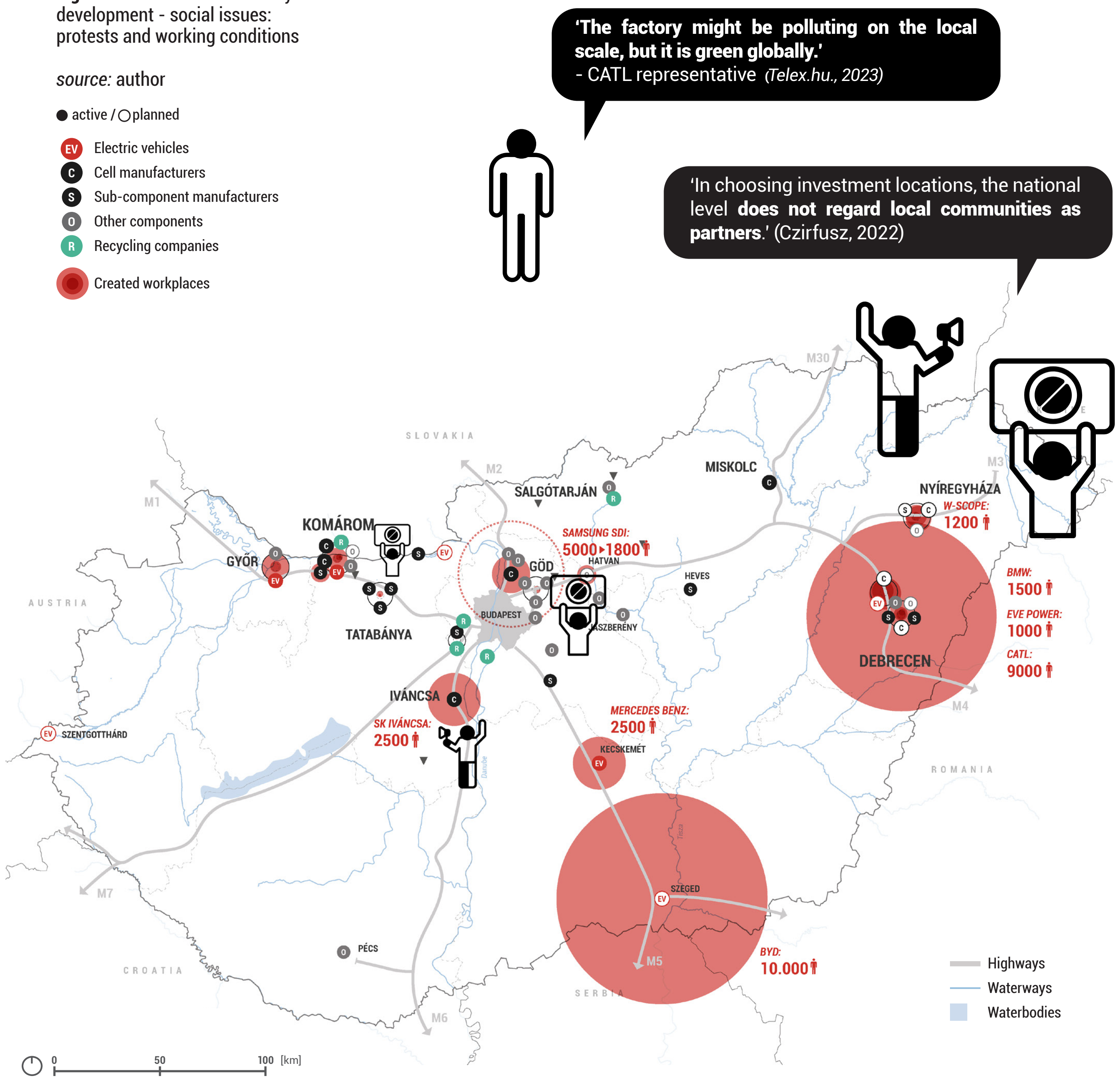
Beyond spatial considerations, the social dimensions of this transition also lack site-specific attention (Czirfusz, 2022). The environmental threat associated with the factories have sparked numerous local protests and lawsuits, particularly concerning the CATL factory in Debrecen, centring around non-transparent procedures and violations of environmental regulations (Telex.hu, 2023). Although companies promise job opportunities, in some cases almost half of the workers come from foreign countries, limiting the use of local workforce and knowledge capital, diminishing potential economic benefits for the community (Előd, 2023a).

Fig. 3.9: Uncontextual battery development - spatial disparities

source: Google Earth

Fig. 3.10: Uncontextual battery development - social issues: protests and working conditions

source: author



[North-East Hungary]

Reindustrialisation of a Shrinking Region

While most factories operate in the North-Western regions of Hungary in already industrialized areas, battery manufacturing has triggered a high-volume reindustrialization process in the North-Eastern regions. This development has created further contradictions, as the Debrecen-Nyíregyháza-Miskolc 'battery-triangle' (Orbán, 2023) is being **developed in a shrinking region that is both environmentally and socially vulnerable, classifying it as one of the most disadvantaged areas in the country** (Kocsis, 2024; Kolosi et al., 2022; KSH, 2023; KSH, n.d.). Considering that the developments lack spatial or social context, apart from a slight economic gain, the presence of the factories is further worsening local conditions by contributing to pollution and redirecting scarce resources, such as energy and water, to the battery facilities (Czirfusz, 2022).

Fig. 3.12 (right): Regional vulnerabilities

(data based on Kocsis, 2024; Kolosi et al., 2022.; KSH, 2023; KSH, n.d.)

source: author

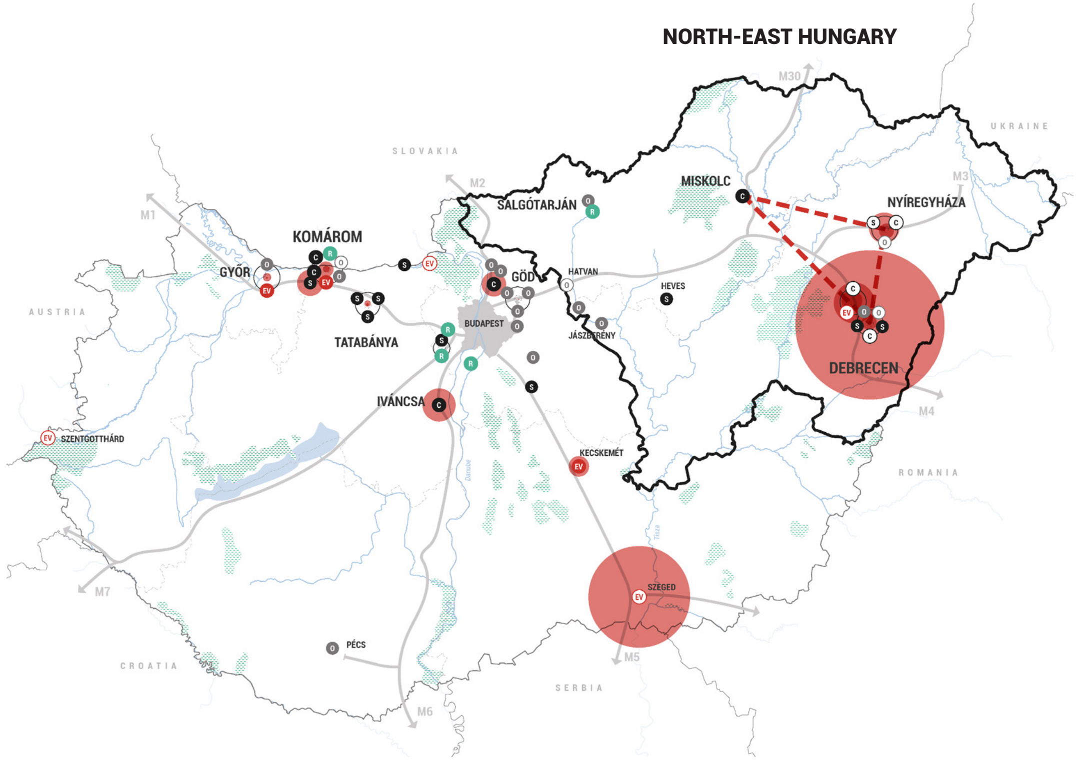
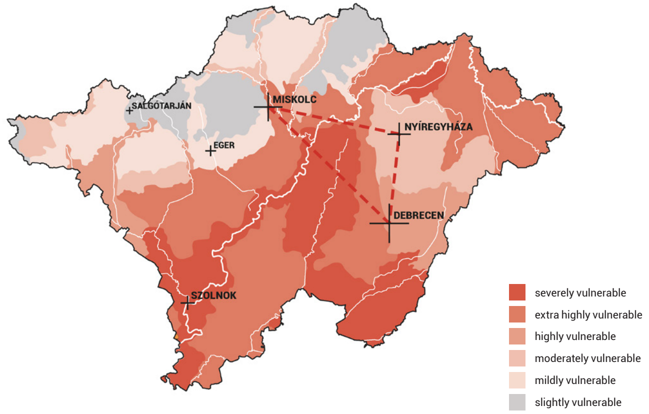


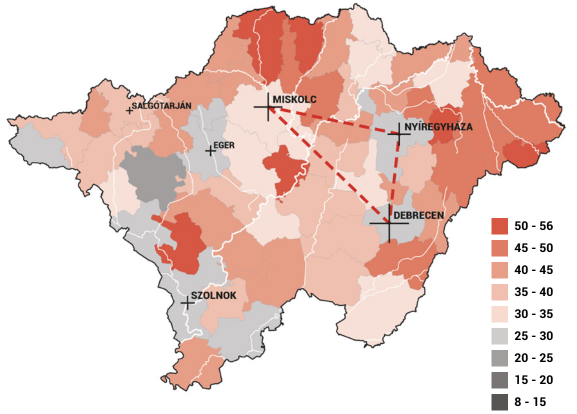
Fig. 3.11: Reindustrialisation of North-East Hungary: The battery triangle

source: author



Climate vulnerability

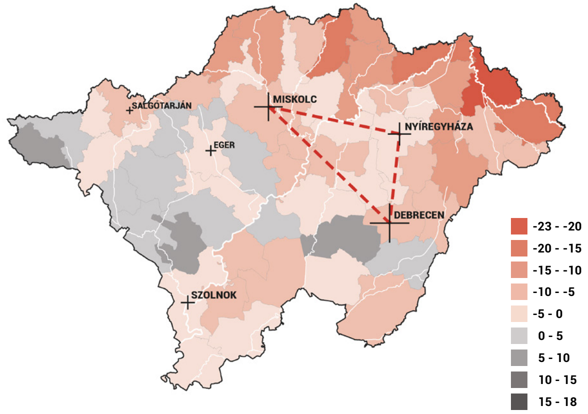
Summary of vulnerability based on earthquakes, surface movements, wind erosion effects, floods, inland waters, droughts, and downpours



Poverty

Proportion of people living in severe material deprivation (%)

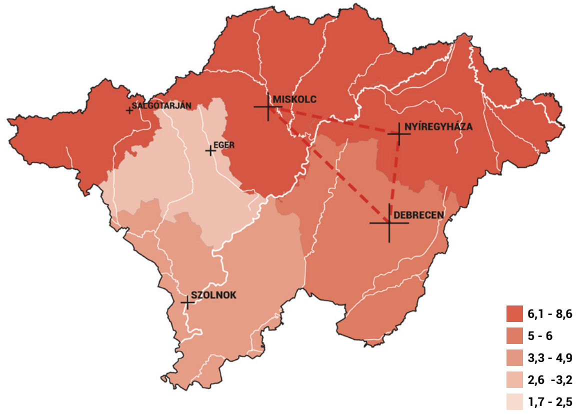
→ *constantly below the EU average in the past 10 years*



Shrinking

Total domestic migration balance per thousand inhabitants, 2022 (%)

↗ *increasing trend, constant population decline in the past 10 years*



Unemployment

Unemployment rate of the population aged 15–64, 2022 (%)

↘ *declining trend, - 6-7% compared to 2015*

0 25 50 [km]

Problem Statement

Hungary is currently experiencing a rapid (re)industrialisation process under the banner of sector electrification, pushed by the economic vision of the government. Resulting in uncontextual development patterns both spatially and socially, the process can be described as an 'unsustainable sustainability transition'.

Despite promises of growth and the industrial boom of the future, Hungary only serves as a stepping stone between East-Asian and Western-European companies in a system of friend-shoring (the Economist, 2024). In this arrangement, the country itself gains minimal economic benefits from the presence of the factories, while bearing the burden of increasing pollution and hazardous waste (Czirfusz, 2022). This parallel process contradicts the ambitions of the European Union as well, which strives to build its own independent supply chain based on critical raw materials (Draghi, 2024).

The uncontextual nature of this development disproportionately impacts the inhabitants of North-East Hungary, one of the most vulnerable regions of the country. The sole concentration on manufacturing without Research and Development diminishes economic opportunities for local communities, while scarce energy and water resources are redirected for industrial use, worsening existing spatial, social and environmental challenges. It also affects the ecology of the region due to soil, water and air pollution caused by the industrial activities (Elȍd, 2023).

The loose system of regulations and policies regarding the social and environmental impact of the industrial transition is a possible root of the problem, enabled by a centralised, populist government. Moreover, the lack of an integrated vision or participative planning and design strategies has resulted in profit-driven developments that disregard local spatial and social characteristics (Czirfusz, 2022; Weiler, 2023a).

The effects of the one-sided, battery- and car-manufacturing-focused economy of Hungary are already becoming evident. Since the end of 2023, demand for electric vehicles has declined (Weiler, 2025b), exposing vulnerabilities within the Hungarian industrial system. This has led to mass layoffs and production slowdowns. **In this sense, we can speak of a current battery crisis, as well as a future one that is likely inevitable given the present mono-sectoral economic structure – leading to a double-crisis situation.**

To ensure a sustainable, resilient and circular future for North-East Hungary, a fundamental shift from the current practices is needed. It is crucial to build on local characteristics, offer alternatives for integrating battery manufacturing into the spatial and social fabric of the region, and explore transformative solutions to address the currently untenable transition.

Battery = Current & Future Crisis

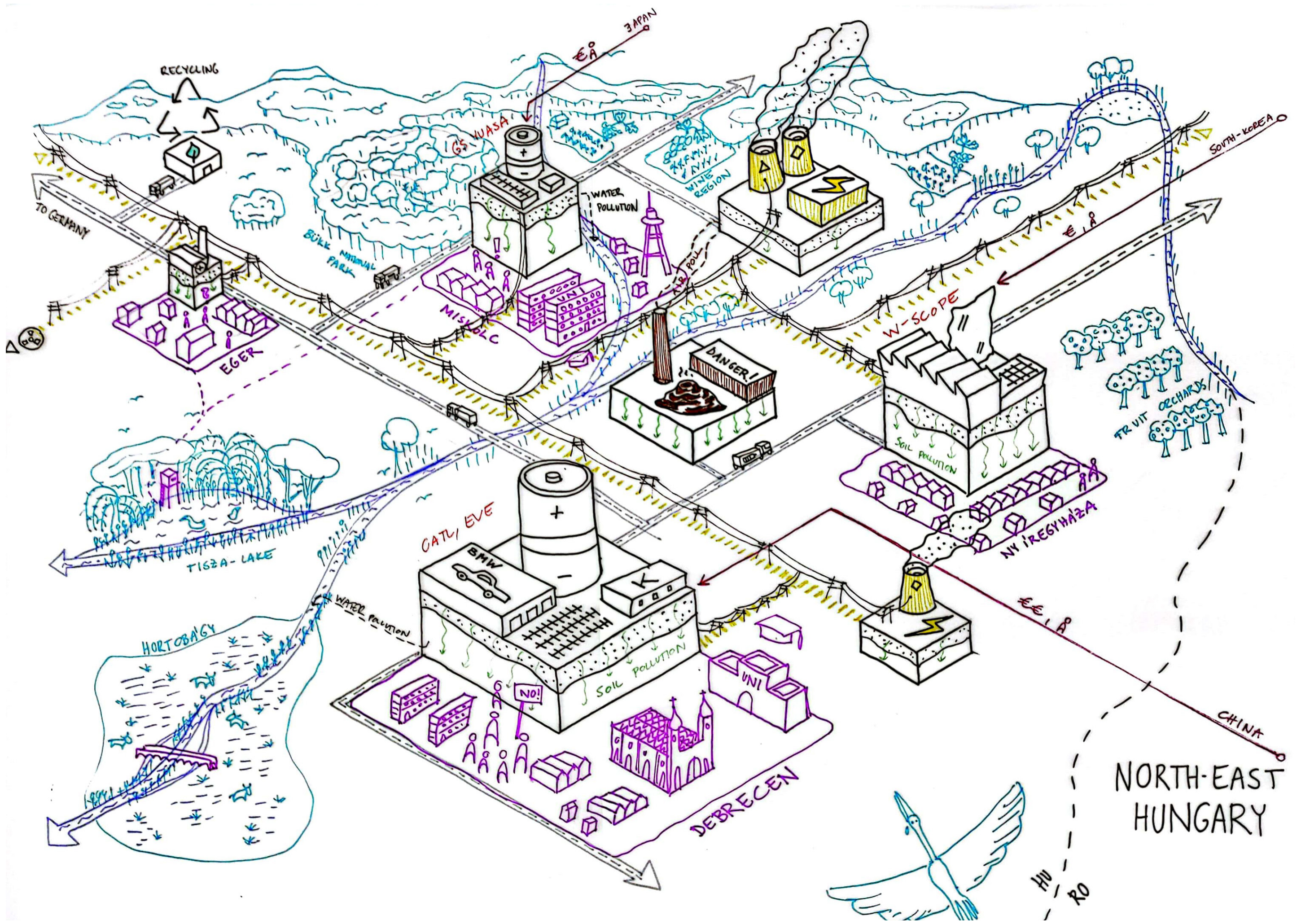
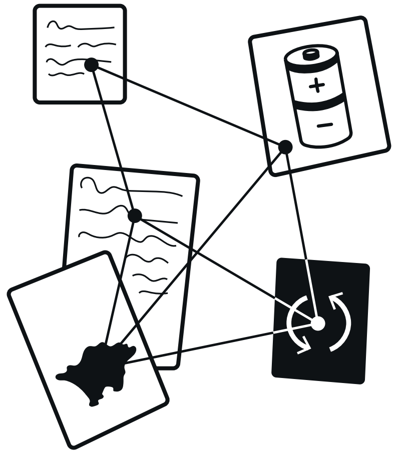


Fig. 3.13: North-East Hungarian reality – battery-hotspots and the systems that serve them

source: author

THEORIES AND CONCEPTS



Theoretical Framework

The Problem Field chapter concluded that the current processes of industrial electrification and battery development in Hungary are uncontextual and not sustainable, even though they are part of a sustainability transition. Therefore a paradigm shift, a deeper change towards sustainability transformation is needed.

Transformability (or transformative resilience) is a system's ability to 'bounce forward' after disruption, using crisis events as an opportunity (Folke, 2016). The leading theoretical fields are transition theory, change theory, and sustainability theories. Sustainability transformation builds on Panarchy (Gunderson and Holling, 2002), and resilience-thinking (Folke, 2016), where the need of transformability manifests in complex adaptive systems, characterised by the inevitability of change. Through the enablers of transformability the thesis focuses on the spatial aspects and principles of transformability by understanding, exploring, and operationalising the concept on the regional scale. Therefore these three terms outline the structure of the thesis, leading to a transformative battery territory that provides short-term answers to the battery crisis, as well as long-term perspectives for the region.

To conclude, this chapter explains how to shift from an unsustainable transition to contextual territorial development through transformability, explaining the theoretical underpinning of the project.

From Transition to Transformation

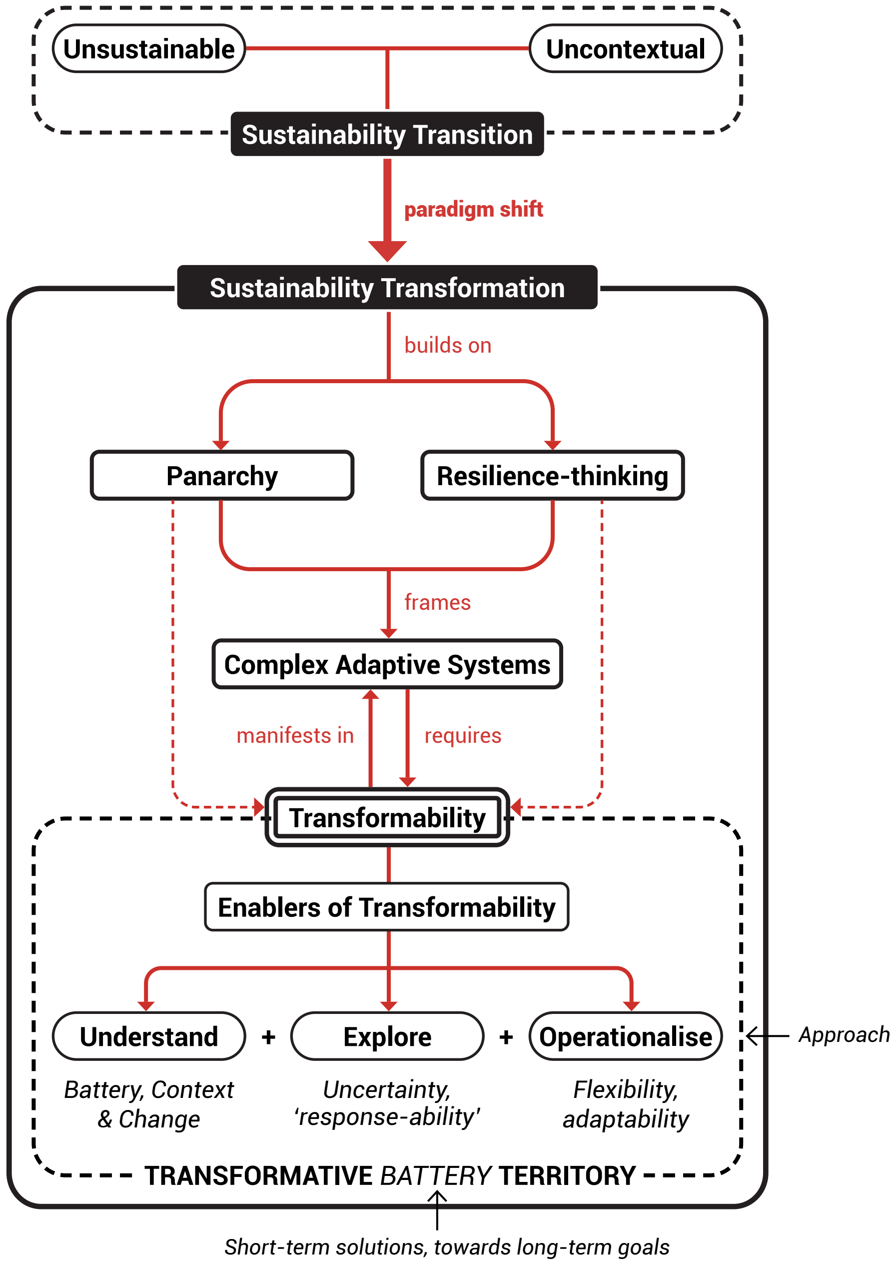


Fig. 4.1: Theoretical framework

source: author

From Sustainability Transition to Sustainability Transformation

As stated previously in the Contextualisation chapter, industrial electrification is part of the broader energy transition, an ongoing sustainability transition. Geels (2002) introduced the **Multi-Level perspective** (niches, regimes, landscape) to understand transitions towards systemic change in socio-technical systems, which became a core concept of the field. This framework describes transitions as an evolution, an adaptive processes, in contrast to more disruptive transformations. Rotmans et al. (2001) emphasised the role of **transition management**, advocating for long-term goals and coordinated actions. Markard et al. (2012) defined socio-technical transitions as a set of processes leading to a fundamental shift in socio-technical systems, highlighting the necessity of **interdisciplinary perspectives** to achieve climate goals.

However, Smith et al. (2010) **criticised** the Multi-Level perspective approach of Geels for **downplaying the role of power-dynamics and politics**, which they argue results in a narrower interpretation of systemic change. As the industrial electrification transition is highly influenced by powerful global actors, this is an important point to take into account when looking at the ongoing Hungarian example.

For a transition to be successful, all of the above mentioned aspects should be addressed. However, in Hungary, non-liberal governance structures and power dynamics have hindered this process, leading to an unsustainable, uncontextual and poorly managed transition. With this thesis I propose a deeper change towards sustainability transformation, as it is evident that a transition is not enough in the case of North-East Hungary.

To justify this paradigm shift, it is crucial to understand the **difference between sustainability transitions and transformations**. According to Hölscher et al. (2017), although both concepts focus on systems, transitions tend to deal with sub-systems of society, whereas transformations concentrate on large-scale societal change processes (e.g. global, regional), looking at emergent, complex and uncertain patterns of change. Transitions aim to move systems from an unsustainable to a sustainable state, whereas transformations prioritise creating safe and just operational spaces to avoid undesirable system change. In summary, **transitions involve reorganisation and adaptation**, while **transformation** can be understood as a **transcendence, creating entirely new systems** (Fazey et al., 2017). Therefore a **paradigm shift** based on *transformability* is needed in Hungary.

According to the socio-ecological resilience perspective, humans are embedded within nature (Folke et al., 2010). In order for sustainability to be taken seriously, Folke (2016) states that sustainability **transformations need to operate in synergy with the biosphere** in order to achieve critical objectives. These goals, which form the core values of this thesis in relation to the United Nations' Sustainable Development Goals (2015), include:

1. Development **within planetary boundaries** (Rockström et al., 2009),
2. **Just society**, and
3. A **resilient biosphere** for humanity and ecosystems.

By embracing this transformative paradigm, the region of North-East Hungary can move beyond incremental changes and work toward a sustainable future that integrates these core values. The theoretical background and nature of transformability are discussed in the next sub-chapter.

Values

DEVELOPMENT WITHIN THE PLANETARY BOUNDARIES

JUST SOCIETY

RESILIENT BIOSPHERE FOR HUMANITY AND ECOSYSTEMS

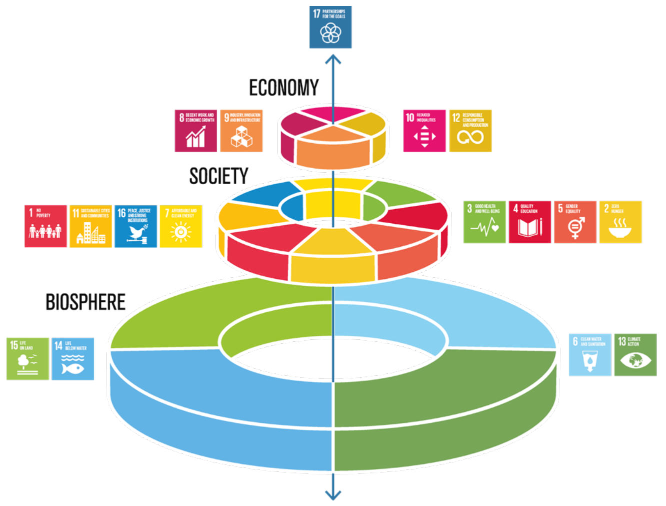


Fig. 4.2: The wedding cake of SDGs aligned with transformability values

(The SDGs wedding cake, 2016, June 14.)

source: Stockholm Resilience Centre

Resilience and Transformability

Transformability is rooted in change theory, particularly its focus on how systems undergo fundamental shifts when existing structures become untenable. To deepen understanding of transformability, this discussion draws on Panarchy (Gunderson & Holling, 2002) and resilience thinking (Folke, 2016), two foundational frameworks that explain the dynamics of systemic change across scales.

Panarchy

Panarchy is a concept that describes adaptive cycles of complex systems and how they evolve and interact across different scales of time and space (Gunderson & Holling, 2002). The concept is based on social-ecological systems (human in nature) understood as **complex adaptive systems,** which are characterised by unpredictable outcomes, requiring 'management with the expectation of surprise'. In Panarchy **resilience** is defined as 'a system's ability to withstand disturbance and still continue to function'.

Adaptive cycles consists of four phases (rapid growth, conservation, release and renewal), are multiscalar, and they interact with each other, enabling global processes to cause local issues - like the industrial electrification transition in North-East Hungary. This can lead to two types of **cascading change: revolt** (rapid scale-up of a process), and **remember** (slower system influences lower levels). ***Transformability*** can be both, and is discussed alongside incremental and lurching change, representing the deepest level of learning. It is defined as a 'cascade of change reconfiguring panarchies' due to cross-scale interactions or novelty, resulting in **new paradigms** at times of great uncertainty.

Resilience-thinking

Commonly, resilience is a system's ability to bounce back to its original state after a disturbance, which implies the goals of resisting change and maintaining stability. Opposing to this, Resilience-thinking (Folke, 2016) observes **complex adaptive system dynamics**, and deals with true **uncertainty**. It encompasses learning how to live with, and utilising constant change to the advantage of the system, while embedded in the biosphere. Folke (2016) defines three types of change, similar to Gunderson and Holling (2002). **Persistence** means being resilient and developing with change, **adaptation** is 'human actions that sustain development on current pathways', while ***transformation*** (or transformational change) 'shifts development into other emergent pathways, even creating new ones'.

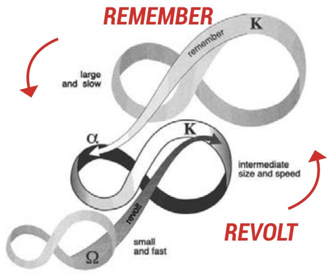


Fig. 4.3: Cascading change between Panarchies

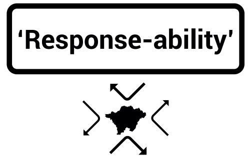
source: Gunderson & Holling (2002)

Transformative Resilience [Transformability]

Walker et al. (2004) define transformability as 'the capacity to create a fundamentally new system when ecological, economic or social (including political) conditions make the existing system untenable'. This introduces new scales and variables, transforming the whole panarchy and reflecting the **system's ability to 'bounce forward' after a disruption**.

Multiscale resilience is closely linked to transformability, as 'transformational change at smaller scales enables resilience at larger scales', through mechanisms like cross-learning and new initiatives (Folke et al., 2010). Transformation is typically characterised by **three phases:** 1. Preparation for change, 2. Navigating the transition (where crisis serves as opportunities for change), and 3. Building resilience for the new social-ecological system.

Developing transformative capacity is critical to keep the planet in a Holocene state (Folke, 2016), to avoid future lock-ins, and to ensure that the region can perform well in face of (ongoing or future) crisis events. This characteristic is summarised with the term 'response-ability', and is a key principle of the thesis. It requires **flexible systems, scenario planning, adaptive resource management and adaptive governance** (Walker et al., 2004; Folke, 2016).



In the context of North-East Hungary, the rapidly evolving and unsustainable nature of battery manufacturing, coupled with the government's heavy reliance on this industry as a cornerstone of their economic vision, underscores the urgency of transformation.

The Enablers of Transformability

One of the main tasks of the project is to further the spatial understanding of transformability, in relation to regional planning and design. To translate the concept to the physical realm, six enablers were carefully chosen based on the regional context and a thorough literature-review, building on the concept of general resilience (Folke et al., 2010; Folke, 2016) and the proxies for resilience in the urban form (Feliciotti et al., 2016).

Breaking down the resilience of the current system to build transformative resilience is key for deliberate transformations, therefore general resilience fits the aim of the project, providing resilience for the 'unknown and unknowable' (Folke, 2016). Folke (2016) lists diversity, modularity, openness, reserves, feedbacks, nestedness, monitoring, leadership and trust as the main enablers of the concept. The study of Feliciotti et al. (2016) discusses the spatial form of resilience, with significant overlaps between the enablers of general resilience and their five proxies, which are: diversity, connectivity, redundancy, modularity and efficiency. Considering these two approaches, the thesis proposes the following enablers of transformability through a spatial lense:

Efficiency

Efficiency in complex systems cannot be understood as a short-term optimisation process, as in that case it would contradict the other enablers, and cause a decrease in transformative resilience (Feliciotti et al., 2016). It **requires increased structural complexity at all scales,** therefore it can only be used and understood through a multi-scalar approach. This leads to **hierarchic organisation patterns**.

Redundancy,
reserves

Redundancy is an **insurance mechanism, providing 'similar but not the same' elements** and pathways that can act as reserves in case of crisis, in consequence when one (or some) fails, the others can take over (Feliciotti et al., 2016). By having interchangeable components, redundancy ensures continuity, providing 'buffer capacity' through the degree of internal variation – therefore it does not result in duplicated functions.

Connectivity,
accessibility

'Connectivity describes the ease of flow within a system and across systems' (Feliciotti et al., 2016). With transformability (and resilience) it is important to note that the balance of high and low connectivity is crucial, as the former enables knowledge and recovery to spread, while the latter reduces the extent of disturbance in face of crisis, preserving 'pockets of memory'. Accessibility, especially on the local scale, steers towards a more just and liveable organisation for everyone.

Polycentricity,
modularity

'Modularity describes a system where functions or services are locally distributed and spread across decentralised sub-systems' (Feliciotti et al., 2016). In the context of Hungary, it is crucial that polycentric, modular systems (individual and autonomous, but part of a whole) are introduced next to the current extremely centralised patterns, providing strong local connections with weaker long-range ties. This relates to redundancy, while multi-scalarity plays a big role in ensuring stability.

Multi-scalarity,
scalability, layering

Multi-scalarity ensures that change can be accommodated at different scales by fostering **nestedness, feedback loops and the coexistence of efficiency with redundancy** and polycentricity (Feliciotti et al., 2016). In order to achieve transformative resilience, scalability and layering play a crucial role in providing flexibilities for future transformations and uses.

Diversity

The ability of the system to **'implement multiple coping strategies'** in case of a disturbance, leading to stability through changing conditions and a higher potential for innovation (Feliciotti et al., 2016). We can differentiate functional and response (in case of crisis) diversity.

As described above, there are certain contradictions between these enablers. **To achieve transformative resilience and crisis 'response-ability', ultimately resulting in flexible and adaptable systems, a certain balance has to be reached.** The following diagram on Figure 4.4. explains the relations of the six enablers:

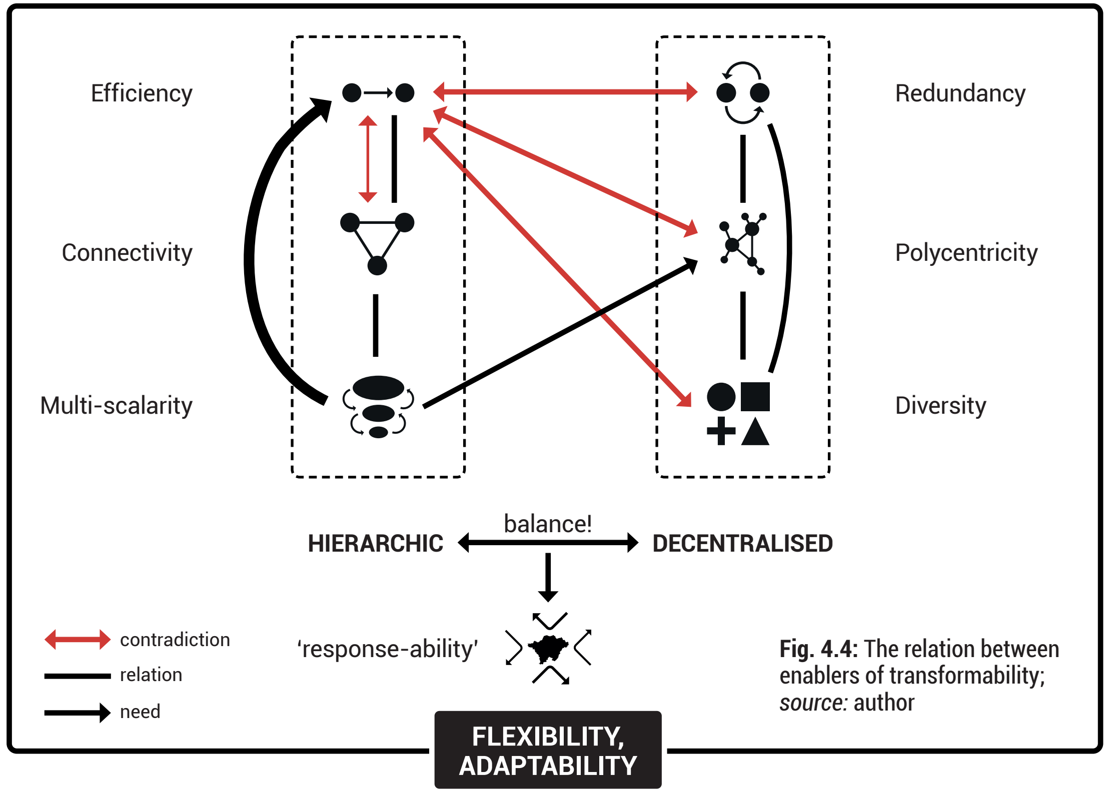
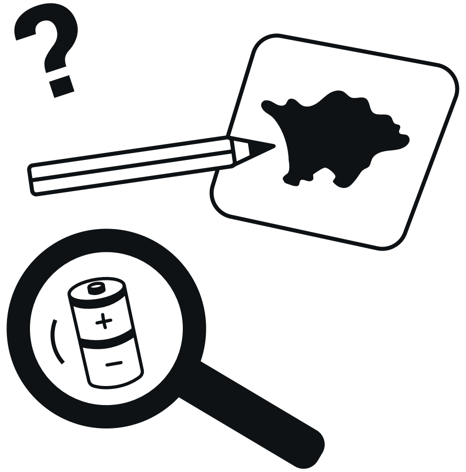


Fig. 4.4: The relation between enablers of transformability; *source:* author

RESEARCH DESIGN AND METHODS



Research Aims, Research Questions and Approach

? How could the **current battery crisis be leveraged** to enable **long-term spatial, transformative change** in **North-East Hungary?**

Q1: What are the **spatial, social and economic dimensions of industrial development** in the region through time, and how does the **battery industry** fit into this picture?

Aim: To explore the relation of industry and territory, and to understand how the new battery industry relates to the territorial fabric.

Q2: What is the **territorial capital and transformative potential** of North-East Hungary, and how is it affected by the pace of change?

Aim: To identify the territorial capital of the region to understand the context of the project, and estimate the frequency of change of different territorial layers and elements in order to define its transformability potential.

[research aim]
The overall goal of the research is to offer a long-term vision for the region of North-East Hungary that allows for transformability at points of crisis, at the same time responding to the ongoing unsustainable and uncontextual battery development patterns in the country.

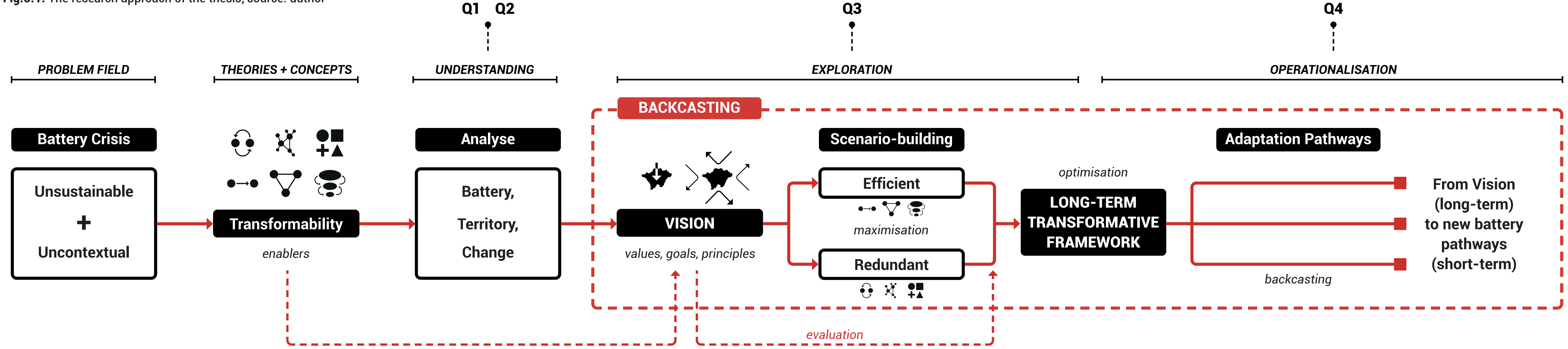
Q3: What spatial organisation allows for transformation at points of crisis? How could that be translated into a long-term future vision and spatial framework for the region?

Aim: To explore scenarios with different spatial organisation patterns, based on transformability principles, that allow for building transformative capacity on the long-run, in order to construct the future framework of a transformative North-East Hungary.

Q4: How could the **contradiction between short-term responses to the battery crisis and the pursuit of long-term territorial transformation** be addressed?

Aim: To construct different, contextual, sustainable pathways towards transformability by changing the current battery system, while incorporating the uncertainty of future production patterns.

Fig.5.1: The research approach of the thesis; *source:* author

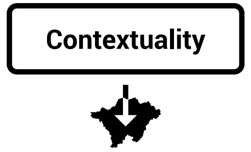


Approach Theories - Conceptual Framework

The following pages detail the theoretical underpinnings of the three main parts of the research approach: understanding, exploration and operationalisation. While the Theories and Concepts chapter focuses on explaining the roots and enablers of transformability, this sub-chapter describes concepts that make possible using transformability in spatial planning and design.

[Understanding]: Territorial Capital and Change

One of the most important conclusions of the problematisation chapter is that all **future interventions regarding the battery industry or the region has to be contextual,** both spatially and socially. In order to understand what contextuality means, it is important to familiarise ourselves with North-East Hungary.



To build a basic understanding, the concept of **'elementarism'** by Paola Vigano (1999) is used. By deconstructing the region (originally: the urban fabric) to its basic elements, fundamental patterns can be identified, and overlaying them can reveal hidden relationships, common themes and urgencies. Vigano (1999) calls this urban stratification.

The next step towards a deeper understanding is to look at strengths, weaknesses, barriers and potentials, by defining the **Territorial Capital(s) of the region**. This concept was developed by Roberto Camagni (2017). It looks at the endogenous potential of the region to identify context-specific spatial assets that can act as a base for future supply-oriented development and tailor-made strategies (Orsi et al, 2024). The 3x3 matrix on Figure 5.2 is the **theoretical taxonomy**, organised along the axis of rivalry (from low to high) and materiality (from tangible to intangible), where the coloured squares form the so-called innovation cross (Camagni, 2017).

Rivalry	Tangible goods (hard)	Mixed goods (hard + soft)	Intangible goods (soft)
High rivalry (private goods)	Private fixed capital stock Pecuniary externalities (hard) Toll goods (excludable)	Relational private services operating on: - external linkages for firms - transfer of R&D results University spin-offs	Human capital: - entrepreneurship - creativity - private know-how Pecuniary externalities (soft)
(club goods) (impure public goods)	Proprietary networks Collective goods: - landscape - cultural heritage (private 'ensembles')	Cooperation networks: - strategic alliances in R&D and knowledge - p/p partnerships in services and schemes Governance of land and cultural resources	Relational capital: - cooperation capability (trust) - collective action capability (participation) - collective competencies
(public goods) Low rivalry	Resources: - natural - cultural (punctual) Social overhead capital: - infrastructure	Agencies for R&D transfer Receptivity enhancing tools Connectivity Agglomeration and district economies	Collective action: - conventions - behavioural codes - representations - values

Materiality

Fig. 5.2: The theoretical taxonomy of territorial capital; *source:* Camagni, 2017

It is a theory mainly used in regional economics, thus Orsi et al. (2024) argue that it often **lacks spatial thinking and imagination**. They developed a method to fill this gap, resulting in a multiscalar SWOT analysis. This approach is **overly growth-oriented**, resulting in areas of possible expansion, which is not the goal of this thesis.

The proposed capital layers of settlement capital (occupation), infrastructural and relational capital (networks), economic capital (functions) and human capital (demographics) of Orsi et al. (2024) are adapted to this study, with the addition of natural capital (landscape), and social capital (governance), shown on Figure 5.3.

To offer an alternative spatialisation method, a combination of the concepts of transformability and territorial capital is used. In this sense, the thesis looks for the spatial potential of transformability, through identifying elements of static and dynamic frequencies of change in each layer of territorial capital.

By observing **frequencies of change** (Urhahn, 2021), it is possible to sort the elements of the Territorial Capital layers into **dynamic** – having high frequencies of change – and **static** – having low frequencies of change – groups. Dynamic elements change often and are more unpredictable, therefore they require greater attention and more urgent action, similar to the **'revolt'-type changes** of Panarchies (Gunderson & Holling, 2002). Their static counterparts are slow-changing, more predictable elements, that are characteristic to the region, and can be connected to the **'remember'-type changes** of Panarchies (Gunderson & Holling, 2002). **In consequence, elements of high frequency have also a higher transformability potential.**

Determining the frequency of territorial elements was done based on the diachronic analysis, the concept of Urhahn (2021), the publication of Wegener et al. (1986) about 'time-scales of urban change' and empirical observations.

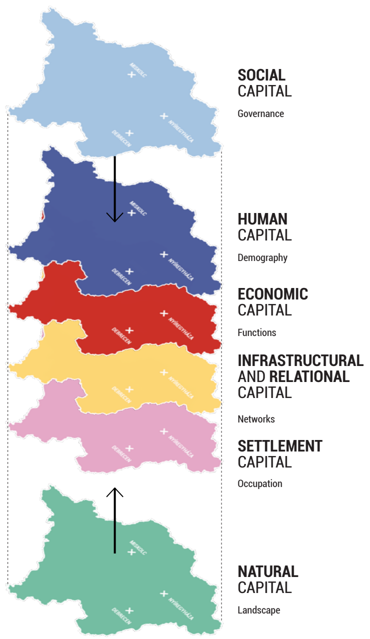


Fig. 5.3: Territorial capital layers; *source:* author

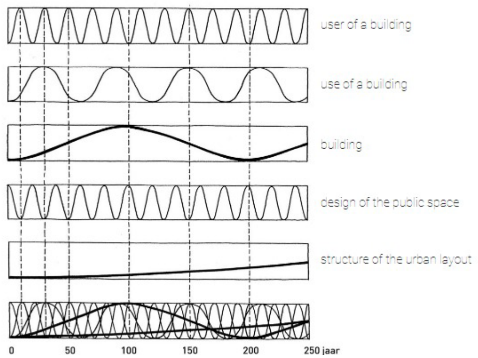


Fig. 5.4: Example of Frequencies of change (for urban environments); *source:* Urhahn, 2021

Approach Theories - Conceptual Framework

[Exploration]: Planning with Uncertainty

The socio-ecological system of the territory acts as a complex adaptive system (Gunderson & Holling, 2002), thus **accepting change and planning with the uncertain – seeing a crisis as an opportunity - are of core interest.** Folke (2016) describes resilience-thinking as the 'science of surprise', and states that the resilience approach to transformability is 'about preparing for opportunity or creating conditions of opportunity for navigating the transformations', rather than attempting to control or plan out the process. He promotes arenas for safe-to-fail experimentation, transformative experiments on the local scale, cross-learning and new initiatives.

To identify and leverage these opportunities, Walker et al. (2004) argue that **scenario-planning is a powerful tool for envisioning change and plausible transformations.** When conducted together with stakeholders in a comprehensible way, scenario-making can facilitate discussions and encourage future action.

In this thesis, scenario-planning is incorporated into the **process of backcasting**, to discover different pathways based on the values, goals and principles of the vision. Two scenarios are created by maximising the seemingly contradictory enablers of transformability: efficient and hierarchic, redundant and polycentric. The two scenarios are then evaluated and a long-term transformative framework is created. The process of the scenario-construction is further detailed in the exploration chapter.

[Operationalisation]: Adaptation Pathways

In order to be able to work with uncertainties in the design and implementation phase, the need arises for flexible ways of operationalising transformability. Doing a masterplan or concrete design projects would go against the nature of the project, therefore a new working method is proposed: adaptation pathways.

This decision-focused approach emerged around 2010, with the goal to create adaptive policy pathways by **incorporating flexibility and future uncertainties into decision-making** (Haasnoot et al., 2013; Werners et al., 2021). These pathways are 'sequences of actions' with tipping points and transfers between them, and are implemented in a parallel way, or one after the other, depending on externalities and decisions made. 'No-regret' measures – no matter the future outcome, it is beneficial to implement them - and maladaptive paths – leading to undesirable futures - can also be identified.

Werners et al. (2021) describe three main approaches, which are (1) performance-threshold oriented pathways development, (2) multi-stakeholder oriented pathways development, and (3) **transformation-oriented pathways development**. Regarding the topic of this thesis, the third category is used, as it recognises the need for transformation, therefore it can serve as an instrument to steer the region towards the envisioned goal, a deeper change. This approach **acknowledges the unsatisfactory nature of the current system, and is able to combine short-term answers to the current (battery) crisis, and long-term goals**. Consequently, visioning and backcasting are crucial steps of transformation-oriented pathways development (Werners et al., 2021).

This projects attempts to not only construct possible pathways, but also to **spatialise** the main interventions and steps leading to the long-term vision in an abstract way. Multi-stakeholder perspectives, uncertainties in future battery production, as well as ownership can be taken into account using this method, leading to a variety of different possible outcomes, represented by 'postcards' depicting glimpses into the future.

In this thesis, the adaptation pathways therefore become 'TRANSFORMATION PATHWAYS'.

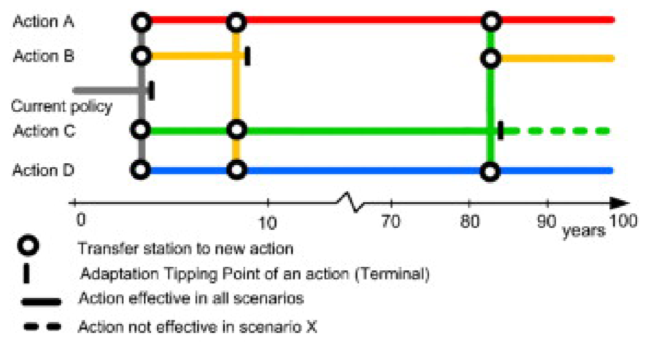


Fig. 5.5: Adaptation pathways map; *source:* Haasnoot et al., 2013

Analytical Framework

The Analytical Framework functions as a roadmap to the project. It connects research questions with methods used to answer them, as well as the expected outcomes of each question.

METHODS:

- LR Literature Review
- FT Field Trip
- IN Interviews
- DA Diachronic Analysis
- AM Analytical Mapping
  - M_T M_F *Territorial, Frequency of Change*
- SA Stakeholder Analysis
- B Backcasting
  - V *Envisioning the Future*
  - MS *Maximised Scenario Construction*
  - SE *Scenario Evaluation*
  - O *Optimisation*
  - AP *Adaptation pathways*

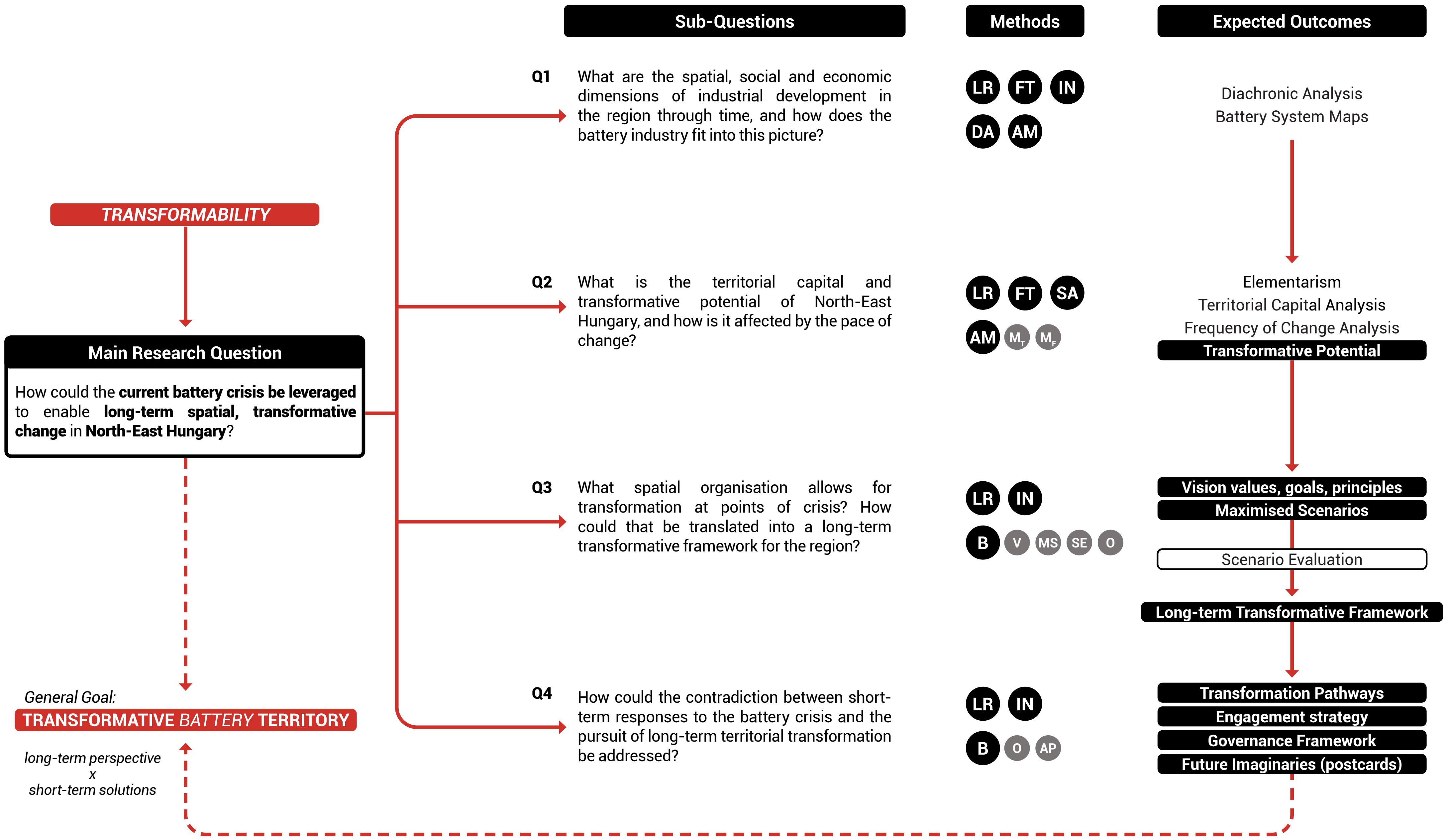


Fig. 5.6: Analytical framework; *source:* author

Methods

LR Literature Review

Reading and reviewing literature (scientific articles and reports, newspaper articles, studies, relevant books, ...).

Aim: To create an understanding, compare different perspectives and research possible solutions regarding the contextualisation, problematisation, theories and concepts, understanding, exploration and operationalisation phases.

Connects to: Q1, Q2, Q3, Q4

FT Field Trip

Visiting the region of North-East Hungary, including the battery factories.

Aim: To observe and better understand the spatial conditions and consequences of battery-related developments, as well as to explore the spatial and social dimensions of the regional context of North-East Hungary in order to identify morphological elements and territorial capitals.

Connects to: Q1, Q2

SA Stakeholder Analysis

Identifying crucial stakeholders related to battery manufacturing and the territory, as well as analysing their intentions and goals, relations, power and interest, and distribution in space.

Aim: To understand the complex system and relations of actors connected to the topic, in order to see their goals, react to their needs or make them seen with proposed strategies, as well as to uncover hidden influences or relations between them.

Connects to: Q2, Q4

DA Diachronic Analysis

Comprehensive analysis of the evolution of the relationship of industry and the region from the late 19th century until today by combining elements of both history and case study (Widdersheim, 2018).

Aim: To identify reoccurring characteristics, spatial, social, and economic relations between industrial elements and the region of North-East Hungary through time, and to observe how battery manufacturing fits into this context, whether its patterns relate to or differ from those of previous industrial eras.

Connects to: Q1

AM Analytical Mapping

M_T M_F

Mapping out trends, tangible and intangible elements, territorial capitals, spatial structures and potential.

Aim: To analyse and synthetise observations, research and spatial elements while representing them in a visually understandable way, uncovering patterns and interrelations between different topics and structures. Analytical mapping is used on multiple scales, including global, European, national, and regional. There are special types of mapping used in this thesis, including:

1. _Territorial Capital mapping_: to map out the tangible and intangible layers of the territory, sorted into groups of territorial capital, which are: natural, settlement, infrastructural and relational, economic, human and social capitals. This method is based on Camagni (2017) and Orsi et al. (2014).

2. _Frequency of Change mapping_: to map out the static and dynamic elements of the region by using the concept of 'frequency of change' (Urhahn, 2021). This allows to determine which elements are more unpredictable, therefore require urgent transformative solutions because of their dynamism, while their static counterparts provide the main regional characteristics.

Connects to: Q1, Q2

IN Interviews

Conducting interviews with experts in the field of battery development and spatial planning in Hungary.

Aim: To further understand the main effect of the rapid development of battery manufacturing on the Hungarian spatial (and social) fabric, and to see what are the feasible future pathways to integrate this industry on a regional scale, with an emphasis on transformability.

Connects to: Q1, Q3, Q4

B Backcasting

It is a type of explorative scenario construction method, where first a desired future state is envisioned, then the steps of how to get there are defined by working backwards, connecting present and future (Bishop et al., 2007). In this thesis this method is used in combination with the maximisation method, and adaptation pathways.

Aim: To create a future free of the 'burdens of the present', by first envisioning the goals, then working towards them backwards.

Steps:

V **1. <u>Envisioning the Future</u>:** Setting values, goals and principles for the future of North-East Hungary.

Aim: To formulate a vision for the territory that can lead to long-term transformative change, allowing the region to shift to a new system at points of crisis. It also offers an alternative to current practices, and builds on spatial imagination, as a tool to engage stakeholders. (Q3)

MS **2. <u>Maximised Scenario Construction</u>:** vmaximising contradicting principles of transformability.

Aim: To explore the difference between spatial organisation patterns resulting in transformative capacity: efficient (vertical, hierarchical) and redundant (horizontal, decentralised). (Q3)

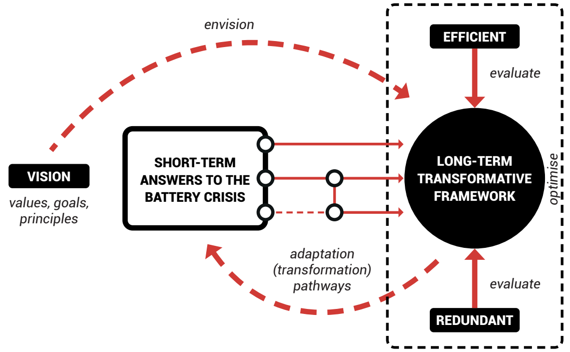


Fig. 5.7: Backcasting scheme; _source:_ author

3. <u>Scenario Evaluation</u>: Analysing and comparing the outcomes of the two scenarios in a systemic manner, based on a scenario evaluation framework built on the values of the sustainability transformation. SE

Aim: To discover the strengths and weaknesses of each scenario, in order to be able to derive strategies from them and come to a spatial framework. (Q3)

4. <u>Optimisation</u>: Using the lessons of the evaluation to construct an optimised, balanced and integrated transformability vision and spatial framework for the territory from the previously explored two scenarios. O

Aim: To define the 'end criteria', the desired future state for the backcasting with goals that have to be reached by working backwards. (Q3, Q4)

5. <u>Adaptation (transformation) Pathways</u>: Transformation -oriented pathway-development allows for discovering directions of deeper change, by discovering multiple possible and adaptive options depending on future uncertainties, bridging present and desired states (Werners, 2021). It can also be used to depict different stakeholder perspectives. AP

Aim: To connect the present battery crisis with the goals described by the vision, by offering multiple possible paths (spatial interventions and policies), incorporating the uncertainties of battery production. (Q4)

Planning

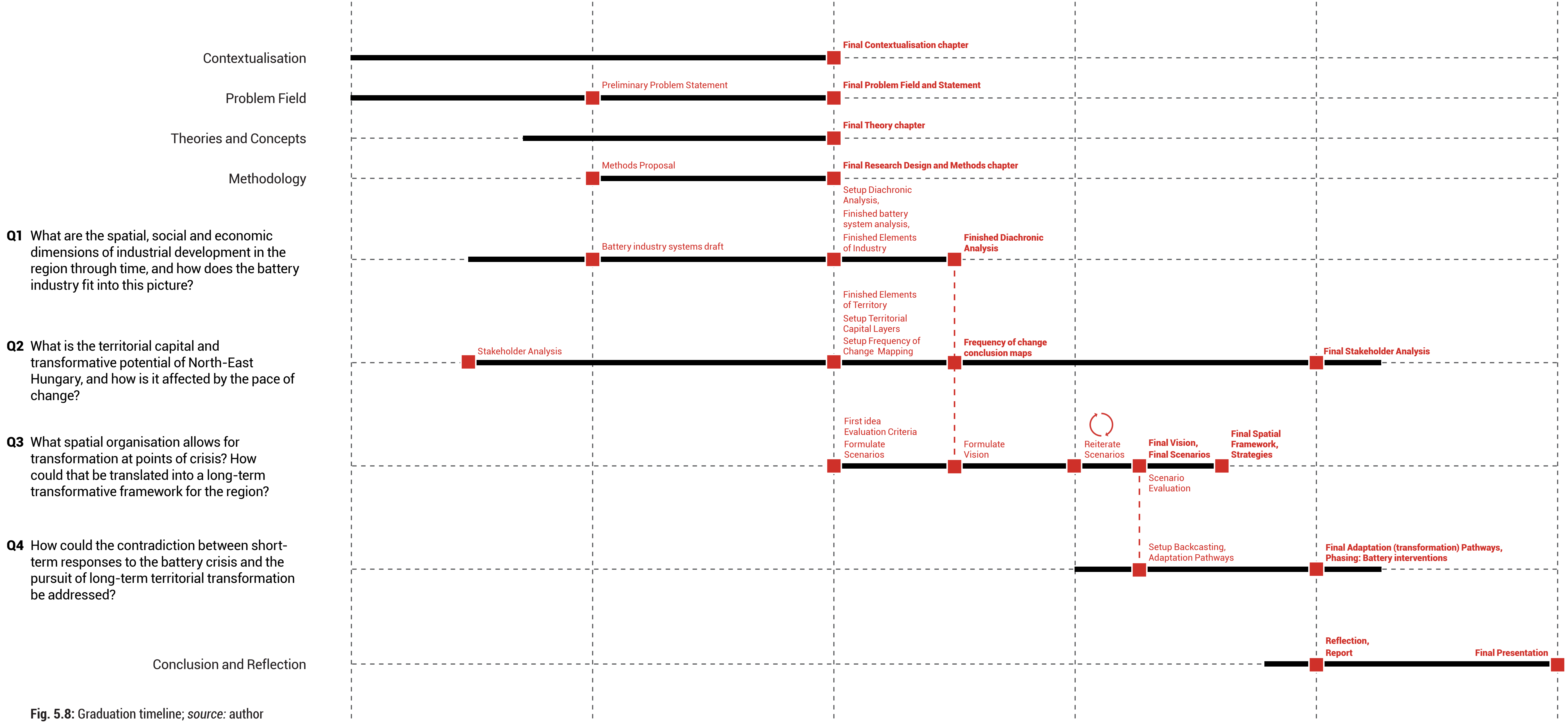
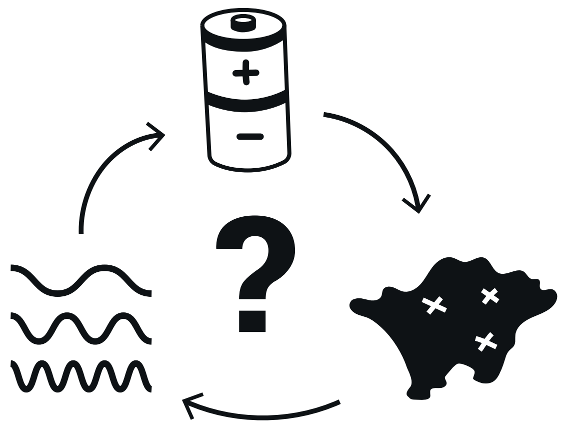


Fig. 5.8: Graduation timeline; *source:* author

UNDERSTANDING



Industry, Space and Time

Diachronic Analysis

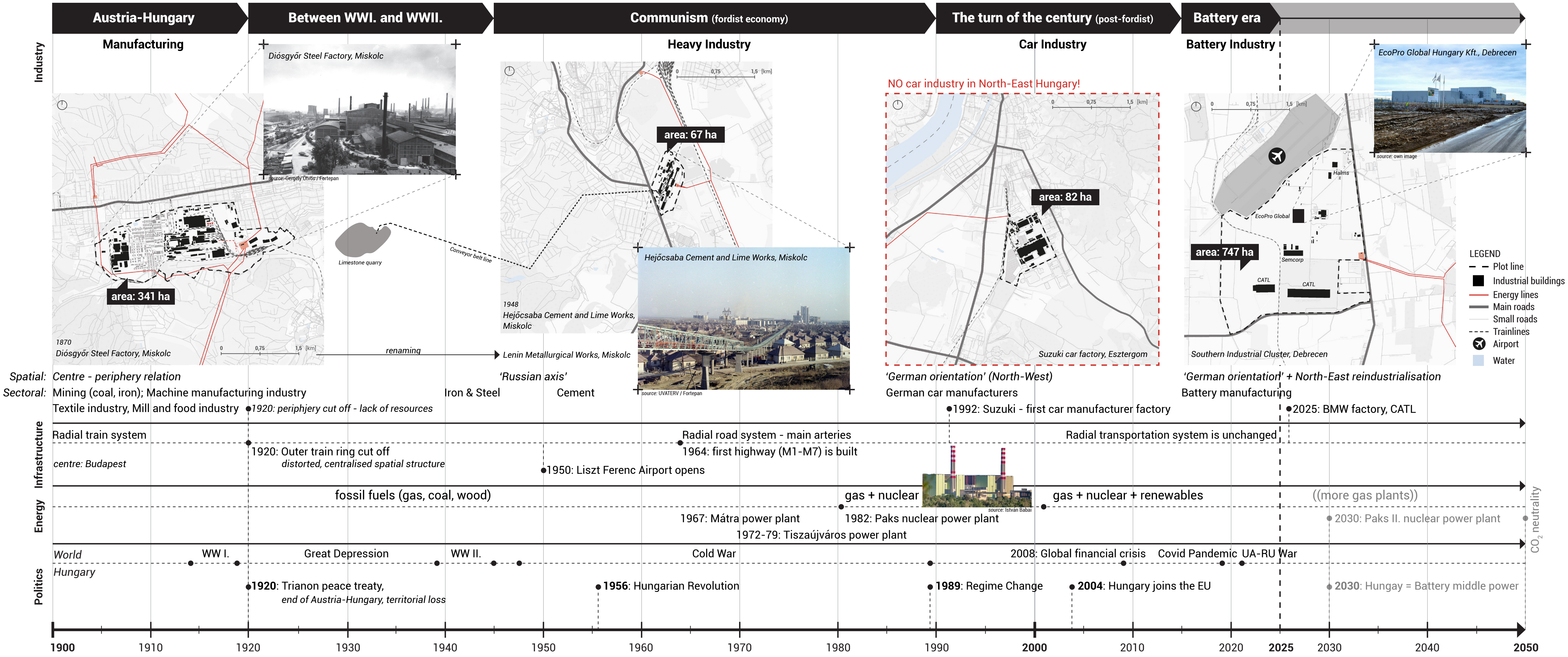


Fig. 6.1: Diachronic analysis; *source:* author

Industry, Space and Time

Diachronic Analysis

Austria-Hungary: Manufacturing
Late industrialisation process: first the textile and food industry with equal distribution, than the heavy industry. The latter was characterised by a centre-periphery relationship, with manufacturing concentrated around Budapest, while resources were coming from the periphery (Carpathians, Transylvania, Slovakia). The train- and road system was also radial, with Budapest in the centre. After the first World War, Hungary lost the peripheries, making the industrial system untenable and without sufficient resources.

Communism: 'The country of Iron and Steel'
During the communist era, the industry followed the South-West - North-East infrastructural lines (direction towards Russia), and many new cities were built around factories (e.g. Dunaújváros, Tiszaújváros), with completely newly-built living districts for the workers – a form of social infrastructure. Hungary did not have significant resources, yet the governance pushed the vision of the country becoming the 'land of iron and steel' (Így épült a vas és acél országa, 2013). Major power plants were built, both coal, gas and the Paks nuclear power plant (1982).

After the system change: Car industry
After the fall of the Soviet Union (1989), a major regime change took place in Hungary. Car industry became the leading sector, with primarily German companies building factories in the country (Opel - Szentgotthárd, Mercedes - Kecskemét, Audi - Győr, Suzuki - Esztergom). The industrial axis shifted towards the Western side.

Battery Industry
Compared to the previous eras, the battery industry partly follows old patterns, and it partly deters from them. The concentration of factories around Budapest and in the North-Western regions follow the development path of car industries, while the reindustrialisation process on the North-Eastern regions introduces a new pattern while partially revitalises the industrial heritage of Miskolc and its surroundings.

In conclusion, it can be observed that Hungarian industrial development follows politics, not only by the type of production, but also in space, as the industrial axis orients towards the countries of origin of the leading industrial sector. The supporting infrastructure remains fairly constant through different times, keeping its radial centrum-periphery structure.

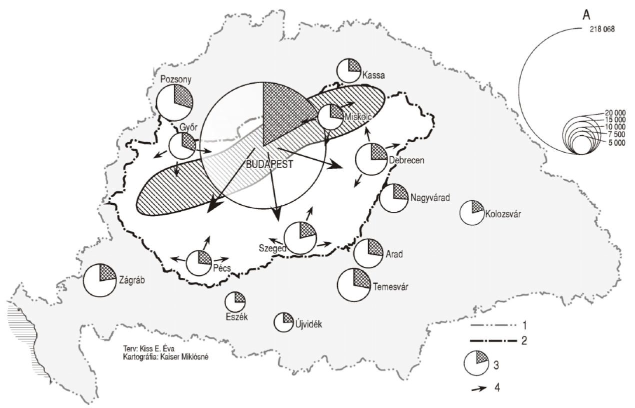


Fig. 6.2: The pre-World War I. situation of industrialisation - centre and peripheries of Greater Hungary

source: Kiss (2002)

BATTERY SYSTEM
● active / ○ planned or being built
- EV Electric vehicles
- C Cell manufacturers
- S Sub-component manufacturers
- O Other components
- R Recycling companies

POST-FORDIST SYSTEM: CARS
- Cities with major car factories
- The industrial axis after 1989

COMMUNIST (FORDIST) SYSTEM
- Industrialised cities of the era
- The communist industrial axis *1947 - 1989*

AUSTRIA-HUNGARY SYSTEM
- Budapest, the centre of manufacturing
- Other cities with the potential for industrial activities

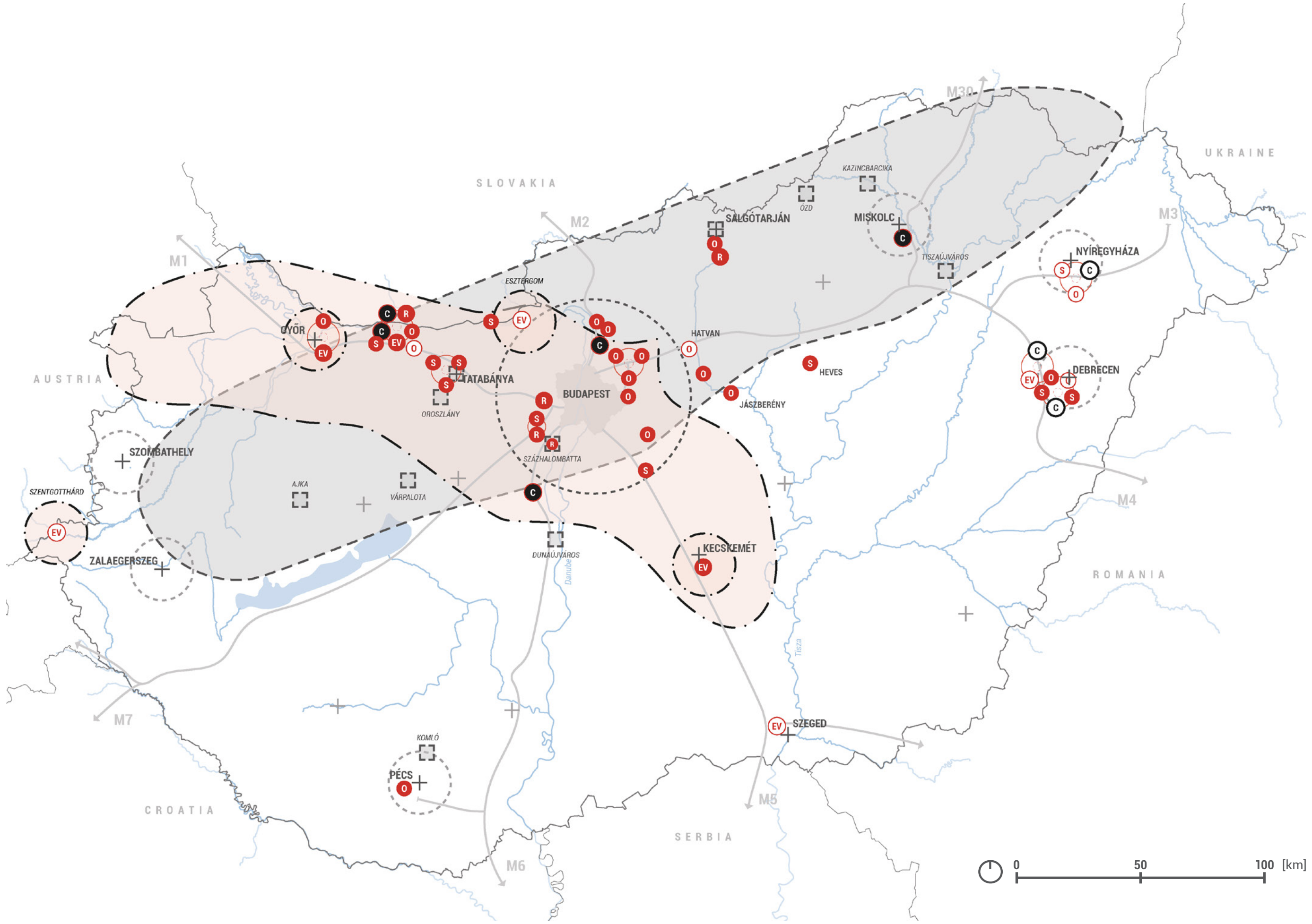


Fig. 6.3: Synthesis of the shifting industrial axes through time

source: author

Industry, Space and Time

The Hungarian Battery-system

The battery industry requires three main supportive systems: energy, water and transport infrastructure. One of the most pressing questions is of energy, as the country might not have enough to power the new battery factories (Weiler, 2023c). The main energy sources of Hungary are nuclear energy (produced at Paks nuclear power plant) and imported Russian gas (IEA, n.d.-a). Major gas pipelines and electricity powerlines go through the country, from the direction of Russia and also from the South, towards Western-Europe. Relying too much on imported resources can hinder the resilience of the country in case of crisis, especially regarding the current uncertainties of the geopolitical situation. Thriving for decentralised energy systems could be a potential towards decreasing these dependencies.

In hilly areas with sandy soil, like Debrecen, water scarcity is already causing issues, as droughts in the summer are getting worse year by year due to climate change (Előd, 2023b). In order to supply the battery factories with water, new pipelines are being built, and more water is taken away from the inhabitants and agriculture (Bolcsó, 2023). For example, the factories in Debrecen are obliged to reuse their waste water, but is not enough to meet the needs of these facilities (Éltető, 2025).

The infrastructure of the country needs renovation, many of the trainlines are not suitable for the capacity that is required for the battery facilities (Molnár, 2024). Spending money solely on the infrastructure related to the factories leads to further spatial inequalities, causing stagnation and missing money for development at other parts of the country (Éltető, 2025).

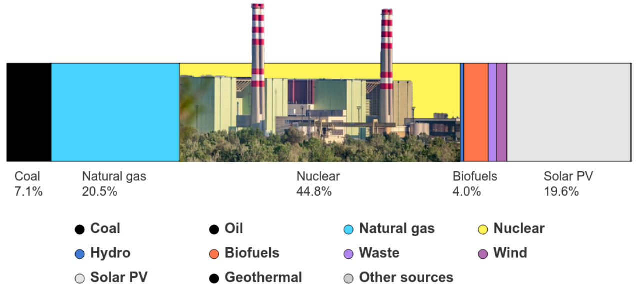


Fig. 6.4: Electricity generation sources in Hungary, 2023; *source:* IEA, @ István Babai [image]

BATTERY SYSTEM
active / planned or being built
Electric vehicles
Cell manufacturers
Sub-component manufacturers
Other components
Recycling companies
Value chain connections
Hazardous material dumpsites

ENERGY SYSTEM
coal plant
nuclear power plant
hydropower plant (planned)
750 kv power-line
400 kv power-line
220 kv power-line
electricity substations
oil / gas plant
>1000 D gas pipeline
600<D<800 gas pipeline
300<D<500 gas pipeline
gas nodes

TRANSPORTATION SYSTEM
Highways
Main roads
Train tracks

NATURAL SYSTEM
Waterways
Waterbodies

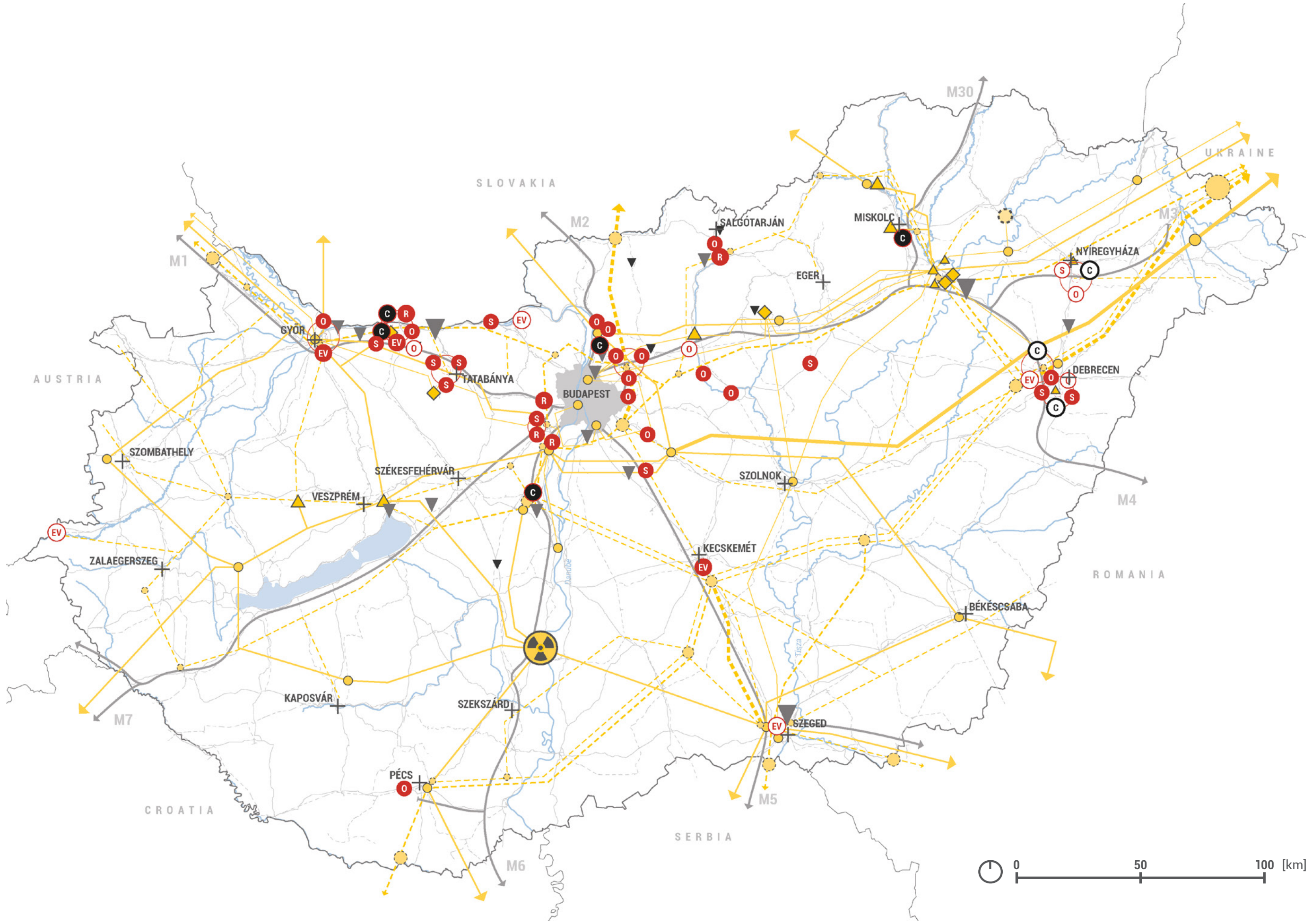


Fig. 6.5: Hungarian battery industry and the related systems

source: author

Path Dependencies

Based on Czirfusz et al. (2022) and the expert interviews (Czirfusz, 2025; Éltető, 2025), I mapped the most important relations between the different actors of the supply-chain (Fig. 6.6). **A general trend is that every bigger assembly factory has its own sub-component providers and recyclers, thus the building of one factory often results in the establishment of several more. This phenomenon is called path-dependency.** For example by building the new CATL factory in Debrecen supplies batteries to the BMW factory in Munich, while the new BMW factory requested EVE Power as its supplier. EVE Power has its own sub-component manufacturers, one of them being Hoayou Cobalt, that is also building a factory in the country at the moment (Éltető, 2025).

These processes are the example of not being redundant in a good way. There is a lack of cooperation between providers from different countries (e.g. Chinese companies refuse to work with South-Korean or Japanese ones), due to immense competition, leading to lack of transparency. At the same time, they are all producing the same products, there is no diversity, only EV batteries. In this sense, in case of a crisis the factories have to close and let people go, as there are no reserves or other types to production, as it is happening at the moment (Weiler, 2025b).

Path dependencies are also noticeable with the infrastructure. High-voltage power-lines, highways and main train connections are structures that last for a long time, and it is very difficult to replace or transform (Czirfusz, 2025).

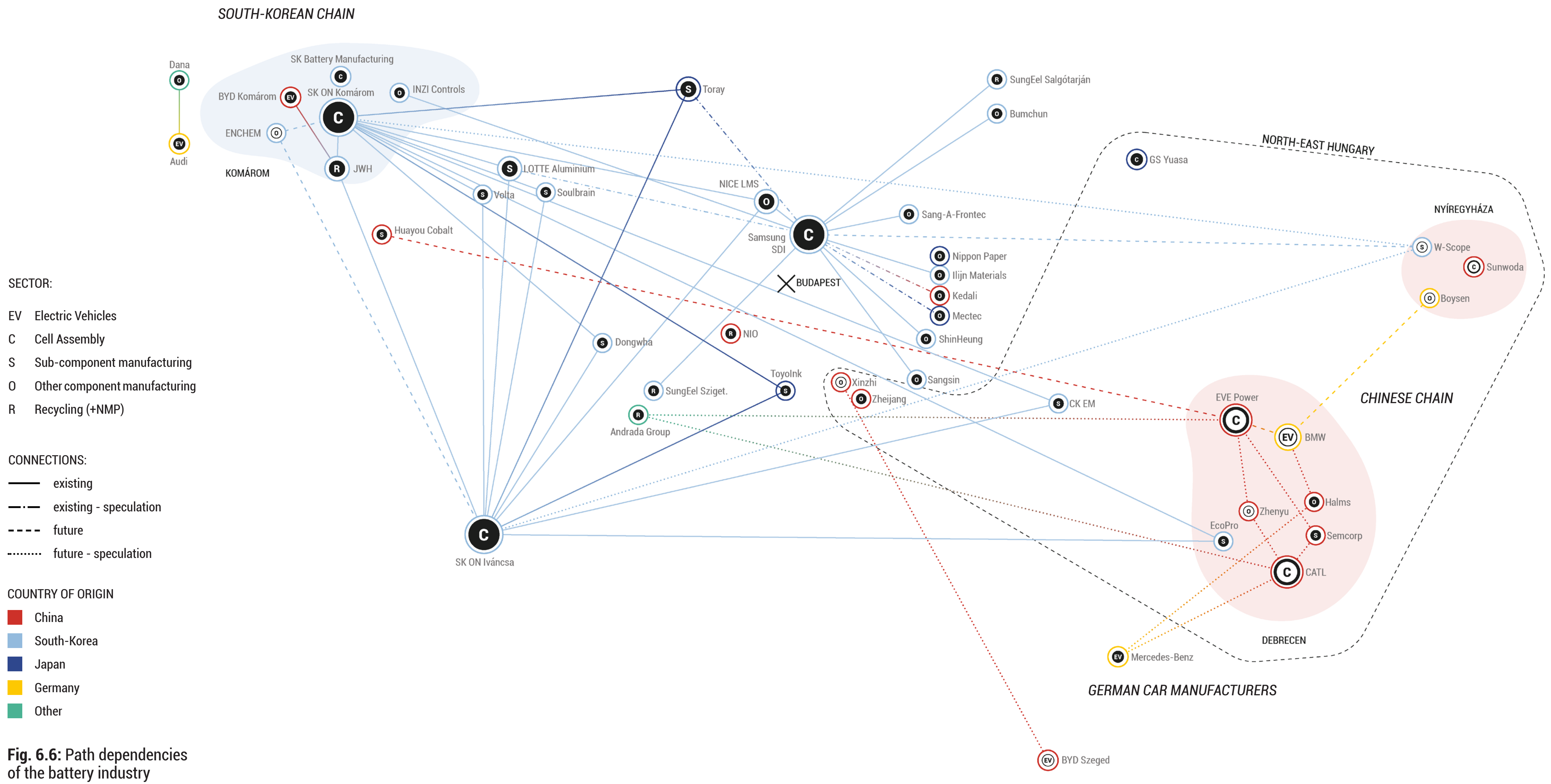


Fig. 6.6: Path dependencies of the battery industry

source: author

Industry, Space and Time

An 'Average' Battery Factory

Battery factories are isolated islands of production, in their own path-dependent supply system. They do not communicate with the outside world (apart from infrastructure), and they can be described as a group of closed-off grey boxes.

Their main characteristics (based on matrix, see in the appendix):

- Situated next to main roads and highways;
- They all have a train connection for transporting the products and a high-voltage energy connection to power the facilities;
- They need a lot of water, therefore they are connected to waterbodies by pipelines, and they often reuse wastewater, therefore wastewater-treatment facilities are nearby;
- They are situated on 'dry land', areas without flood risk;
- They are situated in industrial clusters, or next to residential areas;
- They are closed off with fences, levees, hills, or even moats in some cases – partially to reduce nuisance, but also to secure their privacy;
- They are often built by pouring a concrete slab on good agricultural soils;
- There is not a lot of social infrastructure being built, apart from some housing for migrant workers
- In some cases there is a company busline (Czirfusz, 2022) to collect people going to work from nearby areas (e.g. Samsung SDI, Göd).

A general trend for the future is that in the upcoming 50 years the company will most likely change, while the structure of the building and the concrete slab foundation will remain.

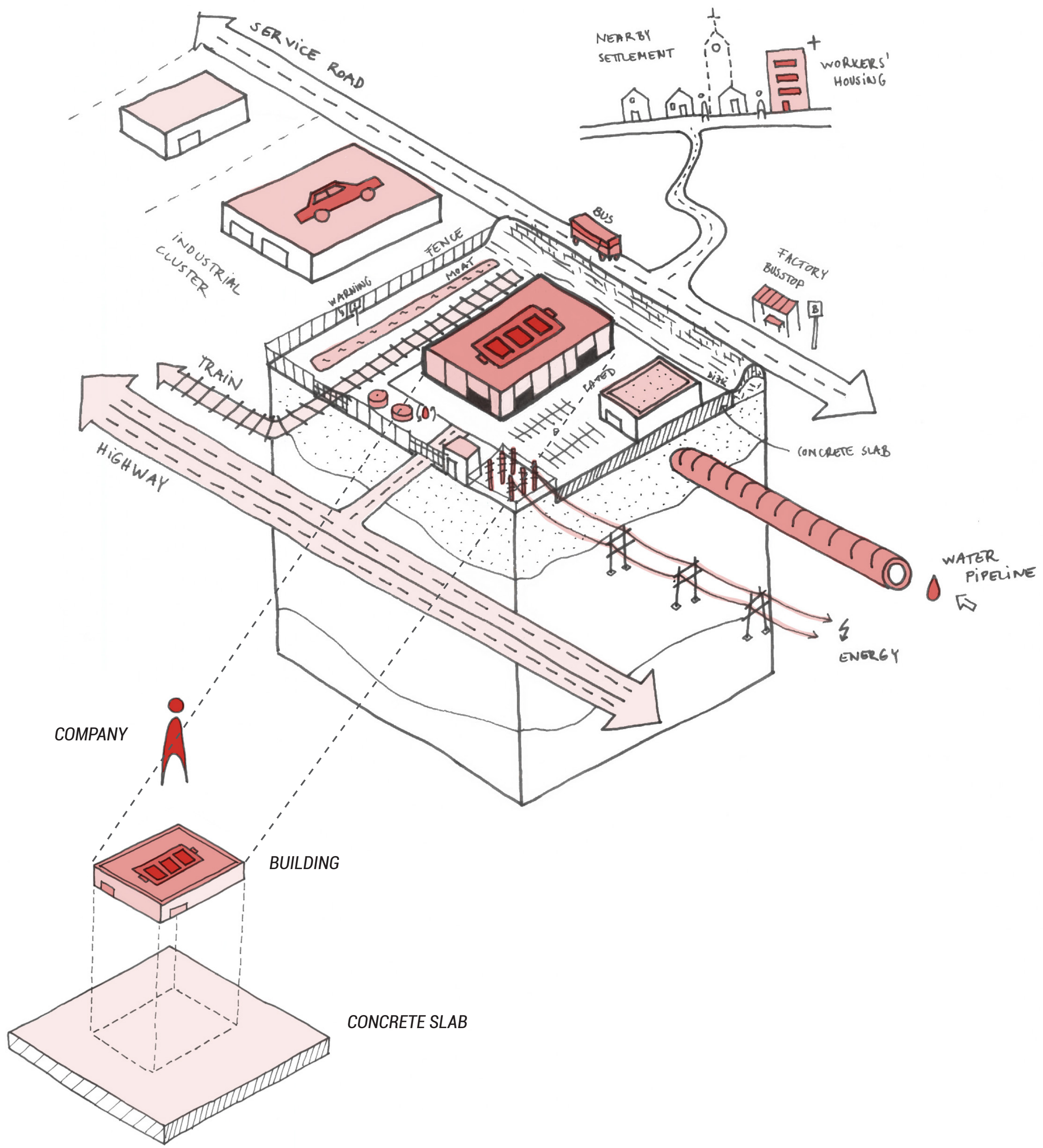


Fig. 6.7: General characteristics of battery factories

source: author

Concluding on (Battery) Industry in Space and Time

In Hungary industrial development has been defined by the governing forces, which had (and has to this day) a spatial manifestation as well, manifesting in a shifting industrial axis. There are similarities between the different industrial eras and sectors, but it can be concluded that the battery development of North-East Hungary is a reindustrialisation process, and partially a novel pattern around Debrecen. The infrastructure – apart from energy types – is practically unchanged throughout the years.

To conclude, the goal of the project is not to redesign factory sites, but to envision a sustainable future for the region of North-East Hungary. Nevertheless, **due to path dependencies and the current system of governance it is inevitable that more factories will be built. Therefore I suggest the following rules for future developments:**

- Promote brownfield developments;
- Use participation and co-creation;
- Establish strict environmental regulations, provide respect for nature and humans;
- Use systems-thinking when considering placement: is there a potential for industrial symbiosis, regional revitalisation or other types of improved qualities due to the new facility?
- Compulsory contribution to the region: monetary, development of (social) infrastructure, improvement of nature, education or other types of regulations and policies;
- Chance of partial Hungarian ownership.

Towards transformability, the following potentials can be phrased for the already built factories:

- **Changing ownership**: partially Hungarian, publicly owned, community-owned, …
- **Compulsory contribution to the region:** monetary, development of (social) infrastructure, improvement of nature, education or other types of regulations and policies;
- **Shared interest:** for example improving regional infrastructure that the factories also need to use, but considering spatial justness;
- **Changing battery production: diversifying** production (functionally: EV batteries, renewable energy uses, grid storage, shared battery networks, emergency backup systems, ICT use, …; or technologically, for example direct recycling (Éltető, 2024), or **localising** production by producing batteries for the domestic market, not only for export
- **Adding function – circular or other – to the facility, that can be used by the locals**. A circular hub or material bank has a great potential due to the compatibility with the industrial environment.
- **Industrial symbiosis:** fostering mutually beneficial collaborations between industries to optimize resource use and minimize waste. It concentrates on the flow of materials, energy, water, and by-products, looking for synergistic relationships and possibilities between different industries through the scales of local and regional economies (Chertow, 2000). For example: Research and Development (R+D) facilities, channelling in other Hungarian industrial sectors, using excess heat for nearby neighbourhoods or agricultural uses (greenhouses), …

Territorial Capital and the Pace of Change

Determining Spatial Transformative Potential

After looking at the battery-system, in the following sub-chapter the territorial understanding is brought into focus. The analysis has three main steps: elementarism (Vigano, 1999), territorial capital analysis (Camagni, 2017; Orsi et al., 2024) and finally determining the frequencies of change (Urhahn, 2021) of the analysed elements and layers. **The first two allow for a deeper socio-spatial understanding and a context-specific approach, while the latter provides the temporal understanding of the region and change.**

The synthesis of the analytical steps on each layer results in a map that describes the different frequencies of each analysed element. The frequencies are estimated based on literature review, the fieldwork, expert interviews and the diachronic analysis. **Apart from dynamic and static elements inside a given territorial capital layer, there are also differences between these layers**, which is illustrated on the diagram on Figure 6.11. The natural layers and the urban form, as well as main infrastructures are slowly changing elements, while functions, economic activities and human movements are relatively more dynamic.

The social capital layer is treated separately. Even though it should be a fast-paced process, as governance changes approximately every four years, in Hungary it is not the case. In this thesis, this layer summarises the governance and planning scales, and provides a stakeholder analysis.

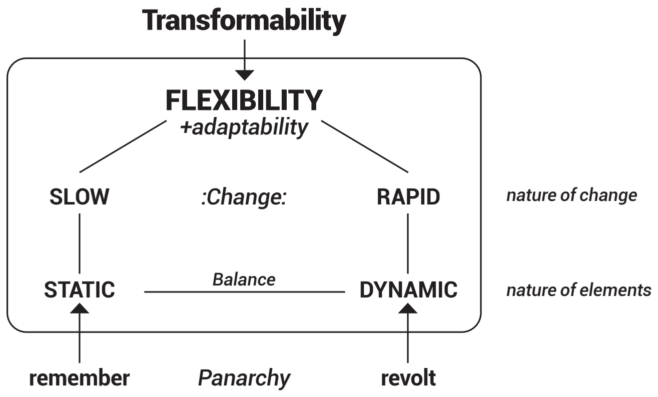


Fig. 6.9 (left): From transformability to static and dynamic elements

source: author

Fig. 6.8 (right): The Workflow of the Understanding chapter

source: author

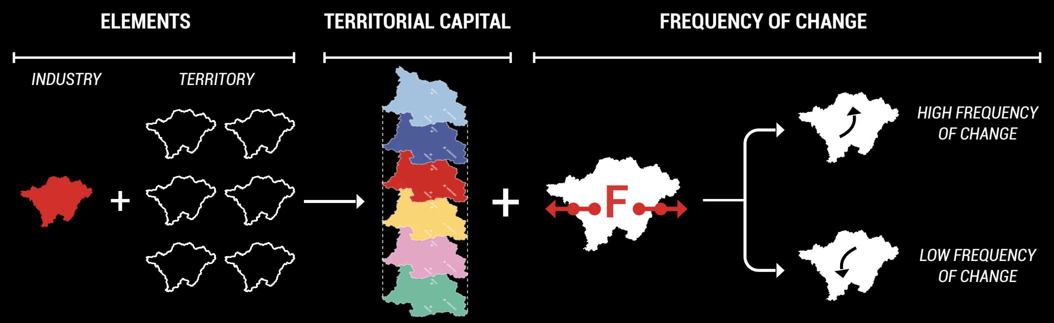
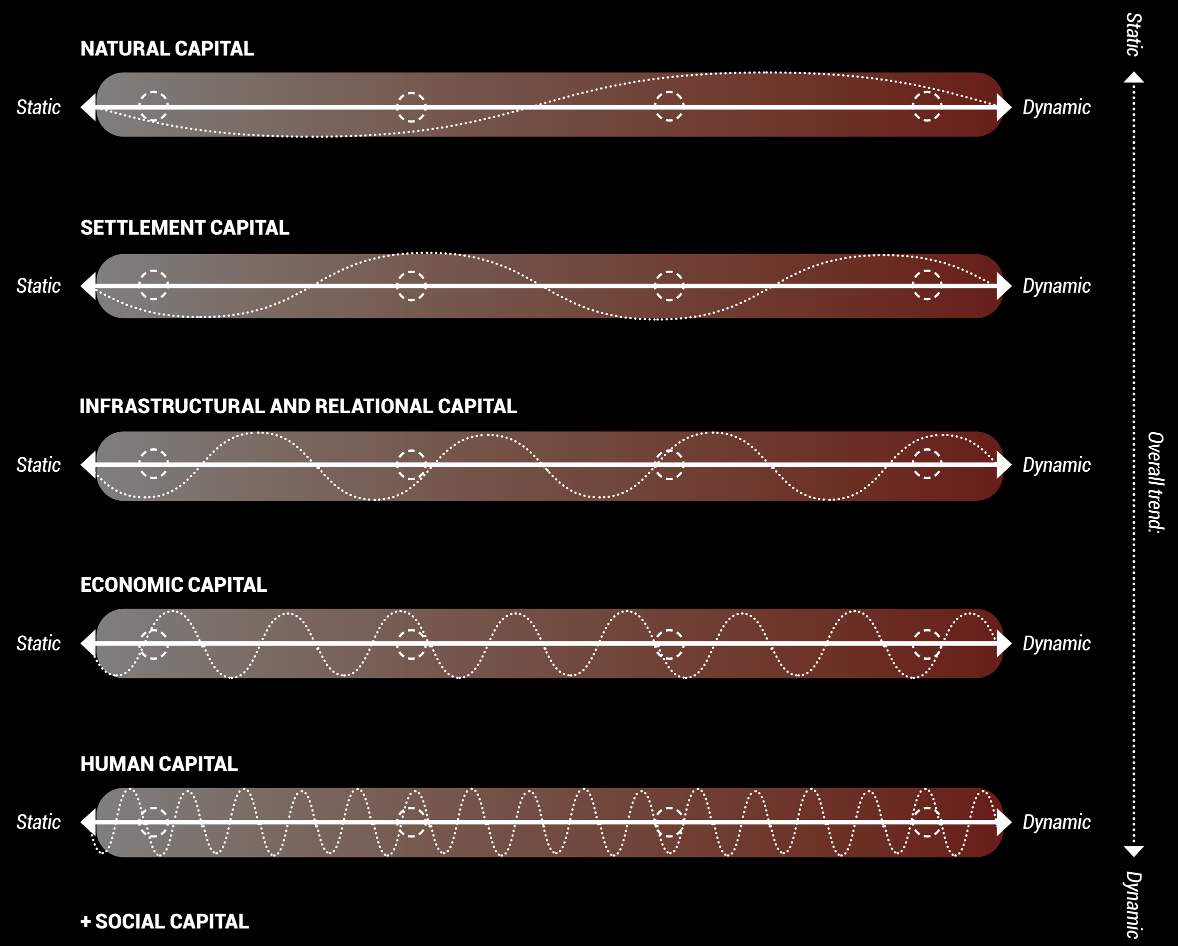


Fig. 6.10 (right): The different scales of the frequency of change in relation to the Territorial Capital layers

source: author



Territorial Capital and the Pace of Change

Land-use Typologies

As a first step, in order to tackle the complexity of the region, the territory is dissected into its elements based on land-use types. These are: water, nature (vegetation), agriculture, settlement, transport, energy and industry.

The region is divided into two halves by the river Tisza, the second biggest river of Hungary (a side-river of the Danube), which originates from the Carpathian mountains in Ukraine. The territory has diverse landscapes. To the north a volcanic mountain range (the North-Hungarian mountain range) is situated, with vast forests and protected natural areas, to the East there are hills with sandy soil, while the rest of the region is flat. The few bigger settlements are at the foot of the hills, along the river, or in case of Debrecen (the second biggest city of Hungary), at the intersection of flatland and hills. There are a lot of peripheral areas with small villages along the borders and in the mountains. Main infrastructural lines (M3 highway, electricity powerlines, gas and oil pipelines, train tracks) cross the region towards Budapest in a radial direction, resulting in a strong centrum-periphery relation. Agriculture (food) and heavy industry are the leading economic sectors, with pastures and arable land taking up the biggest percentage of the land use (based on EEA, 2018 dataset).

The bigger maps with legends can be found in the appendix of the thesis.

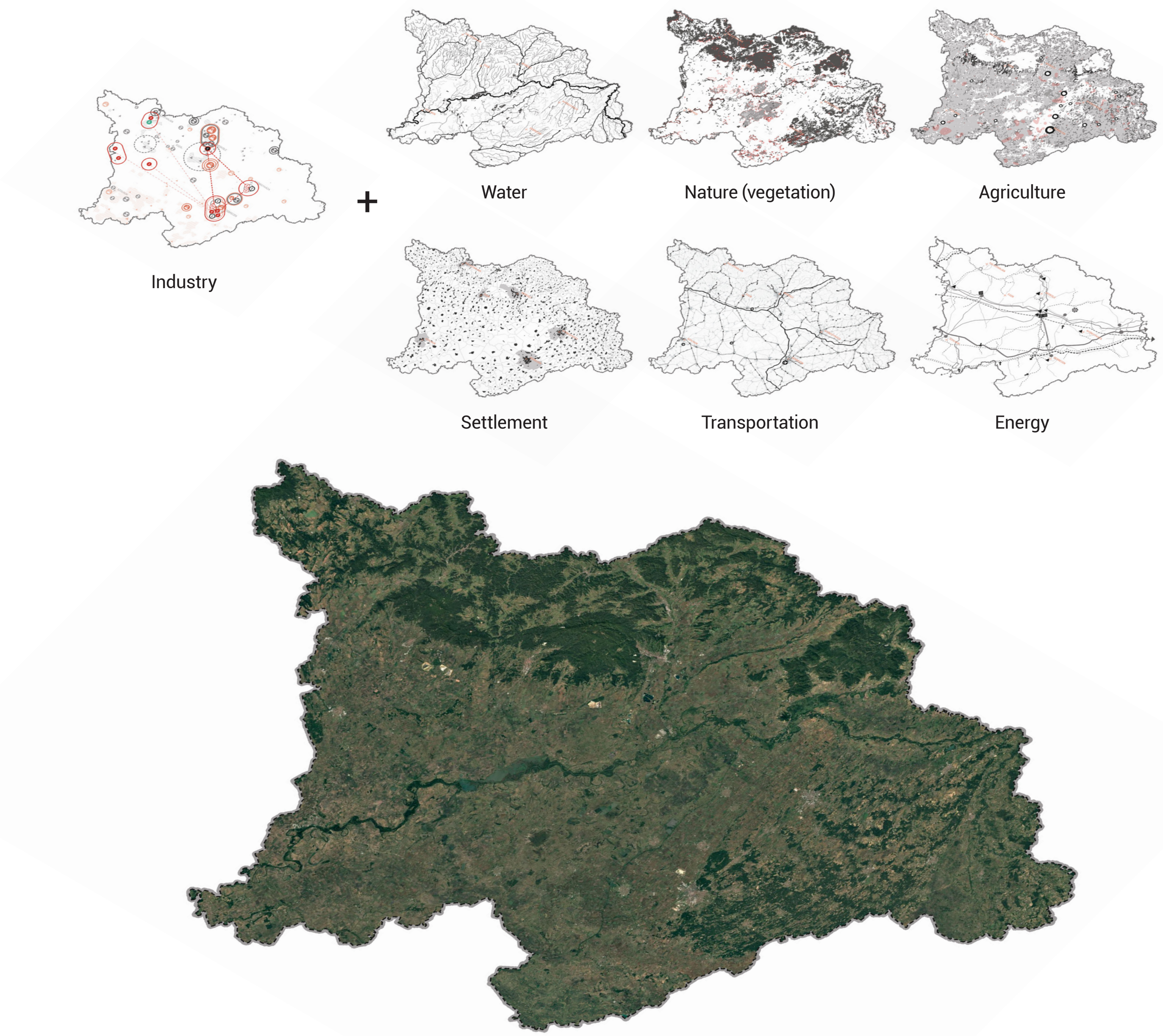
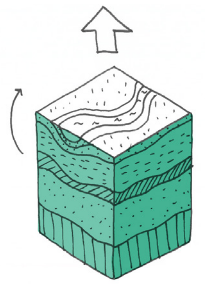


Fig. 6.11: The land use typologies of the territory (for legends and bigger maps: see appendix)

source: Google Earth, author

Natural Capital

Potential:



Landscape-based development

Geomorphology, Topography, Soil

Based on the subsurface (geomorphology, topography and soil), four main landscape types can be defined: mountains, hills, flatlands, and rivers (as a separate category). These are depicted on the section below.

They all have different characteristic soil types, flora and fauna and cultural heritage, **the subsurface have been, and will be defining all aspects of territorial development in the region.**

A future potential is to consciously steer the region based on soil and water, **promoting landscape-based development.**

SOIL TYPES

- Sand (arenosol)
- Black soil / humous (chernozem)
- Leached black soil (phaeozem)
- Young river sediment (fluvisol)
- Swamp soil (histosol)
- Salinated soil (solonetz)
- High-swelling clay soil (vertisol)
- Brown forest soil (cambisol)
- Brown forest soil with clay (luvisol)
- Rock-like soil (leptosol)
- Waterlogged soil (gleysol)
- Town

GEOMORPHOLOGY

- Sand
- Loess
- Clay with sand
- Sedimentary rock
- Mezozoicum rock mix with basalt
- Vulcanic rocks
- Rivers
- Topography

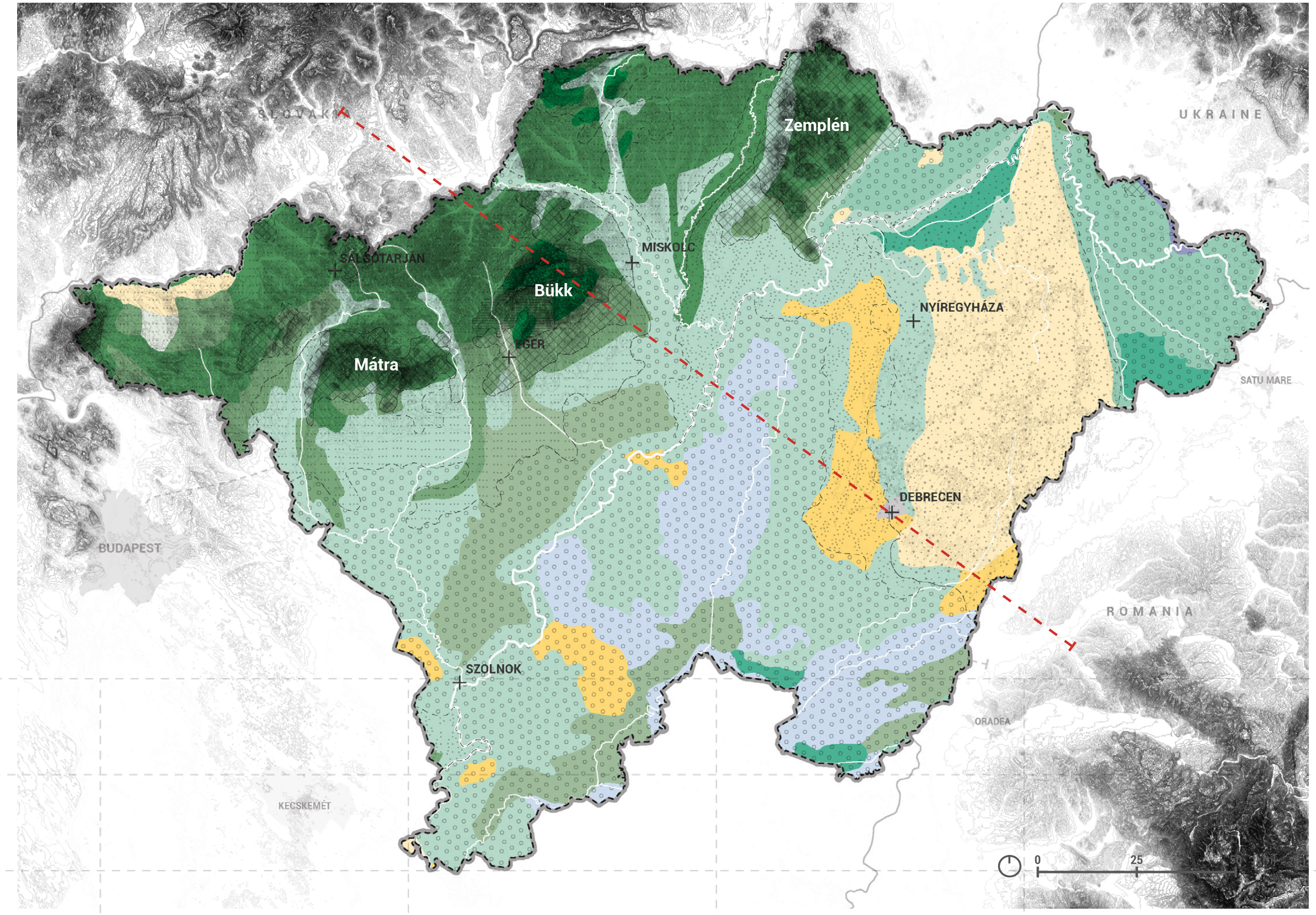


Fig. 6.12: Topography, soil types and geomorphology

source: author

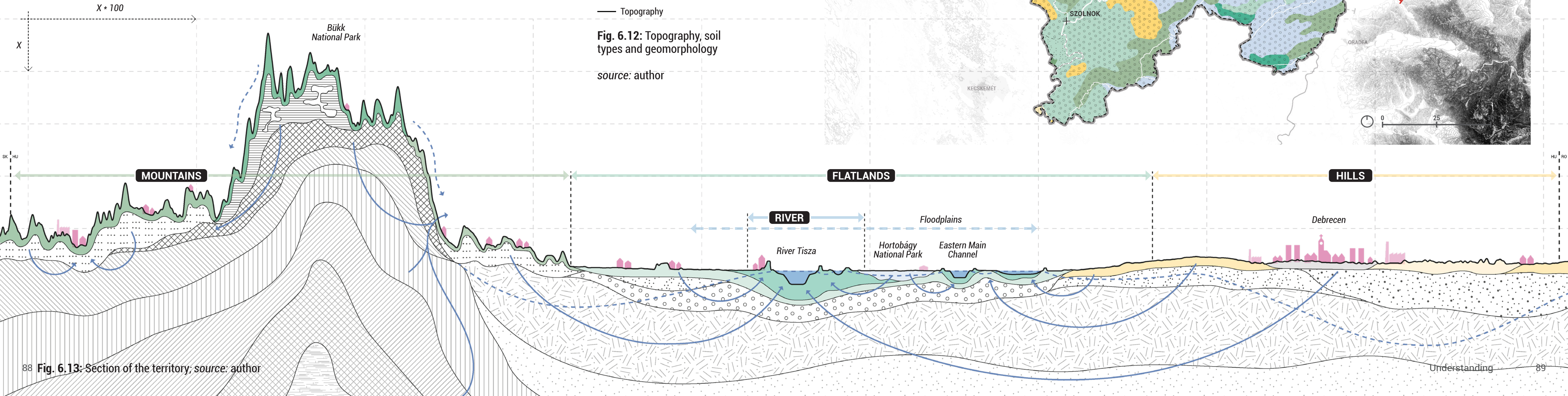


Fig. 6.13: Section of the territory; *source:* author

Natural Capital

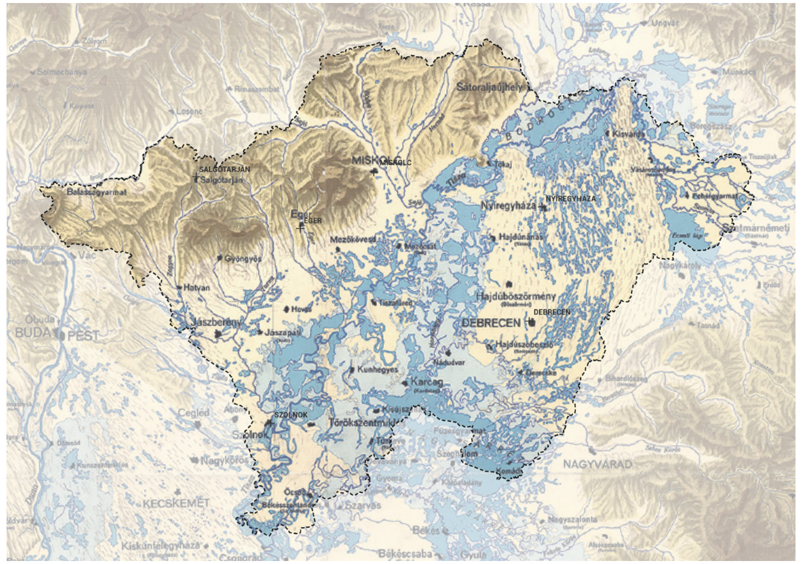
Water

The dynamics of water used to shape the landscape, but nowadays the water system is heavily regulated by humans (levees, reservoirs, ...). This departure from the natural state combined with climate change causes flood-drought issues in the region.

Before regulating the system, most of the flatland used to be all year long, or temporarily underwater (Kocsis, 2024), as shown on Figure 6.16. Due to the urge to transform these lands into agricultural areas, most of these wetlands disappeared. Every year, there are significant flooding along the river Tisza, while severe droughts are common during the summer months, especially at the hilly areas.

The rivers, especially river Tisza, are the most dynamic element of the natural capital layer. They are often unpredictable, and change by the season.

Concerning water, the following potentials can be concluded based on the history and present problems of the region: floodplain regeneration, significant flood-drought buffers in cities and agricultural areas, water storage in sandy soils, and voluntary inundation of agricultural fields as an already happening bottom-up approach (Fehér, 2025).



FLOOD PROBABILITY
- High risk
- Mid risk
- Low risk

GROUNDWATER
- 200
- 400
- 600
- 800
- 3000

depth from the surface [cm]

- drought-prone areas

DROUGHT
- Most severe droughts
- Severe droughts
- Fairly strong droughts

SURFACE WATER
- Main rivers
- Creeks, hydrology
- Lakes

Fig. 6.14: Surface water, groundwater, flooding and droughts

source: author

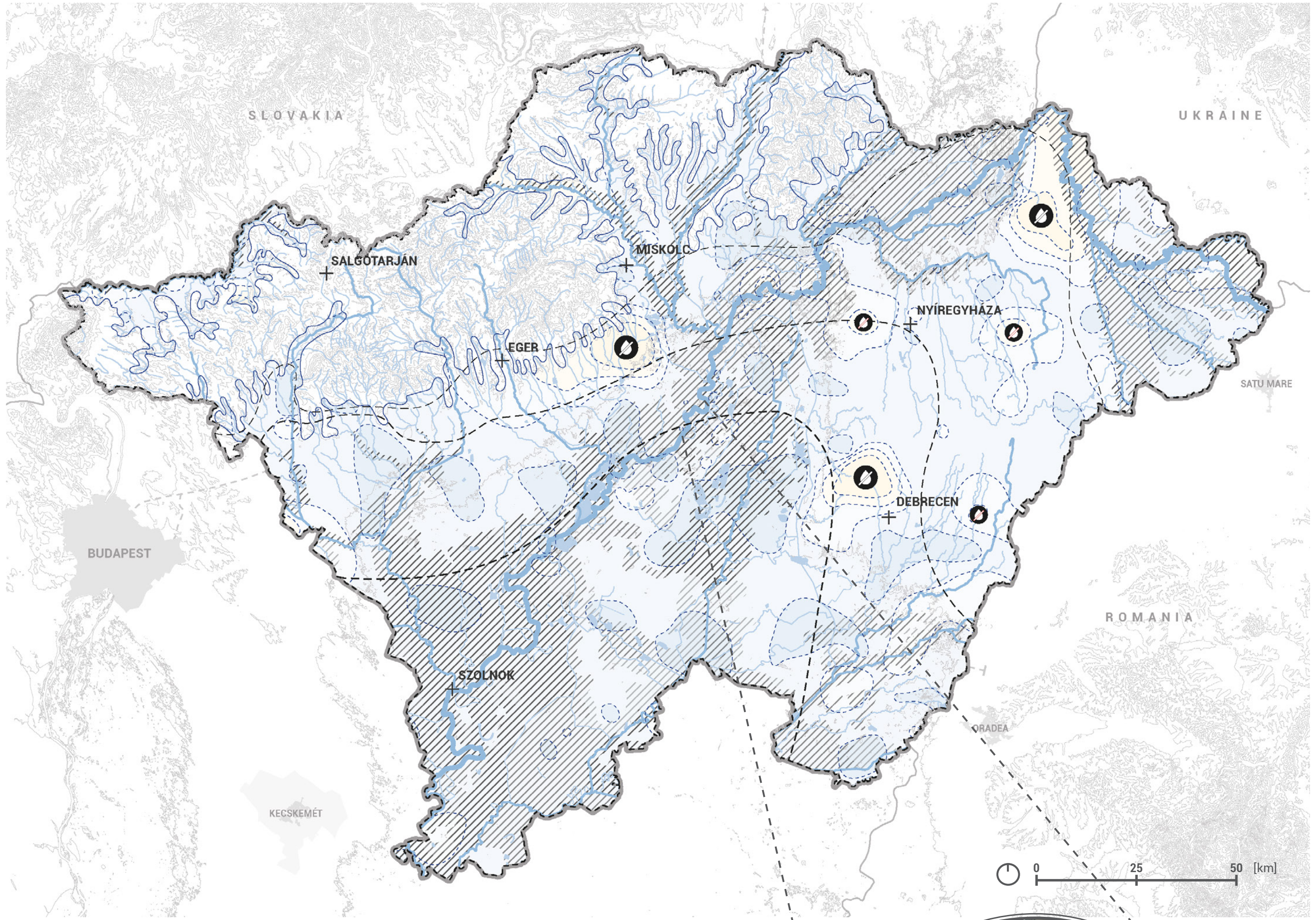
- Areas permanently under water
- Areas prone to flooding (min. 1x / year)

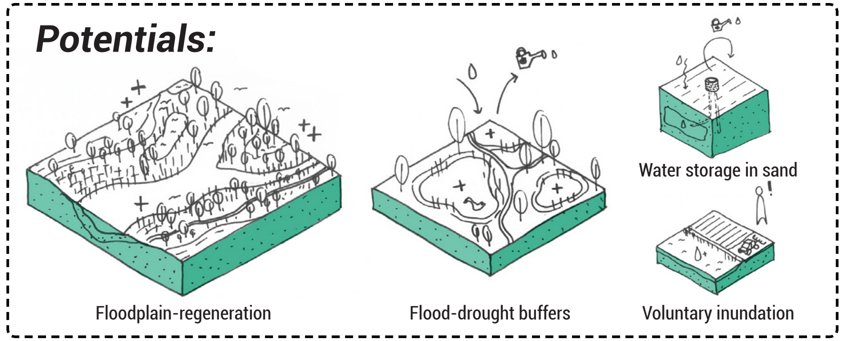
Fig. 6.15 (left): The hydrology of the region before regulating the system

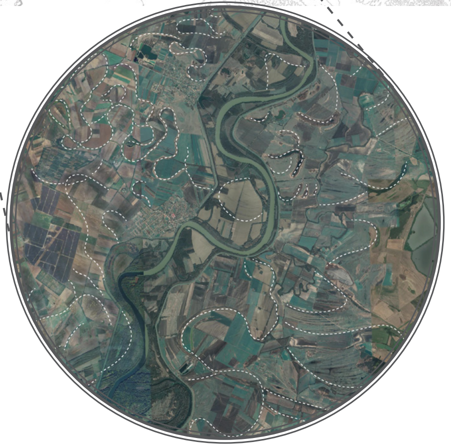
source: Kocsis, 2024

Fig. 6.16 (right): The remnants of the old water system

source: Google Earth







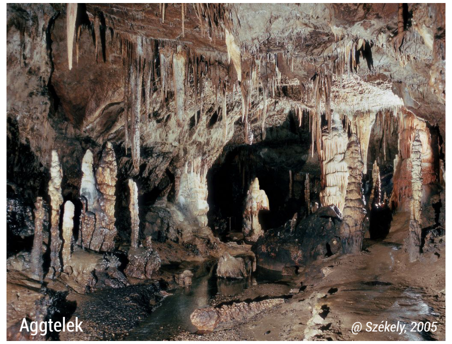
Territorial Capital and the Pace of Change

Natural Capital

Natural Heritage

The region has an intertwined natural and cultural heritage, closely connected to livelihood based on the land (agriculture, wine, ...). This also defines the main identity of the territory.

There are diverse protected landscapes, from ancient forests to vast grasslands with saline soils, which are the most static elements of this territorial capital layer. Due to the developing battery industry, nature is under threat of heavy pollution. Connected to these elements following potentials can be identified: establishing well-connected natural buffers and eco-corridors, restore the balance of the human-nature relationship and cultivation patterns, use of natural pollution reduction measures (e.g. phytoremediation).



PROTECTED NATURE
- Protected areas (Natura 2000)
- National parks
- World heritage
- Nature parks
- Geoparks
- Natural vegetation (forests)

SURFACE WATER
- Main rivers
- Creeks, hydrology
- Lakes

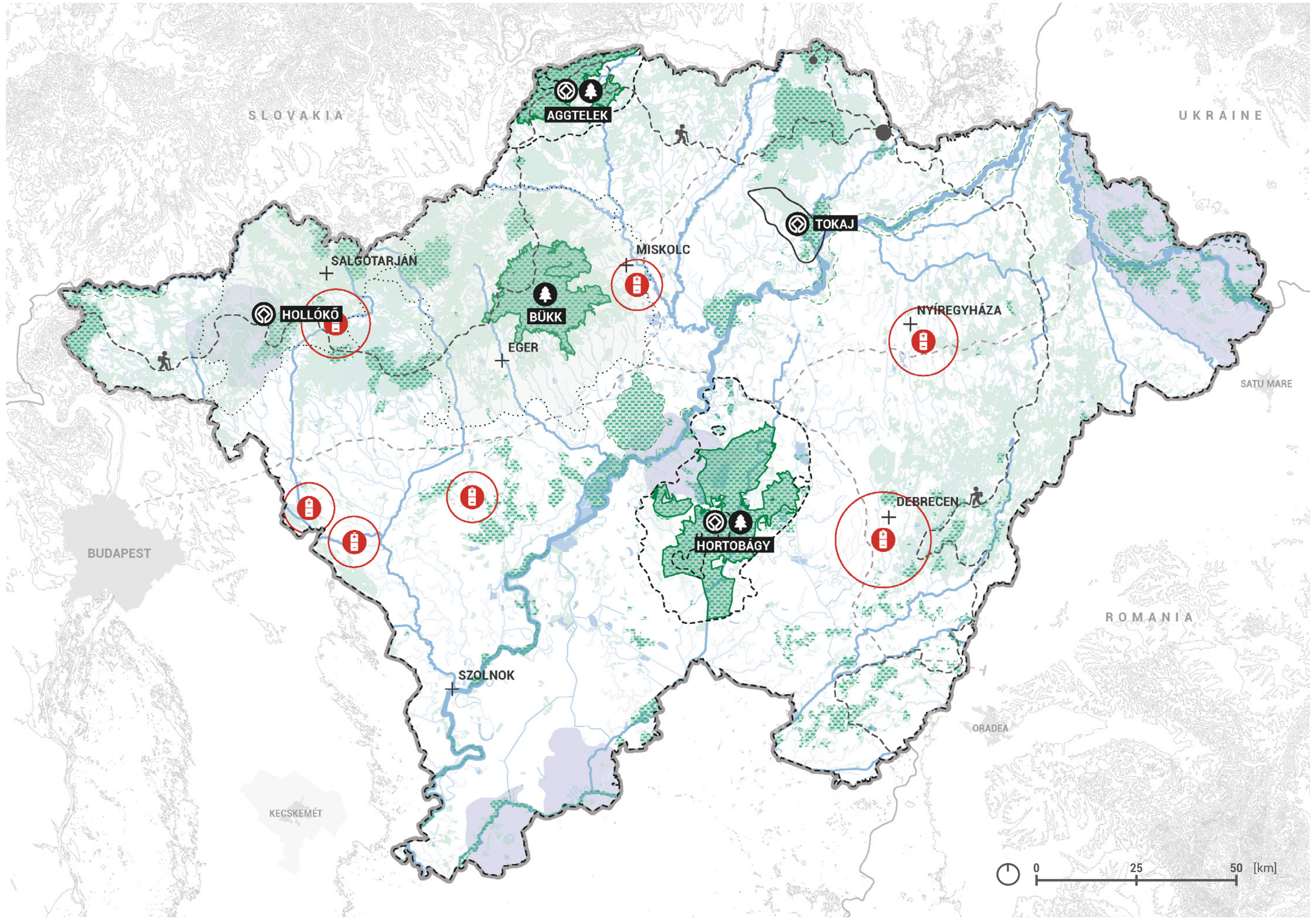
- 'Blue hike' national hiking trail
- Battery factories - pollution points
- Highways

Fig. 6.17: Protected nature, vegetation and the battery factories

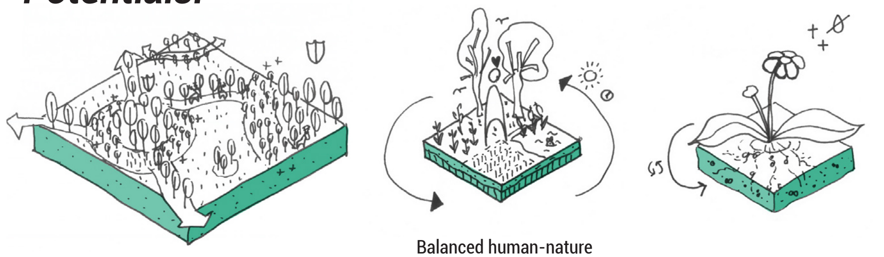
source: author

Fig. 6.18: DIverse national parks and world heritage sites

source: see on images



Potentials:



Natural buffers, eco-corridors

Balanced human-nature relationship

Natural pollution reduction

Natural Capital

Frequency of Change

The following map depicts the dynamisms of the natural elements and processes, which is based on the four landscape-types. Natural processes are in general slow, but they are increasingly more unpredictable due to climate change. Special attention has to be paid to rivers and their floodplains. Mountains are isolating elements, therefore the landscapes is fairly static. Hills are in-between mountains and flatlands. The current spatial qualities of the four landscapes are depicted on the following axonometric drawings:

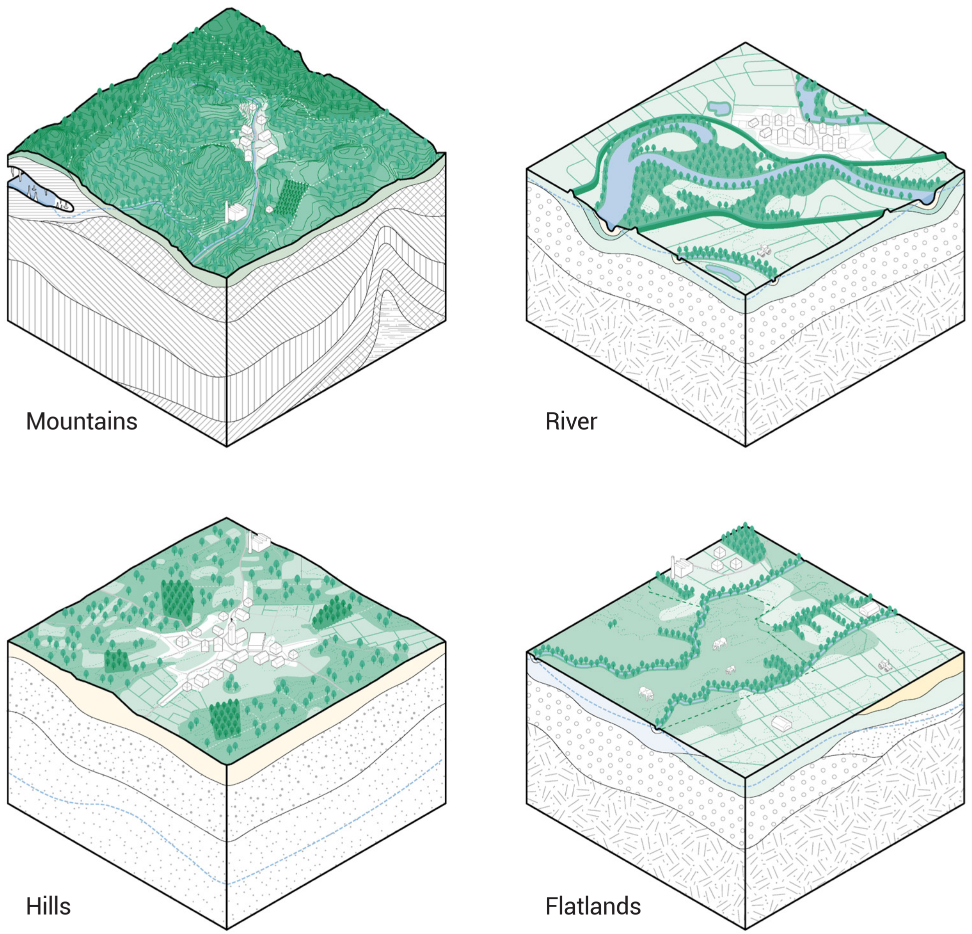


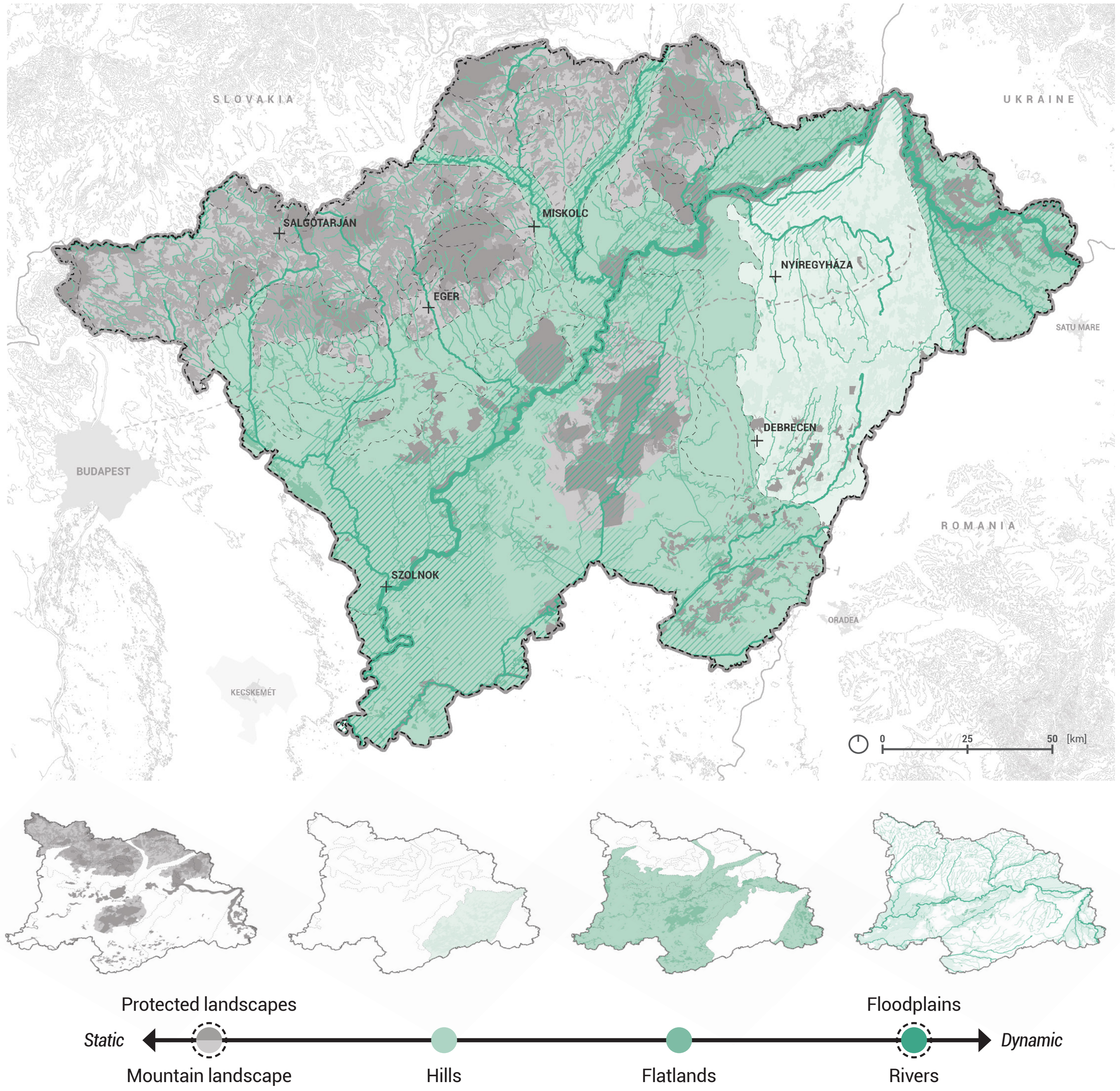
Fig. 6.19: The four landscape-types

source: author

FLoodplains
Highways

Fig. 6.20: Natural capital: frequency of change

source: author



Territorial Capital and the Pace of Change

Settlement Capital

Settlement Size

The size of a settlement often defines its dynamism and pace of change, as bigger cities attract more functions and services and are more accessible. On the other hand, there is a big problem with shrinking and emptying among small settlements in the region, with the threat of losing the cultural aspects of village life.

SETTLEMENT SIZES

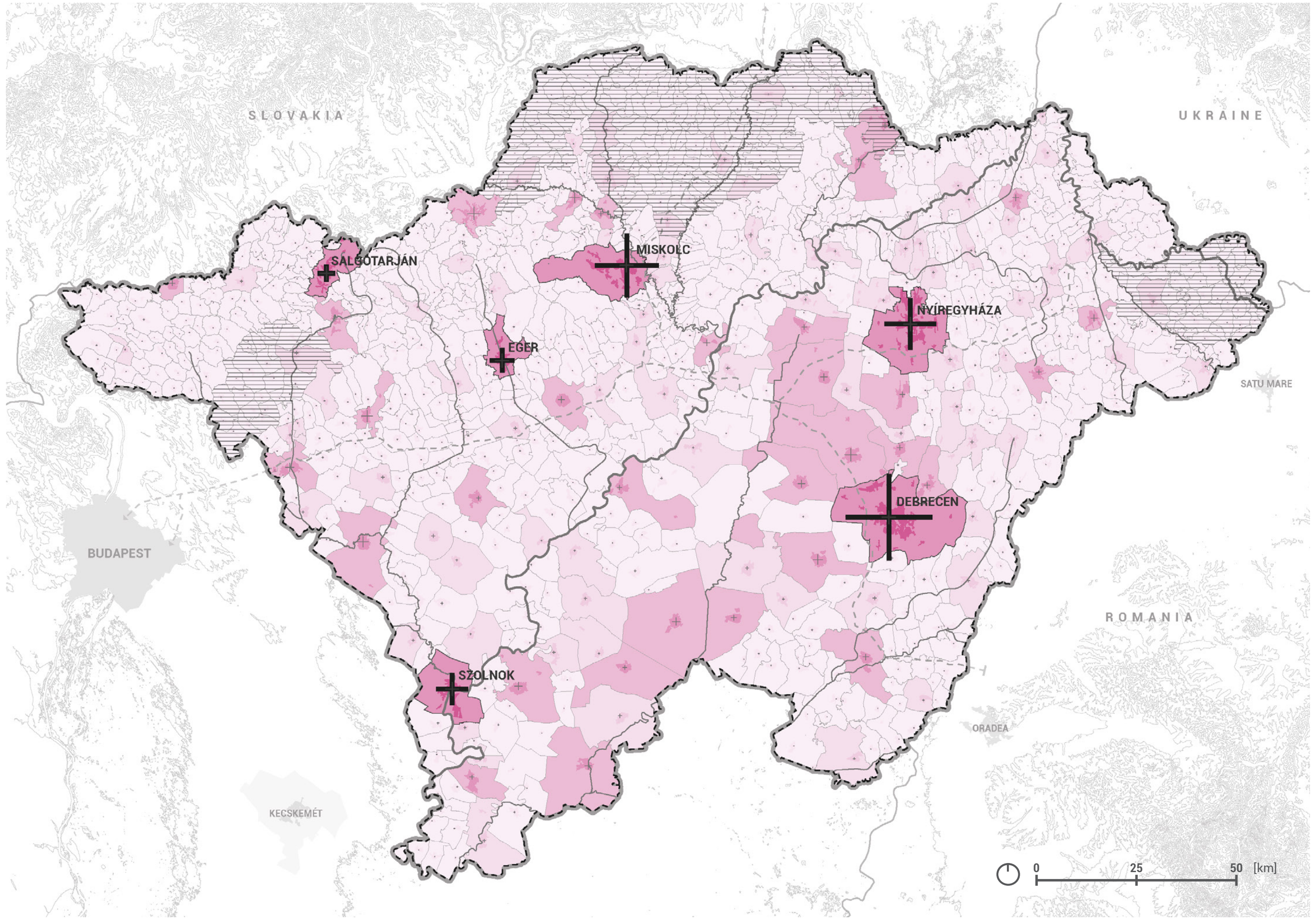
- Cities with county right
- Mid-sized cities (10.000 < ppl.)
- Small cities (5.000 - 10.000 ppl.)
- Villages (5.000 > ppl.)
- Areas with micro-villages
- Population density
- Main rivers
- Highways

Fig. 6.21: Settlement sizes

source: author

Fig. 6.22: The static nature of Hungarian villages and settlement form

source: Fortepan, Wikipedia



Territorial Capital and the Pace of Change

Settlement Capital

Settlement Identity

The identity of a settlement also defines its dynamism and pace of change. Identities often depend on the given landscape type they are on, and the economic sectors present.

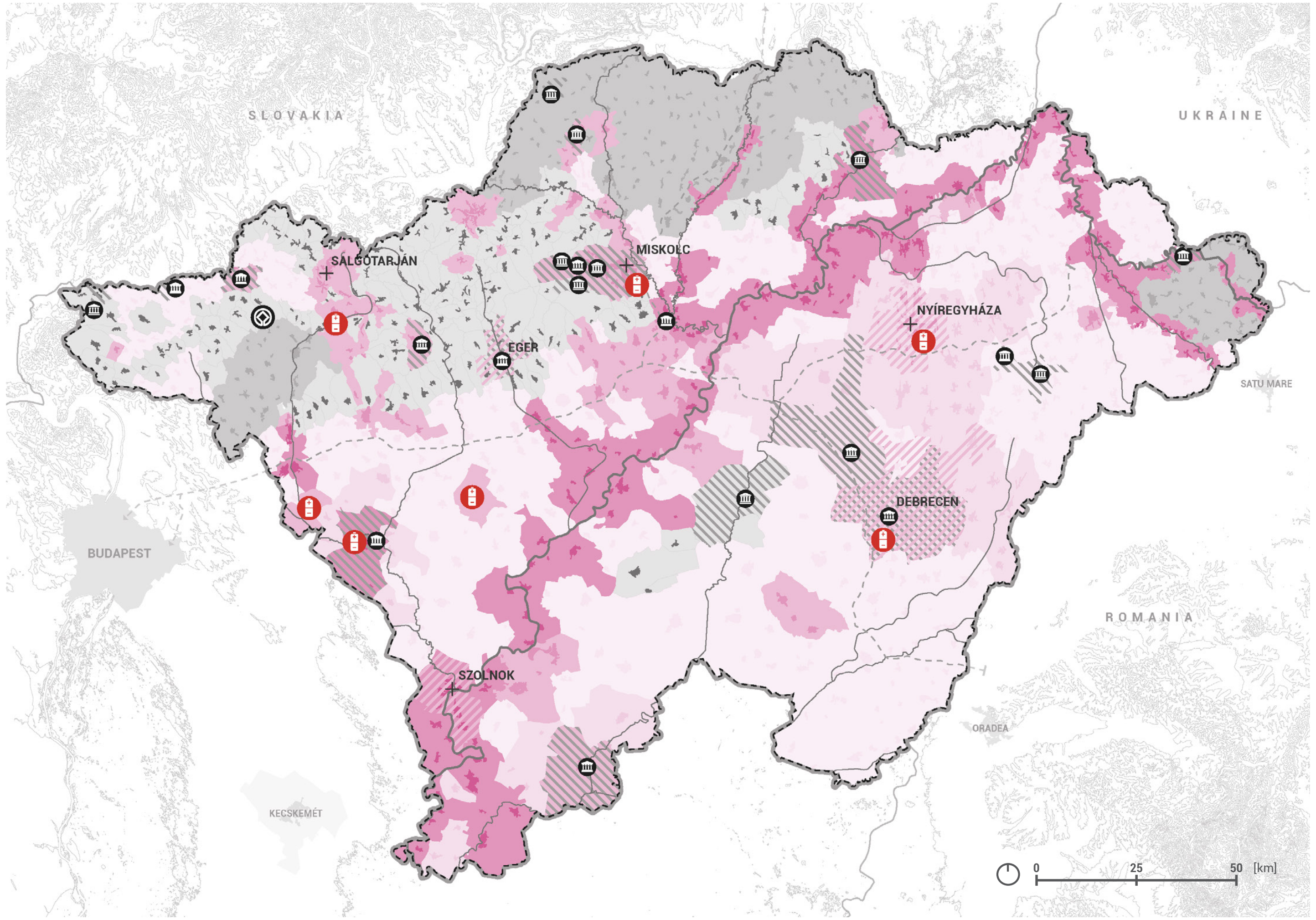
Settlements next to rivers and with an industrial profile change more dynamically, while settlements with an agricultural or heritage profile are more static. Cities with newly built battery factories like Debrecen have a shift in their identities towards battery and car industry (although it was originally an agricultural town).

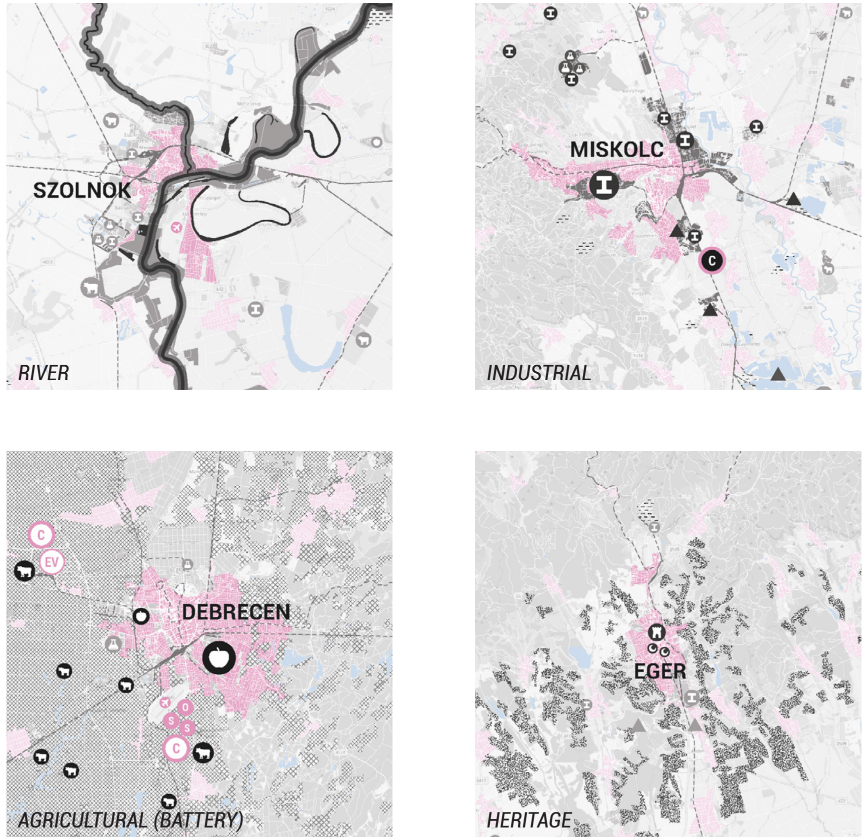
SETTLEMENT IDENTITIES

- 'River' settlements
- Industrial settlements
- Areas with micro-farms
- Agricultural settlements
- Natural- and cultural heritage
- Micro villages (slow change)
- Cultural heritage sites
- World heritage site
- Battery factories
- Main rivers
- Highways

Fig. 6.23 (right): Settlement identities

source: author





- airport
- Electric Vehicle factory
- battery industry
- cultural heritage
- minerals industry
- chemicals industry
- metals industry
- food and beverages industry
- intensive farming
- rail
- river Tisza
- mines
- water
- wine yards
- agricultural land
- natural area
- urban facric

Fig. 6.24 (left): Four examples of the different settlement identities

source: author

Territorial Capital and the Pace of Change
Settlement Capital

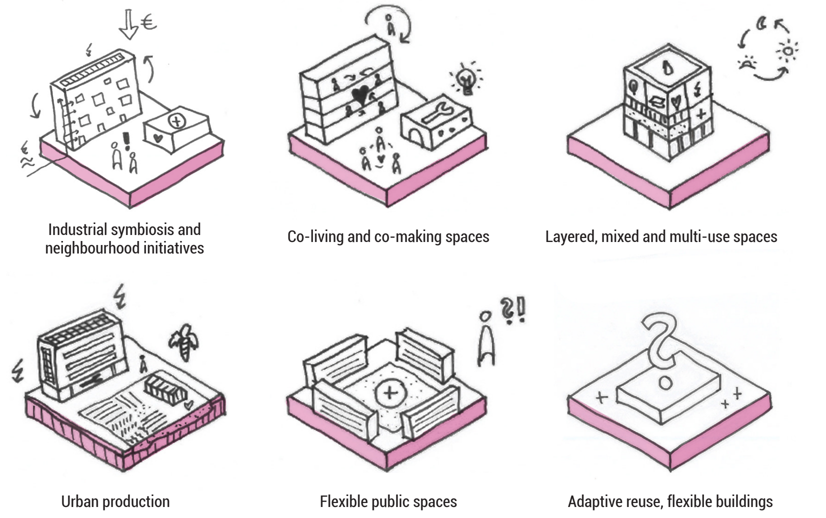
Settlement Morphology

Morphology (spatial structure, layout) of a settlement relates to its dynamism and pace of change as well.

Different identities, functions, size and geographical locations result in various spatial structures. While bigger cities with old cores do not differ a lot from other European examples, there are multiple place-specific typologies for the smaller-sized settlements. The most characteristic examples are presented on Figure 6.25.

A small-scale transformability potential lies in finding flexibilities in the public space for urban production (energy, food), layered and mixed uses, bartering, community-owned co-living and co-making spaces, places of circular activities and hubs and various functions among others. These could result in more diverse, adaptive and redundant elements, increasing the overall transformative resilience of cities and villages.

Potentials:



IDENTITIES AND MORPHOLOGIES:

- Settlements next to river
- Industrial settlements: newly built soviet-era towns and neighbourhoods
- Agricultural settlements with characteristic concentric circles and radial roads
- Small (heritage) villages, especially in the mountains and hilly areas

FLEXIBILITY POTENTIALS

- Areas of flexibility - radial roads
- Areas of flexibility - alongside traintracks
- Areas of flexibility - squares
- Areas of flexibility - clusters of private gardens
- Areas of flexibility - waterfront
- Water

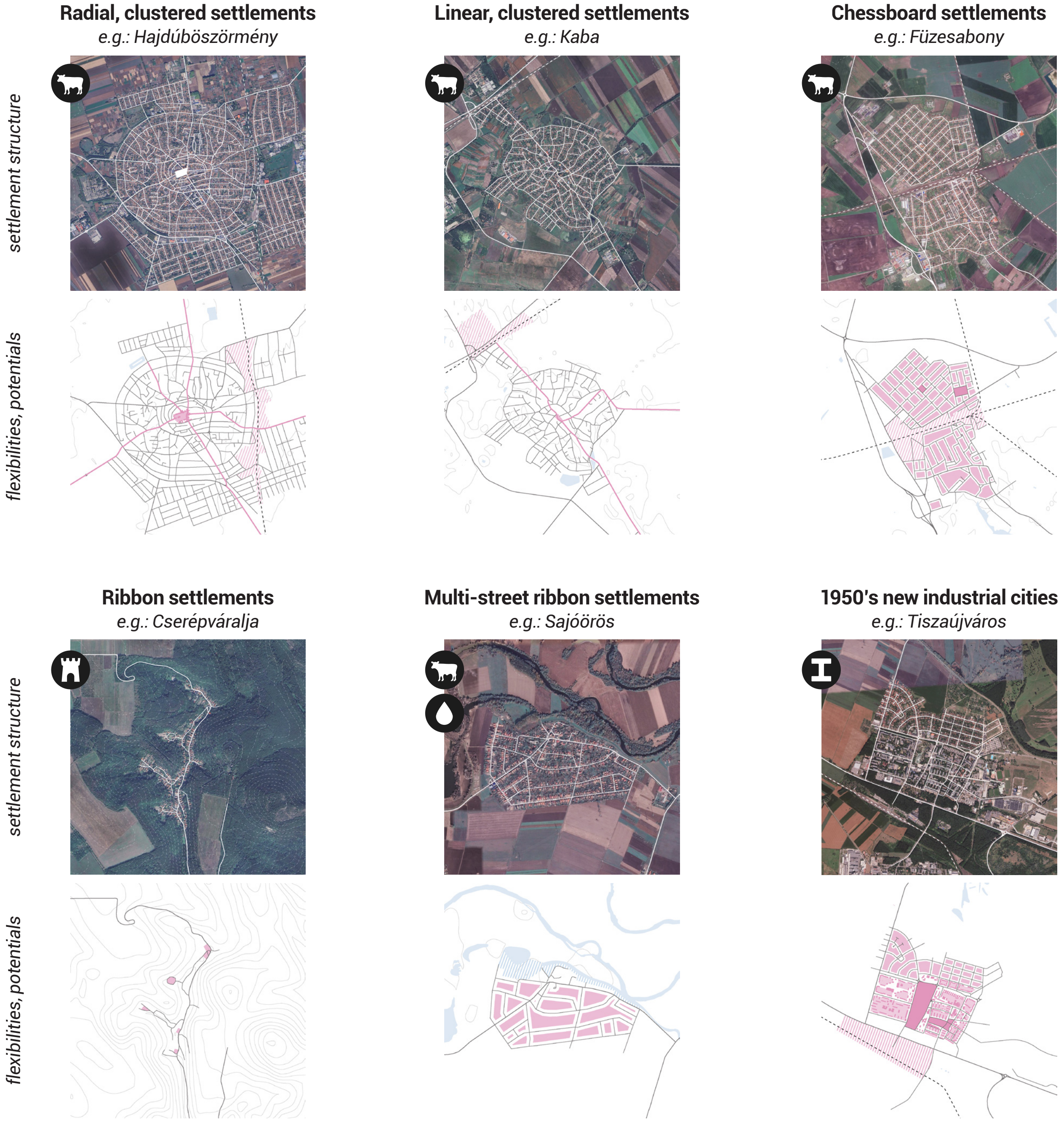


Fig. 6.25: Transformability potentials and the relation of identity and morphology

source: *Google Earth*, author

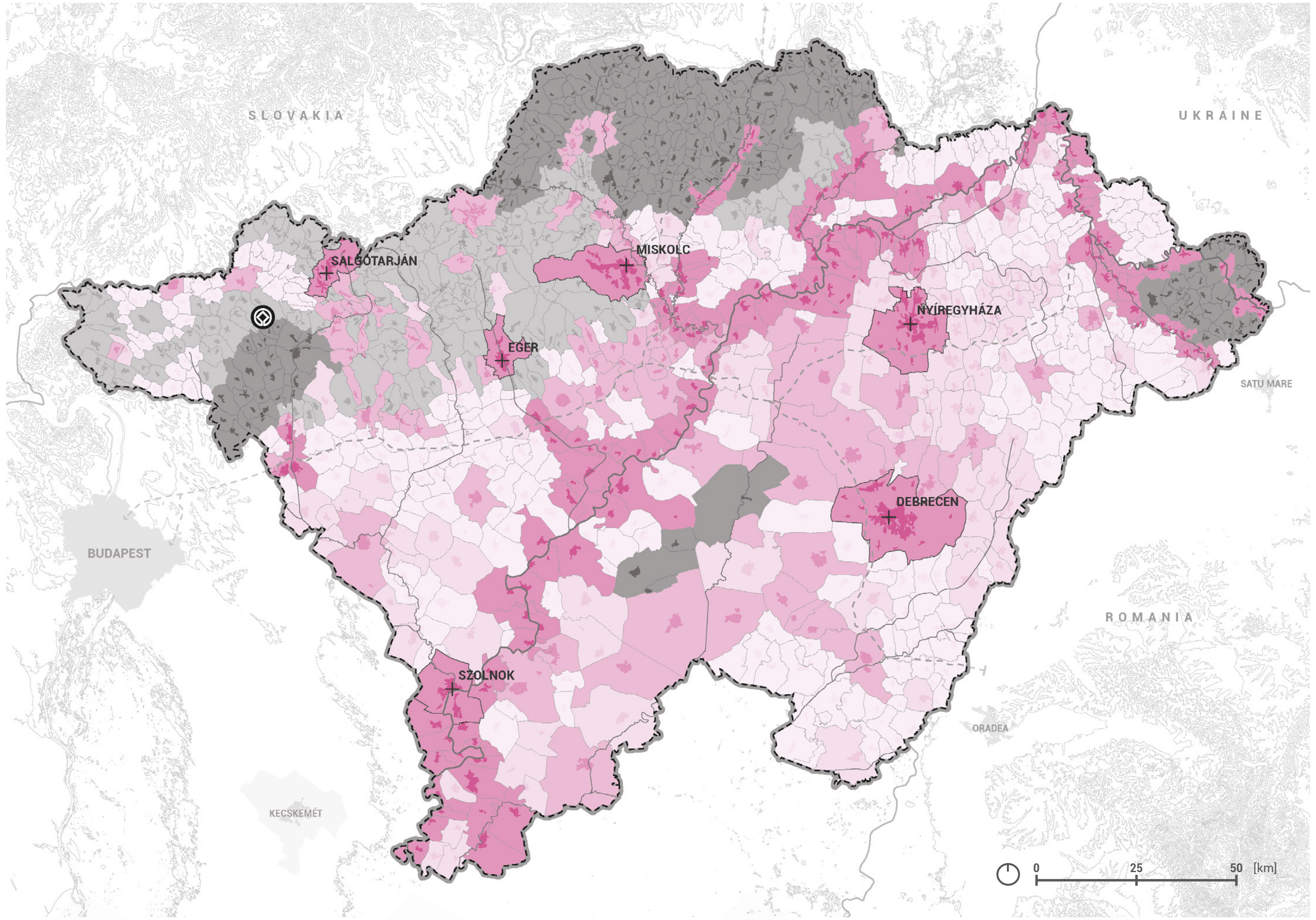
Territorial Capital and the Pace of Change

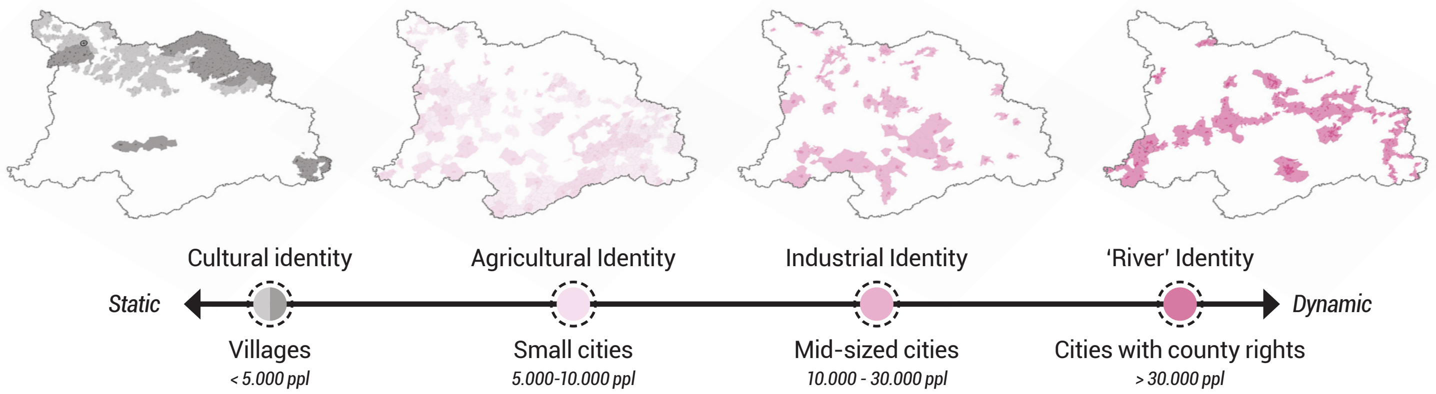
Settlement Capital

Frequency of Change

The frequency of change of the elements of the settlement capital layer are based on a synthesis of size, identity and morphology.

There are a few main cores, as well as the settlements next to rivers that represent dynamic change, while the peripheries can be described as static, where change is slow-paced. Although the elements with high frequencies have more transformability potential, it is crucial to think about the role of the static villages in the future, preserving cultural values and fostering a just transformation.





World heritage site
Main rivers
Highways

Fig.6.26: Settlement capital: frequency of change

source: author

Territorial Capital and the Pace of Change

Infrastructural and Relational Capital

Transportation Networks

Transportation networks have a clear centre-periphery relationship in Hungary, with Budapest in the centre.

The radial connections of highways (M3) and main train tracks related to Budapest are therefore the most developed ones, receiving the most attention and investments. The regional connectivity and physical quality of the train and road systems is low, while the travel times are high (Chronotrains - Europe Train Map, n.d.). Multiple train tracks were closed due to shrinking settlements (MÁV Zrt., 2024). I see a potential in using the abandoned infrastructural elements (tracks and stations) for circular (and other) community-led uses, as the structures are already there and connect different settlements.

airports
hobby / military airports

highways
main roads
small roads

train tracks: double track
train tracks: single track
train stations
train stops

train tracks not in use
abandoned train stations
abandoned train stops
Isochrones: 1 hour distance from main cities

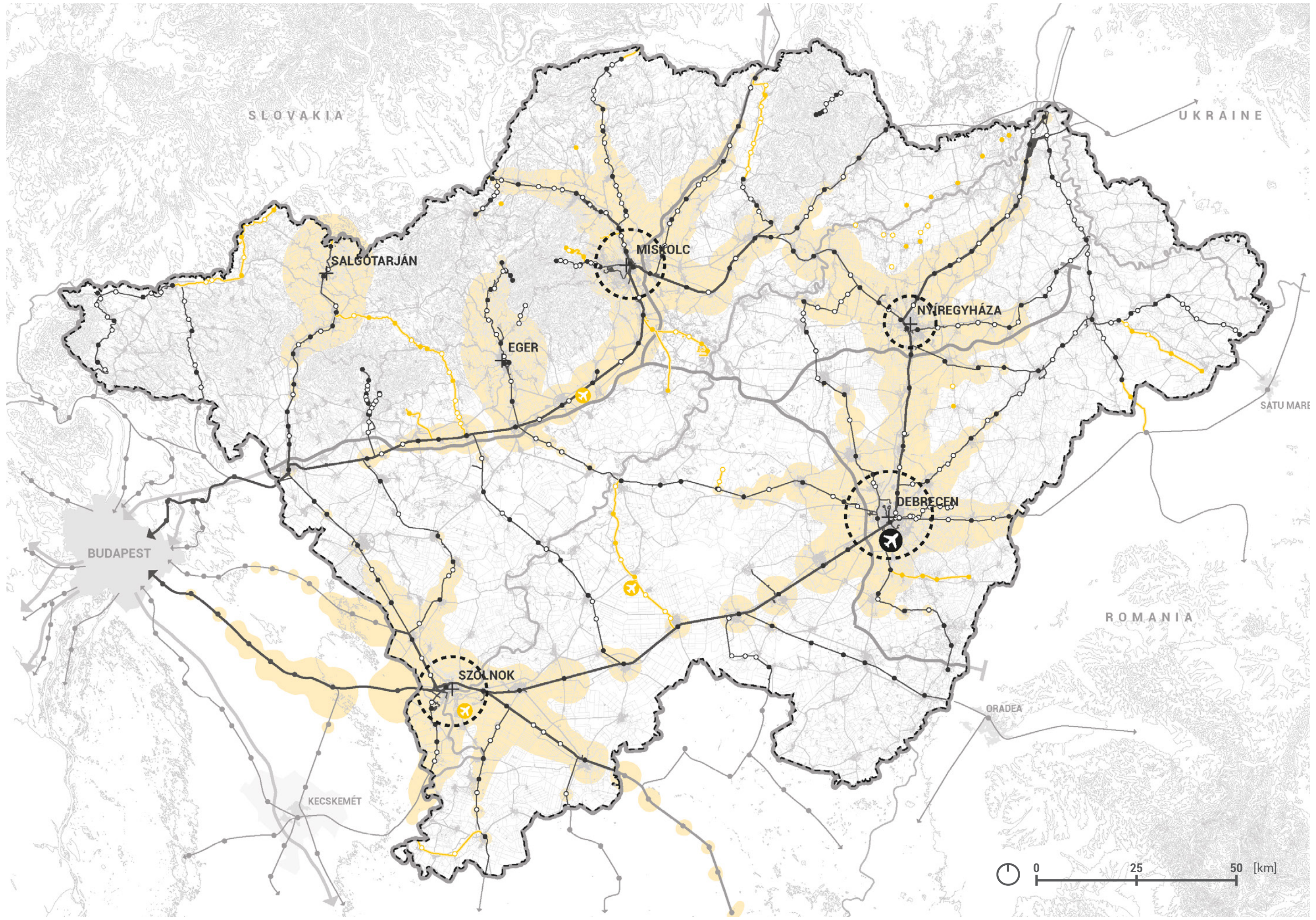
Main rivers

Fig. 6.27: Networks of transportation: hierarchies and use

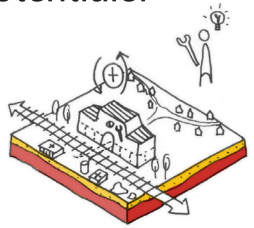
source: author

Fig. 6.28: The morphology of transport infrastructure in the region

source: see on images



Potentials:



Transforming abandoned infrastructure

Territorial Capital and the Pace of Change
Infrastructural and Relational Capital

Connectivity

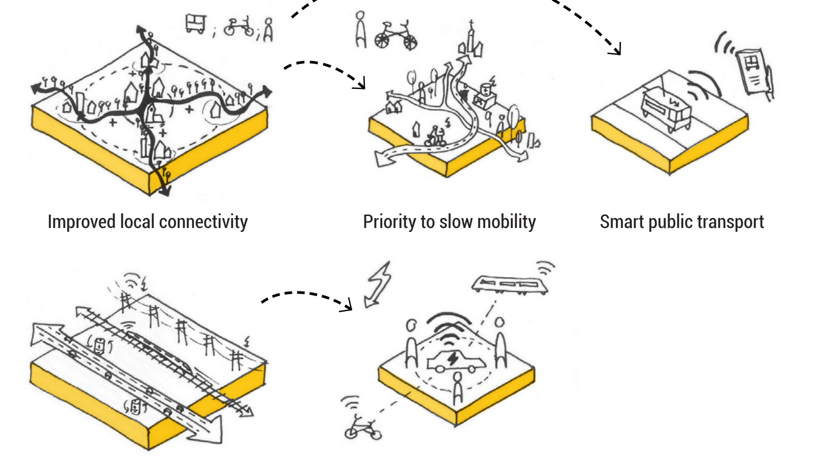
When analysing the connectivity of road networks in the region, the radial nature becomes evident. There is well-connected main corridor between Budapest, Debrecen and Miskolc, while the peripheral networks are underdeveloped and not well-connected.

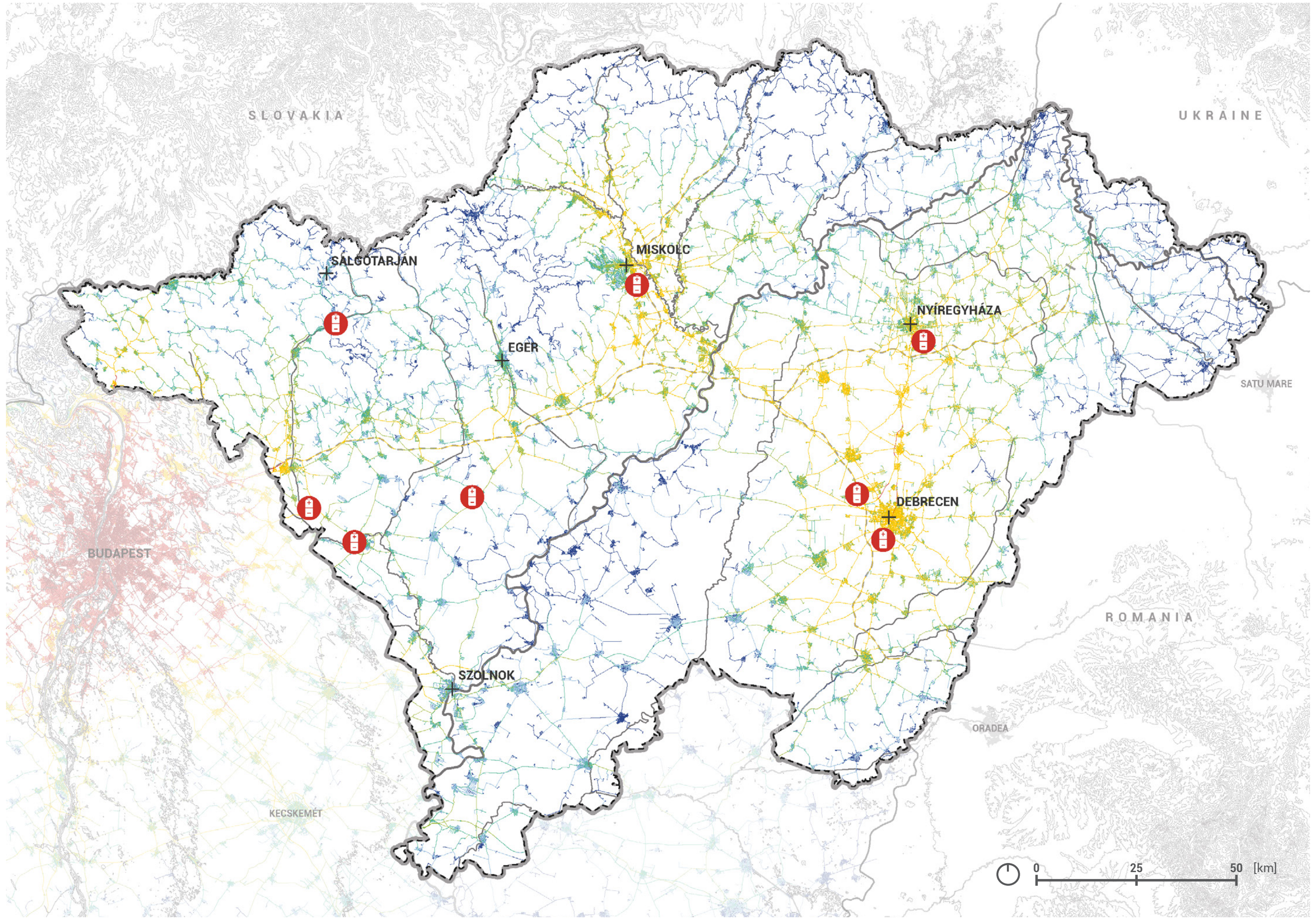
It is important to note that topography influences connectivity, therefore mountain areas and river Tisza act as barriers. An interesting observation is the well-connected nature of the settlements around Debrecen, which roots in the radial city structures. In relation to the battery industry, all facilities are next to well-connected roads, although the connectivity of the triangle is not fully developed between Miskolc and Nyíregyháza.

This regional-scale angular integration space syntax analysis was done with QGIS, with a radius of 50 km.

Transformative potential regarding transformability: high-speed connection to main cities (hyper-connectivity), combined with smart and shared modes of transport, improved local connectivity with focus on slow mobility and public transport.

Potentials:





CONNECTIVITY

- Well-connected
- *Main regional corridors*
- Isolated (periphery)

- Battery factories
- Main rivers

Fig. 6.29: Angular Integration (r = 50 km) connectivity analysis: corridors and periphery

source: author

Infrastructural and Relational Capital

Energy Networks

As analysed before regarding the battery system, energy networks in the region are centralised and dependent on Russian gas, while the powerplants are outdated (coal, gas and oil), and there is a significant energy-poverty at the peripheries.

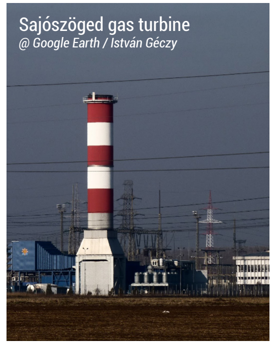
According to a study in the Bükkalja Region, over 15% of households were significantly above the energy expenditure threshold, indicating severe energy poverty (Csontos, 2023). This is primarily due to low income levels, inefficient housing, reliance on fossil fuels (wood, gas, coal) and rural isolation.

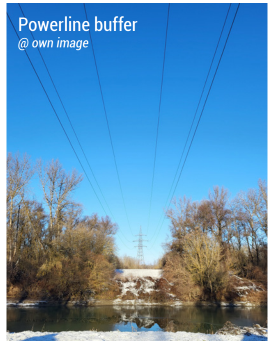
The main energy node in the region is Tiszaújváros, where there is a concentration of powerplants (coal, gas turbines), an oil refinery and chemical industries.


Abandoned coal plant, Tiszaújváros @ own image


Tiszaújváros: energy and landscape @ Google Earth


Visonta coal power plant @ Heves Megyei Hírlap / Tamás Czimer


Sajószöged gas turbine @ Google Earth / István Géczy


Powerline buffer @ own image

main energy nodes
coal plant
hydropower plant (shelved)
750 kv power-line
400 kv power-line
220 kv power-line
electricity substations
oil / gas plant
>1000 D gas pipeline
600<D<800 gas pipeline
300<D<500 gas pipeline
gas nodes
oil pipeline
Main rivers
Highways

Fig. 6.30 (right): Energy infrastructure: electricity, oil and gas

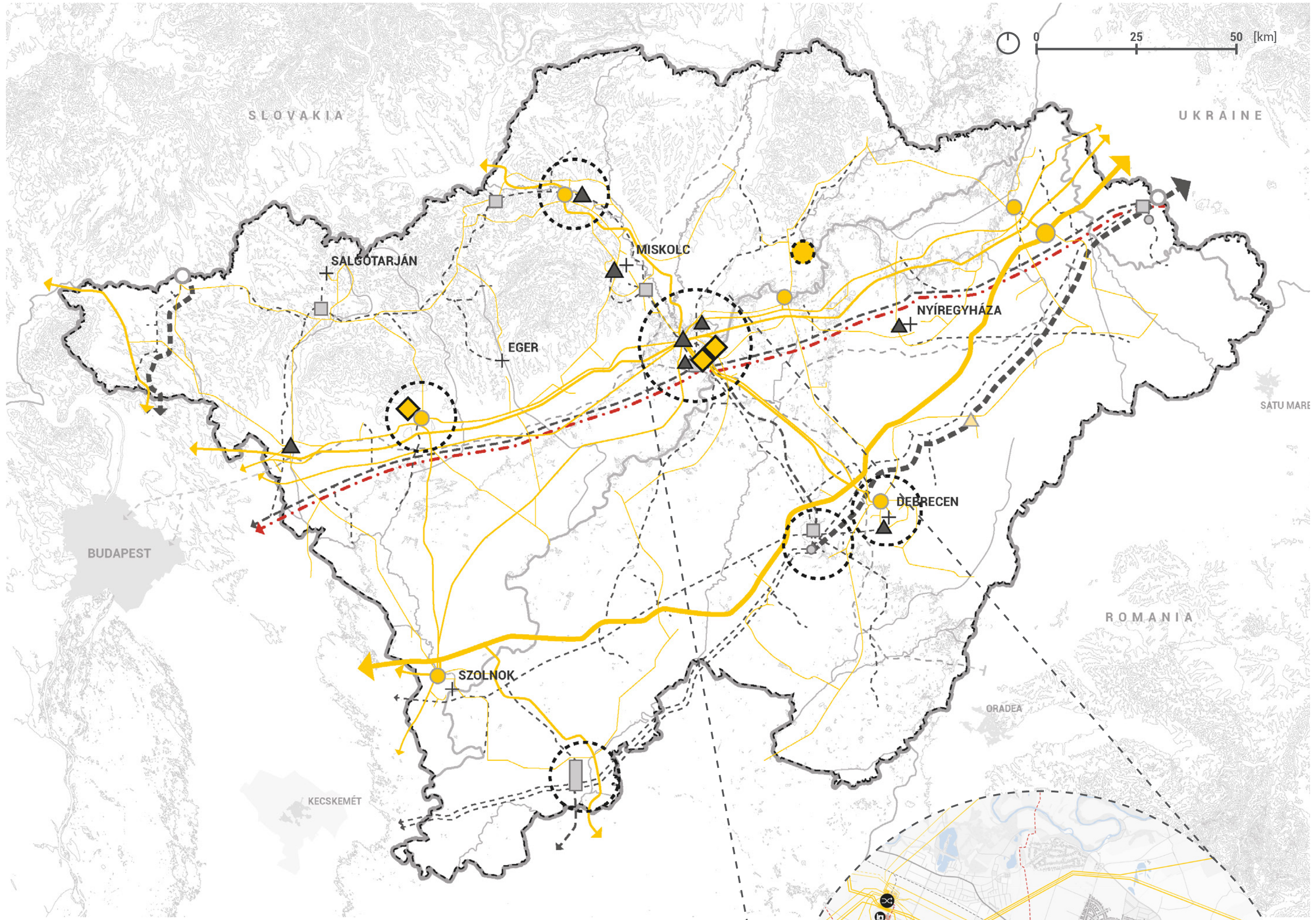
source: author

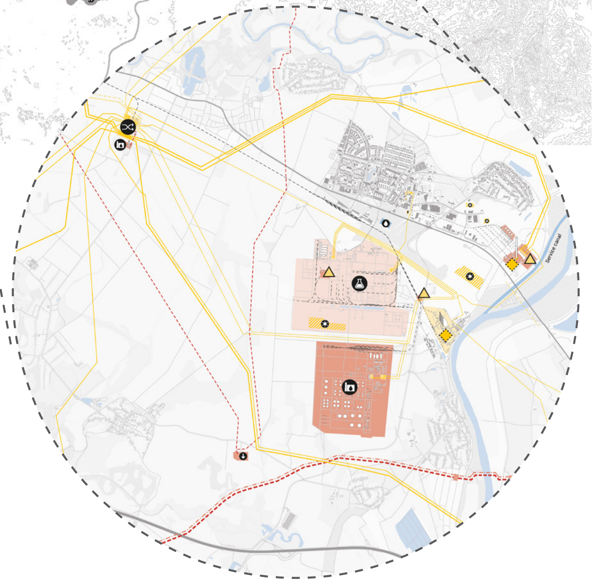
Fig. 6.31 (right): Tiszaújváros: the main 'node' of energy

source: author

Fig. 6.32 (left): Morphology of energy infrastructure in the region

source: see on images





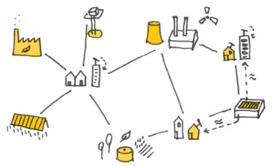
Infrastructural and Relational Capital

Energy System Potentials

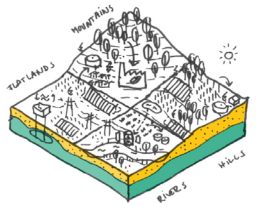
The four main transformability potentials of the region are centred around polycentricity, redundancy and bottom-up initiatives towards autonomous and off-grid solutions, as a response to the highly dependent, therefore exposed energy system.

On the following pages, the different, landscape based energy-potentials will be detailed.

Potentials:

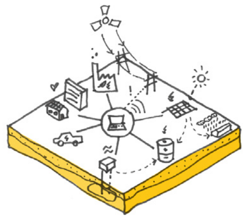


Decentralised energy system



Landscape-based energy-mix

Battery and energy communities



Balanced connectivity and autonomy: microgrids

Geothermal energy potential

Hungary has a high geothermal potential, especially at the South side of the region, and around the cities of Miskolc and Debrecen (the former already has a geothermal heating system). There is also a way to **convert abandoned natural gas and oil wells into geothermal sources** (Tóth et al., 2018), which is relevant at the natural gas-and oil fields of the flatlands.

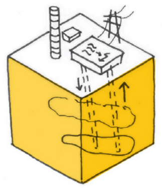
low geothermal potential

high geothermal potential

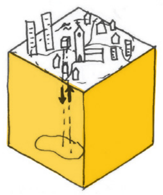
natural oil and gas fields

natural oil and gas extraction

Potentials:



Geothermal power from old gas and oil wells



Geothermal energy in cities

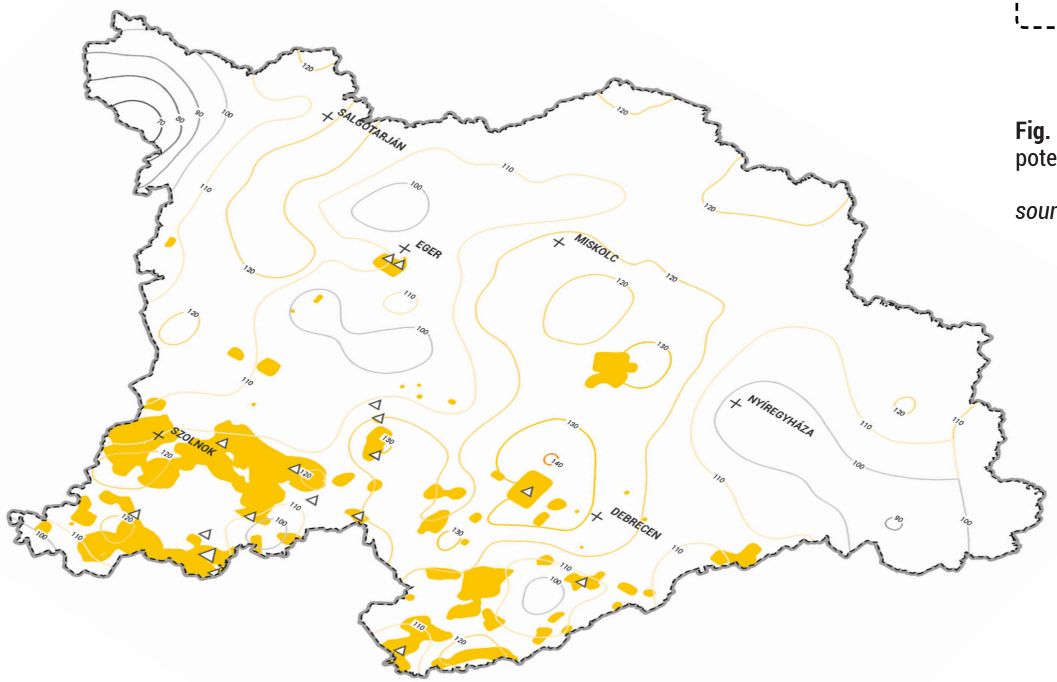


Fig. 6.33: Geothermal energy potential

source: author

Infrastructural and Relational Capital

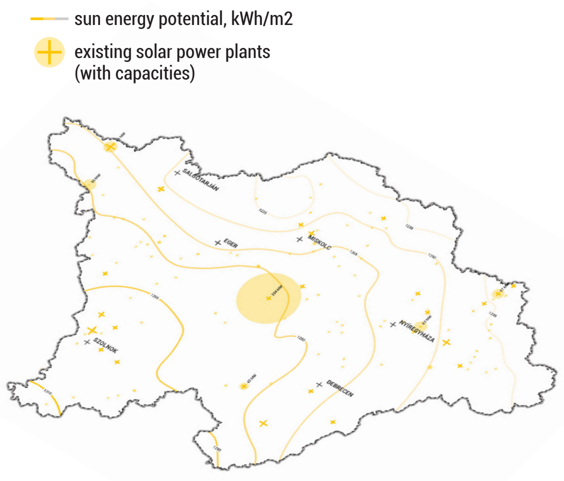
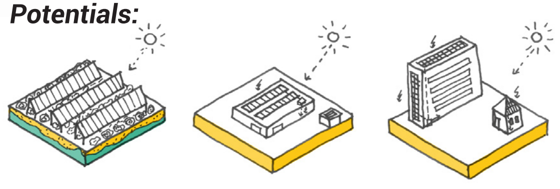


Fig. 6.34: Solar energy potential; *source:* author

Solar energy potential

There is a high potential of solar energy production in the region. Apart from the existing solar farms (only energy production), a layered use of agriculture and energy production could lead to higher transformability potential on the flatlands, while using roofs and facades can add to urban and industrial energy production.

Potentials:



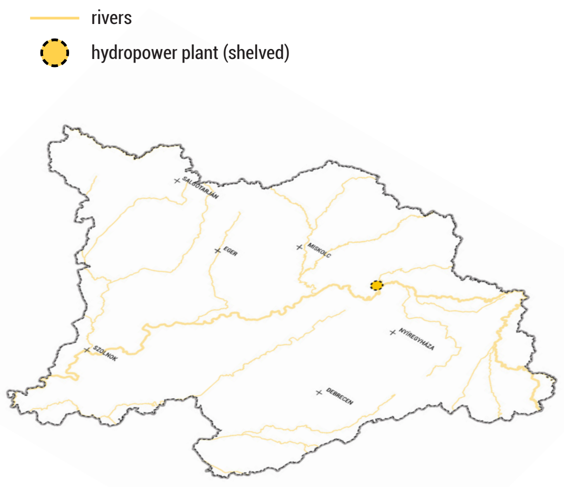
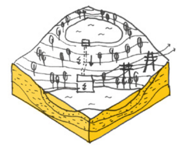


Fig. 6.36: Hydro energy potential; *source:* author

Hydropower energy potential

Although hydropower has a low potential in the region, it could be **used as a hydro-battery for energy storage of the surplus of other renewables,** in case other batteries are not available (Pumped storage hydropower: Water batteries for solar and wind power, n.d.).

Potentials:



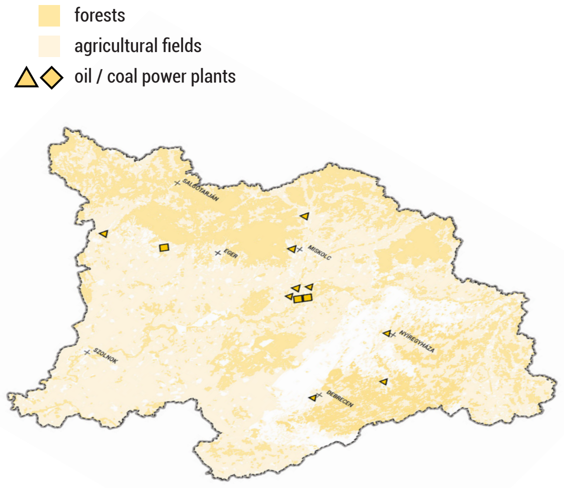
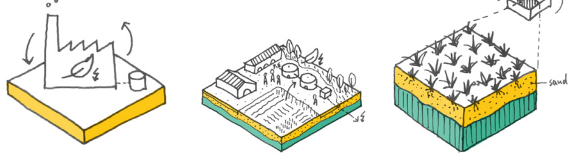


Fig. 6.35: Biomass energy potential; *source:* author

Biomass energy potential

Biomass can be gained from agricultural or household (biological) waste, of forests. **Existing power plants could be retrofitted for biomass energy production, while agricultural and urban biomass communities could be established.** Crops for biomass could be grown also on otherwise barren lands.

Potentials:



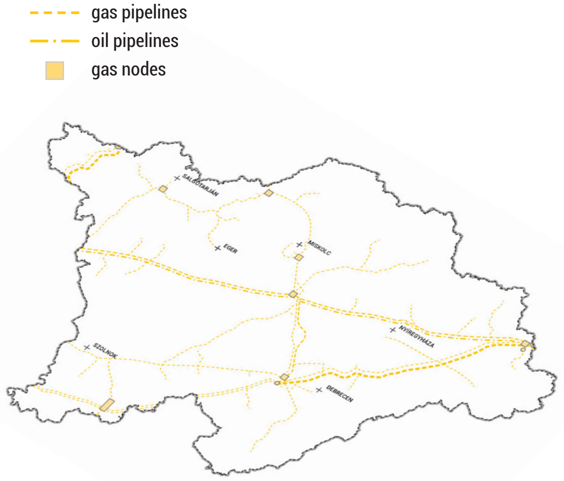
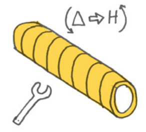


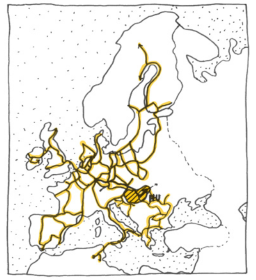
Fig. 6.37: Hydrogen energy potential; *source:* author

Hydrogen energy potential

Using Hydrogen energy is a long-term potential, for when the European Hydrogen Backbone is built – the Hungarian parts are estimated to be done around 2040 (H2 Inframap, 2022). It would be done by retrofitting existing oil and gas pipelines, and would connect from Budapest to Kecskemét, then Debrecen and Miskolc, powering industrial processes.

Potentials:





Connecting to the European Hydrogen Backbone (~2040)

Territorial Capital and the Pace of Change

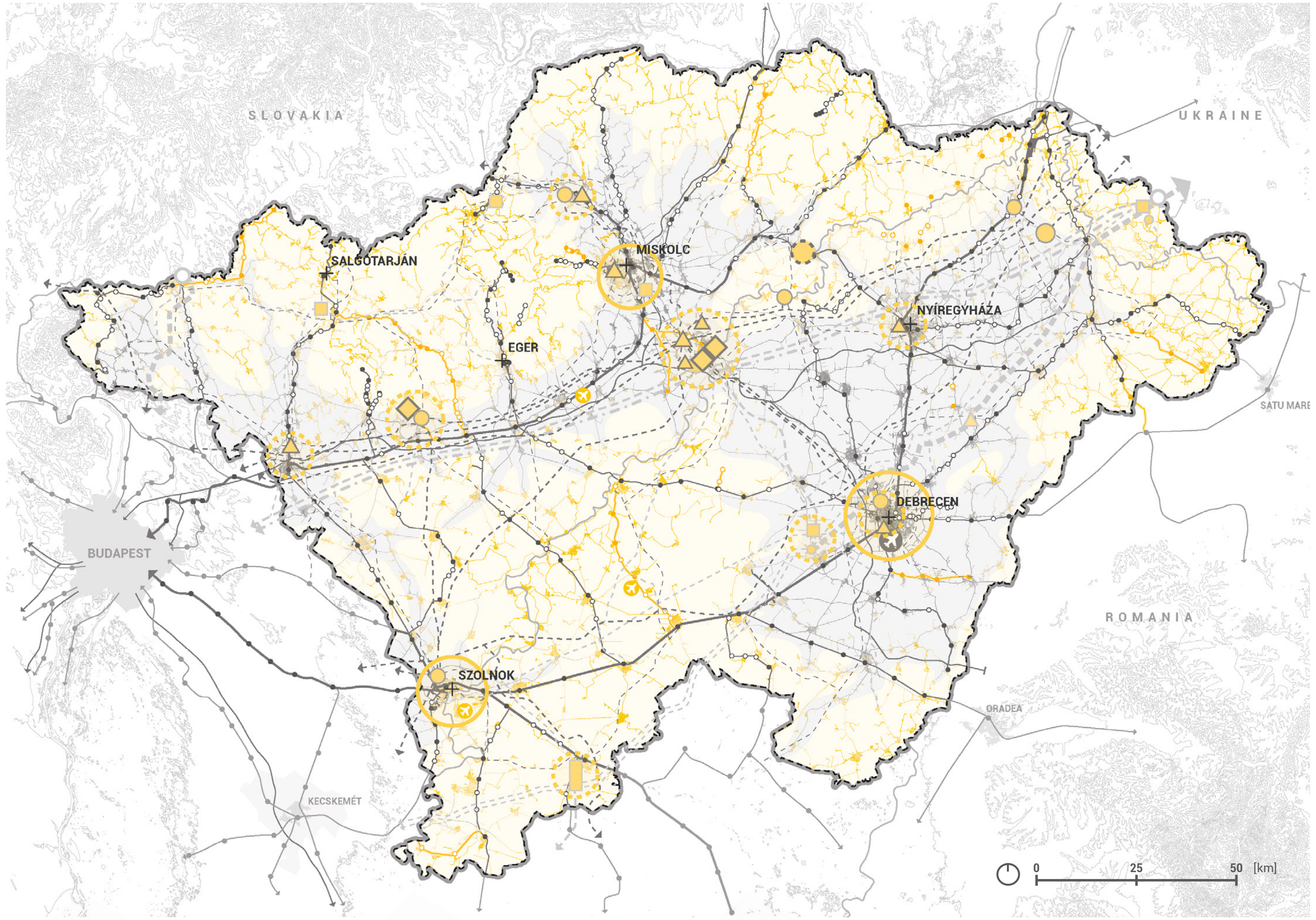
Infrastructural and Relational Capital

Frequency of Change

When 'grading' the frequencies of infrastructural elements, it is important to look not only at the physical properties of the given element, but also its place in the system and its function.

Main infrastructural lines and most connected networks are static and difficult to transform, although gas and oil pipelines can be retrofitted, therefore are more flexible. The main energy and transport nodes are functionally easier to change (e.g. power plants have changes a lot during the past 100 years, introducing new typologies: coal, oil, biomass, solar). The least connected (peripheral) networks and flexible, renewable energy solutions are the most dynamic, and easier to transform, as they are not crucial to the current system.

- train tracks not in use
- abandoned train stations
- abandoned train stops
- airports
- hobby / military airports
- Well-connected roads
- Isolated (periphery) roads
- main transport nodes
- main energy nodes
- coal plant
- hydropower plant (shelved)
- oil / gas plant
- electricity substations
- gas nodes
- >1000 D gas pipeline
- 600<D<800 gas pipeline
- 300<D<500 gas pipeline
- oil pipeline
- 750; 400 kv power-line
- 220 kv power-line
- highways
- train tracks: double track
- train tracks: single track
- Main rivers



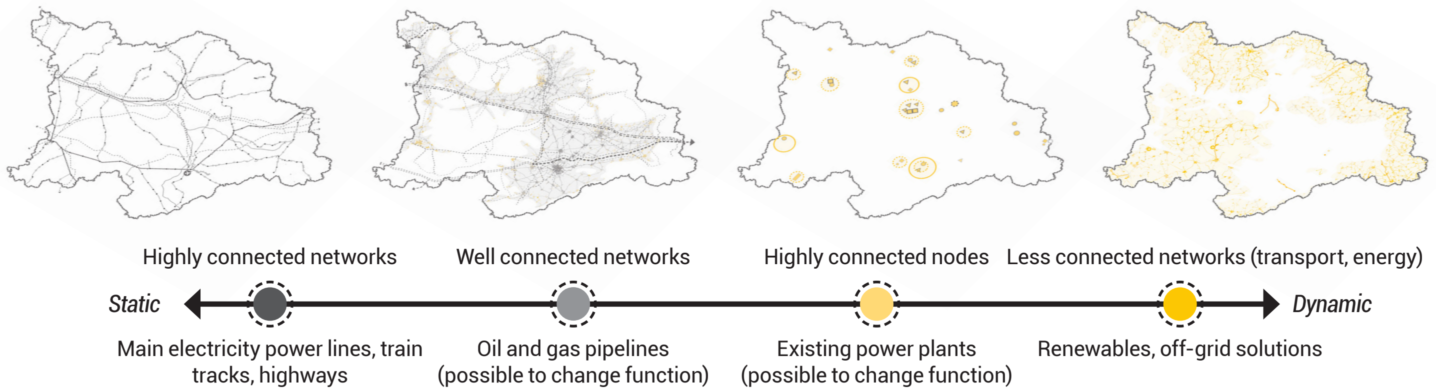


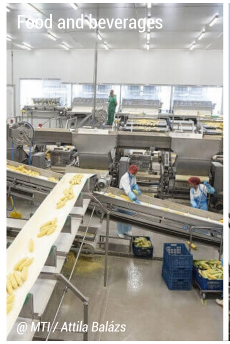
Fig. 6.38: Infrastructural and relational capital: frequency of change

source: author

Territorial Capital and the Pace of Change

Economic Capital

Economic Sectors



The economic capital is dependent on the landscape types, the primary sector is the most static, while tertiary sector is the most dynamic.

Primary sector

The region is very agriculture-based with vast monocultural farmlands at the flatlands. The hilly areas are known for growing fruit trees, while the mountains are famous for grapes and wine. Coal and lignite mining is in the mountains, natural gas and oil extraction at the flatlands.

Secondary sector

Building on the agriculture, food and beverages facilities can be found at the hills and flatlands. The heavy industry has minerals and metal factories primarily connected to the mountains and concentrated around main cities, while chemical industries can be found along rivers (Borsod valley) and in the hills. A new addition to the secondary sector are the battery factories.

Tertiary sector

Services concentrate in the main cities, while tourism is connected to the protected natural areas and cultural heritage (settlements, wine, Hungarian Grey Cattle - special agricultural cultivation). There are multiple tourist routes and castle ruins.

PRIMARY SECTOR
- Agricultural areas
- Intensive farming
- Wineyards
- Mineral extraction
- Mineral mines
- Natural oil and gas extraction
- Natural oil and gas fields

SECONDARY SECTOR
- Food and beverages
- Metals
- Chemical industry
- Battery factories

TERTIARY SECTOR
- Touristic areas

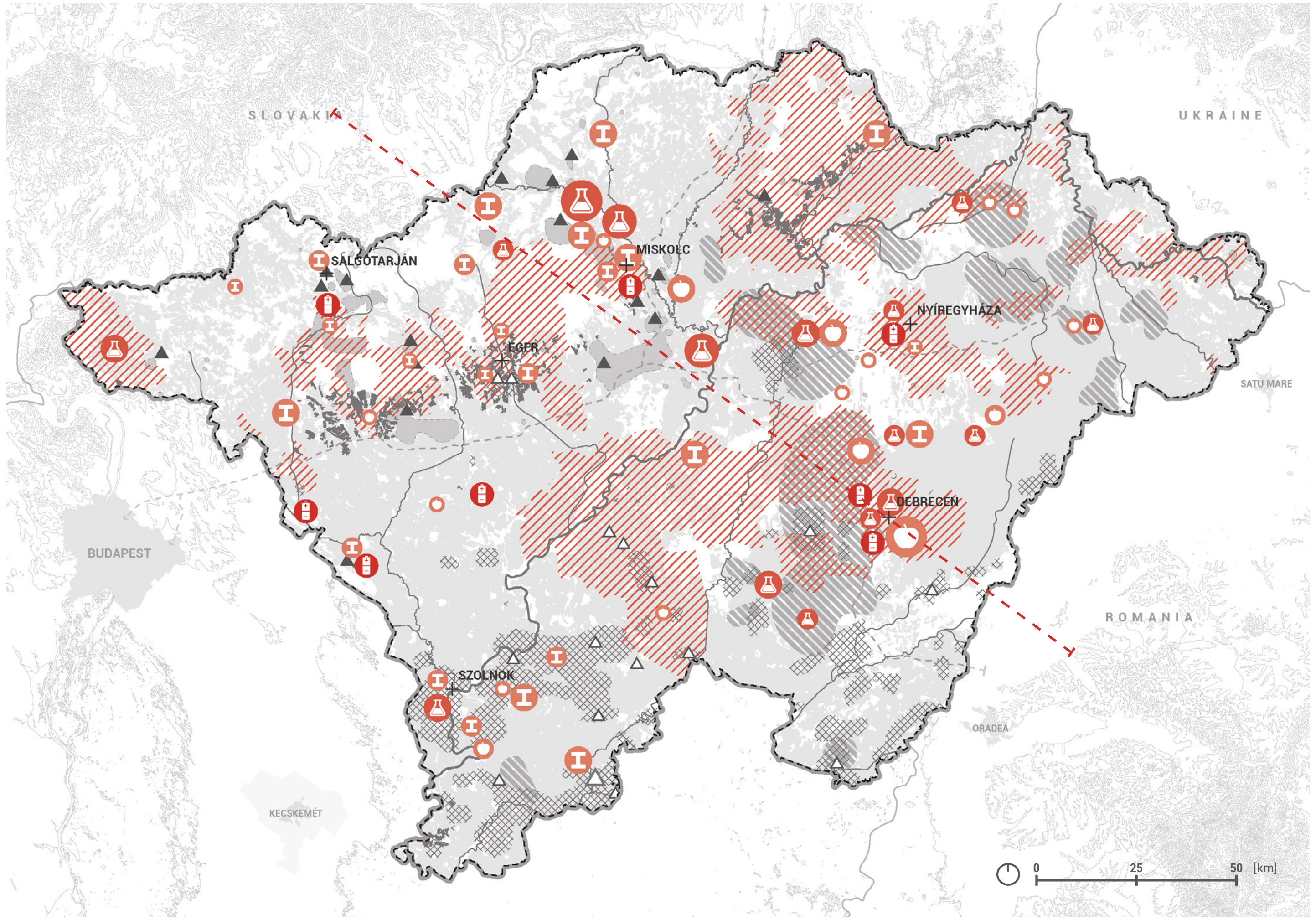
- Main rivers
- Highways

Fig. 6.39 (right): Primary, secondary and tertiary sector activities in the region

source: author

Fig. 6.40 (left): Leading economic sectors in the region

source: see on images



Economic Capital

Food

The section combines the primary, secondary and tertiary sector activities of the food supply chain. Vast monocultural farms serve as the base of the chain, where corn and wheat grow among other products. Pastures with animals are also common. Special export-products from the region include the Hungarian Grey Cattle, and wine from the Tokaj area. Processing happens around cities, and in the factories of the food and beverages industry, at the Southern and Eastern part of the region.

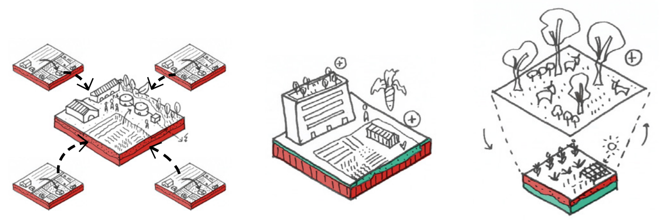
SOILS

- Sand (arenosol)
- Black soil / humous (chernozem)
- Leached black soil (phaeozem)
- Young river sediment (fluvisol)
- Swamp soil (histosol)
- Salinated soil (solonetz)
- High-swelling clay soil (vertisol)
- Brown forest soil (cambisol)
- Brown forest soil with clay (luvisol)
- Rock-like soil (leptosol)
- Waterlogged soil (gleysol)
- Town

ECONOMIC ACTIVITIES

- flows: metals and minerals
- intensive farming / Hungarian Grey Cattle
- butcher
- flows: oil, chemicals
- wheat fields / mill
- corn fields / corn processing
- fruit trees / food and beverages
- storage
- (super) market
- flows: wine production
- grapes
- wine production
- wine
- wheat-based products (flour)
- corn-based products
- fruits, beverages
- meat
- water

Potentials:



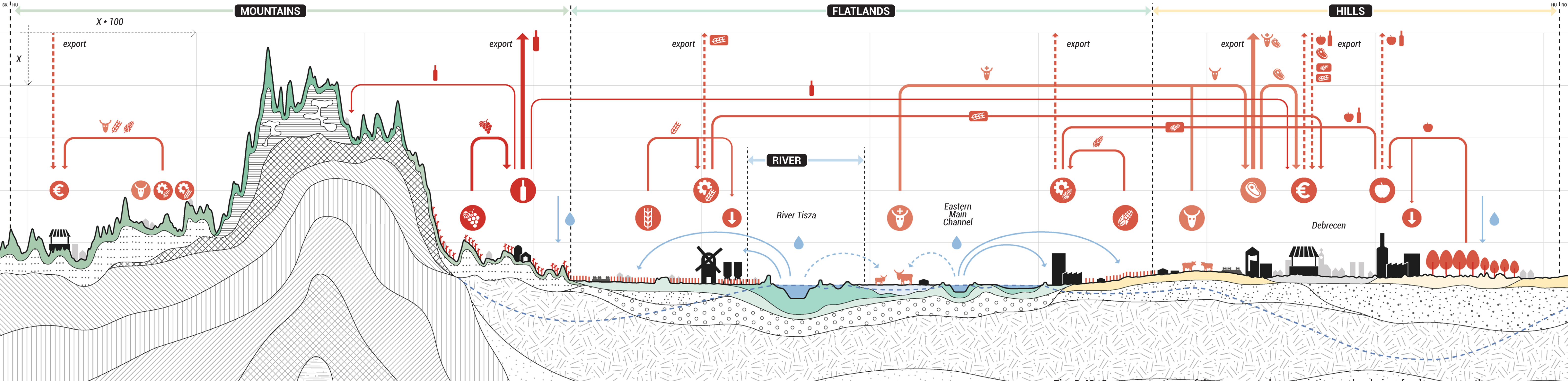


Fig. 6.41: Systemic sections of the two most characteristic supply-chains: food; *source:* author

Economic Capital

Heavy Industry

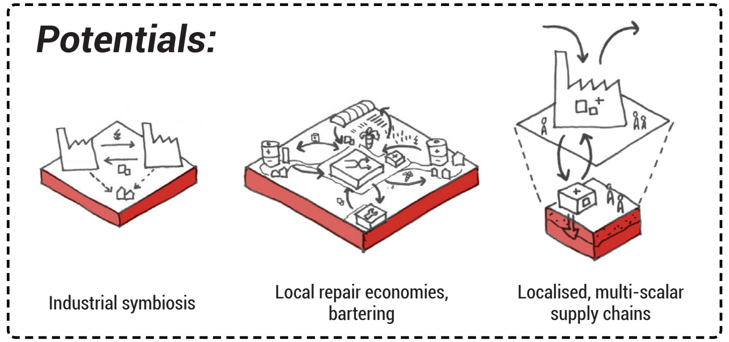
The section combines the primary, secondary and tertiary sector activities of the heavy industry supply chain. The processes are often separated due to path-dependencies, and Hungarian providers do not interact with the battery industry. The factories require well-connected energy networks and water, which is also depicted on the section.

SOILS

- Sand (arenosol)
- Black soil / humous (chernozem)
- Leached black soil (phaeozem)
- Young river sediment (fluvisol)
- Swamp soil (histosol)
- Salinated soil (solonetz)
- High-swelling clay soil (vertisol)
- Brown forest soil (cambisol)
- Brown forest soil with clay (luvisol)
- Rock-like soil (leptosol)
- Waterlogged soil (gleysol)
- Town

ECONOMIC ACTIVITIES

- flows: metals and minerals
- mining
- minerals / metals industry
- flows: oil, chemicals
- oil and natural gas extraction
- oil refinery
- chemicals industry
- gas turbine
- flows: battery industry
- battery industry
- EV factory
- logistic point
- investment
- workers
- raw materials
- water
- refined oil
- medicine
- metal products



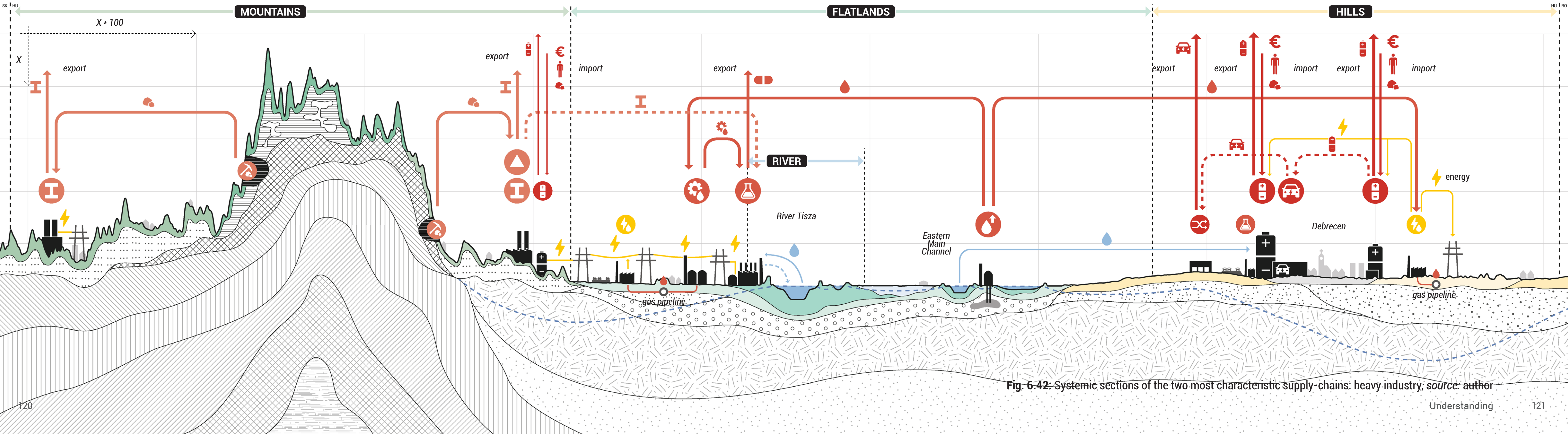


Fig. 6.42: Systemic sections of the two most characteristic supply-chains: heavy industry; *source:* author

Territorial Capital and the Pace of Change

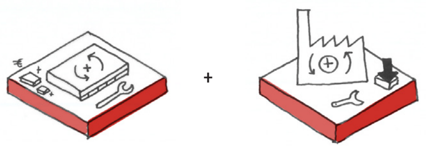
Economic Capital

Density and Diversity of Services

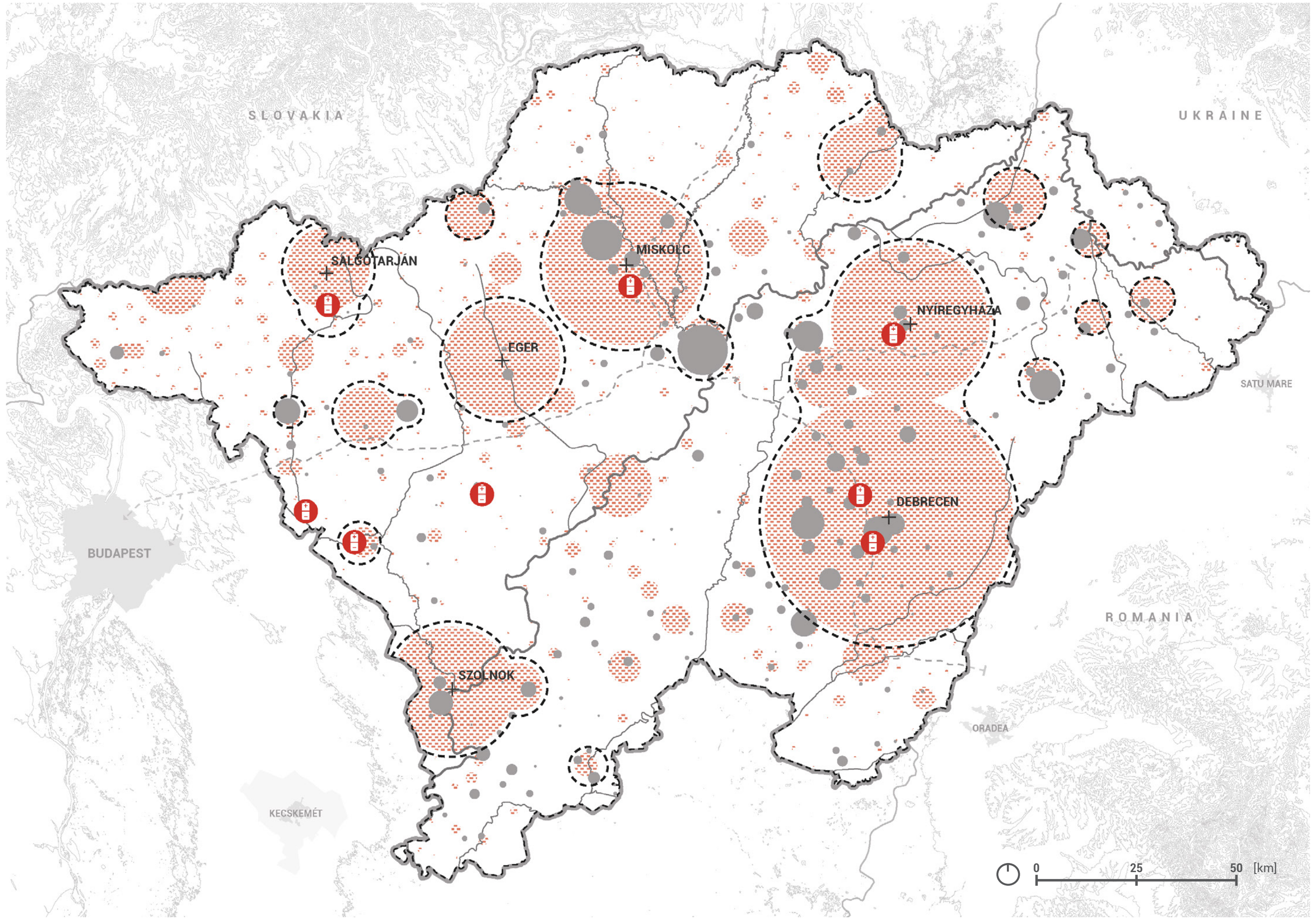
Services are centred around the main cities and change dynamically, while the peripheral areas change statically, lacking (accessible) functions, they are 'functional deserts'.

A main transformability potential is to activate the peripheries with circular (or other) functions. Adding circular hubs and material banks is a needed step towards transformability, therefore it would also be a good starting point for community initiatives.

Potentials:



Activating peripheries with circular functions



most diverse clusters

Diversity + density of services

Diversity + density of industry

Battery factories

Main rivers

Highways

Fig. 6.43: Density and diversity of functions (services, industry) in the region

source: author

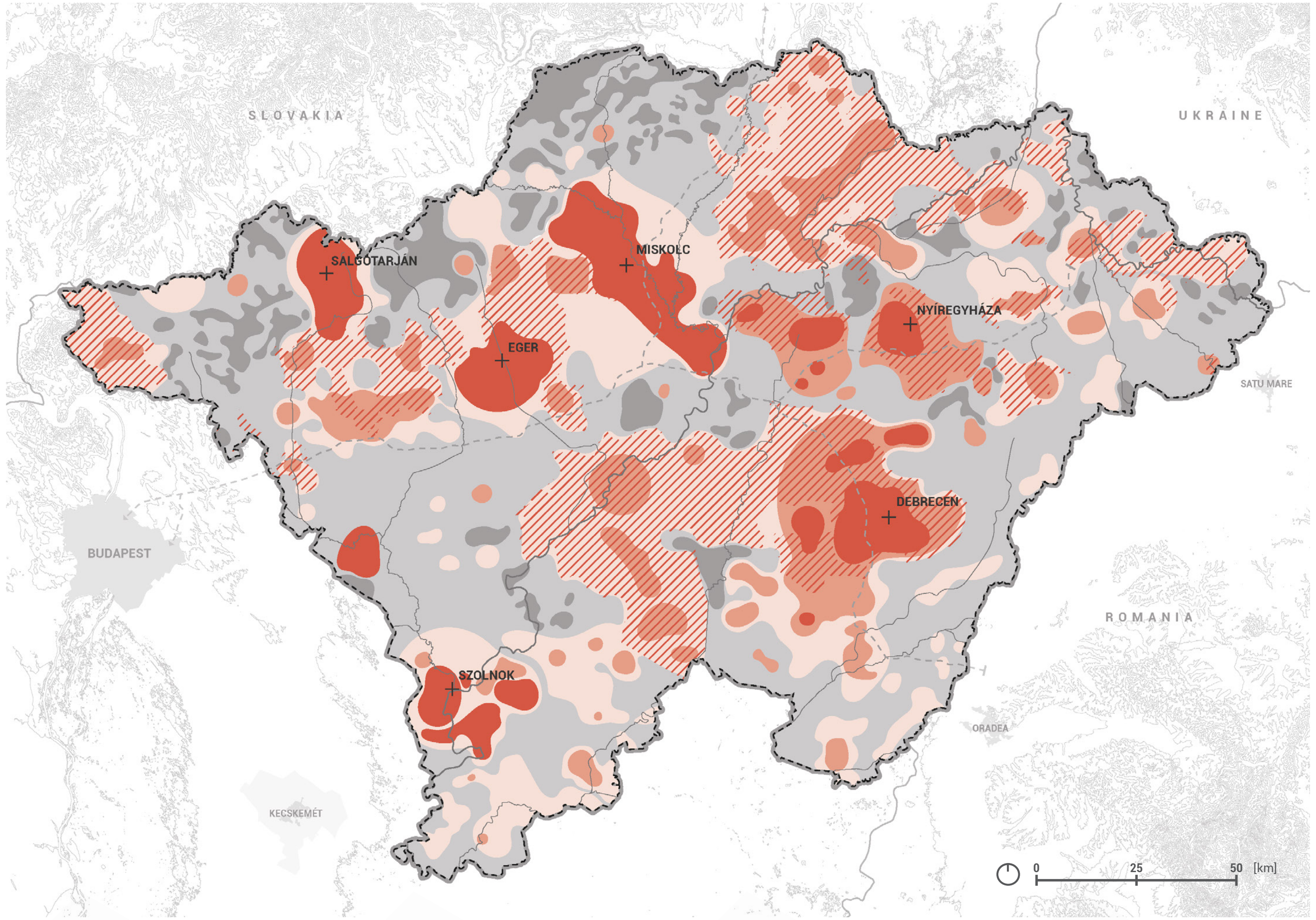
Territorial Capital and the Pace of Change

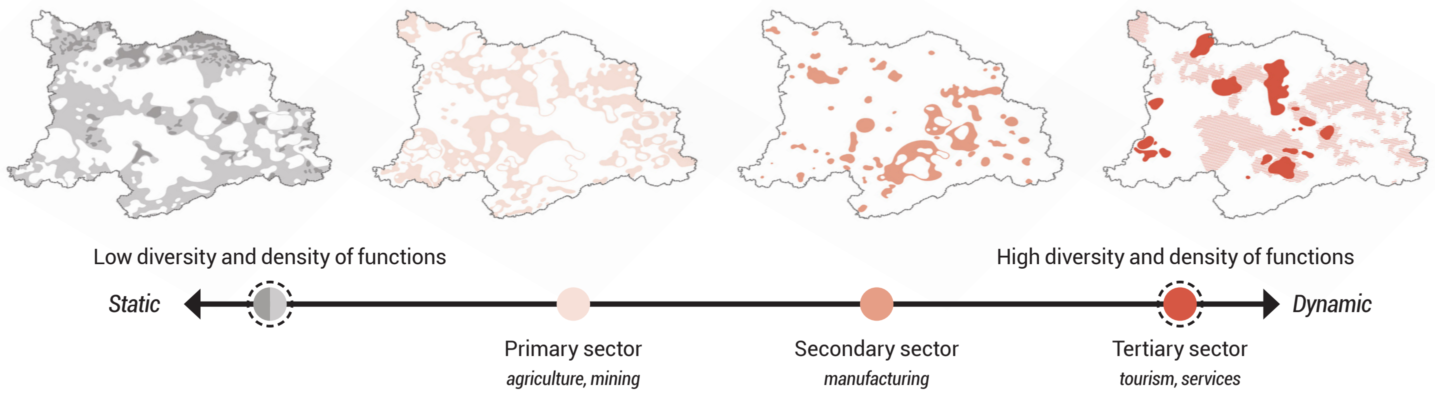
Economic Capital

Frequency of Change

The different frequencies are visualised through the heatmap of economic activities weighed by sectors. There are clear dynamic nodes around main settlements with the most services, while the peripheries are often monofunctional or lack functions completely.

Mountains and river often isolate parts of the region, while protected areas make the conclusion a bit more shaded: they lack function in order to preserve the landscape. With the static elements (primary sector, lack of functions), transformation can be primarily achieved by changing the land use, while at dynamic areas (tertiary sector, many functions) change often happens by coming and going of different companies. The middle ground is the changing of buildings, which is in between static and dynamic change (secondary sector, areas with some functions).





Touristic areas

Main rivers

Highways

Fig. 6.44: Economic capital: frequency of change (heatmap)

source: author

Territorial Capital and the Pace of Change

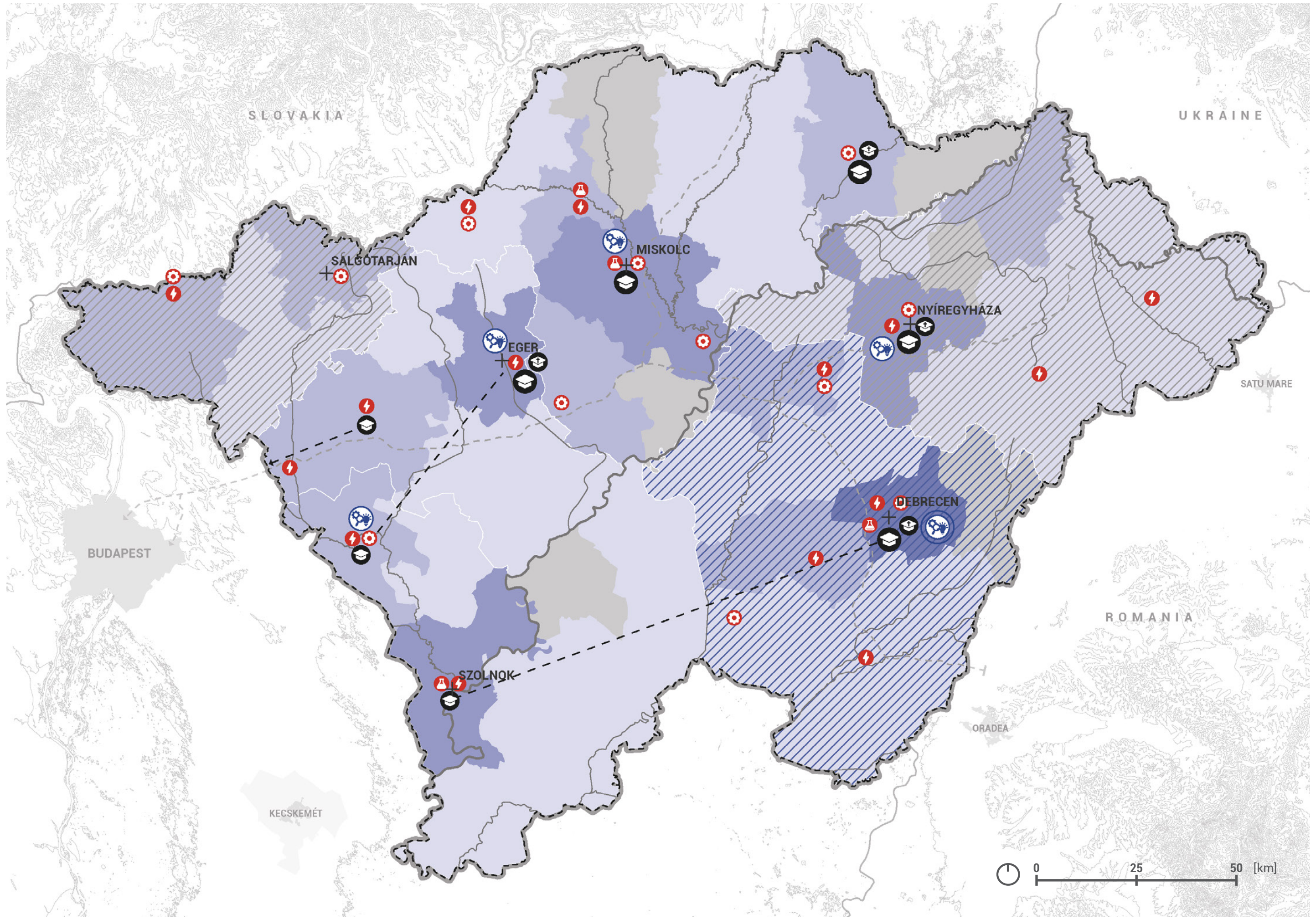
Human Capital

Knowledge and Innovation

Even though there are centres of knowledge and innovation around the main nodes, there is a lack of human capital in the region.

High degrees of knowledge and innovation often results in high degrees of resilience, which is not the case in North-East Hungary, apart from the biggest cities. Due to shrinking and internal migration (KSH, 2023), as well as the underfunded and dismantled education system in the country, there are not enough skilled workers and researchers left in the region. This leads to a lack of workforce, which affects the territory and the battery industry as well, the latter having to invite migrant workers to run the facilities. Therefore transformative change has to start by fixing the education system (Czirfusz, 2025).

Other transformative potentials are clustering Hungarian R+D companies around the (battery) industry in a system of industrial symbiosis, or establishing special education and research hubs around existing knowledge centres (e.g. universities).



% HAS A SECONDARY EDUCATION DEGREE
- 60 - 81,75 %
- 50 - 60 %
- 40 - 50 %
- 30 - 40 %
- 3,18 - 30 %

INSTITUTIONS
- University
- Theological college
- Technical college: electronics
- Technical college: machinery
- Technical college: chemicals

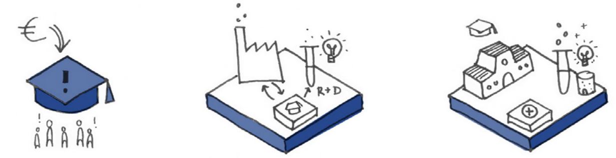
RESEARCH AND DEVELOPMENT
- Companies doing R + D
- areas with most R+D activities
- areas with least R+D activities

- Main rivers
- Highways

Fig. 6.45: Knowledge, research and development

source: author

Potentials:



(Monetary) Contribution to education

Industrial symbiosis with R+D

Special education and research hubs

Territorial Capital and the Pace of Change

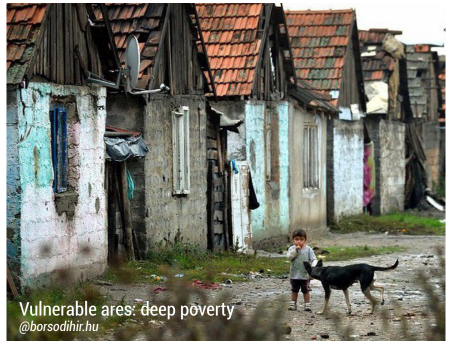
Human Capital

Vulnerabilities

The region shows a high degree of vulnerability, reflected in severe material deprivation (Kolosi et al., 2022) and neglected communities at the peripheral areas (Kocsis, 2021).

The more vulnerable an area is, the less resilience it has in case of crisis. Through unequal distribution of development that concentrate on the main arteries and nodes of the region, the peripheries are often left behind. These kind of sociospatial disparities are difficult to change, they are unfortunately static elements of the territory which are exaggerated due to the centrum-periphery relations of the region (Faragó, 2016; Czirfusz, 2025). One of the most disadvantaged demographic groups in the area are Roma people, most of whom live in deep poverty and suffer institutional bias.

Potentials regarding vulnerability involve peripheries benefitting from major regional projects (and battery development), fostering community-led and bottom-up initiatives (also through EU programs: CLLD (Paneva, 2021), ITI (Inforegio - Guidance fiche: Integrated Territorial Investment, n.d.)), and establishing community centres that could turn into community knowledge banks and foster life long learning over time.



PROPORTION OF PEOPLE LIVING IN SEVERE MATERIAL DEPRIVATION (%)
- 50 - 56
- 45 - 50
- 40 - 45
- 35 - 40
- 30 - 35
- 25 - 30
- 20 - 25

% OF ROMA POPULATION
- 20 - 40 %

most vulnerable areas

Main rivers

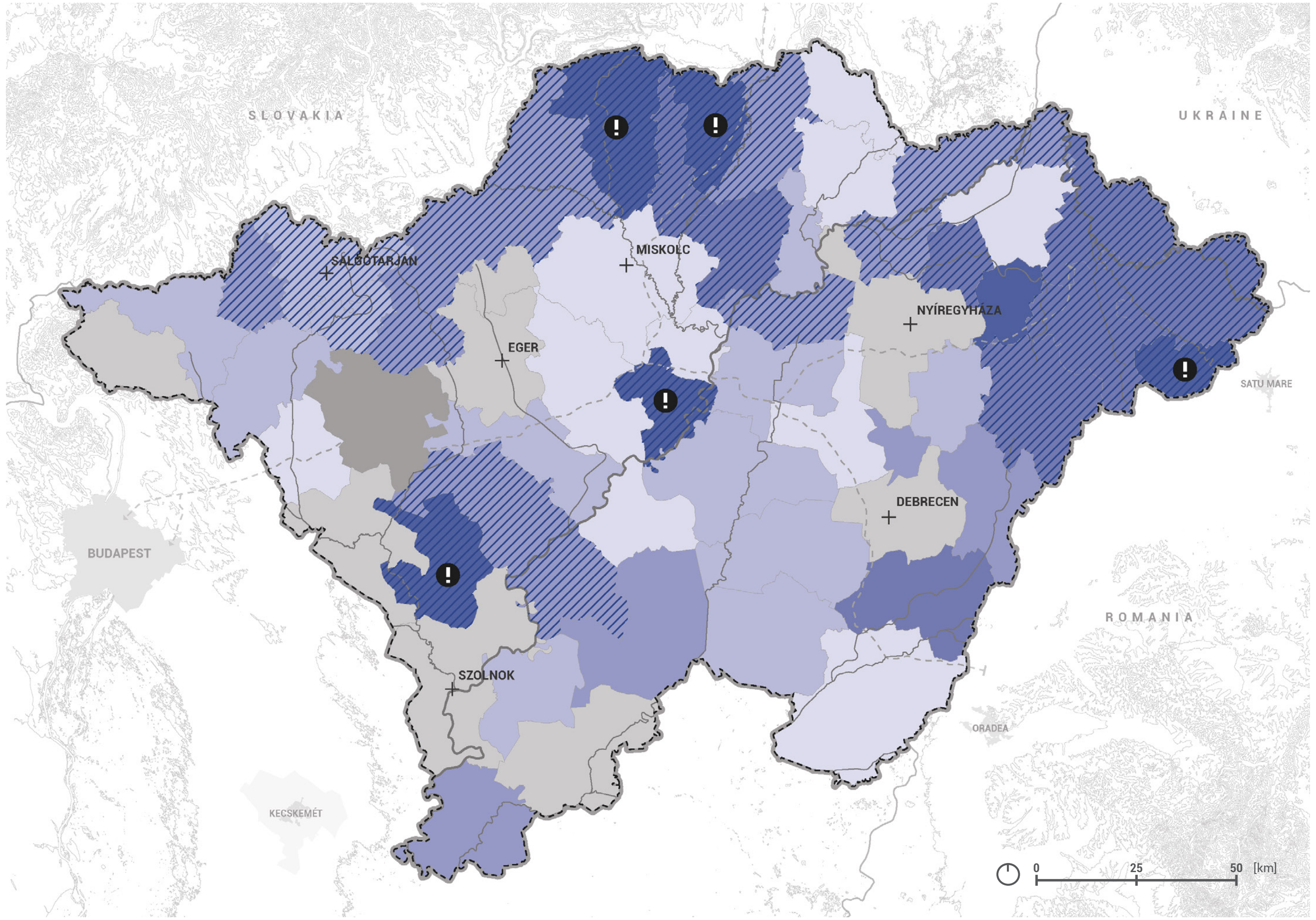
Highways

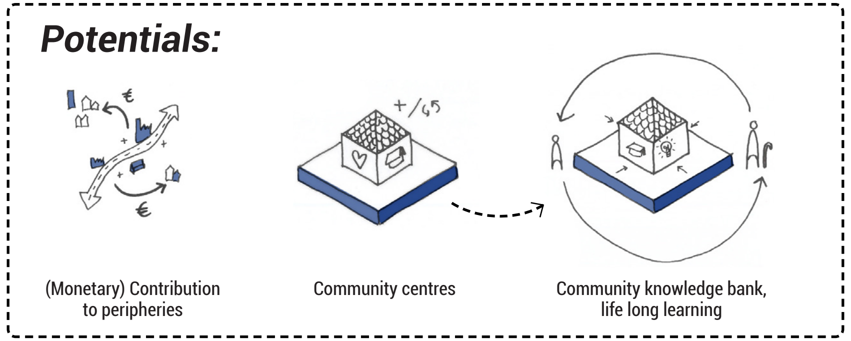
Fig. 6.46 (right): Vulnerable areas of the territory

source: author

Fig. 6.47 (left): Sociospatial disparities of the region

source: see on images



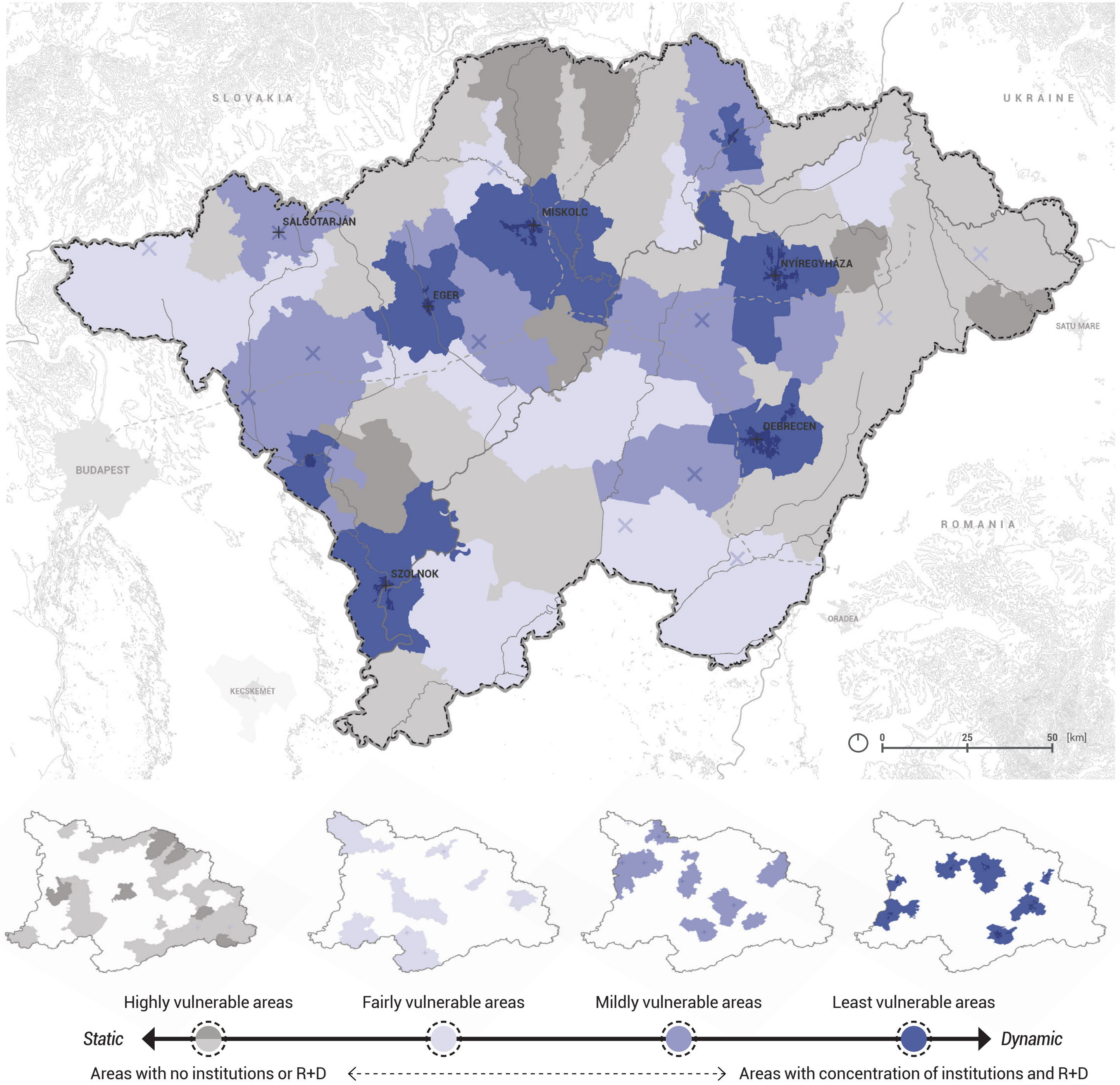


Territorial Capital and the Pace of Change

Human Capital

Frequency of Change

The different frequencies are derived from the synthesis of knowledge and vulnerabilities: the more knowledge and the less vulnerability a place has, the more resilient it is, therefore it has more transformative potential. These central areas and main nodes correlate to the conclusions of the settlement capital. On the other hand, **conscious measures need to be taken in order to achieve positive change at the neglected, peripheral areas. These are the places where transformation is most needed, even though they own the least resources and show little potential.**



Main rivers
Highways

Fig. 6.48: Human capital: frequency of change

source: author

Social capital

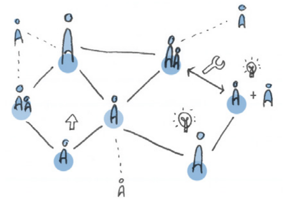
Governance and Planning

In Hungary, there is an extremely centralised and illiberal governance, which reflects in the planning system, combined with the lack of regional-level governance, planning, institutions or actors.

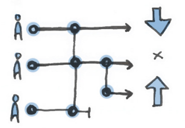
Even though there are five scales of administration – national level, regions (NUTS2), counties, sub-counties and settlements – the main power lies with the national government. Regional and sub-county level governance and planning are not common in practice, while the decisions on county and settlement levels are hindered by the wishes of the national one (Varjú, 2025). A telling example to illustrate the situation is related to the battery industry, where the major of Hatvan (a mid-sized city in the region) learned it from the news that a new factory producing electric motoes will be built next to his town (Weiler, 2025a). This shows a complete lack of communication and cooperation between the different scales. The lack of participation creates mistrust towards the national scale.
The centralised planning system often lacks clear, long-term goals and visions, while relying on the use of 'plaster solutions' to deal with urgent issues. This leaves little space for spatial consideration, and results in profit-driven developments.

Future transformative potentials include polycentric governance structures, transparent, participative and co-creative processes, multi-pathway governance built on nestedness and feedbacks, and the encouragement of learning and experimentation.

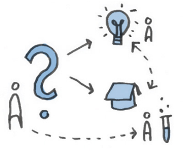
Potentials:



Polycentric governanace with participation and co-creation



Multi-pathway governance (top-down x bottom-up)



Learning and experimentation

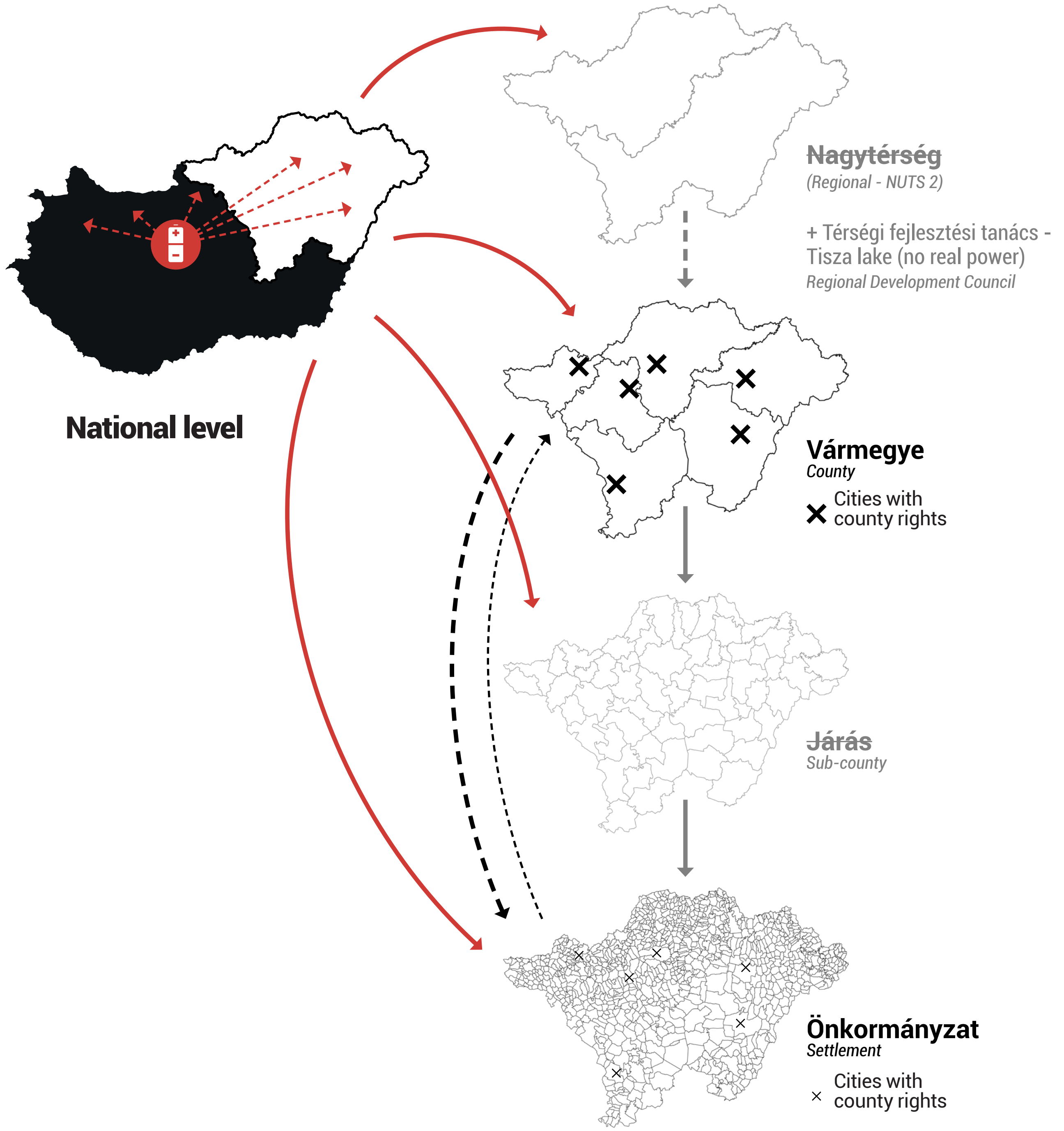


Fig. 6.49: Scales of governance and planning

source: author

Social capital - stakeholder analysis

Stakeholder Relations

To understand the social dynamics and governance background of the region, it is crucial to map out the most relevant stakeholders.

They are sorted into three sectors: public, private and civic society. To understand their motives and roles, I identified their interests, problem perception, goals, resources and dependency to the strategy, and then stated whether they are critical to the project. This is summarised in a table that can be seen in the appendix.

The following onion-diagram depicts the relation between stakeholders, sorted into the three groups of public, private and civil society actors, as well as the scales they operate at. As mentioned on the previous page, the national government has a central role, and a **strong influence** over multiple public and private actors, as well as the church (in the regional Hungarian context it could be an important actor when it comes to mobilising the public). It is important to note that **there is a lack of actors on the regional scale, similar to the planning and governance structure, where it is also a missing step.**

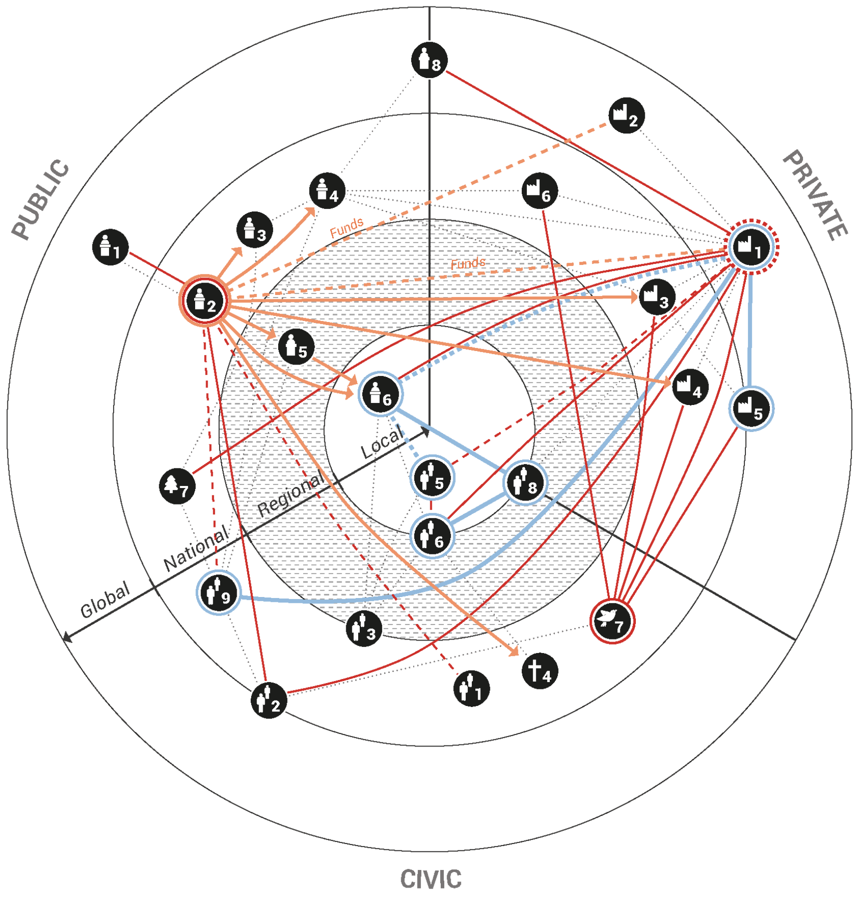
Missing links are also mapped, which mostly happen between two scales: global and local. For example a closer relation between the battery industry (East-Asian companies) and Hungarian universities or other relevant industries (like chemicals – an important actor present in the area) could better integrate the manufacturing into the fabric of the region. The 'general connection' describes dependencies, everyday interactions and co-existence between actors, while conflicts depict opposing views and interests.

PUBLIC
- 1 European Union
- 2 Hungarian National Government
- 3 Ministries
  (Ministry of Technology and Innovation, Energy)
- 4 HIPA (Hungarian Investment Promotion Agency)
- 5 Counties of North-East Hungary
- 6 Settlement municipalities of North-East Hungary
- 7 National Parks (Aggtelek, Hortobágy, Bükk)
- 8 European Battery Association

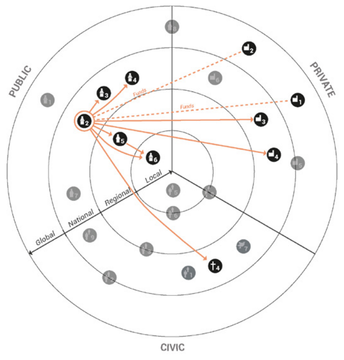
PRIVATE
- 1 Battery industry (CATL, EVE Power)
- 2 Car industry (BMW)
- 3 Energy and electricity providers (MVM, MOL)
- 4 Waste management companies (MOHU)
- 5 Chemical industry (e.g. BorsodChem)
- 6 Transport companies (MÁV, Magyar Közút)
  (train, road)

CIVIC
- 1 Independent media
- 2 Environmental protection groups, NGOs
- 3 Charity organisations (e.g. Hungarian Red Cross)
- 4 Church (catholic, reformat)
- 5 Roma ethnic groups
- 6 (Affected) Citizens
- 7 Non-humans
- 8 Migrant workers
- 9 Academia (University of Debrecen, Miskolc)
  (universities, technical colleges)

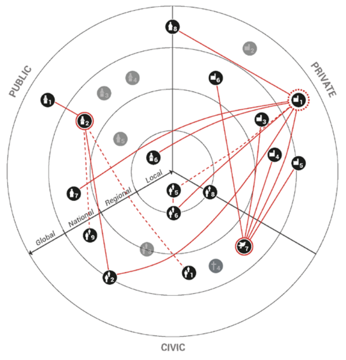
General connection
Conflict
Funds — Strong influence
Missing link
Most missing links
Most conflicts
Most conflicts and influence
Most conflicts and missing links



Corruption



Conflicts



Missing links

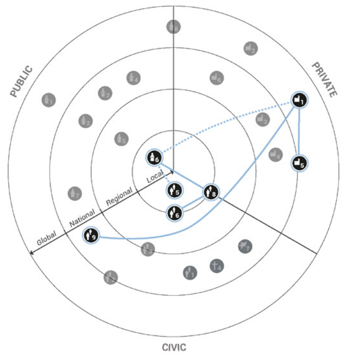


Fig. 6.50: Stakeholder relations: onion diagram

source: author

Territorial Capital and the Pace of Change

Social capital - stakeholder analysis

Stakeholder Power-Interest Matrix

The power-interest matrix on the right further depicts the dynamics of the stakeholders. The highest power lies with the national government and multinational private battery companies, while there are a multiple neglected, powerless, or silent, but heavily affected stakeholders. The arrows show the possible future change in power and interest.

In the future, the EU could gain more power and interest in the region by investing resources (ITI, CLLD) that help empower local stakeholders, 'stepping over' the national government - as it is in the European Union's interest to build an European battery supply chain and control the Hungarian situation better. Moreover, the local governments should have an equal say in spatial questions regarding the manufacturing industry. Another important suggestion is the involvement of academia and energy companies in research and development to further bridge the gap between global and local actors and find innovative solutions. Emphasis is put on channelling in other existing industries at the region, as well as waste-management companies to promote recycling and circularity, in collaboration with environmental protectors and an active group of citizens. Finally, giving more agency to currently neglected groups like the Roma population, the migrant workers, national parks and non-human actors, who previously did not have a voice or power, is crucial.

Potentials:

Bottom-up initiatives

Regional ´umbrella´ (council)

PUBLIC

- European Union
- Hungarian National Government
- Ministries
  (Ministry of Technology and Innovation, Energy)
- HIPA (Hungarian Investment Promotion Agency)
- Counties of North-East Hungary
- Settlement municipalities of North-East Hungary
- National Parks (Aggtelek, Hortobágy, Bükk)
- European Battery Association

PRIVATE

- Battery industry (CATL, EVE Power)
- Car industry (BMW)
- Energy and electricity providers (MVM, MOL)
- Waste management companies (MOHU)
- Chemical industry (e.g. BorsodChem)
- Transport companies (MÁV, Magyar Közút)
  (train, road)

CIVIC

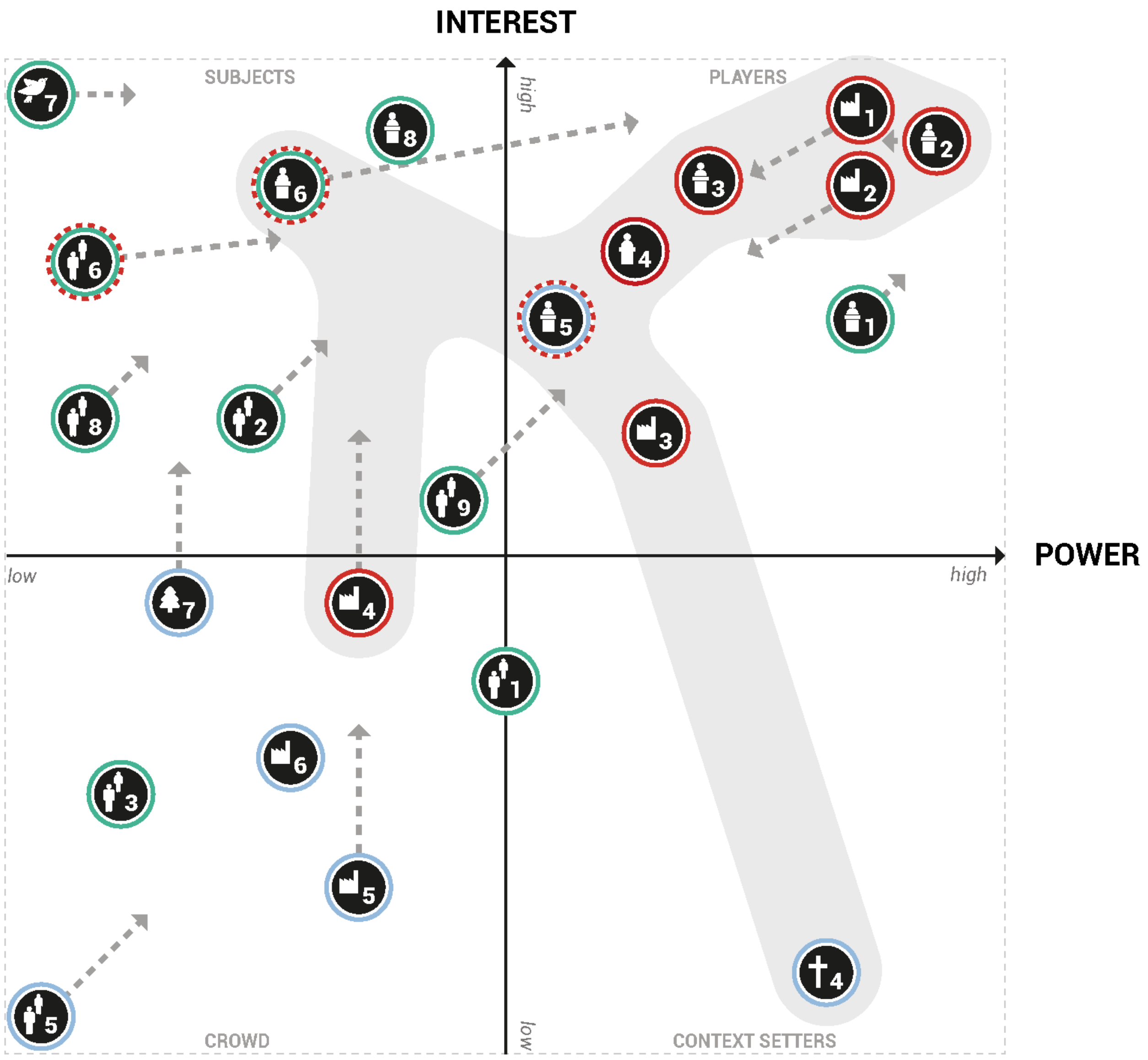
- Independent media
- Environmental protection groups, NGOs
- Charity organisations (e.g. Hungarian Red Cross)
- Church (catholic, reformat)
- Roma ethnic groups
- (Affected) Citizens
- Non-humans
- Migrant workers
- Academia (University of Debrecen, Miskolc)
  (universities, technical colleges)

Attitudes:

- Proponents
- Opponents
- Fence-sitters
- Governmental influence network (corruption)

Fig. 6.51: Power-interest matrix, current situation

source: author



Synthesis

The Synthesis sub-chapter, the elements with the lowest and with the highest frequencies of change of each territorial capital layer are combined and shown on two separate conclusion maps. This allows for a comprehensive understanding of what are the dynamic and static parts of the region.

The transformability potentials, which were identified at each analysis step, are combined into a matrix based on different scales and territorial capital layers. They will be later used as the base of future strategies and interventions.

Synthesis
Low Frequencies of Change

The map is a synthesis drawing that shows the most static, slowly changing (low frequency of change) elements of the region by each territorial capital layer. On the regional scale these are persisting protected natural areas, main infrastructure (due to path dependency), peripheral areas with little function and a long history of spatial inequalities, which has been, and will be shaping the region for a long time. These structures are less unpredictable, and we can regard them as constant in future scenarios and vision.
On the city-scale, static elements are the protected green patches, monofunctional (e.g. only residential) areas, heritage sites and monuments, vulnerable neighbourhoods and the main arteries of the place.

It is important to consider the static areas carefully with future strategies. Even though they have low transformability potential, they are often the elements where the need for change is the most pressing.

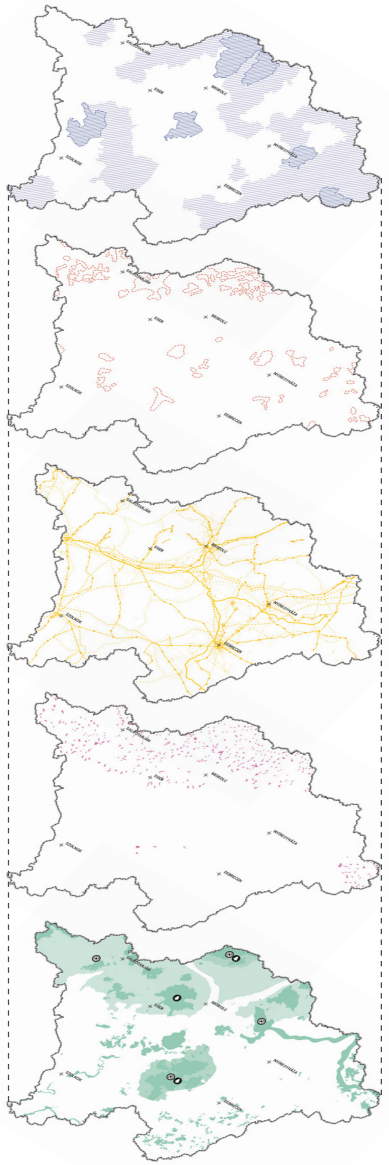


Fig. 6.52: Map of elements of low frequencies of change in the region

source: author

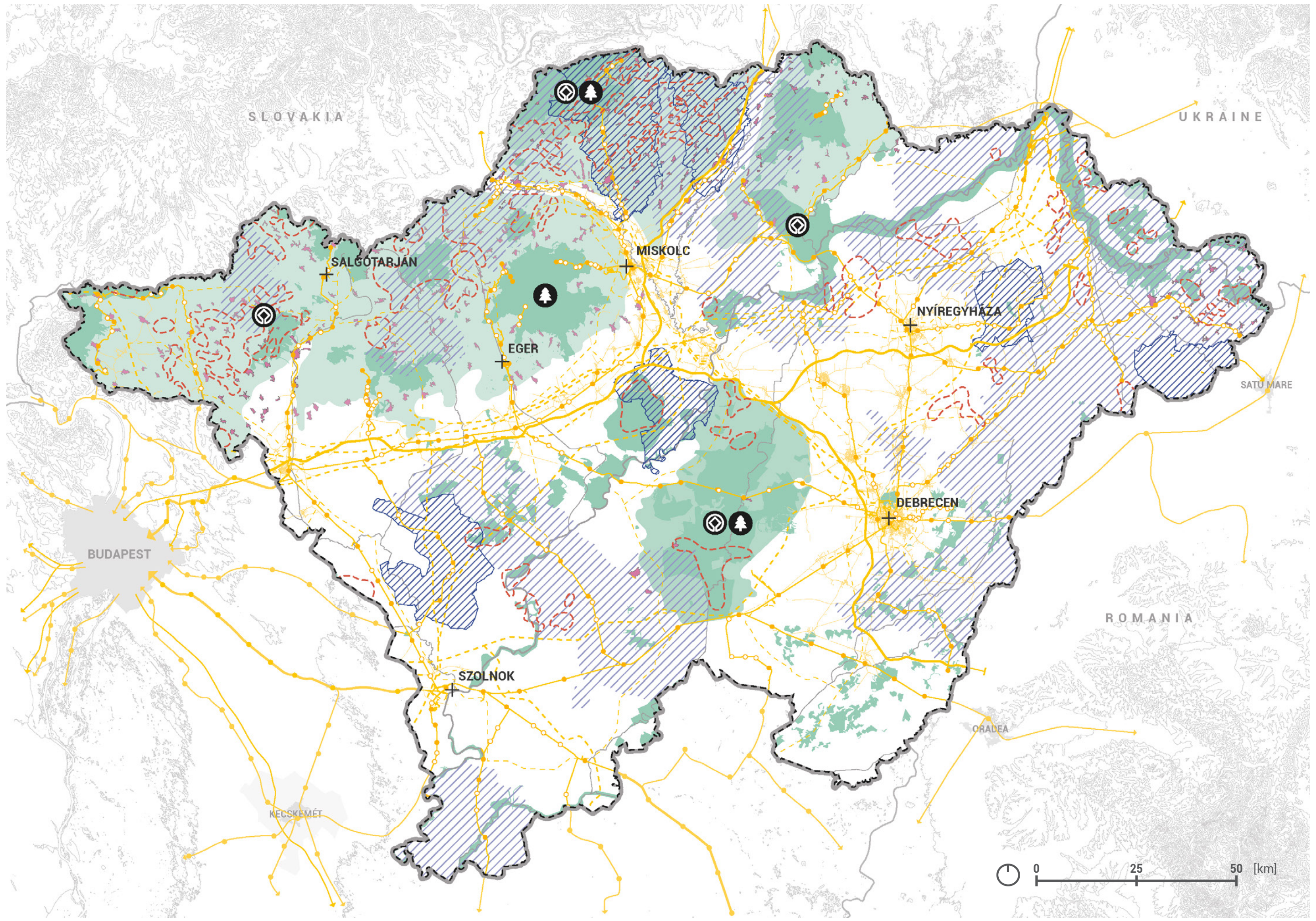
HUMAN CAPITAL
- highly vulnerable, least knowledge

ECONOMIC CAPITAL
- functional deserts

INFRASTRUCTURAL CAPITAL
- 750; 400 kv power-line
- 220 kv power-line
- highways
- train tracks: double track
- train tracks: single track
- well-connected roads

SETTLEMENT CAPITAL
- small villages and settlements with cultural heritage

NATURAL CAPITAL
- protected areas
- biosphere reserves
- mountain landscape



Synthesis
High Frequencies of Change

The map is a synthesis drawing that shows the most dynamic, rapidly changing (high frequency of change) elements of the region by each territorial capital layer. **These elements have the potential to transform in the upcoming years, as they require the highest degree of flexibility due to their unpredictability.** Included are the rivers with natural dynamism accelerated by climate change, as well as the settlement next to them, along with the main nodes of the region where knowledge, innovation and economic activities cluster. The exemption are peripheral roads and abandoned train infrastructure, which are not crucial to the system, therefore easier to change.

On the city-scale, dynamic elements are riverbanks, industrial, commercial or other multifunctional hubs and public spaces, mixed neighbourhoods with diverse typologies, educational institutions and research centres and slow mobility routes.

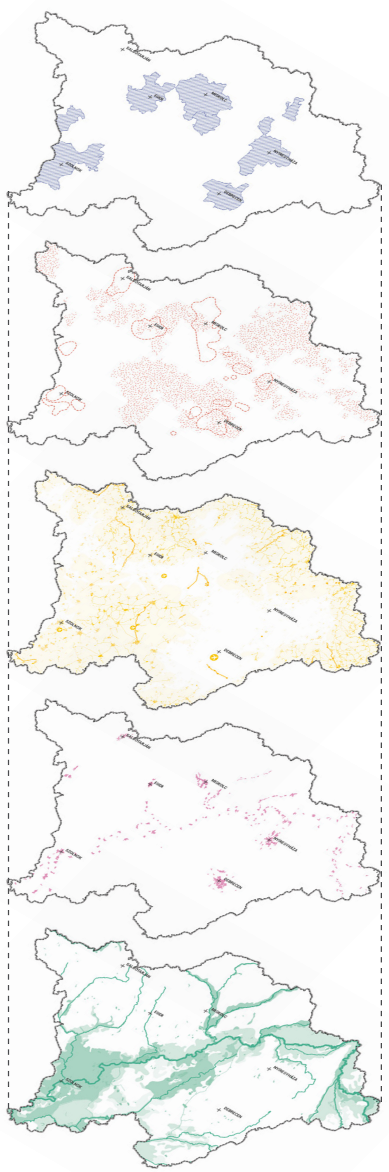


Fig.6.53: Map of elements of high frequencies of change in the region

source: author

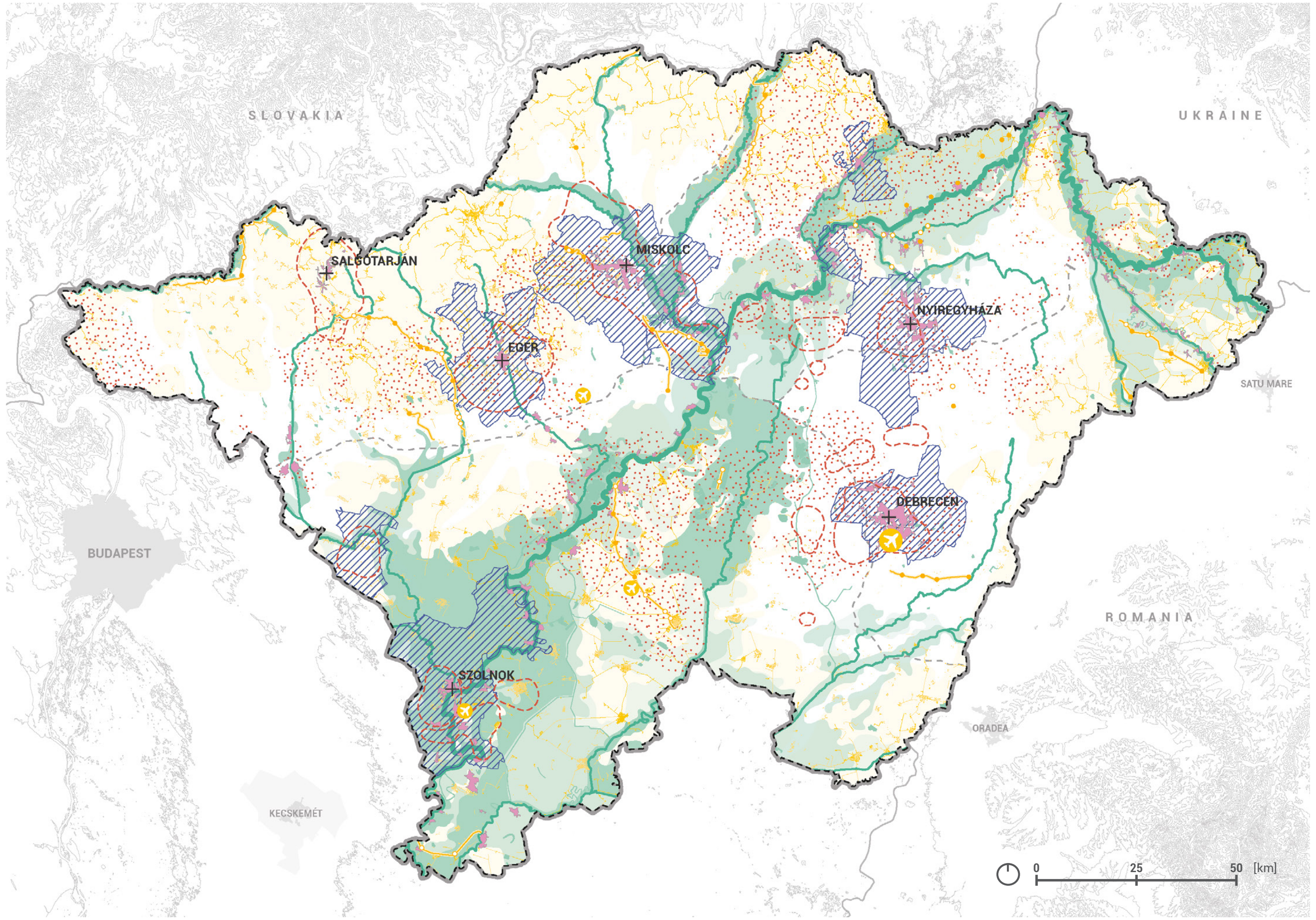
HUMAN CAPITAL
least vulnerable, most knowledge

ECONOMIC CAPITAL
high diversity and density of functions, combined with tertiary sector activities
touristic areas

INFRASTRUCTURAL CAPITAL
train tracks not in use
abandoned train stations
abandoned train stops
airports
isolated (periphery) roads

SETTLEMENT CAPITAL
big cities and settlements with 'river' identity

NATURAL CAPITAL
rivers
floodplains



Synthesis
Concluding on Territorial Capital and Transformability Potential

In this sub-chapter, a territorial capital analysis was conducted on six different layers: natural capital, settlement capital, infrastructural and relational capital, economic capital, human capital and social capital. For each element, transformative potentials were identified. The temporal dimension was taken into account by determining the pace of change of elements and capital layers, resulting in the identification of static and dynamic regional assets.

<u>The main lessons include</u>:

- Territorial development currently depends, has been and will be dependent on the different landscape-types, topographies and subsurface characteristics (geomorphology, soil).
- The region shows plenty of transformative potential, although there are not enough resources (economic, human, social) or willingness to act.
- The main strengths of the territory lies in its diverse landscapes and natural capital, as well as some special local products (Tokaj wine, Hungarian Grey Cattle)
- The main weaknesses of the territory are the lack of human capital (vulnerable areas) and strong dependencies on external factors (Budapest, national government and the battery industry)
- Dynamic elements have a higher transformability potential due to their frequently changing nature
- Static elements have lower transformability potential, even though these are often the elements that are in need of transformation (like sociospatial disparities, primary economic sector, and shrinking villages)

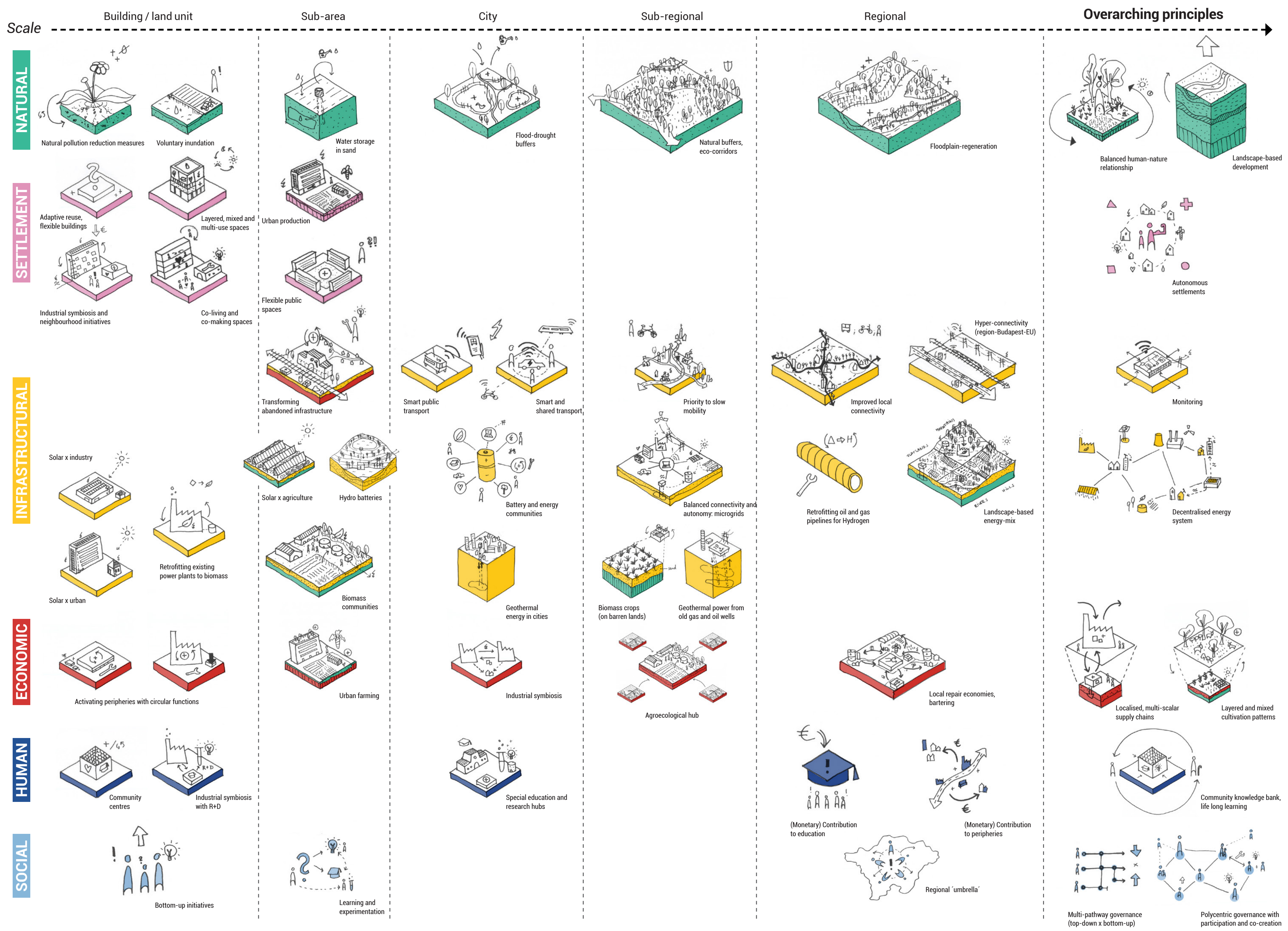
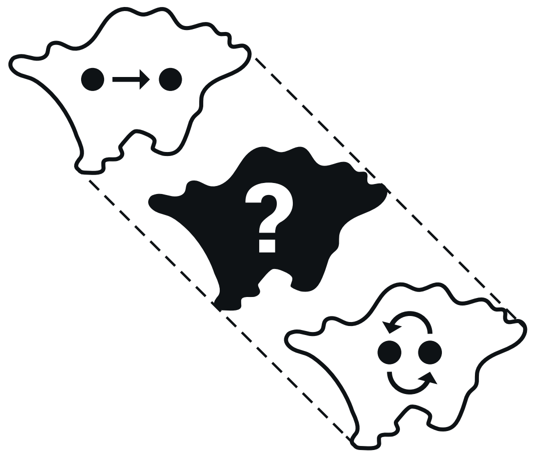


Fig.6.54: Summary of territorial transformability potentials

source: author

EXPLORATION



Vision of a Transformative *Battery* Territory

Hungary currently lacks holistic, integral regional visions, as 'plaster' solutions and impulse decisions of the central power define spatial development in the country.

Therefore the Vision for a Transformative Battery Territory offers an alternative path through spatial imagination and scenario-building, guiding current and future transformations in North-East Hungary. It aims to define the long-term territorial perspective based on transformability and multi-crisis 'response-ability', to later use backcasting and react to the ongoing crisis of uncontextual and unsustainable battery industrial activities.

Starting from the enablers of transformability, which become the principles of the vision combined with 'response-ability' and contextuality, through the means of adaptive resource management, adaptive governance and adaptive land, the vision has the ability to lead to the values of sustainability transformation.

Vision statement:

In the upcoming 50 years, the North-East Hungarian region turned the current battery-crisis into an opportunity by following a just, circular and flexible development path, and established a contextual, sustainable and resilient spatial framework allowing for future transformation in case of need.

The means of the transformation:

Adaptive resource management x CIRCULAR
Adaptive resource management (Walker et al., 2004) is a structured, iterative process of optimal decision-making regarding complex adaptive socio-ecological systems, using system monitoring and feedback-loops to reduce uncertainties. In relation to the intangible elements of the region, if combined with territorial circularity (Furlan et al., 2022), adaptive resource management has the ability to optimise resource flows and minimise environmental impacts.

Integrating resilience-thinking with the circular economy paradigm in this manner ensures that circularity does not coexist within an unsustainable production-consumption system (Suárez-Eiroa et al., 2021). Therefore building transformative capacity and ensuring sustainable, resilient and circular practices when defining the future transformative battery territory is of core concern. Such an approach enables the accommodation of the dynamic flows of the region, ensuring flexibility in face of changing industrial processes and actors.

Adaptive governance x JUST
Rooted in resilience-theory, adaptive governance is an innovative approach, characterised by 'learning by doing', with the goal of creating a system responsive to uncertainties (Gunderson & Holling, 2002), similar to adaptive resource management. It is 'the process of creating adaptability and transformability in social-ecological systems' according to Walker et al. (2004). However, this approach has often failed in practice, as it could not function effectively due to the existing governance systems, which is of concern regarding the North-East Hungarian situation.

In order to achieve a successful sustainability transformation, ensuring a flexible management and governance system is key. Balancing flexibility with just management characterised by inclusivity and equity can ensure that all stakeholders benefit from the transformation process.

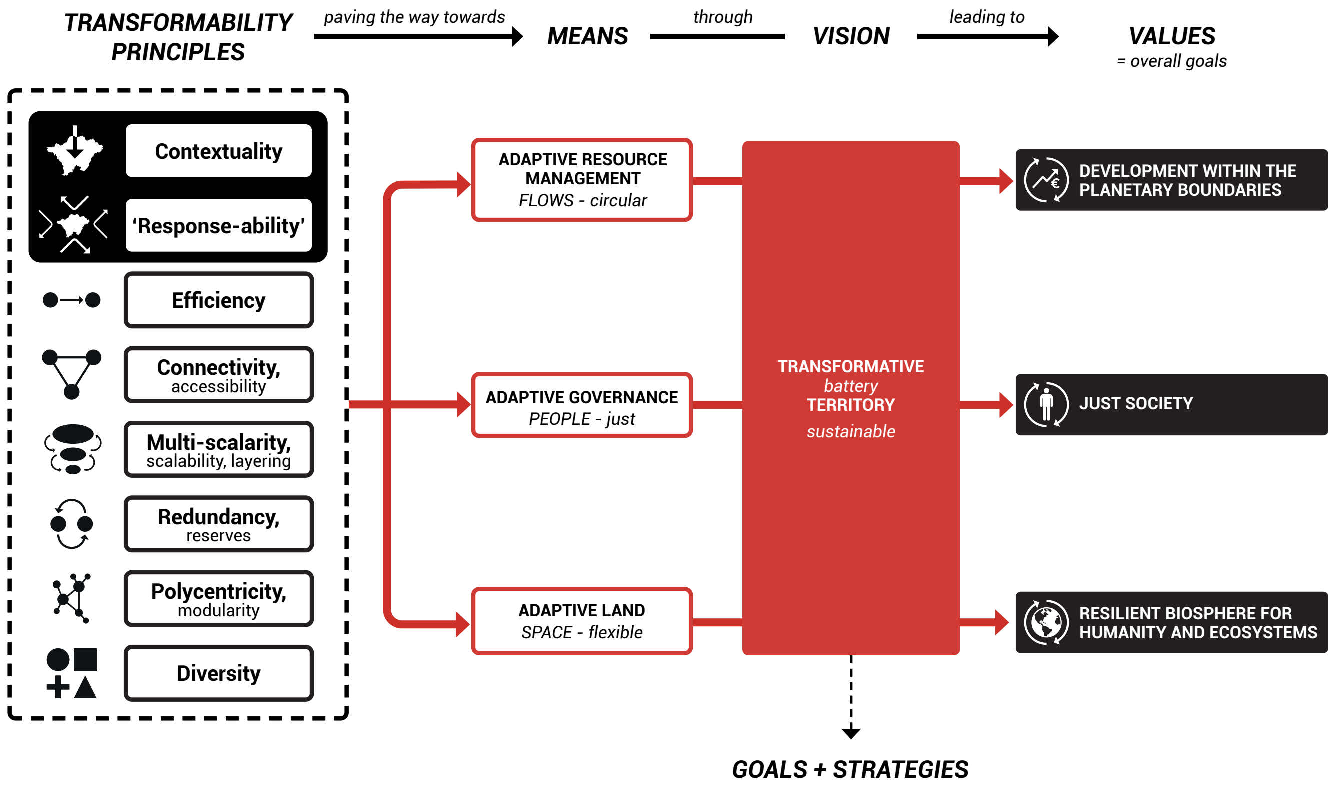


Fig. 7.1 (right): Values, means and principles of the vision

source: author

Adaptive land x FLEXIBLE
This thesis defines 'Adaptive land' as the ability of spatial elements to adapt and transform in face of change. It is characterised by flexibility, as it is the spatial manifestation of the enablers of transformability (Theories and Concepts chapter), connected to general resilience (Folke et al., 2010; Folke, 2016). From the regional, through the city and building scales, multi-use, mixed-use spaces, buffers and thresholds that allow for flexible uses are key to ensure long-term transformability. This is the realm of interventions of urbanism.

Through the transformability principles and these three means, a Transformative battery Territory can be achieved, leading to the desired values of the sustainability transformation. On the other hand, there are known contradictions within the enablers of transformability, which calls for further exploration before defining a spatial vision.

Scenario Construction

The scenario construction is part of the backcasting process, and it is necessary in order to explore different spatial organisations and varying spatial manifestations of transformability based on the principles (former enablers) and the regional context.

To answer the third research question and find a spatial organisation that allows for transformability, this thesis is going to explore two possible scenarios, based on the contradictions between certain enablers of transformability. The first scenario maximises efficiency, resulting in hierarchic, vertical structures, top-down governance, and an optimised, preventative crisis-response. It also follows the current spatial development patterns, preserving the centrum-periphery relations in the region. The second scenario maximises redundancy, as it has a contradicting relation with efficiency, resulting in decentralised, horizontal structures, a bottom-up governance approach, and enough reserves to withstand crisis events with similar-but-not-the-same elements. It introduces a new way of spatial organisation based on the landscape, social and community values, abolishing the centrum-periphery setup of the area.

It is possible to create two main groups of principles around the two maximised enablers. Efficiency is paired with (hyper)connectivity and multiscalarity, while redundancy is in relation with polycentricity and diversity. Both scenarios use all six enabler to some extent, but due to the idea of maximisation, the two groups of three are the most prominent in each respective scenario, which was deducted based on literature review and the local context. Contextuality and 'response-ability' are base criteria, both cases have to adhere to them.

After the scenario construction phase, the results are evaluated, and a long-term transformative spatial framework can be envisioned.

On the next pages, both scenarios will be described in details.

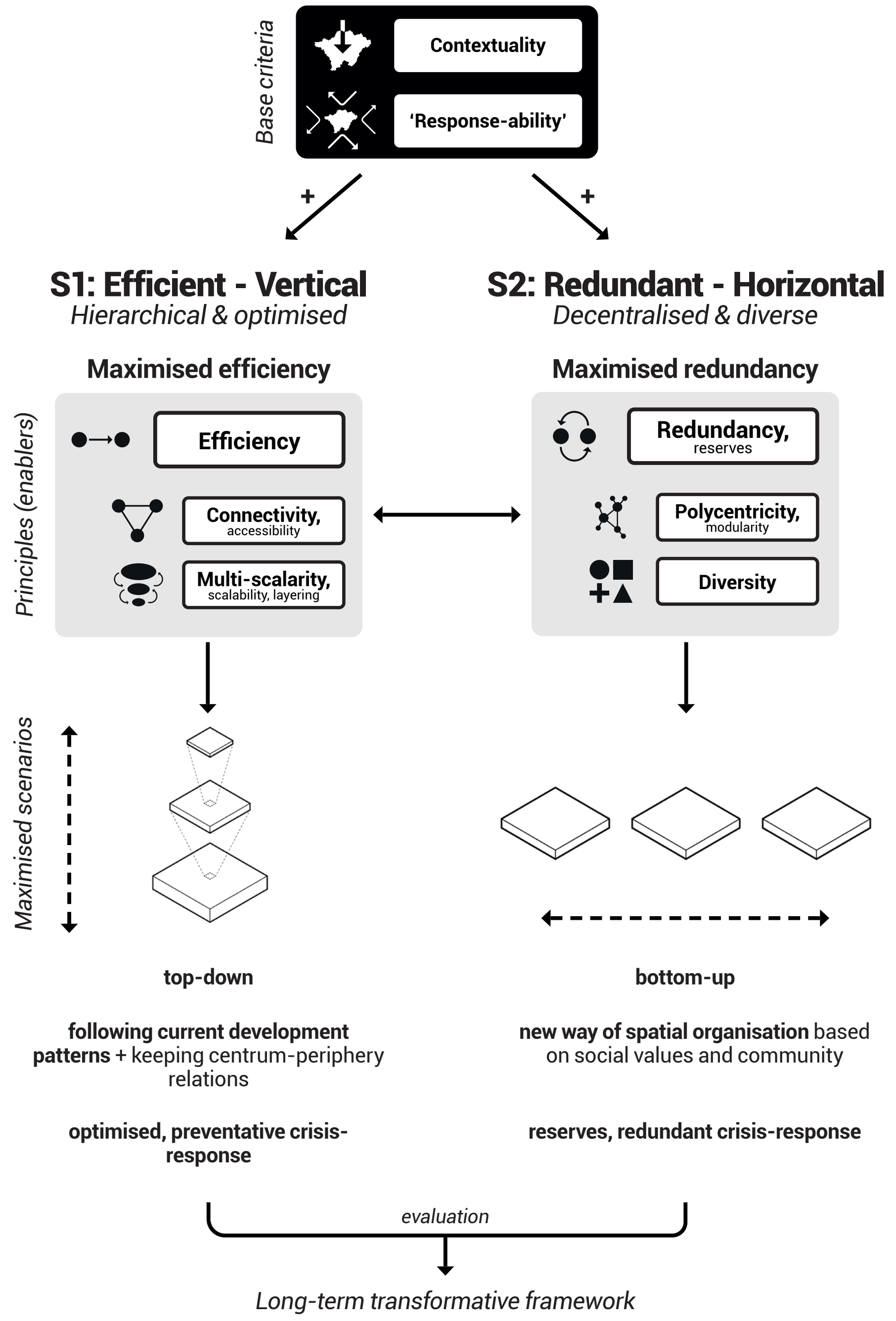


Fig. 7.2: Scenario construction: efficient and redundant cases

source: author

Efficient:
Hierarchical & Optimised

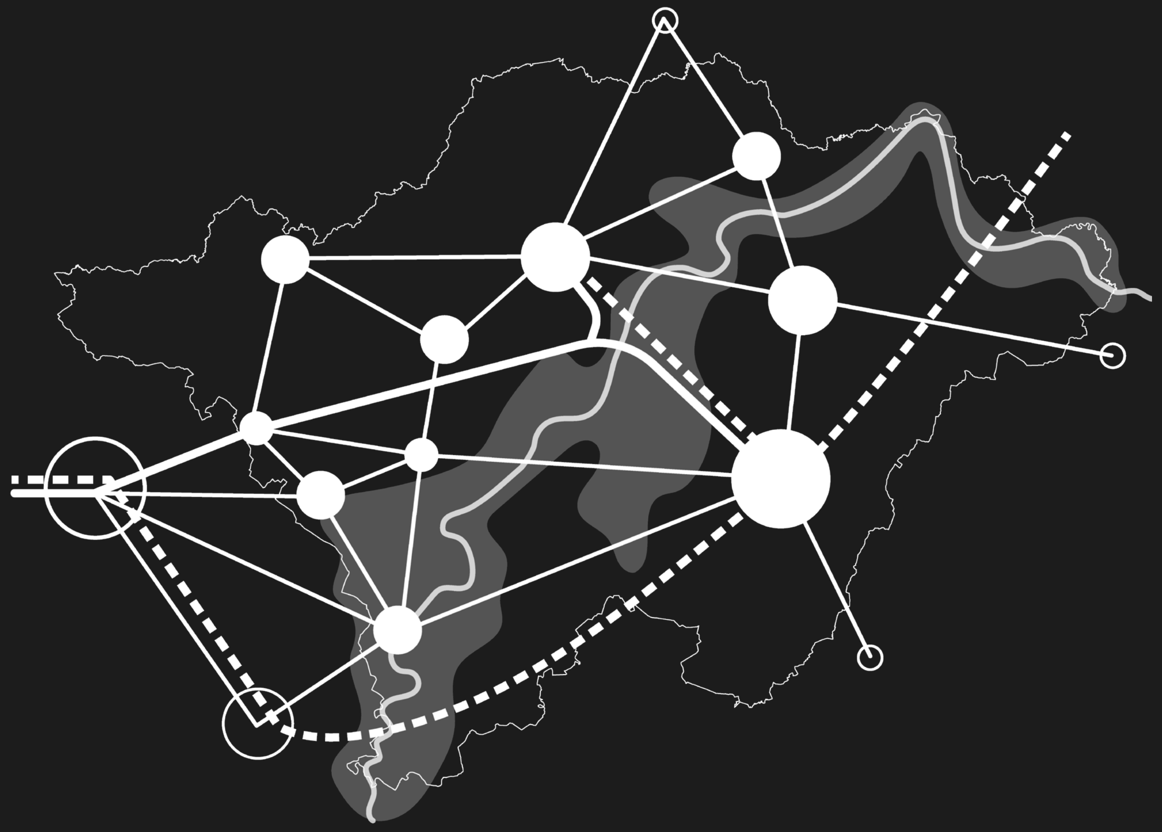


Fig.7.3: Efficient scenario - simplified scheme; *source:* author

Efficient: Hierarchical & Optimised
Strategies

Efficient measures have to pair with multi-scalarity in order to be transformative, therefore the main strategies are described on the regional, city and building scale. The drawing on the right shows the hierarchic relations between them, with a main city node in the centre. Thinking through scales and verticality are key elements.

Nature
As climate change worsens, unpredictability and the severity of flood-drought events grow. As a response, the region decides to restore the floodplains of river Tisza, creating a robust natural buffer across the territory. Main ecological corridors are strengthened, while urban wetlands and temporary flood areas are established in and around cities. The street structures are transformed with wadis and water squares, while water retention is solved on building roofs and raingardens. This results in a multi-scalar, hierarchical water system, mainly built on retention by buffering.

Settlement
There is a concentration and growth around urban centres, clustering knowledge, innovation, and services. The main node is Debrecen, with other important cores of Nyíregyháza, Miskolc, Szolnok, Eger, Sátoraljaújhely, Sárospatak Jászberény and Hatvan. Many of the smaller villages empty or turn into touristic hotspots on the flatlands, partially due to the floodplain restoration.

Transportation
A well-connected high-speed train is established between Budapest, Debrecen and Miskolc, while connections between the main city cores are also strengthened. Roads become Electric Vehicle-ways, with battery exchange stations replacing petrol stations, as a shared battery network for car traffic is created. In the cities, smart and shared transportation (MaaS) serves the inhabitants.

Energy
Adhering to climate neutrality goals, the region shifts to the use of renewable energy. A connection is established to European Hydrogen Backbone (EHB) around 2040, by refurbishing existing gas pipelines. This energy is primarily used by main industries. The hydrogen energy is mixed with local renewable solutions, mostly based on advanced geothermal and solar energy, as they are the most efficient and reliable sources in the region. Solar farms, solar roofs and facades are established in all communities, while geothermal wells take over the old natural gas and oil wells (heat is transformed to electricity with the use of steam engines).

Economy
The economy is characterised by tiered supply-chains that is structured for priority flows and (possible) export. Circular activities centred around industrial activities (clustered along main corridors), while repair hubs and material banks are spread out in the neighbourhoods. As main industries primarily prevail, a system of industrial symbiosis forms with the neighbouring settlements. Core agroecological hubs ensure nature-based farming practices, connected to smaller providers. In the cities urban farming is the new norm.

Human: work and life
Life centres around the cities. Specialised education hubs are established around existing centres of knowledge (universities, R+D), while on the small scale local community houses serve as places of knowledge exchange. New workplaces are established due to the novel appeal of the region, in agriculture, circular activities and R+D.

Governance
A top-down hierarchic regional governance system is established, with local actors representing different groups of society. Debrecen has the most say, along with the main nodes. They are responsible for the core regional structures and crisis management - based on monitoring.

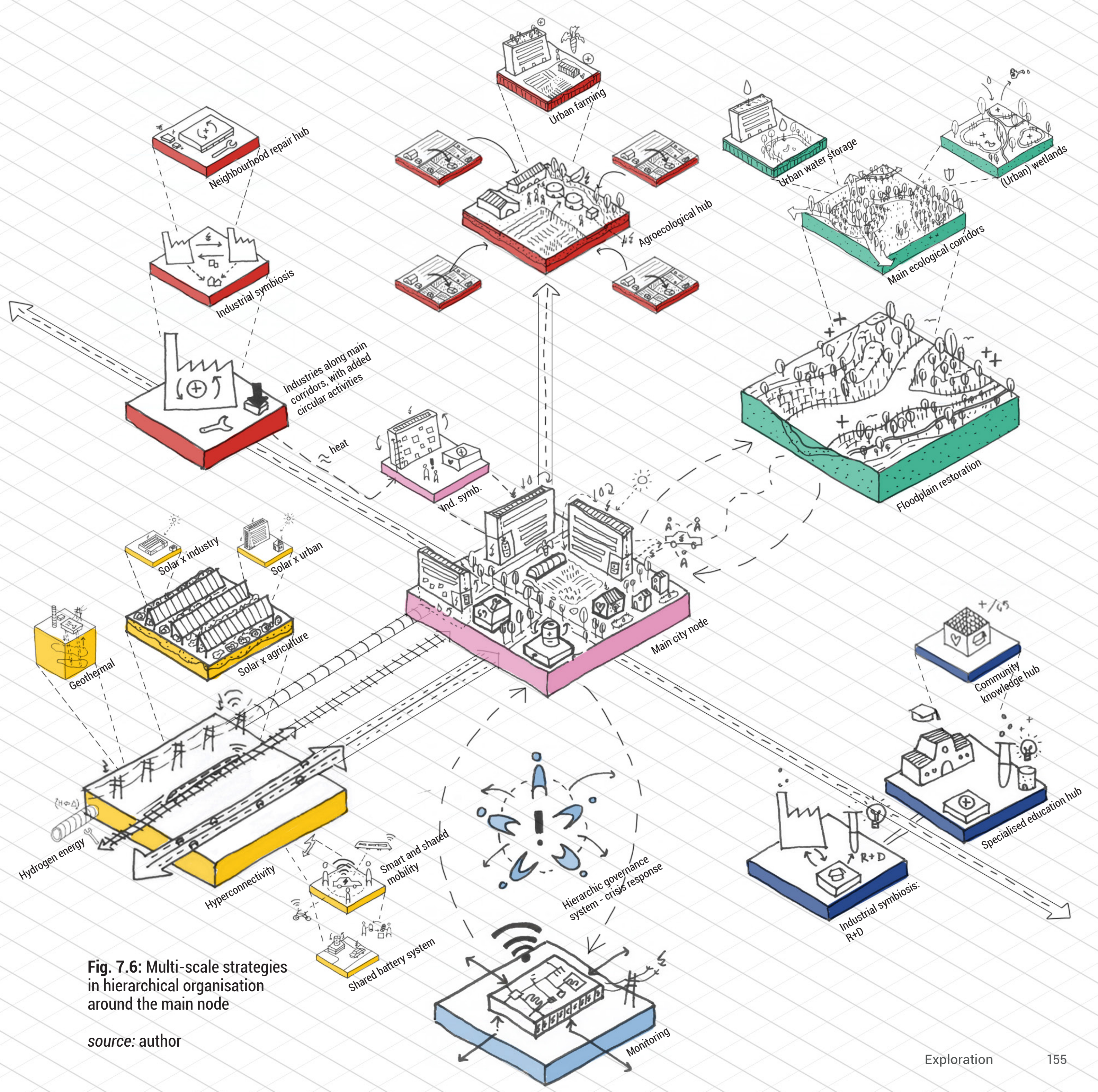


Fig. 7.6: Multi-scale strategies in hierarchical organisation around the main node

source: author

Efficient: Hierarchical & Optimised

Layers of the Efficient Scenario

Following the scenario description, the separate layers of the efficient scenario are depicted on the right.

Territorial capital layers	EFFICIENT
Nature	*Focus on urgent, central structures: floodplain-restoration, main ecological corridors*
Settlement	*Concentration and growth around urban centres, in a hierarchical structure (main city: Debrecen)*
Transportation	*Efficient and fast radial networks (roads, train), and routes between main nodes of the region.*
Energy	*Connection to European Hydrogen Backbone (EHB) by refurbishing existing gas pipelines, mixed with most efficient local renewable solutions (solar)*
Economy	*Tiered supply-chains, structured for priority flows and (possible) export; agroecological hubs*
Circularity	*Circular activities centred around industrial activities (clustered along main corridors), industrial symbiosis with settlements*
Human - life + work	*Specialised education hubs, most work and knowledge concentrates in main nodes (cities)*
Social - governance	*Hierarchic, regional governance, with local actors representing different groups, central crisis-management - mainly top-down*

Infrastructure

river Tisza
natural buffer
floodplains
waterbodies
smaller river buffers
protected areas

low-hierarchy settlements
mid-hierarchy settlements
growing settlements

highways
primary roads
high speed train
train tracks
hydrogen network (EHB)
local hydrogen network
regional energy hub
airports
local energy mix (solar, geot.)

agroecological hubs
Budapest: centre of knowledge
Szolnok: water capital
added (circular) function
optimised circular and knowledge network

R + D hubs
special knowledge hubs

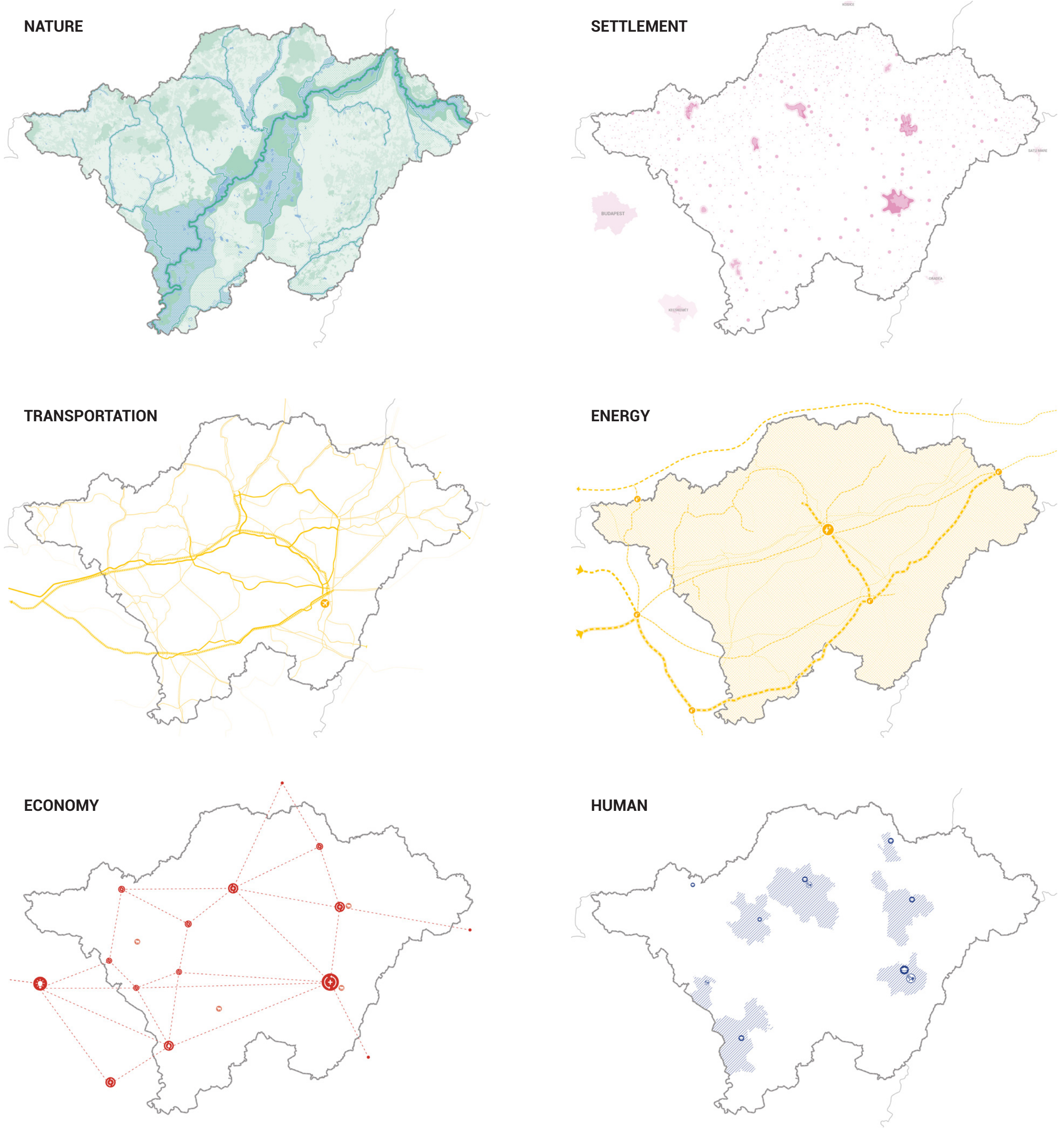


Fig. 7.5: The separate layers of the efficient scenario

source: author

Efficient: Hierarchical & Optimised
Spatial Organisation

As a conclusion, this map depicts the spatial organisation of an efficiency-based North-East Hungary. To achieve transformability, a continued focus on the core structures and hierarchies remains essential, solidifying the existing centrum-periphery relation. The region turns towards the EU with an extroverted mindset, stepping out of past dependencies (e.g. connecting to the European Hydrogen Backbone instead of Russian gas). Compulsory contributions to the peripheries ensures that these areas benefit from the primary developments.

The crisis response is characterised by prevention: optimising the existing system, using smart technologies and monitoring to predict and avoid disruptions.

- river Tisza
- natural buffer
- floodplains
- waterbodies
- smaller river buffers
- protected areas
- low-hierarchy settlements
- mid-hierarchy settlements
- growing settlements
- highways
- primary roads
- high speed train
- train tracks
- hydrogen network (EHB)
- local hydrogen network
- regional energy hub
- airports
- local energy mix (solar, geot.)
- agroecological hubs
- Budapest: centre of knowledge
- Szolnok: water capital
- added (circular) function
- optimised circular and knowledge network
- R + D hubs
- special knowledge hubs

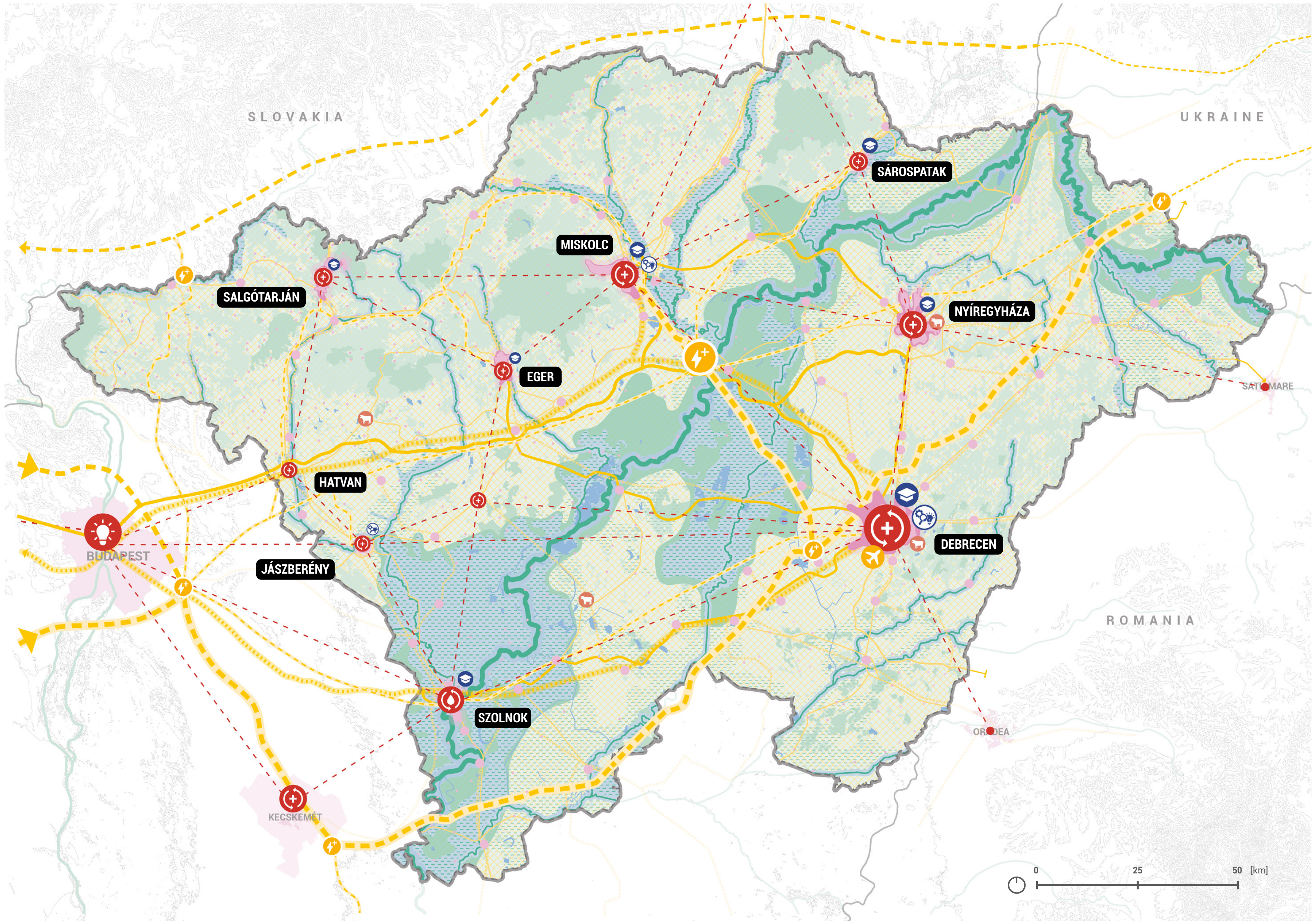


Fig. 7.6: Spatial organisation of an efficient North-East Hungary

source: author

Redundant: Decentralised & Diverse

Fig. 7.7: Redundant scenario - simplified scheme; *source:* author

Redundant: Decentralised & Diverse

Strategies: Battery Communities

Steering principles

Landscape-based development | Balanced human-nature relationship | Natural pollution reduction | Landscape-based cultivation *(energy-food-nature)*

<u>Nature</u>
Landscape-based development, steering in regard of the subsurface is the new norm. A balanced human-nature relationship is established, with landscape-based cultivation patterns. Nature-based solutions are preferred over technological ones.

<u>Settlement</u>
Resilient battery and energy communities are the new form of settlements, resulting in revitalised small towns and villages, as well as urban neighbourhood-formations, fulfilling landscape-based roles with a local mindset.

<u>Transportation</u>
Strong regional connections form to help local exchange of knowledge and bartering. Shared and autonomous mobility (also good in settlements with little inhabitants), bike infrastructure and walking paths have priorities. Main arteries remain, but are not in the focus of development.

<u>Energy</u>
Decentralised, landscape-based energy-production, using microgrid-systems that are connected to the main power lines (nuclear fallback supply), but can also be in 'island-mode' (Microgrids | Grid Modernization | NREL., n.d.). Shared batteries and battery backup systems are common, allowing for off-grid solutions.

<u>Economy</u>
Local repair economies, bartering, and landscape-based, similar-but-not-the-same production characterises the region, using abandoned train tracks for circular functions, activating the peripheral areas. Factories are taken over by communities, and are combined with circular activities, material banks and repair hubs as well. Agriculture is combined with ecology, nature-based solutions and indigenous methods resurface.

<u>Human</u>
Multi-generational knowledge and learning are of core importance in the communities. Life Long Learning is cherished, community knowledge banks are established in community centres. Mixed livelihood schemes and working and living in the community are common, along with a digital nomad lifestyle.

<u>Governance:</u>
The autonomous communities form a web of polycentric and participatory local governments, loosely connected to each other in the more pressing questions of the region (e.g. through a regional forum). Bottom-up approaches and initiatives are the new norm.

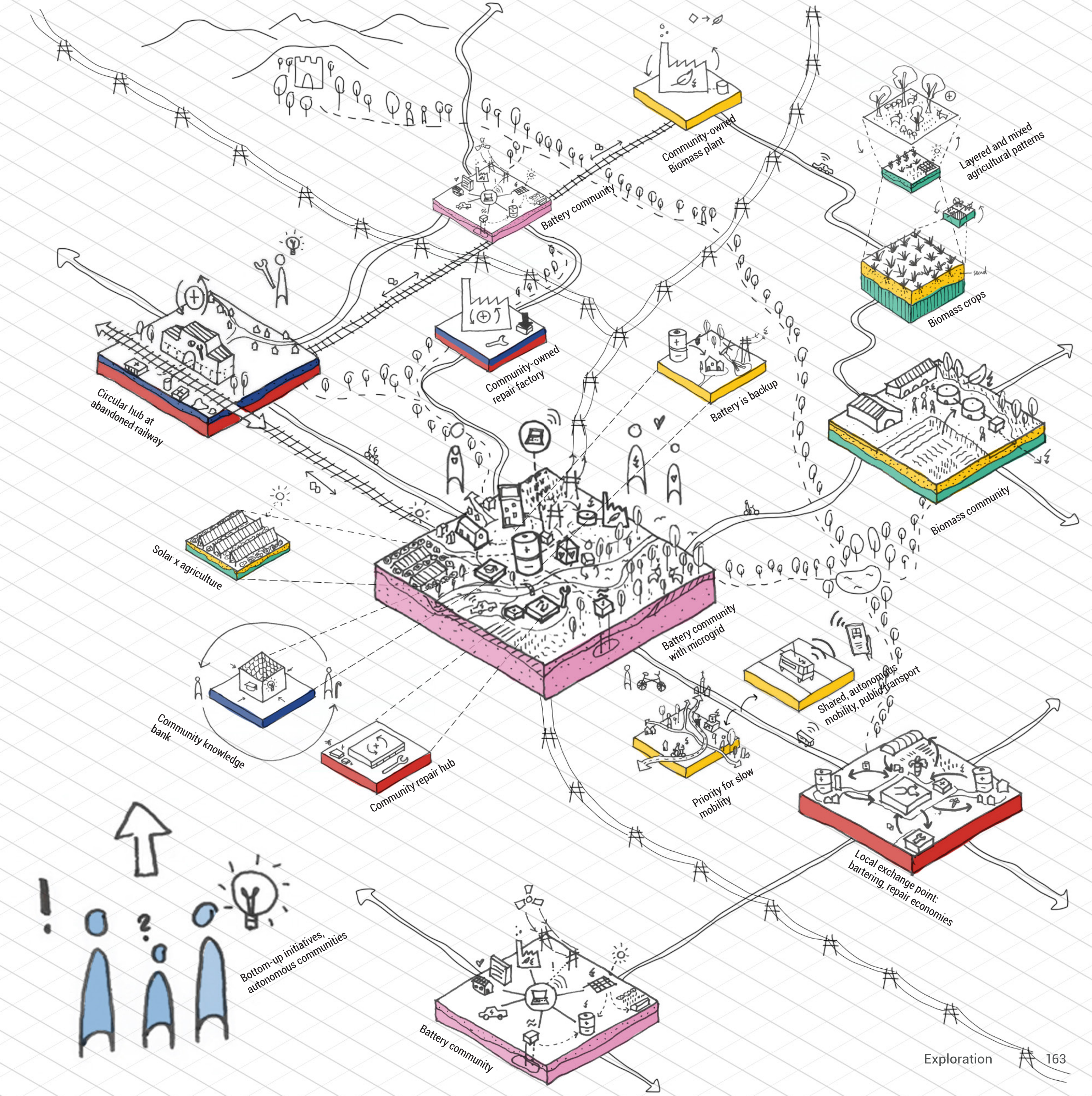


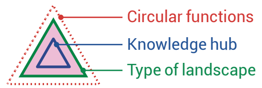
Fig. 7.8: Battery communities: the new way of living - abstract relations: horizontal organisation

source: author

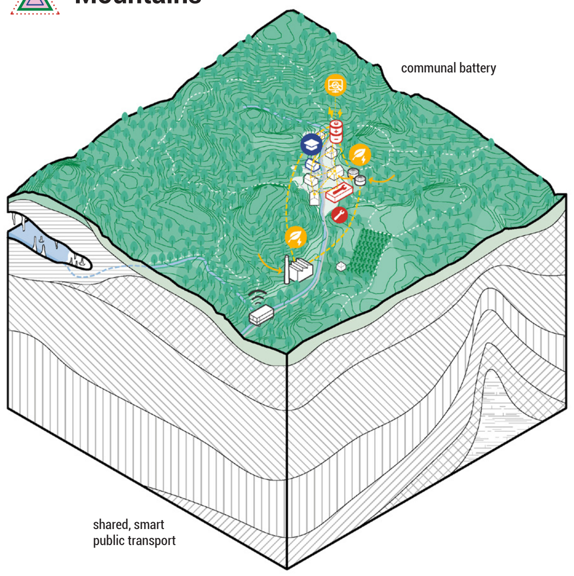
Redundant: Decentralised & Diverse

Strategies: Landscape as Base

Meaning of the 'lines':



Mountains



Nature: mix of forests, grasslands and protected areas, which become part of the landscape-fabric, no need for future protection. Soil: brown forest soil, rocks

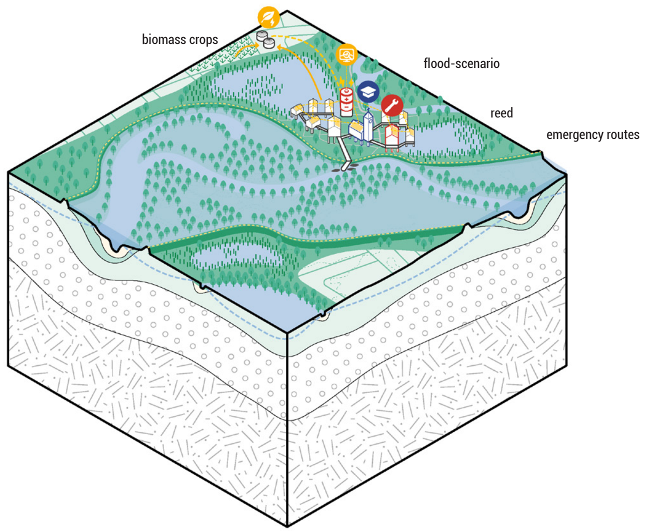
Settlement: nature-based, small-scale, heritage and industry

Transport: slow mobility, hiking and e-bike routes, smart public transport (bus), shared mobility

Energy: biomass from wood and transformed power-plants, solar on roofs, shared batteries (+fallback)

Economy: wine production, wood-based manufacturing, minerals and metals with added circular functions and repair

Rivers



Nature: wetlands and natural floodplains on clay soils and river sediments

Settlement: floodable river communities, living with the natural dynamisms

Transport: safety walkways on old dikes, floating structures, boat-based

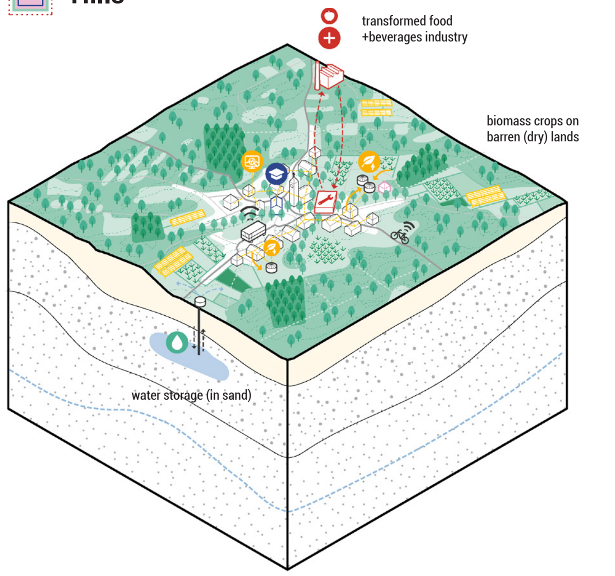
Energy: hydro-batteries, battery fallback-system (backup), solar on buildings and biogas from communal waste

Economy: water-based agriculture (plants and fish), bio-based building materials (reed, ...)

- microgrid (controller)
- biomass
- knowledge (community) hub
- circular function

Fig. 7.9: Landscape-based strategies and differences; *source:* author

Hills



Nature: sandy soils, drought-resistant ecosystems

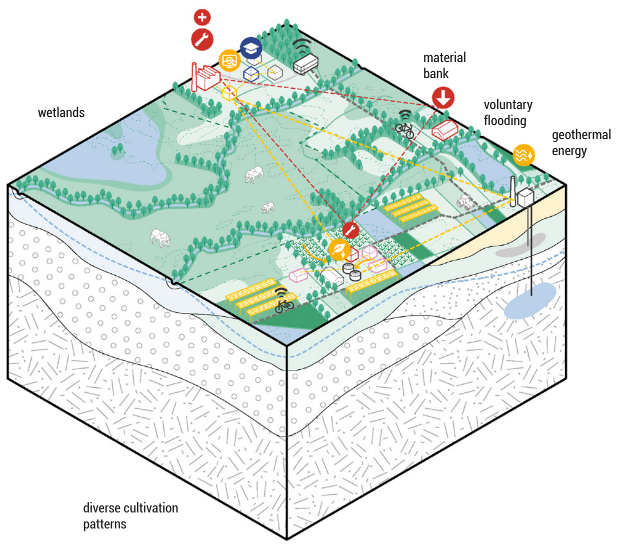
Settlement: agricultural and industrial settlements in valleys, based on dry conditions

Transport: improved valley roads, slow mobility, e-bike routes, smart public transport (bus), shared mobility

Energy: solar energy (combined with agricultural and on roofs), biomass (crops on barren lands)

Economy: dry cultivation (mediterranean species, fruit trees), repair economy

Flatlands



Nature: grasslands, wetlands and drylands, combined with different cultivation patterns. Diverse soils: black soil, saline soils, river sediments, clay

Settlement: agricultural and nature-based settlements, bigger cities

Transport: main arteries of the region, focus on local connectivity, slow mobility, e-bike routes, smart public transport (bus), shared mobility

Energy: solar energy (combined with agricultural and on roofs), biomass (communities, transformed power plants), geothermal energy (at old natural gas and oil wells)

Economy: bio-based agriculture, agroecology, battery production, repair economies, R+D

Redundant: Decentralised & Diverse

Layers of the Redundant Scenario

Following the scenario description, the separate layers of the efficient scenario are depicted on the right.

Territorial capital layers	**Redundant**
Nature	*Landscape-mosaic (mixed- and multi-use areas), based on the four landscape-types*
Settlement	*Resilient, smart and autonomous communities with landscape-based roles - new purpose to small towns and villages*
Transportation	*Strengthening local connections and mobility (shared, autonomous), bike infrastructure and walking paths*
Energy	*Battery communities using landscape-based energy-types (solar, geothermal, biomass, hydropower, ...), microgrids, off-grid solutions*
Economy	*Local repair economies, bartering, landscape-based, similar-but-not-the-same production*
Circularity	*Community-run factories and circular hubs (repair, material banks, ...)*
Human - life + work	*Life Long Learning, community knowledge banks, mixed livelihood schemes - work and life in the community*
Social - governance	*Polycentric and participatory local governance, loosely connected autonomous settlement governments - mainly bottom-up*

Infrastructure (Transportation, Energy)

- protected areas
- cultural heritage settlements
- mountain vegetation (forests)
- mountain-based energy mix
- mountain settlements
- hills vegetation
- hill-based energy mix
- hill settlements
- flatland vegetation
- flatland-based energy mix
- flatland settlements
- rivers
- floodplains: mostly underwater
- floodplains: vegetation, floodrisk
- river settlements
- border of different geomorphological areas
- transformed food industry
- transformed chemicals industry
- transformed metal industry
- added (circular) function
- reuse of abandoned train tracks
- local roads: circular routes
- connection to nuclear power plant
- transformed mineral industry: energy production
- transformed powerplants: biomass
- main powerlines: fallback system
- powerlines
- natural gas and oil fields: geothermal wells
- highways
- train tracks

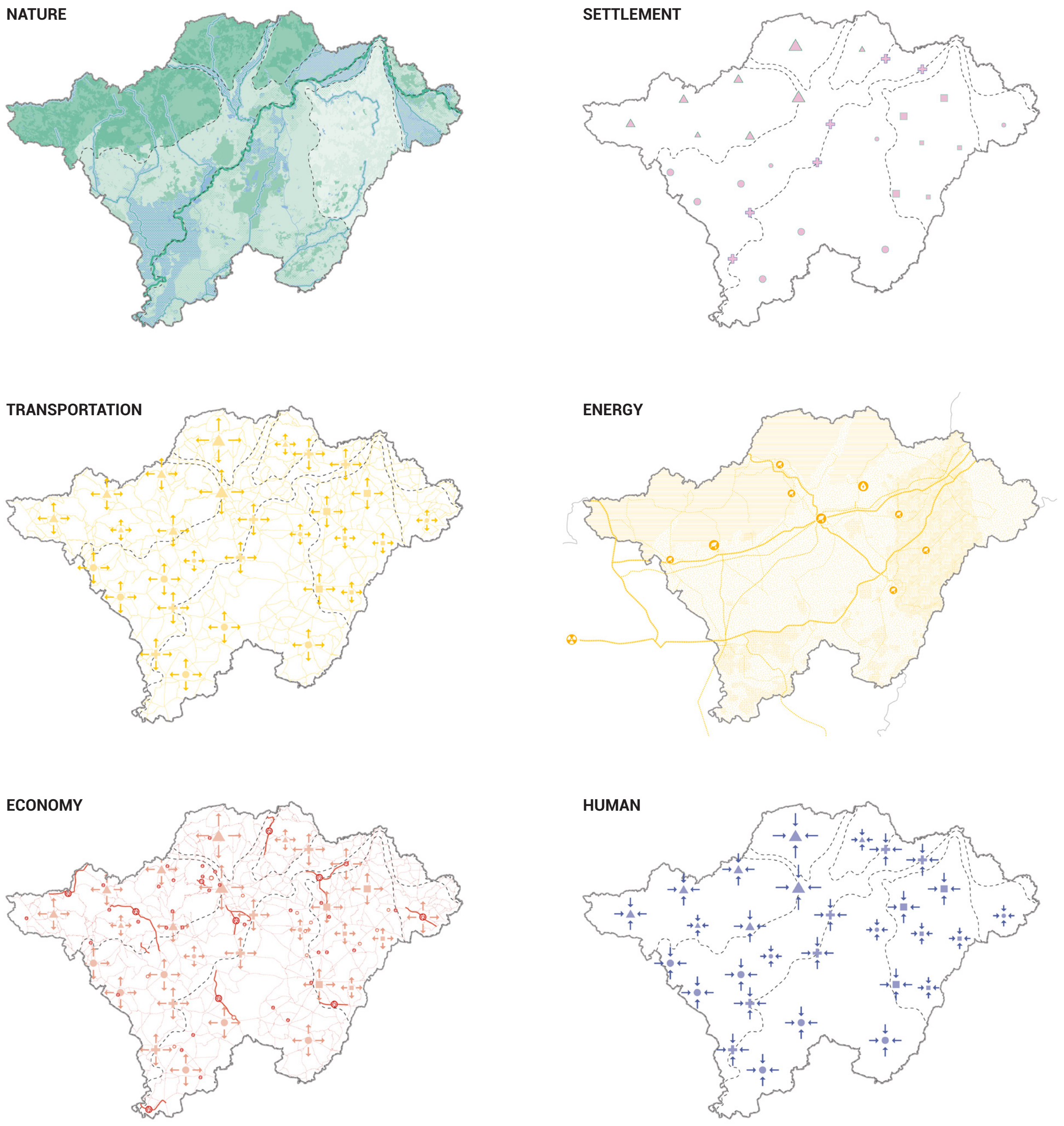


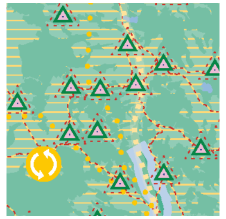
Fig. 7.10: The separate layers of the redundant scenario

source: author

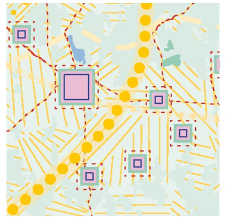
Redundant: Decentralised & Diverse

Spatial Organisation

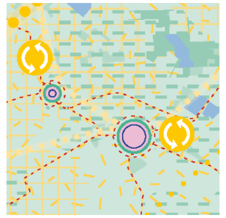
As a conclusion, this map depicts the spatial organisation of a redundancy-based North-East Hungary. Transformability is achieved through changing priorities towards social values, due to external (and internal) factors, such as population decline, leaving industries and frequent climate catastrophes. The focus shifts towards resilient communities and landscape-based solutions (based on the four landscape-types), with enough reserves to survive after disparities. This means leaving behind the current social and spatial patterns, combined with a 'back to the roots', local and introverted mindset.



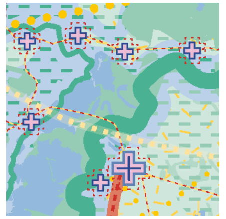
MOUNTAINS
- natural vegetation (forests)
- landscape-based energy mix
- mountain settlements



HILLS
- natural vegetation (forests)
- landscape-based energy mix
- hill settlements



FLATLANDS
- natural vegetation (forests, grass)
- landscape-based energy mix
- flatland settlements

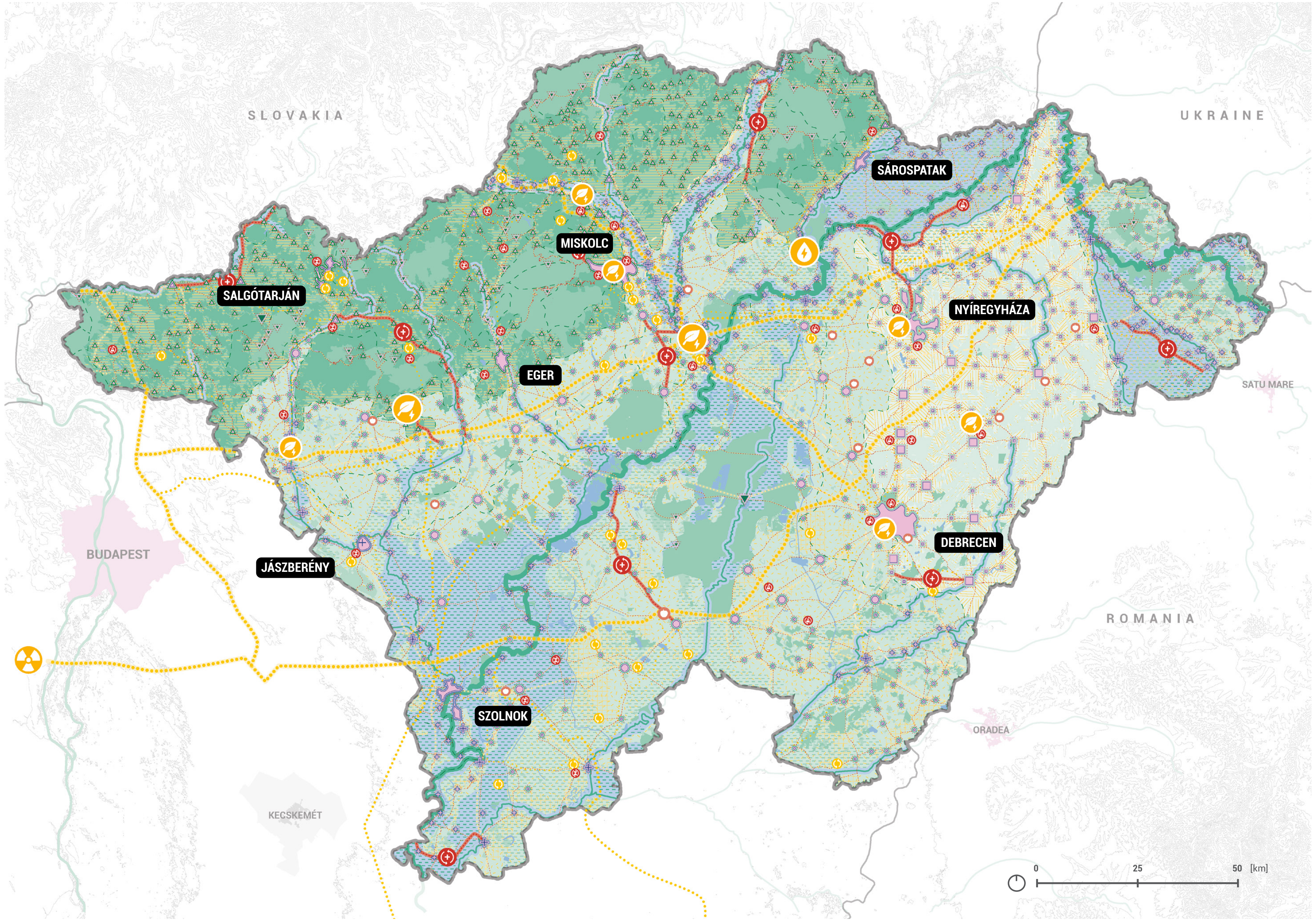


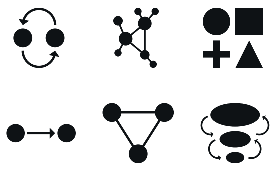
RIVER
- rivers
- floodplains: mostly underwater
- floodplains: vegetation, floodrisk
- river settlements

- protected areas
- cultural heritage settlements
- border of different geomorphological areas
- transformed food industry
- transformed chemicals industry
- transformed metal industry
- added (circular) function
- reuse of abandoned train tracks
- local roads: circular routes
- connection to nuclear power plant
- transformed mineral industry: energy production
- transformed powerplants: biomass
- main powerlines: fallback system
- powerlines
- natural gas and oil fields: geothermal wells
- highways
- train tracks

Fig. 7.11: Spatial organisation of a redundant North-East Hungary

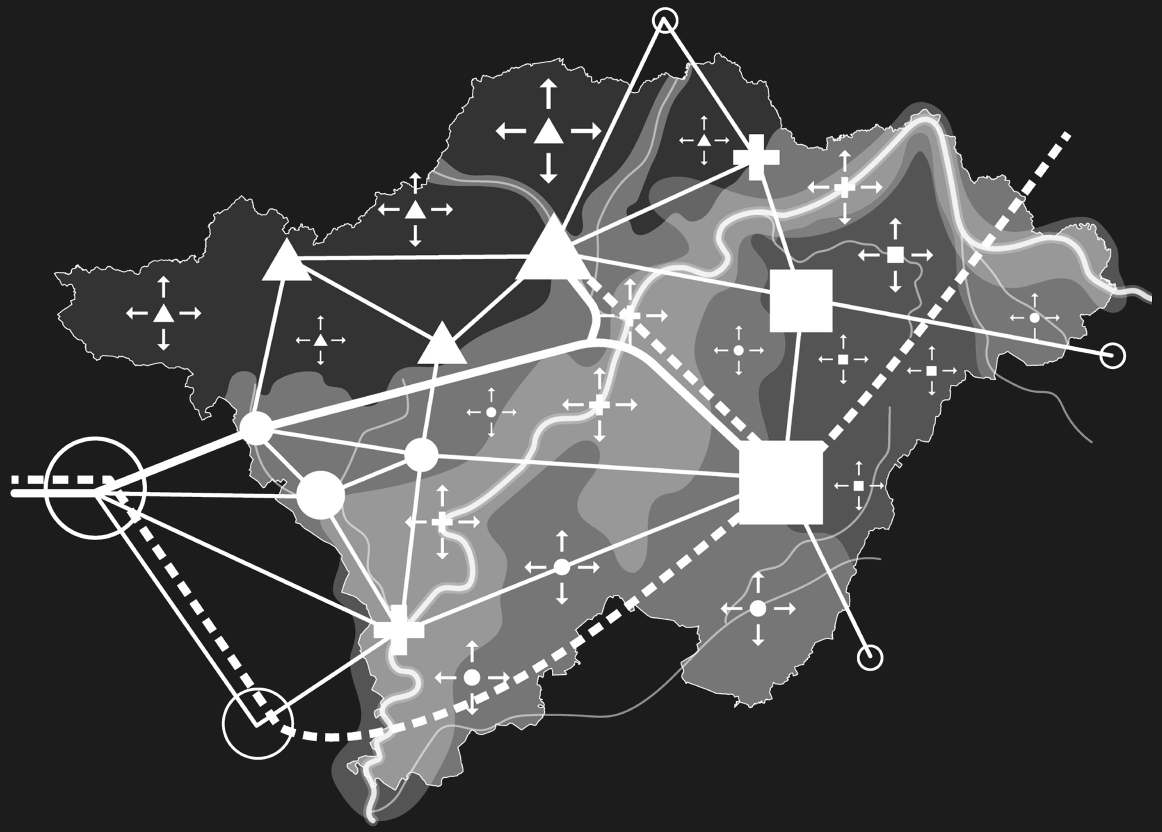
source: author





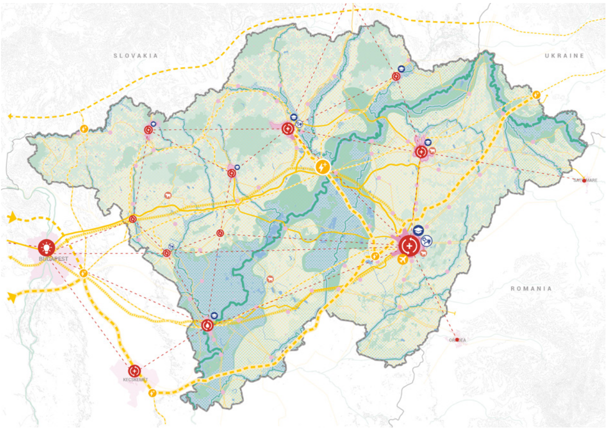
Long-Term Transformative Framework

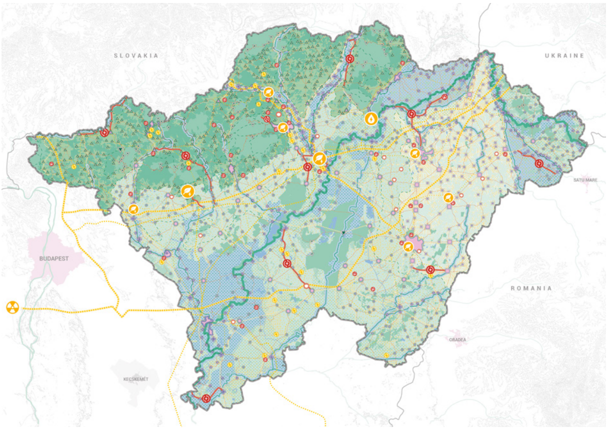
Fig. 7.12: Transformative framework - simplified scheme; *source:* author



Long-Term Transformative Framework

Scenario Evaluation





+ economically viable, optimised and crisis preventive

- too profit-oriented and technology-based, cannot handle sociospatial disparities, depends on industries

+ strong social values, sufficient reserves in case of crisis

- depends on the motivation of communities, might not be economically viable on the long-run

None of the two scenarios are able to handle future uncertainties on their own. Although they can respond to certain probable futures, overall flexibility and transformability is lacking.

A scenario evaluation framework was created based on the values of the project, in order to compare the two. The efficient scenario is more profit-oriented and technology-based, while the redundant one has strong social values. On the other hand, accepting the latter would be a difficult process compared to the first one, and requires strong communities. Both have a positiveecological impact, although the efficient option prioritises certain structures, while the redundant one develops a place-based mosaic.

They have different crisis management approaches: the efficient relies on optimisation and close monitoring to prevent crisis and act fast if it happens, while the redundant option has reserves (if one fails, other takes over) in case of crisis. In the first scenario the centrum-periphery relation remains, while in the second it changes.

In conclusion, a carefully chosen overlap of the two scenarios is necessary in order to reach a balance between the principles of transformability. Combining the economically viable elements of the efficient with the social elements of the redundant scenario, while following a landscape-based, subsurface-led steering could lead to contextual, 'response-able' solutions.

Fig. 7.13: Scenario evaluation framework

source: author

		EFFICIENT	REDUNDANT
DEVELOPMENT WITHIN THE PLANETARY BOUNDARIES	Economic viability and regional competitiveness	++ *Efficient structures cater to tiered supply-chains, fast and well connected*	- *Does not provide enough flexibility for export and big-scale production activities*
	Balanced dependencies and autonomy	- *Dependency on most efficient structures and main hierarchies (non-replaceable), EHB, global production*	- *Autonomous - therefore not enough connectivity between places and actors, catered to local needs*
	Ecological impact: amount of emissions and resource consumption	0/- *Stagnates or slightly grows, due to export and economic growth*	+ *Local repair economies and bartering, leading to reduced emissions and resource consumption (changing behaviour)*
JUST SOCIETY	Local agency (ownership, bottom-up initiatives)	- *Hierarchical structures still require mainly top-down solutions, even with the inclusion of local actors*	++ *Bottom-up, community-based initiatives and ownership*
	Impact on everyday life, social acceptability	+ *Mainly requires technological advancements, does not reshape current norms*	- *Requires big societal shift towards local values and agency, community-living and production*
	Impact on spatial inequalities	- *Keeps current spatial development patterns, enhances centres, but does not prioritise peripheries*	++ *Offers tools for community-based improvements, better social cohesion, strategic functions at periphery*
RESILIENT BIOSPHERE FOR HUMANITY AND ECOSYSTEMS	Climate-robust landscape	+ *Central, but closely monitored buffers, especially along river Tisza*	+ *Landscape-mosaic creates resilient, multi-functional areas that can react to the climate crisis*
	Balanced human-nature relationship	0 *Human and natural systems remain mostly divided, large-scale infrastructure vs restored floodplains*	++ *Human in nature, community-living and cultivation (food, energy, ...)reshapes current relationship*
	Multi-crisis response	+ *Optimised (smart), hierarchical systems, based on monitoring and prevention, main nodes are non-replaceable*	++ *Diverse and resilient units, similar-but-not-the-same functions (in case of failure, another takes over), reserves*
		↓ TECHNOLOGICAL CHANGE	x ↓ SOCIETAL CHANGE

++ / + : positive impact; 0: neutral; -- / - : negative impact

Long-Term Transformative Framework
Strategies and Goals of the Vision

Following the scenario-evaluation, the long-term goals of the vision are defined based on efficient and redundant principles, which are depicted on Figure 7.15. They are not concrete design interventions, but rather guidelines towards which we have to strive in the next decades. This can happen in various manners, depending on external and internal factors.

The most important goals are the ones in the middle – in the overlap of efficient and redundant measures, ensuring the balance. Landscape and subsoil-based development and a balanced human-nature relationship can directly lead to a resilient biosphere. Battery (and energy) communities can foster social values, and together with multi-pathway governance and learning and experimentation they can contribute to a just society, through adaptive governance (Gunderson & Holling, 2002, Walker et al., 2004). Finally, territorial circularity can ensure proportionate development within the planetary boundaries (Rockström et al., 2009), through adaptive resource management (Walker et al., 2004).

These goals are abstract, but combined with a spatial framework, they have the ability to provide a contextual and 'response-able' future.

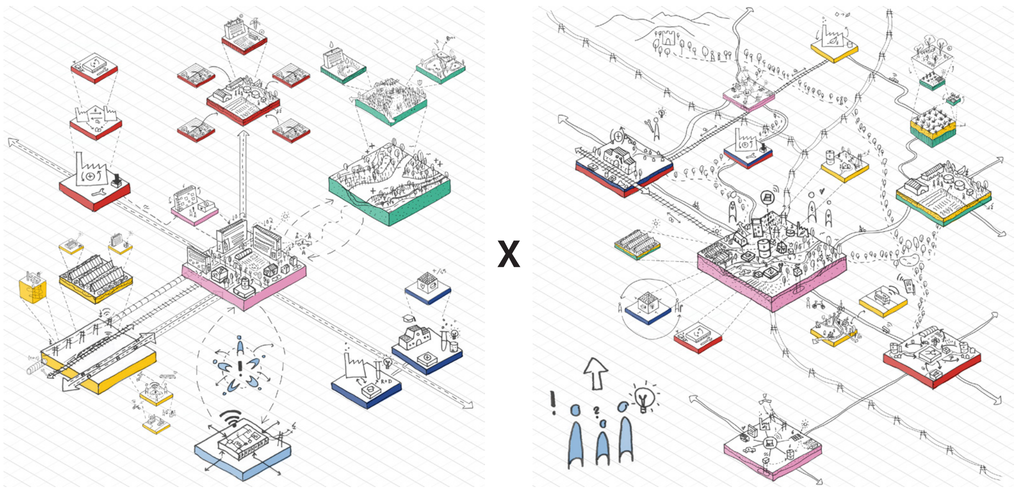
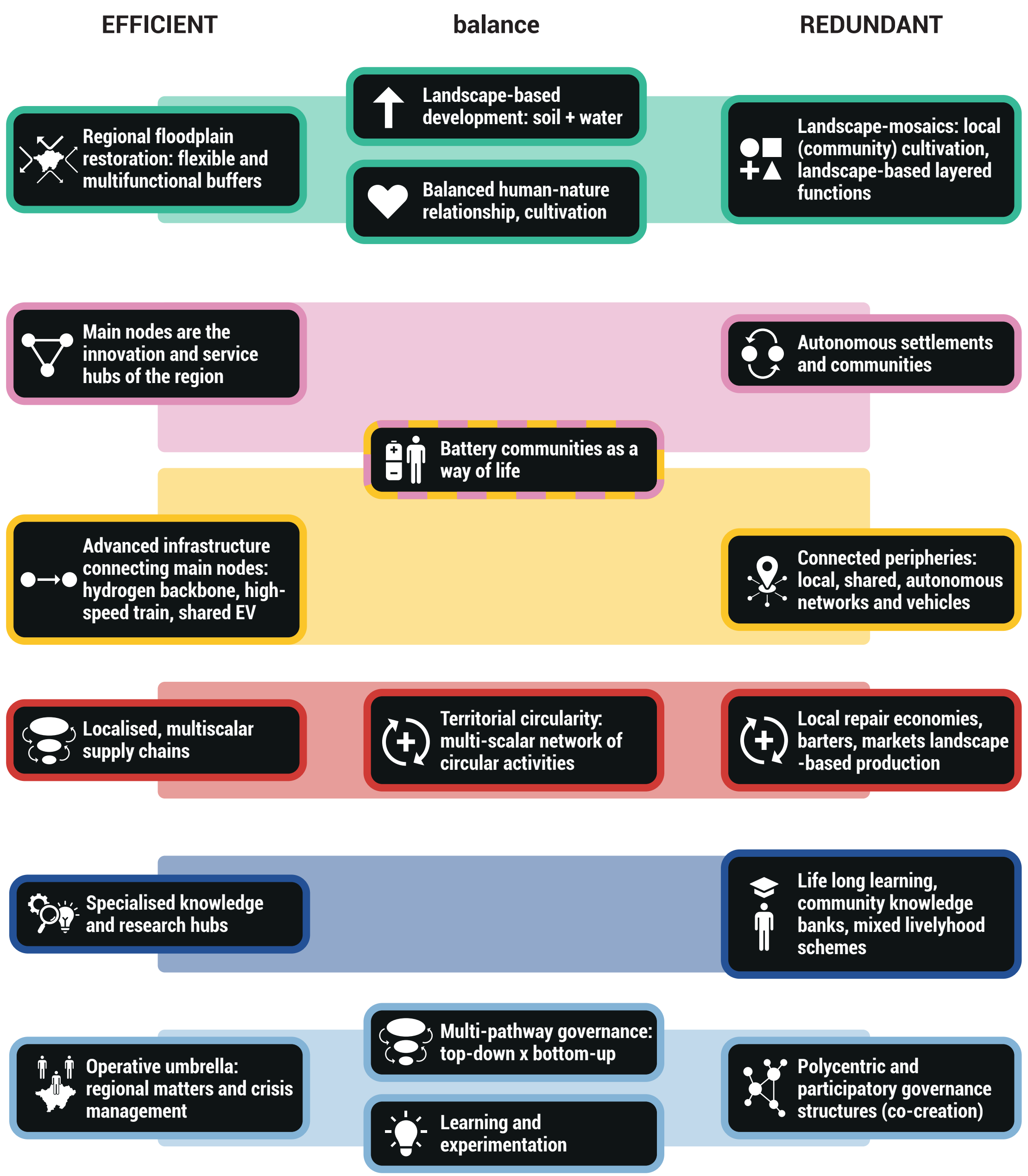


Fig. 7.14 (left): The vision is a combination of strategies from the redundant and efficient scenarios

source: author

Fig. 7.15 (right): Long-term transformative goals of the vision

source: author



Long-Term Transformative Framework

Strategies and Goals of the Vision

The drawing on the right (Figure 7.16) uses the interventions proposed in both scenarios (originally the transformability potentials of the analysis chapter conclusion), and organises then based on the outcomes of the scenario evaluation and the goals of the vision. It combines hierarchic structures with decentralised and vertical measures, depicting the 'new ecosystem' of the region in an abstract manner.

Every settlement develops based on the landscape, and has the opportunity to establish a rural or urban battery (or energy) community, although the regional centres of the efficient scenario have a more central function, as knowledge and service hubs of the territory.

Apart from the main regional arteries – where a high-speed train between Budapest and Debrecen is built, highways are transformed into EV-ways with shared battery-exchange stations, and the gas pipes are retrofitted for hydrogen-energy, - local connectivity is strengthened, relying on slow-mobility, Mobility as a service and electric vehicles with improved and order-based public transport systems. Energy production utilises decentralised, landscape-based principles, relying on local microgrids with a regional fallback system (nuclear energy, hydrogen energy or batteries, based on the place and availability).

Food production and economy adapts better to the landscape characteristics, with combined technological advancements and 'back to the roots' solutions ensuring a resilient livelihood. Multi-scalar production is established, ranging from urban farming, through biomass communities, to main agroecological hubs. Tiered and multi-scalar supply-chains, repair hubs and material banks ensure regional circularity, relying on local repair economies.

Specialised education hubs are formed around universities and main industrial nodes (in a system of industrial symbiosis). On the smaller scale community hubs and knowledge banks are established to support life long learning and the re-skilling of workers to adapt to new economies.

The governance is a combination of top-down and bottom-up measures, using monitoring, multi-pathway governance and learning and experimentation to steer towards a transformative region. A detailed governance framework is provided in the operationalisation chapter.

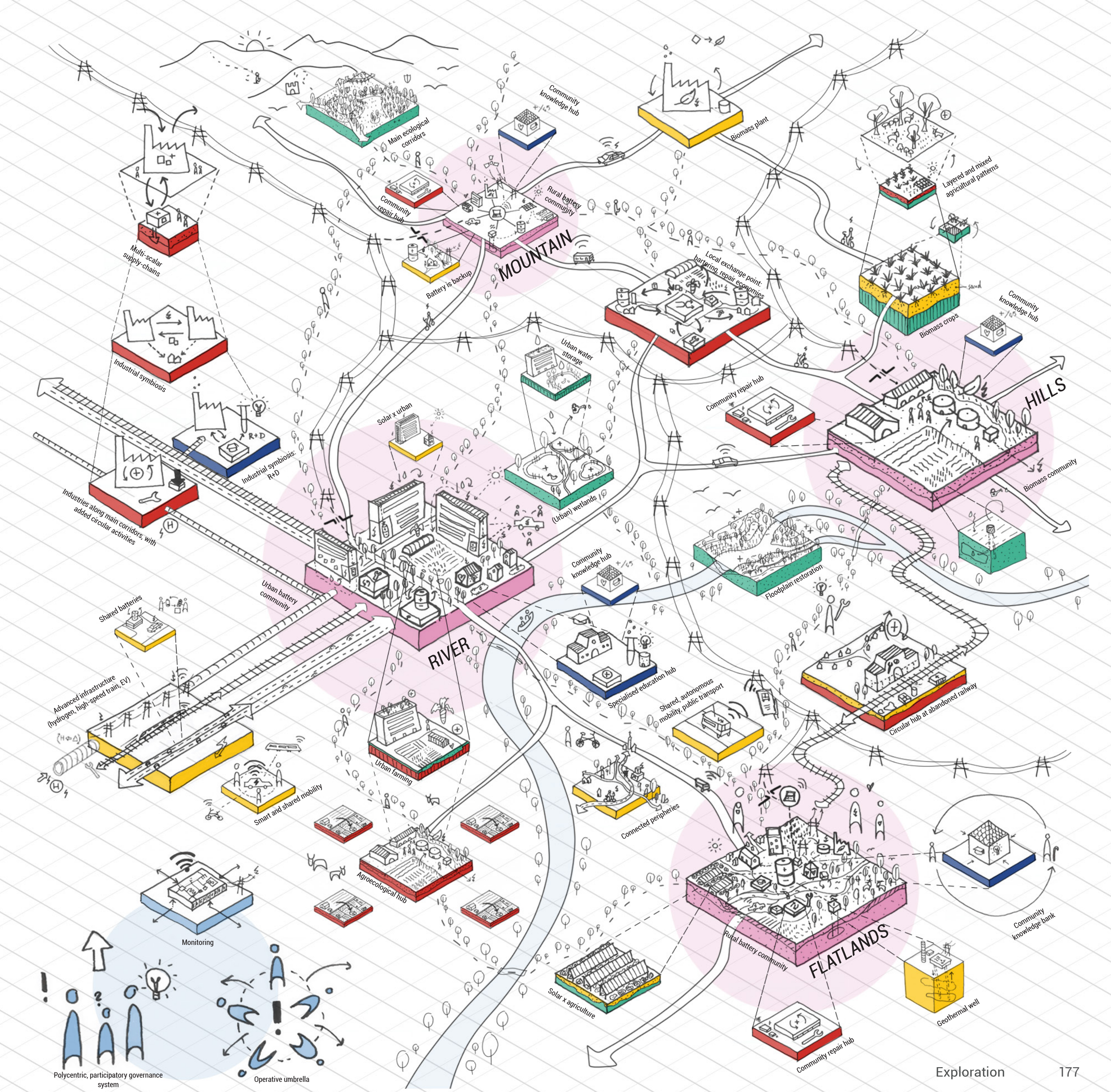


Fig. 7.16: The future ecosystem of the region of combined efficient and redundant measures, based on the four landscape-types

source: author

Long-Term Transformative Framework
Layers of the Vision

The long-term transformative framework thus combines elements from both hierarchic and decentralised scenarios, thriving for balance. The core idea is not to create one design for region in 50 years, but to envision a framework that is able to cope with various future uncertainties, leaving flexible thresholds for different development paths. Considering current, alarming global trends and geopolitical threats, I believe that such an approach could offer a viable alternative for the region.

The following schemes (Figure 17) explain the different layers of the vision (following the territorial capital layers), while the spatial organisation map on the next page (Figure 18) presents an attempt to combine the efficient and redundant ideas and interventions into an integral spatial framework for the region.

- waterbodies
- protected areas
- mountains: forests
- hills: natural vegetation (forests)
- flatlands: natural vegetation (forests, grasslands)
- rivers
- floodplains: mostly underwater
- floodplains: vegetation, floodrisk
- natural buffer

- border of different geomorphological areas
- high-priority settlements
- cultural heritage settlements
- mountain settlements
- hill settlements
- flatland settlements
- river settlements

- highways
- primary roads
- high speed train
- train tracks
- airports

- hydrogen network (EHB)
- local hydrogen network
- regional energy hub
- transformed mineral industry: energy production
- transformed powerplants: biomass
- powerlines
- natural gas and oil fields: geothermal wells
- mountains: landscape-based energy mix
- hills: landscape-based energy mix
- flatlands: landscape-based energy mix

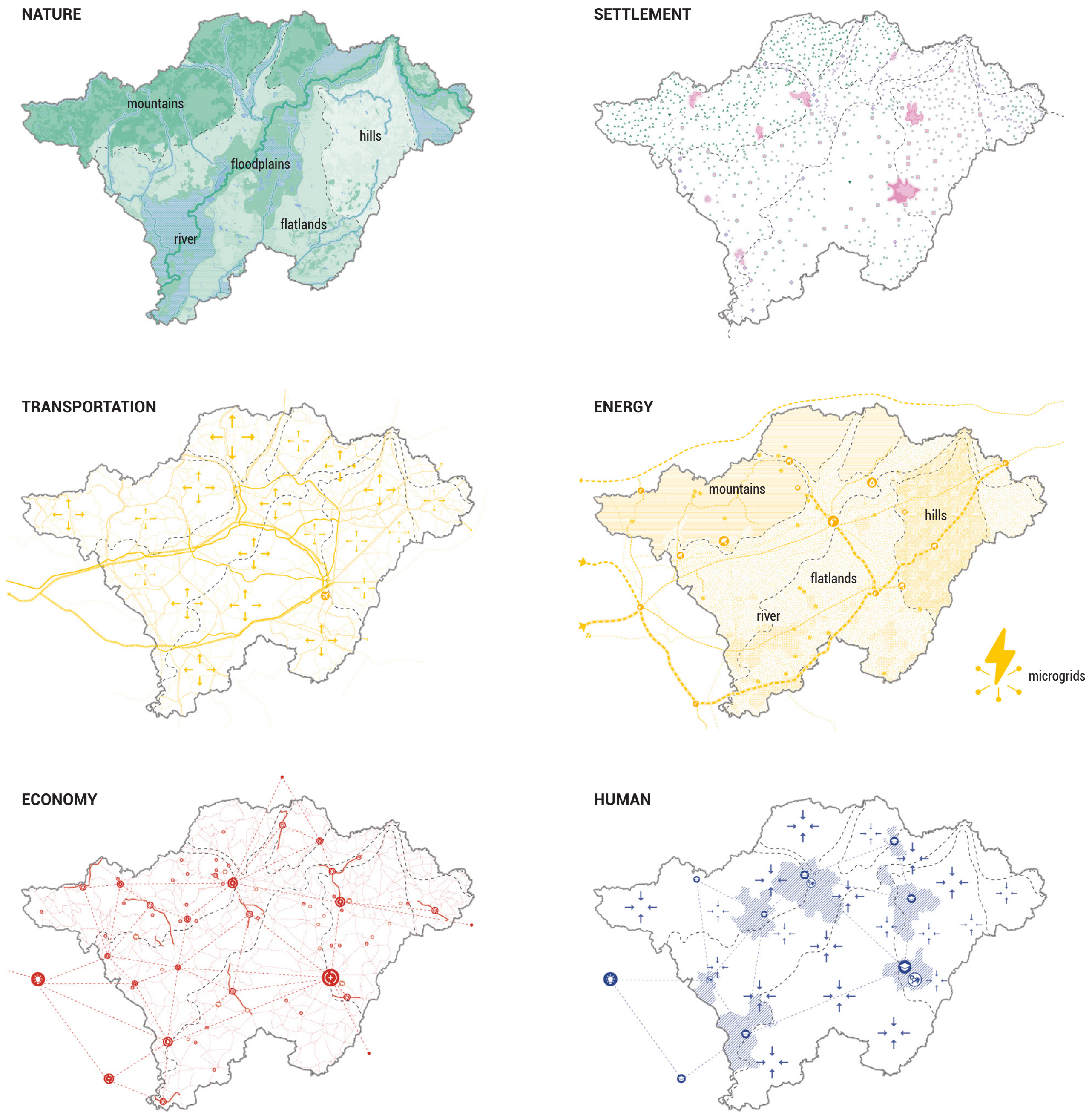
- Budapest: centre of knowledge
- Szolnok: water-based life
- added (circular) function
- optimised circular and knowledge network
- transformed chemicals industry
- transformed metal industry
- added (circular) function: train tracks

- transformed food industry
- agroecological hubs
- reuse of abandoned train tracks
- local roads: circular routes

- R + D hubs
- special knowledge hubs

Fig. 7.17 (right): The separate layers of the vision

source: author



Long-Term Transformative Framework

Spatial Framework

- border of different geomorphological areas
- waterbodies
- protected areas
- cultural heritage settlements
- high-priority settlements

MOUNTAINS

- natural vegetation (forests)
- landscape-based energy mix
- mountain settlements

HILLS

- natural vegetation (forests)
- landscape-based energy mix
- hill settlements

FLATLANDS

- natural vegetation (forests, grass)
- landscape-based energy mix
- flatland settlements

RIVER

- rivers
- floodplains: mostly underwater
- floodplains: vegetation, floodrisk
- river settlements
- natural buffer

- highways
- primary roads
- high speed train
- train tracks
- hydrogen network (EHB)
- local hydrogen network
- regional energy hub
- airports
- transformed mineral industry: energy production
- transformed powerplants: biomass
- powerlines
- natural gas and oil fields: geothermal wells
- transformed food industry
- agroecological hubs
- Budapest: centre of knowledge
- Szolnok: water capital
- added (circular) function
- optimised circular and knowledge network
- transformed chemicals industry
- transformed metal industry
- added (circular) function: train tracks
- reuse of abandoned train tracks
- local roads: circular routes
- R + D hubs
- special knowledge hubs

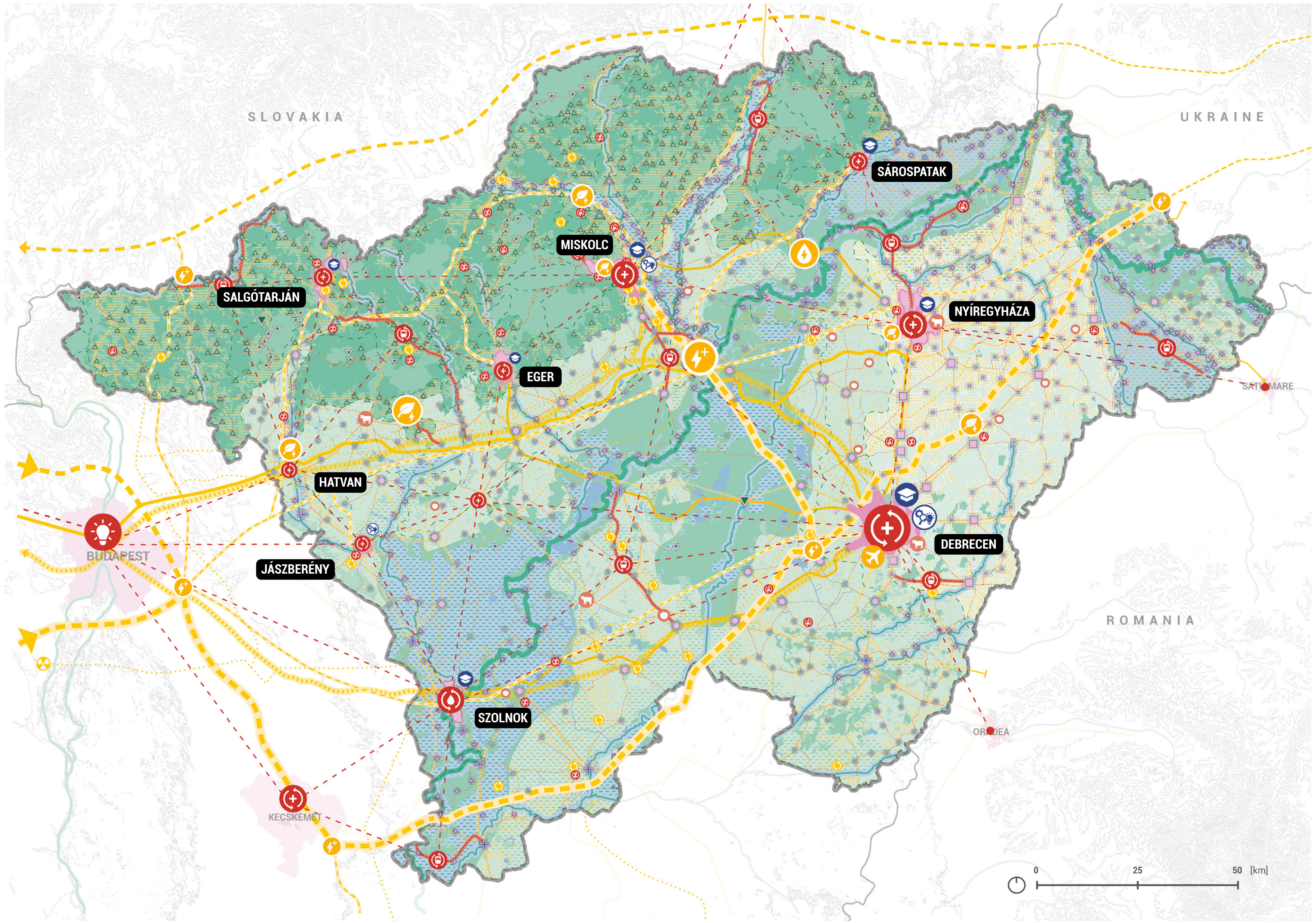


Fig. 7.18: The long-term transformative framework of North-East Hungary: efficient and redundant elements

source: author

Long-Term Transformative Framework

Long-Term Flexibilities on the Factory Scale

The vision has yet to make remarks on the starting point of the thesis: the battery industry and factories. As the goal is transformability, there is no clear future state these facilities should be in. Their future depends on the scale of production, supply and demand, and the dynamisms of the global supply chain among others, which are impossible to predict with 100% certainty.

On the other hand, based on the principles of transformability, the economy of the region, that is becoming highly dependent on the battery industry, has to change. It must become more diverse, redundant, multi-scalar, efficient, polycentric and connected. **The main economic profile of the region has to shift from only EV battery manufacturing to fostering other functions, industries and local economies. This means that the current battery factory sites have multiple future forms, as the battery industry might remain, it might be paired with other functions, or it might completely disappear and give space for new uses at a given place.**

Going back to the dilemma of the company, building and the concrete slab that remains, it is important to find other functions that can thrive in an industrial environment, and could adapt to the existing factory site (even using the remaining structures from the original building). The drawing on the right (Figure 7.19) summarises these possible future functions.

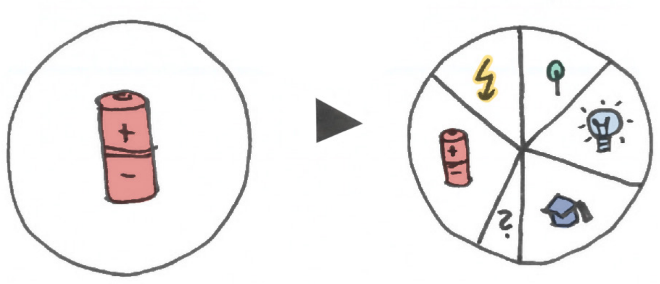
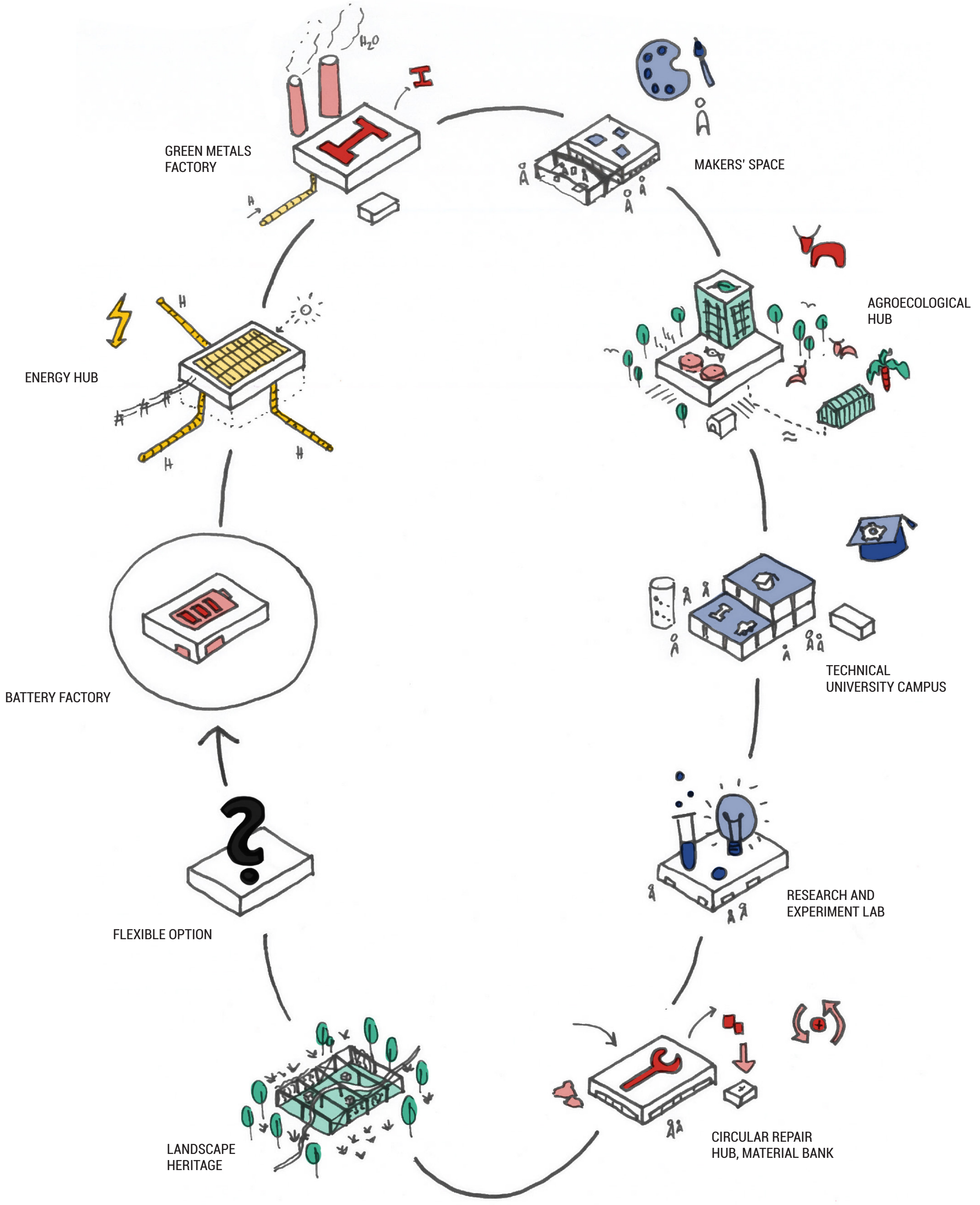


Fig. 7.19 (right): Possible functions that can coexist with or exchange the battery industry

source: author

Fig. 7.20 (left): Scheme of the changing regional economy

source: author



Concluding on the Exploration Chapter

In this chapter, the vision of a transformative battery territory was framed, then explored through two possible scenarios of efficient and redundant spatial organisation, which resulted in a long-term transformative framework for the region.

The main lessons include:

- Without balance, transformability cannot be achieved, therefore a context-based exploration on how principles can work together was necessary, resulting in the two scenarios.
- The vision is a long-term, transformative framework. It is not a plan or a design, it is a guide, containing thresholds and goals that we have to strive for. It is flexible in space and function-wise, yet it is made based on the territorial context.
- The timeframe of the project and the planned use of this framework in the future is shown on Figure 7.20, summarising how it can help transform the region in case of a disruption. Therefore this vision and framework can be used as a territorial base document to tackle future uncertainties. Consequently, it has to be constantly revised and adapted to the current needs.
- Finally, the vision so far focused on the long-term end goals, but the question remains of how to get there from the current battery crisis. The next chapter will bridge this gap by connecting theory, battery and territory with the phasing and sequence of strategies of the project.

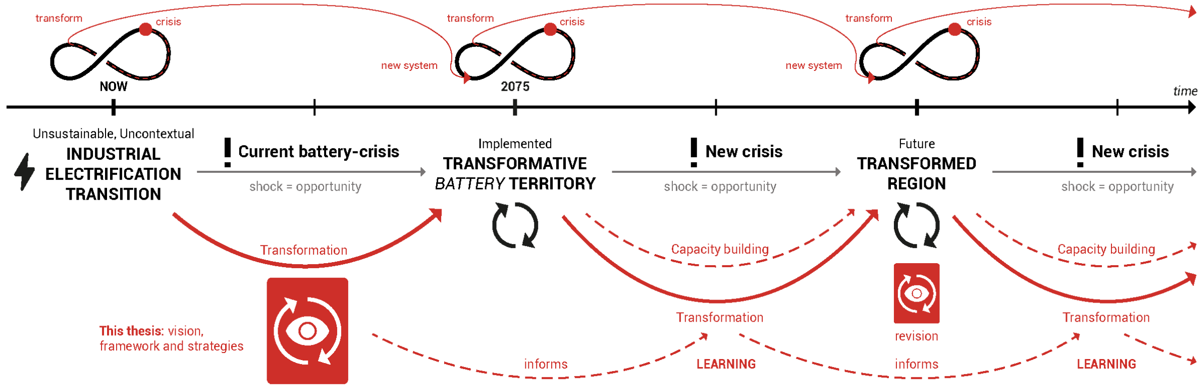
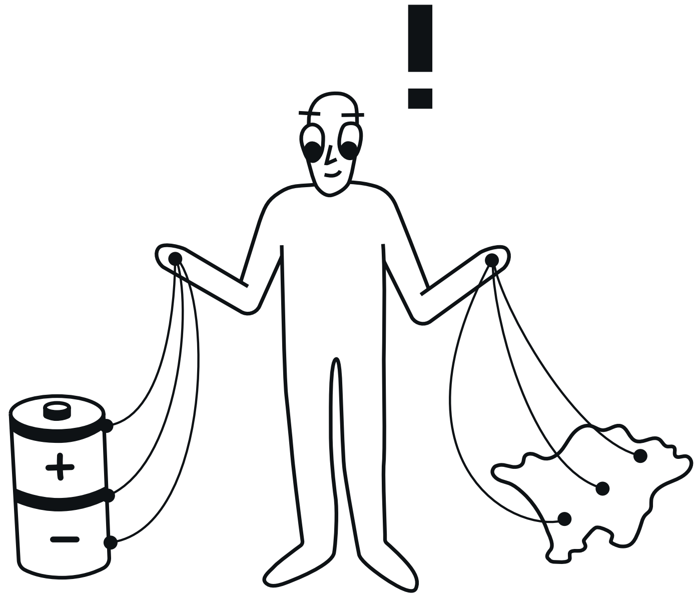


Fig. 7.21: Understanding transformability in the scope of the project

source: author

OPERATIONALISATION



Transformation Pathways

After the visioning phase, backcasting follows by going back to the root cause: the battery crisis. In this sub-chapter the method of adaptation pathways (Haasnoot et al., 2013) will be used to connect the long-term transformative framework with short-term answers and decisions that has to be made regarding the current state of battery development in the region, as depicted on the scheme on Figure 8.1. In this thesis they are pathways towards transformability, therefore a new name is given: *transformation pathways*.

Thinking backwards, short-term pathways will be created and 'no-regret' measures will be identified, based on uncertainties and ownership. The no-regret measures (Haasnoot et al., 2013; Werners et al., 2021) are pinpointed due to their nature of having a great impact on both battery industry and long-term goals, and can act as catalysts for various pathways.

After an overview and phasing, different pathways will be discussed, based on plausible future possibilities and stakeholder preferences. They are depicted as a classical 'metro map' pathway first used by Haasnoot et al. (2013), accompanied by a 'glimpse into the future' postcard. These show an in-between development state towards transformability, with strategies emphasised based on the chosen path.

The long-term goals and the possible interventions towards them are spatialised using the combination of abstract schemes and axonometric tiles showing spatial qualities. These align with the territorial capital layers, and are a combination of potential and strategies from the previous chapters.

The adaptation pathways offer solutions for the already built factories, as it is not the goal to build more. The guidelines for the inevitable newly announced ones are summarised in the Understanding chapter, on Page 82.

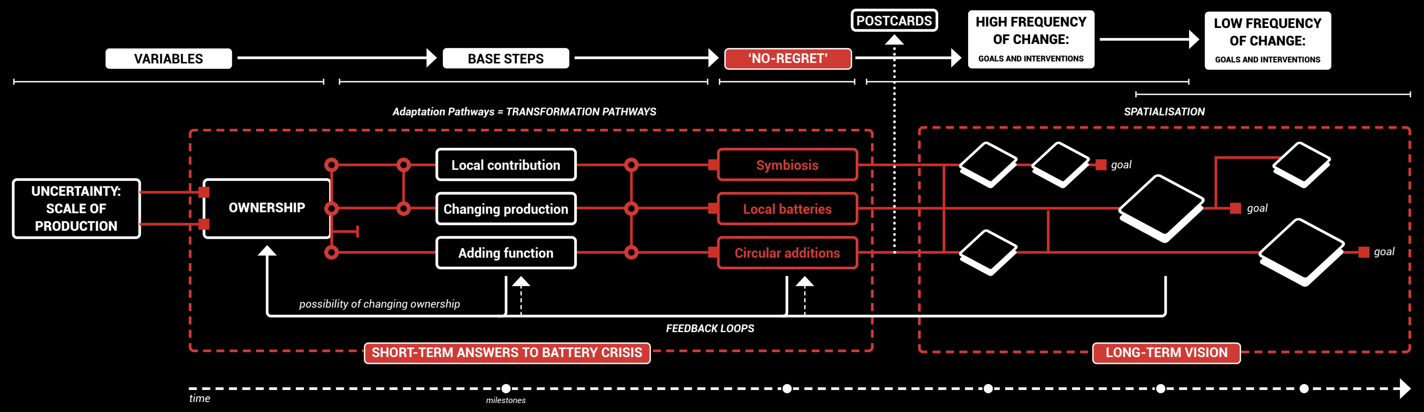
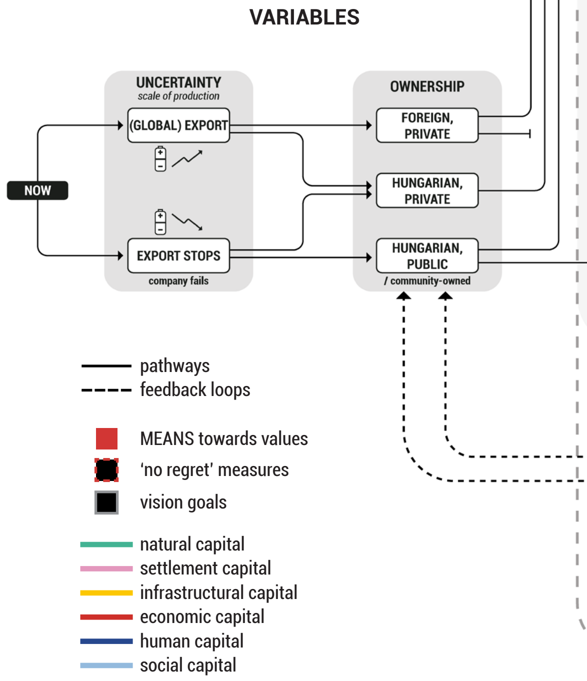


Fig. 8.1: Explanation of the workings of the adaptation (transformation) pathways in this thesis; *source:* author

Pathways Overview

This is the overview of the transformation pathways, depicting the possible routes and relations between measures. The means of long-term transformation are highlighted. The pathways guide territorial development towards transformability by leveraging the current battery crisis, therefore the long-term goals that are connected closely to the battery industry and economy will be reached first.

The first row of landscape-based development is a base measure that is required for long-term transformability.



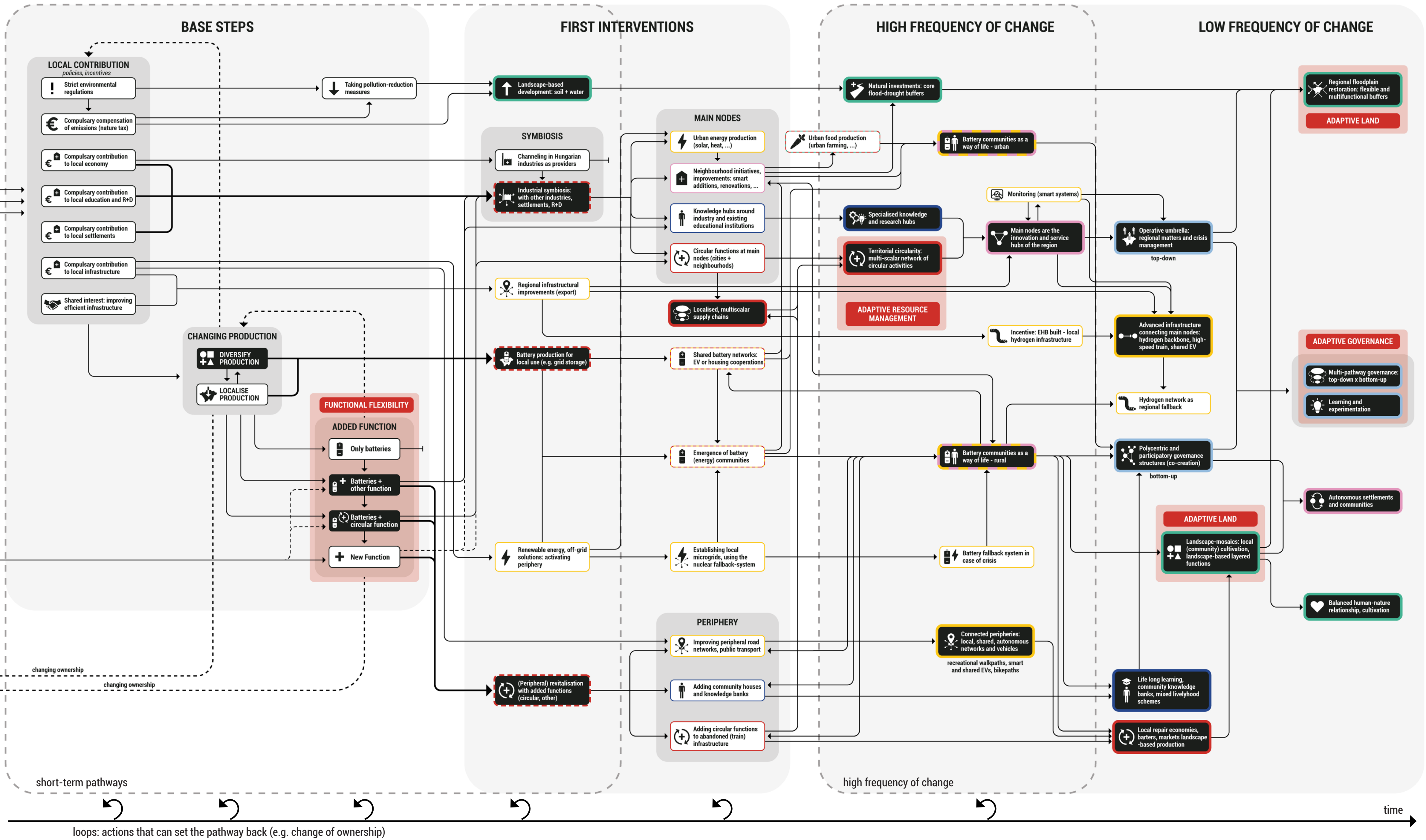


Fig. 8.2: From battery crisis to a transformative future; *source:* author

Phasing: Milestones

Certain chosen pathways can be achieved in shorter times than others, therefore it is not possible to draw a clear timeline. Nevertheless, it is important to indicate possible thresholds and deadlines for actions. As Hungary still aligns with European sustainability goals, various milestones are highlighted connected to pathway interventions that can help achieve them.

Sources of the milestones: European Commission, 2023; NNLT, n.d.; The European Green Deal, 2021

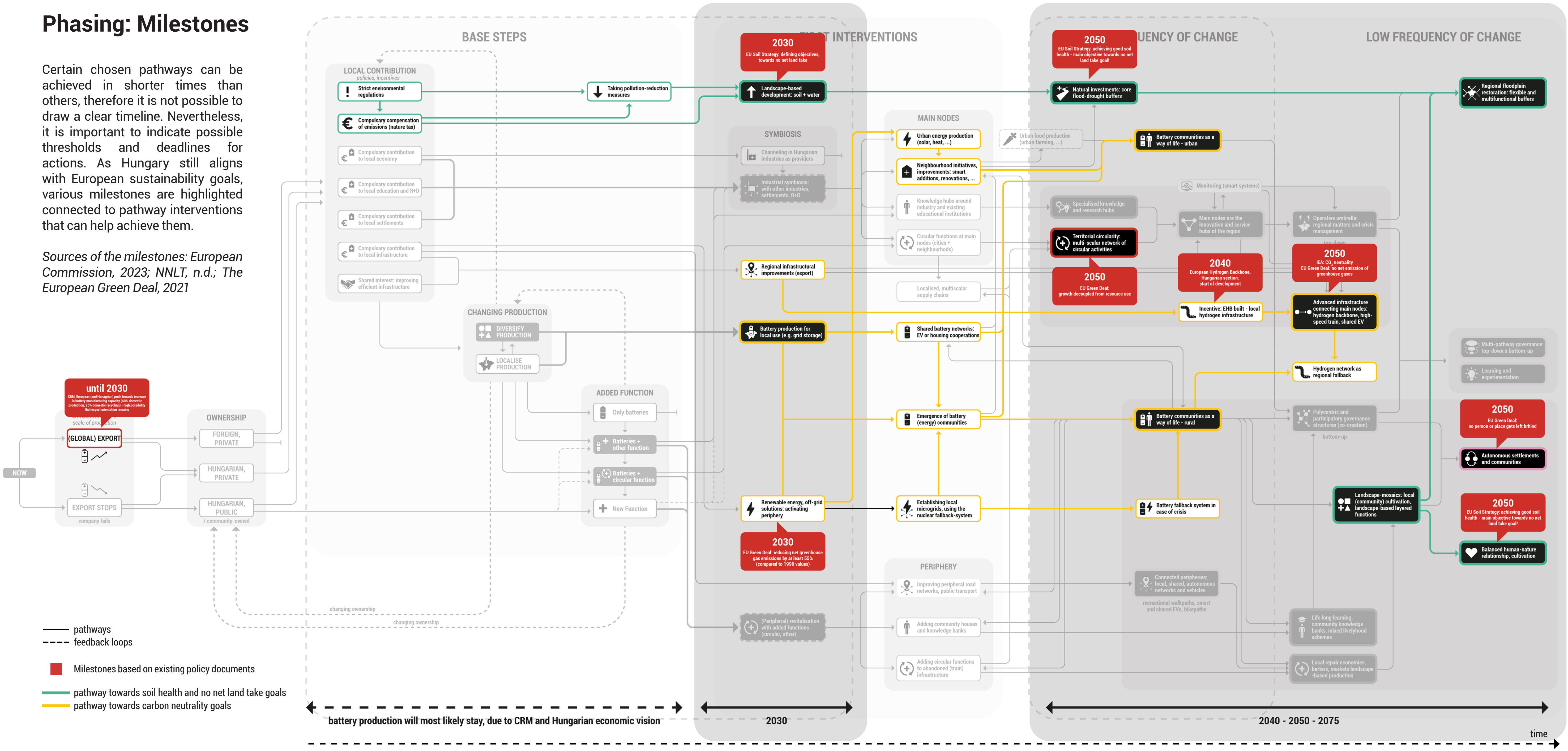


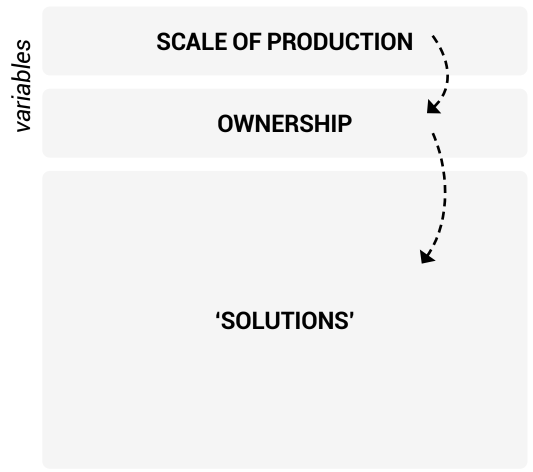
Fig. 8.3: Pathways leading to main milestones, in relation to European sustainability goals; *source:* author

Short-term Pathways

Zooming in to the first half of the pathways, we can conclude some 'base steps'. These are the most important decisions that can be made on the short-term timespan to start the transformation from an uncontextual and unsustainable battery industry towards 'no regret' measures and a transformative region.

There are two main variables: uncertainties and ownership. In the future it is not determined whether there will be battery production for export or not, which influences whether the current company stays or leaves. Different kinds of ownership have a different impact on the region and the possible pathways. Ownership can also change through time, as private foreign companies without any Hungarian ownership lead to a tipping point on the long run.

After setting the variables, pathways can be chosen depending on the given stakeholder interests or on external criteria (uncertainty). There can be parallel interventions, but also consequential ones (e.g. one intervention happening enables another).



1. calibrate uncertainty

2. decide ownership based on uncertainty

3. generate pathways based on the possible interventions, and the given combination of uncertainty and ownership

transfer station to new action

adaptation tipping point

adaptation (transformation) pathways

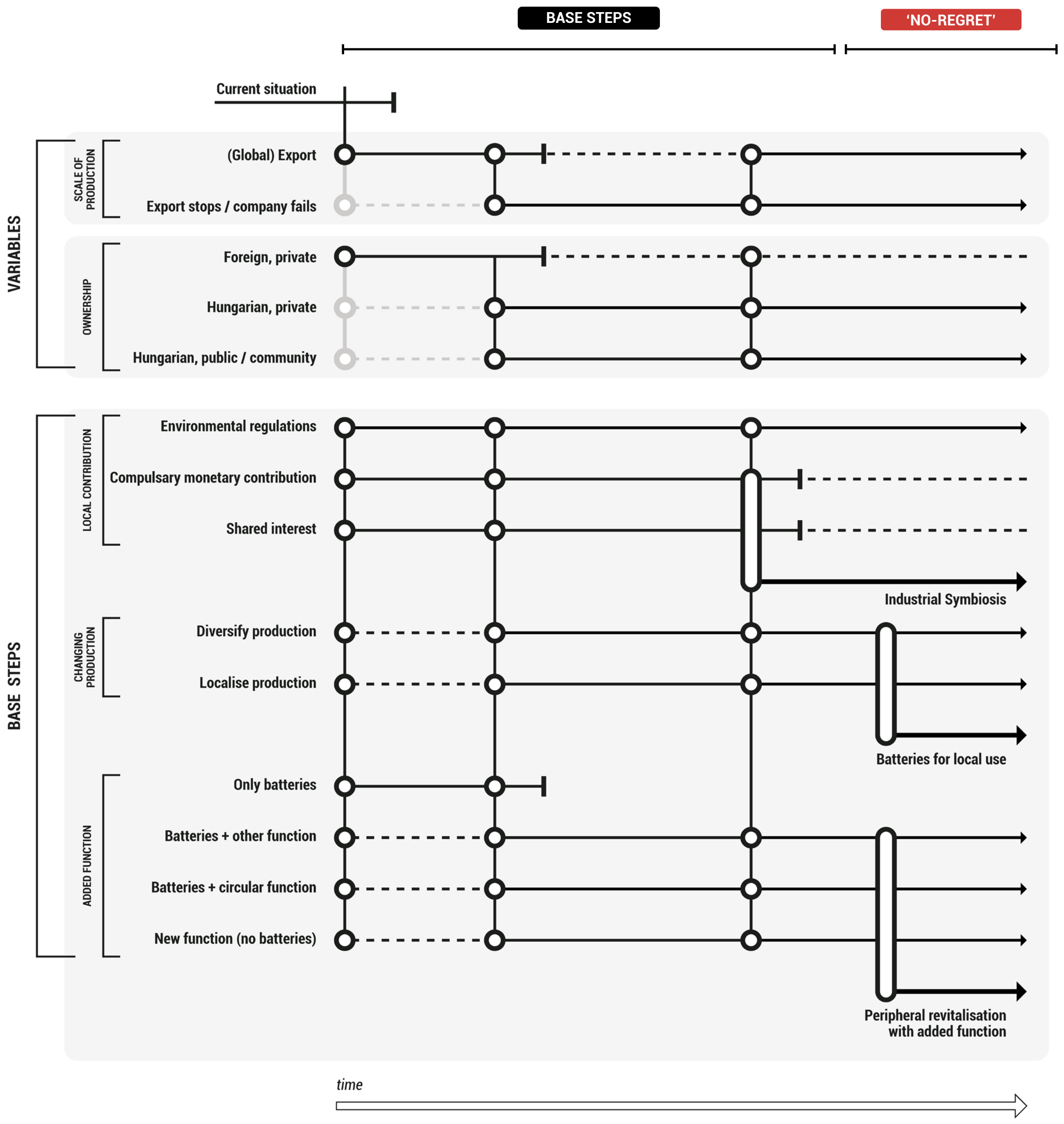
pathways that are not necessarily possible or preferred

Fig. 8.4 (right): Parallel pathways: variables and base steps

source: author

Fig. 8.5: The sequence of setting variables and choosing solutions

source: author



Spatial Translation of the Pathways

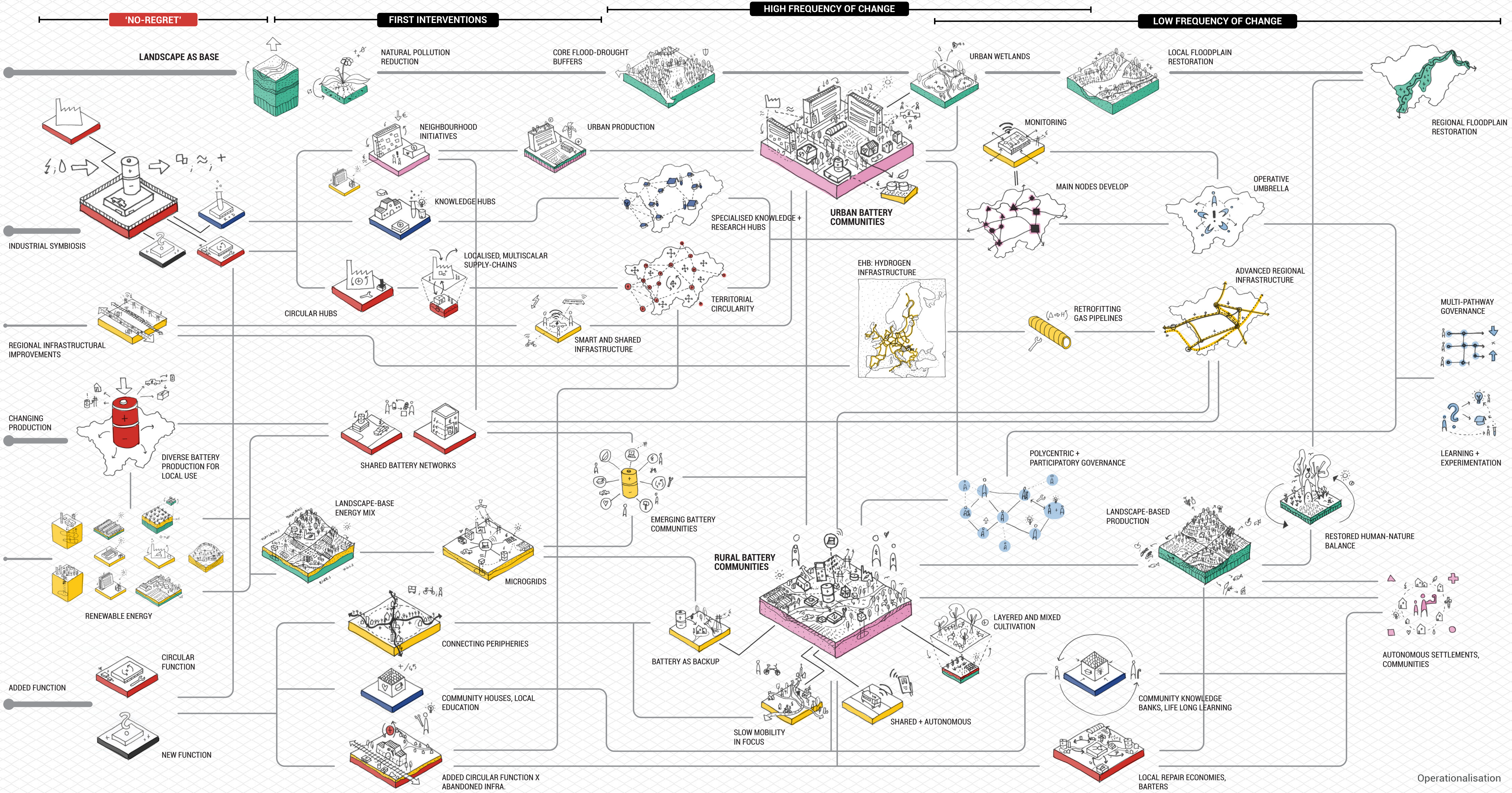


Fig. 8.6: The spatial translation of adaptation pathways; *source:* author

Governance and Positioning

Creating transformation pathways is not sufficient without an integral view on how to implement them in a co-creative manner, with the involvement of stakeholders. Therefore an engagement strategy and a future, landscape-based governance framework – as the counterpart of the spatial framework – is introduced in this sub-chapter.

As designers, we inherently make political decisions with our projects. This chapter serves as my positioning in this matter, in face of the illiberal, centralised government system in Hungary. I believe that a combined bottom-up and top-down approach, by first raising awareness to the crisis and activating the people could be a viable pathway towards lasting change. Establishing just practices of regional planning and design that can facilitate participative processes is a crucial criteria in this regard.

'The network periphery is the place where unfamiliar innovations take hold and spread.'

- Centola, 2021

Engagement Strategy

The engagement strategy consists of three main parts, with an additional step 0. of 'AWARENESS', as recognising urgencies and the need for change is crucial. The first step is 'ACTIVATE!', where the chosen critical stakeholders are approached separately, as they require different forms of engagement due to their diverse nature. In each session, the participant are asked to choose or construct their preferred transformation pathway, based on their needs and priorities, while activating their spatial imagination and showing alternative options opposing current practices. The possible outcomes of the first step are therefore a collection of pathways, from which spatial needs, claims and conflicts can be deducted.

The second step is called 'ALIGN!', which refers to the need of a common ground. The strategy offers a plenary session where representatives from all of the previously engaged groups are present. They are to take part in a serious game based on the pathways, with the goal of constructing regional pathways towards transformability that are acceptable by and beneficial for each group. This ultimately results in the construction of a new territorial identity, in face of the constant 'colonised state' by foreign industries in the past decades, even centuries. A game-based approach can enable the stakeholders to see the problem from each other's perspectives and can lead to better understanding, collaboration and conflict resolution. It also creates an atmosphere where everyone can be heard and that all participants can understand, it levels the playing field.

The third step is 'ACT!', where the possible outcomes of the previous step can be operationalised. As urgent actions, battery guidelines are established for both existing and new factories. On the long run, the constructed pathways towards transformability are constantly revised to respond to future uncertainties, and result in flexible and strategic spatial development projects in the region, combined with the establishment of territorial spatial planning and design practices. Lastly, a 'regional umbrella' (action group and council) steers the region towards transformability, and oversees the buildup of transformative capacity.

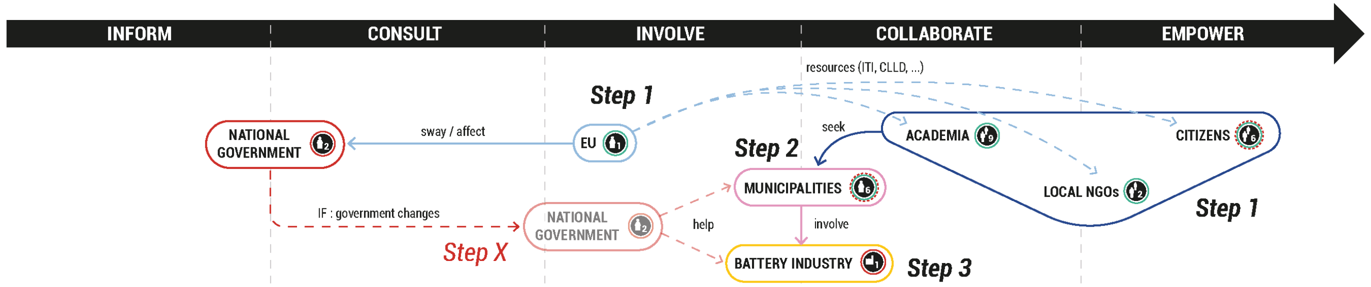
The scheme below depicts the process of how I would approach the different stakeholders based on the current political climate. Staring with the local citizens, academia and NGOs, then going to the municipalities of the bigger cities in the region, followed by the battery industry, gradually awareness could be raised, and the participation process could start. An important aspect of the strategy would be to involve the EU with Regional Innovation Strategies, CLLDs and ITIs to give tools and resources for local stakeholders directly for territorial development in the region, 'bypassing' the national government.

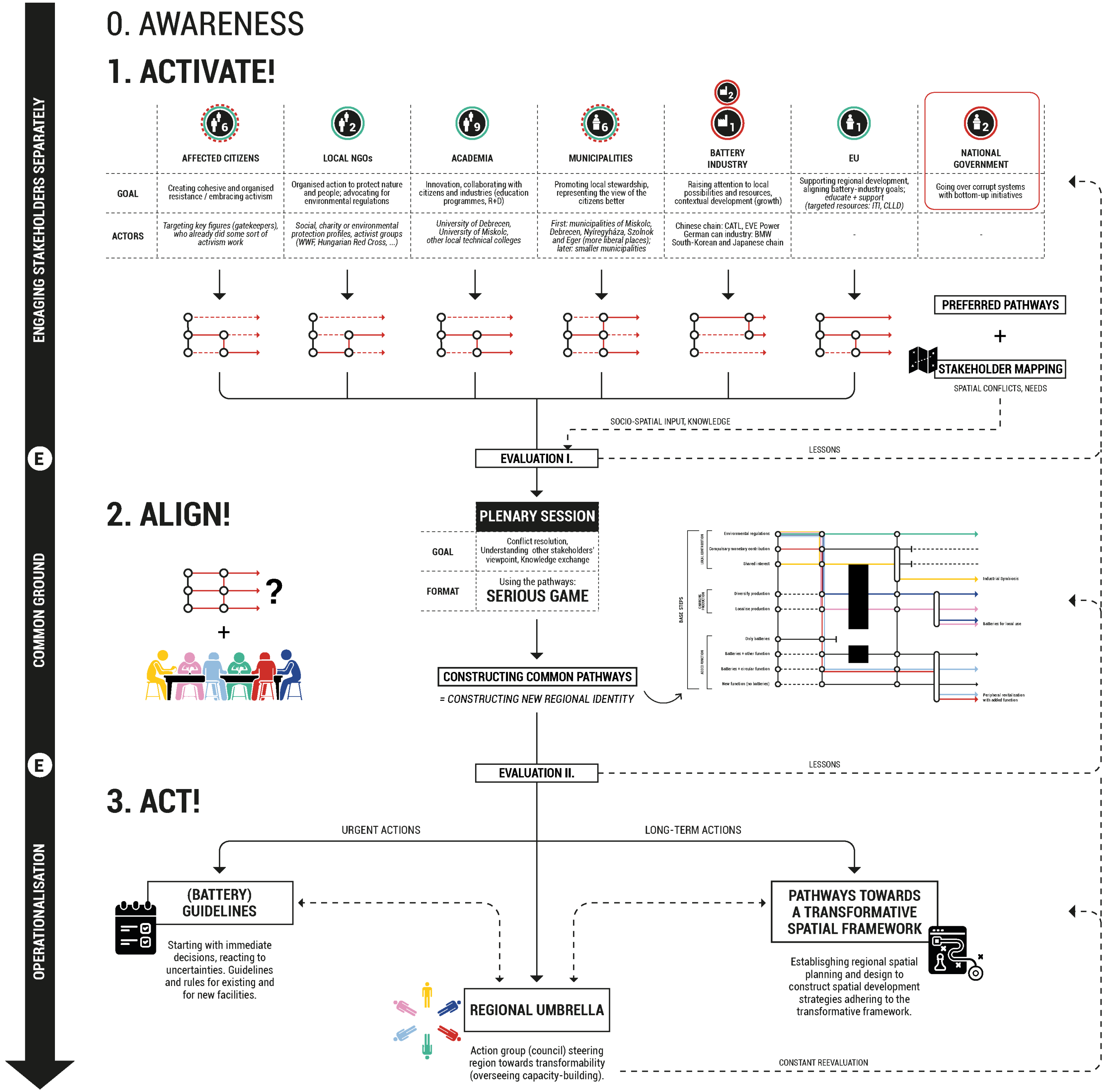
Fig. 8.7 (right): Engagement strategy

source: author

Fig. 8.8 (below): Possible process of the engagement

source: author





Governance Framework

To ensure that the region remains on the path towards transformability, the current governance and planning system has to change. In consequence, as the counterpart of the spatial framework and the pathways, a transparent, decentralised future governance framework is proposed.

This new arrangement follows a mix of top-down and bottom-up steering approaches, by combining horizontal units with vertical, more hierarchical systems on different scales. The regional umbrella acts as a territorial council, and is responsible for regional crisis response, and the overseeing of transformative capacity building, filling the gap of the formerly non-existent regional-scale governance (NUTS2).

On the county-scale a dual system is proposed, keeping the former administrative borders to preserve civil identity and electoral legitimacy, while introducing new meso-regional collaboration councils, based on landscapes and geology, steering economy and planning.

The sub-county scale is currently not a functional level of governance (Varjú, 2025), and in the future micro-regional cooperations based on cultural landscapes would replace them.

The smallest scale is of the settlements, where after establishing initial local action groups, gradually a horizontal system of autonomous settlements could emerge. Representatives of these units are present in the regional umbrella council and the meso-regional forum, and they can decide to form micro-regional cooperations based on their geographic location and characteristics, or economic profile and goals.

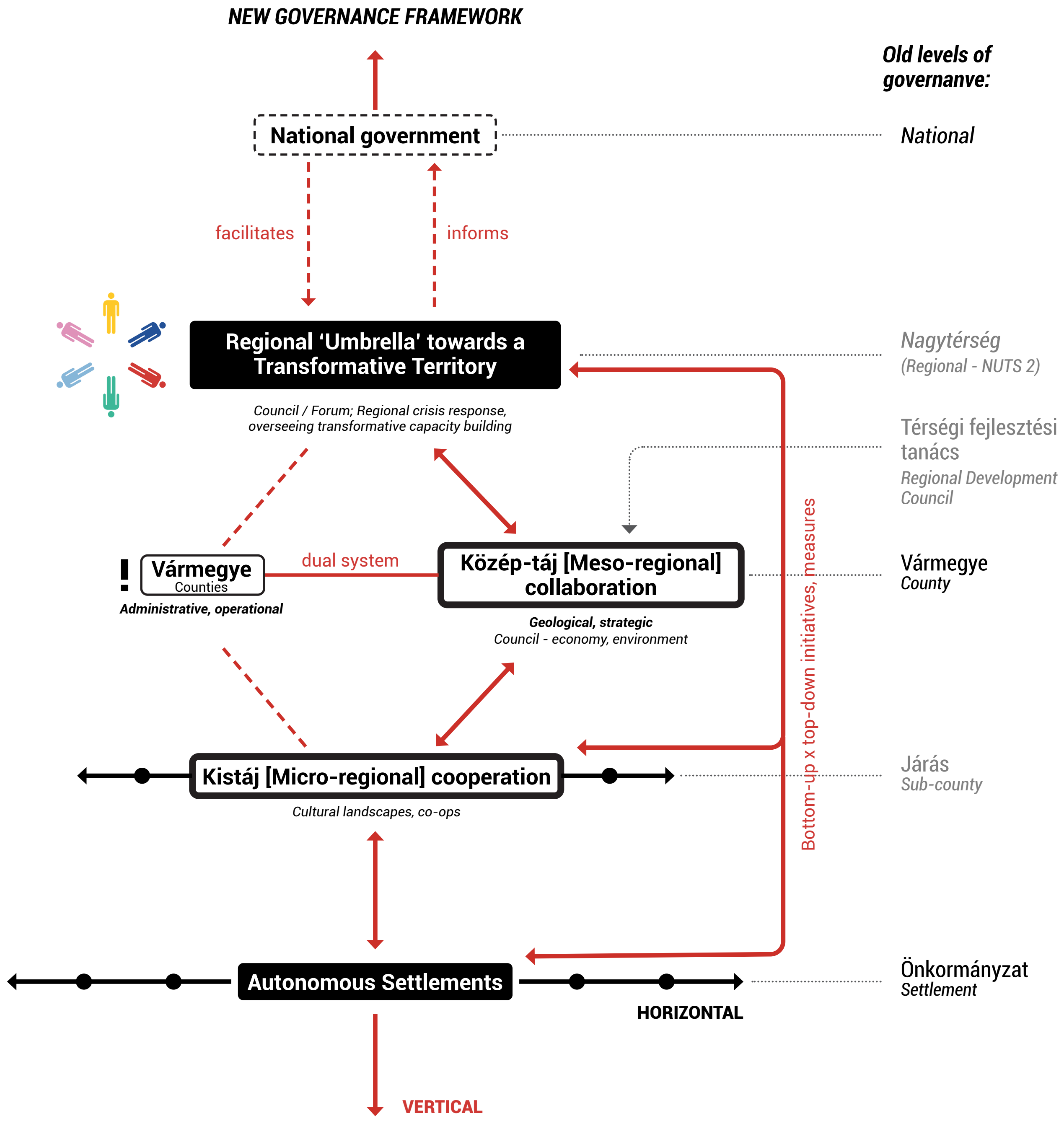
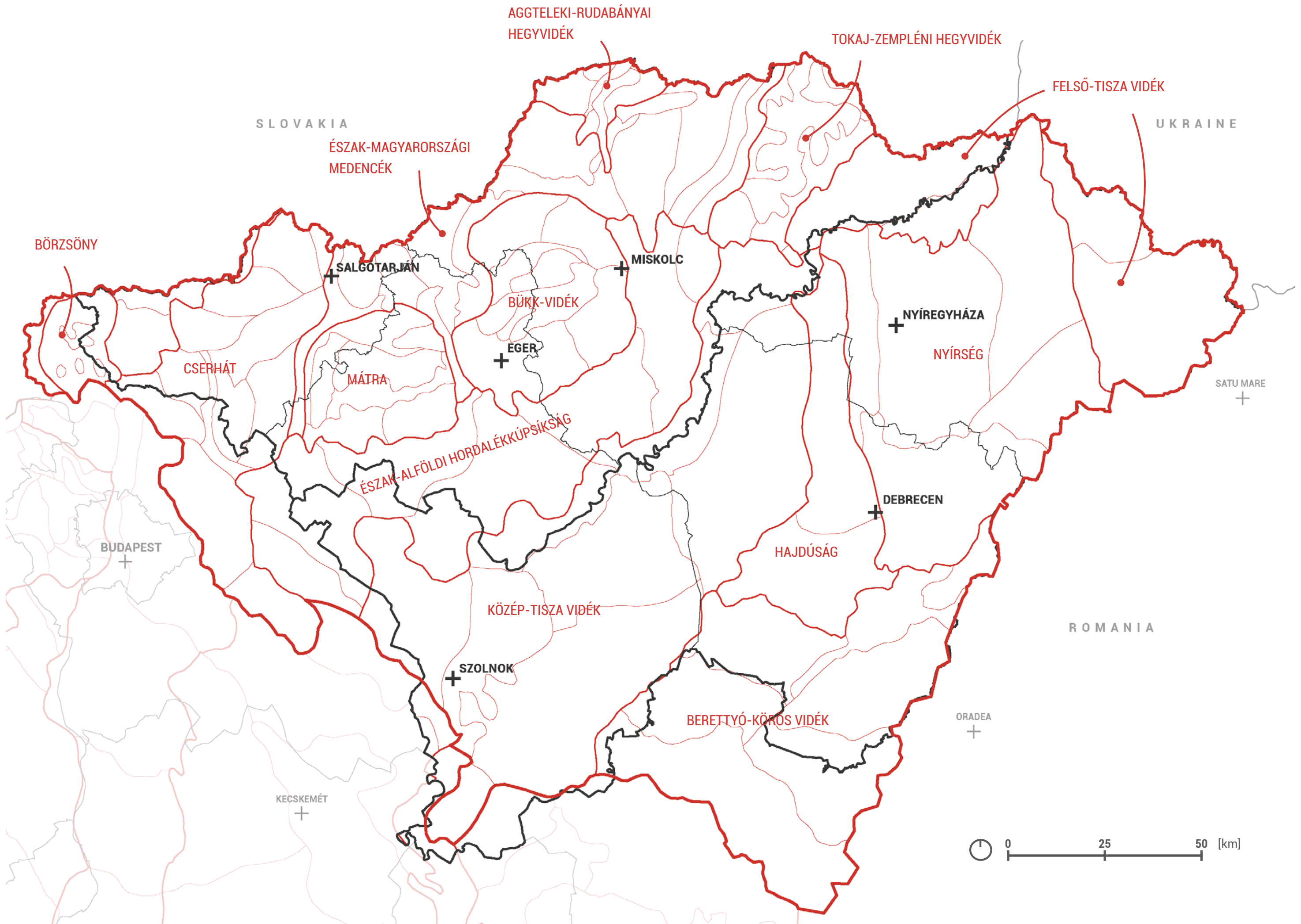


Fig. 8.9: The new framework of governance

source: author

Landscape-based Borders

The map on the right (Figure 8.10) depicts the new configuration of administrative and natural borders in the region. The meso-regional and micro-regional borders (Marosi & Somogyi, 1990) are based on different landscape units. This emphasises and builds on the conclusions of the analysis chapter, where different landscapes – and their geomorphology, soil and topography - were identified as crucial conditions influencing territorial development. This perspective changes what we see as North-East Hungary.



ADMINISTRATIVE BORDERS

- NUTS 2 regions
- vármegyék [counties]
- cities with county-rights

GEOGRAPHY-BASED BORDERS

- new outline of North-East Hungary
- középtájak [meso-regions]
- kistájak [micro-regions]

Fig. 8.10: Natural-cultural landscape formations as the base of future governance

source: author

A Glimpse into the Future

The final sub-chapter of the operationalisation chapter combines the transformation pathways with the view of the different stakeholder-groups, offering hypothetical pathway variations accompanied by 'glimpses into the future' postcards. Showing the outcome of different ownerships and uncertainties of production, varying no regret measures can be achieved. All pathways fall within the realm of possible outcomes.

Exploring Uncertainties

In order to show the workings of the transformation pathways depending on different stakeholder perspectives, four exemplary paths were constructed, envisioning possible futures. These depict (1) export-oriented, (2) community-oriented, (3) no batteries and (4) balanced export and domestic production options. The estimations necessary to build the pathways are based on the expert interviews and literature review.

All four configurations incorporate different future uncertainties, and present various cases of ownership. They represent an in-between stage of the process from different angles, with the same desired outcome: a transformative region. They can be understood as hypothetical outcomes of the first 'ACTIVATE!' phase of the engagement – pathways created based on the desires of a certain stakeholder-group.

On the next pages the four different examples will be further detailed, accompanied by imaginative future postcards that show the spatial consequences of the chosen paths, starting from the battery industry. The base of the postcards is the following image that I took at the site visit:

transfer station to new action

adaptation tipping point

adaptation (transformation) pathways

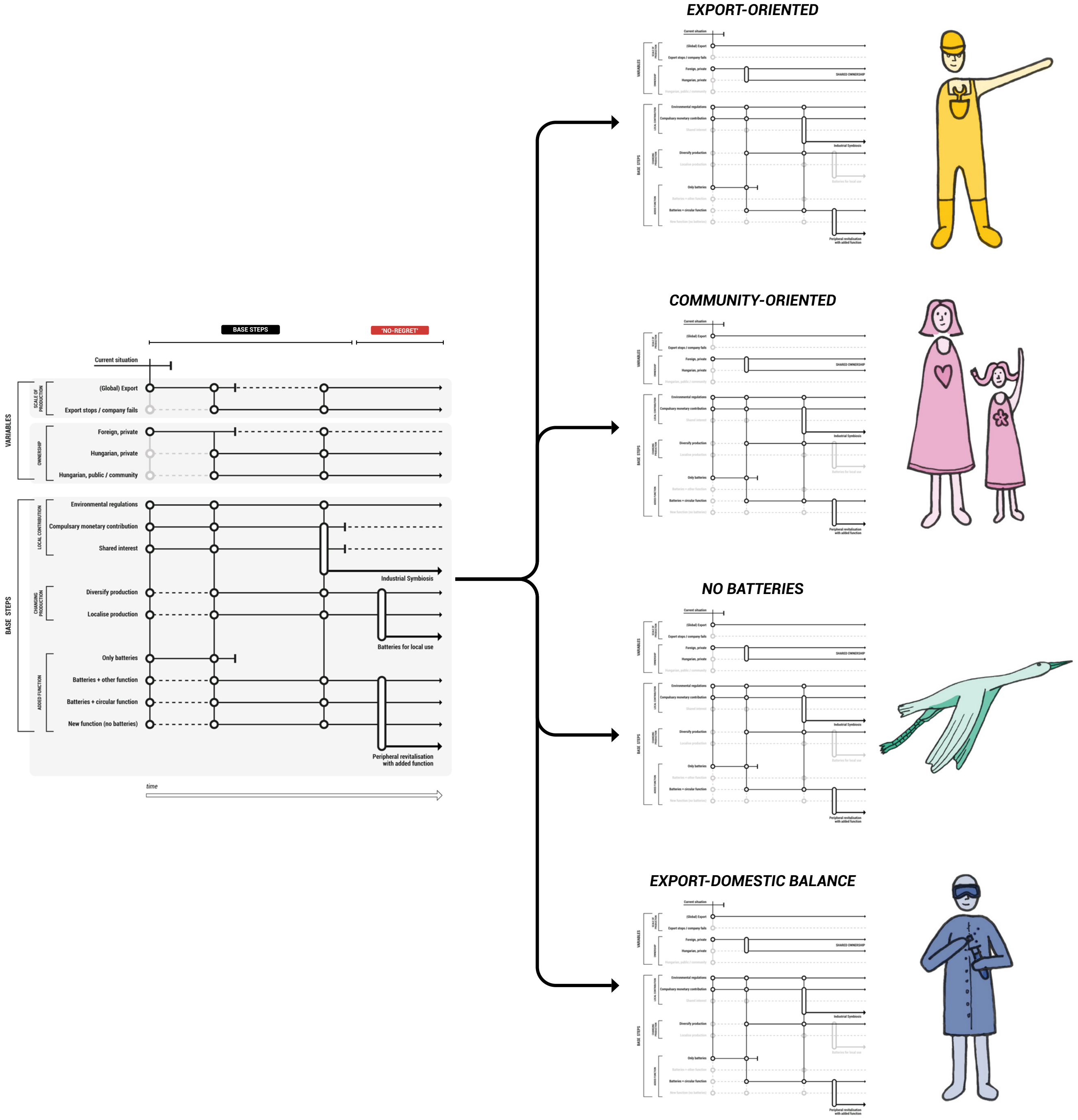
pathways that are possible but not necessarily preferred

Fig. 8.11 (right): Possible pathways based on different production, ownership patterns and stakeholders

source: author

Fig. 8.12: The base photo for the postcards: EcoPro factory now

source: own image



Exploring Uncertainties

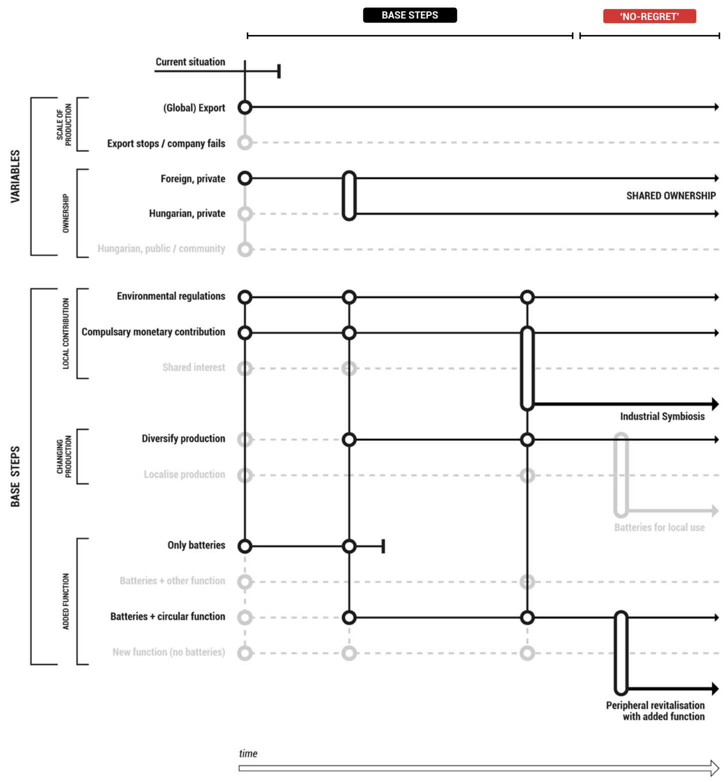
Glimpse into the Future: Export

Even though the factory imports materials and caters to global export, after some time it switches to a shared ownership construction: the foreign company and a Hungarian private company own the place together, ensuring local contribution and context-specific development.

Although there are no batteries for local use, a **system of industrial symbiosis** can be established relatively early in the process, with the factory providing excess heat to nearby neighbourhoods and greenhouses, or other industries, as well as R+D co-development opportunities. **Circular functions and repair hubs** can be later added to the facility to diversify functions and connect to the local flows.

Based on current trends this is a likely option, being a relatively low effort (costs) and high impact solution.

<u>Stakeholders who would prefer this path</u>:
foreign battery companies and other Hungarian industries; factory workers



transfer station to new action

adaptation tipping point

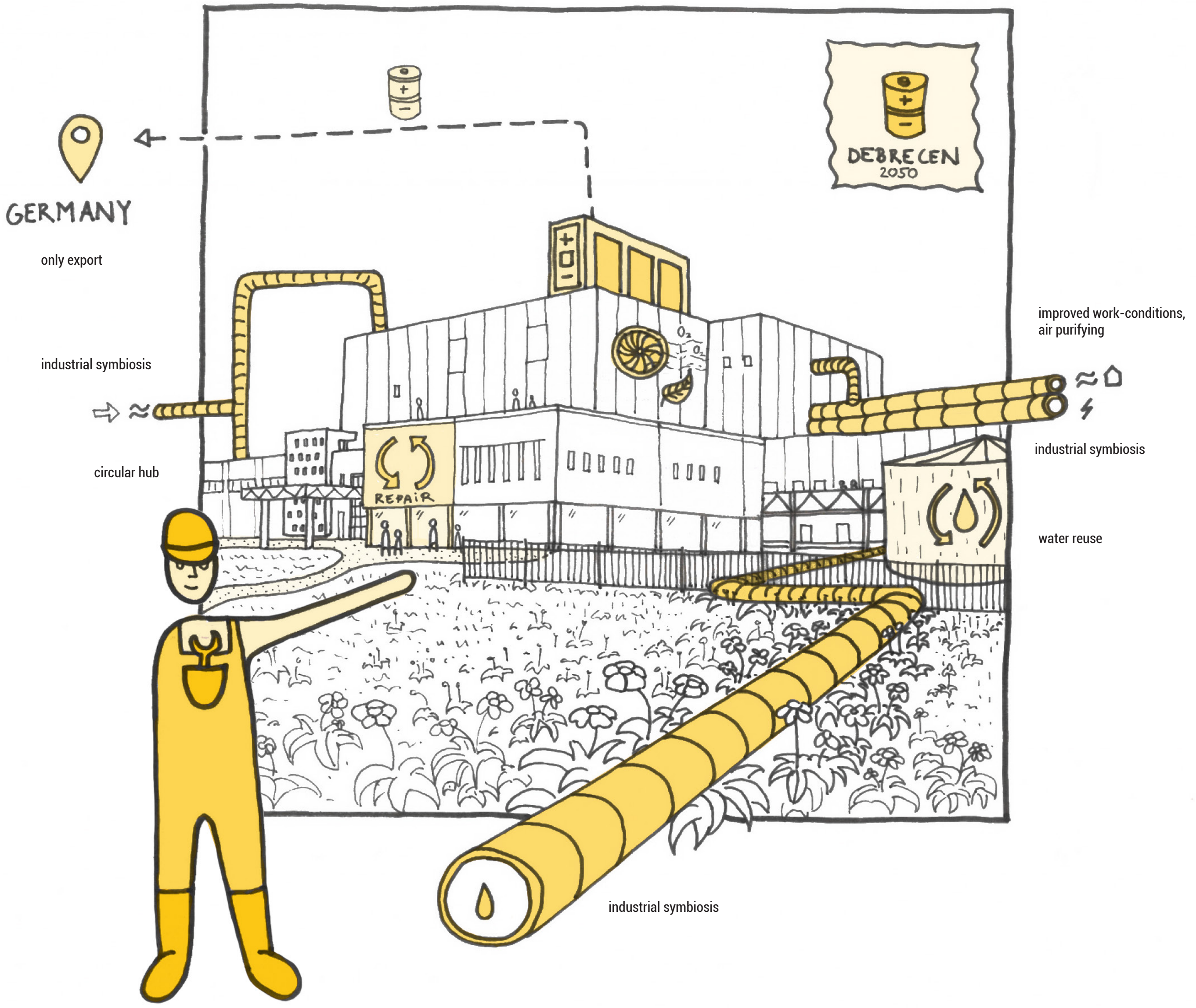
adaptation (transformation) pathways

Fig. 8.13 (left): Pathways in case of an export-oriented approach

source: author

Fig. 8.14 (right): Postcard from an export-oriented near-future

source: author



Exploring Uncertainties

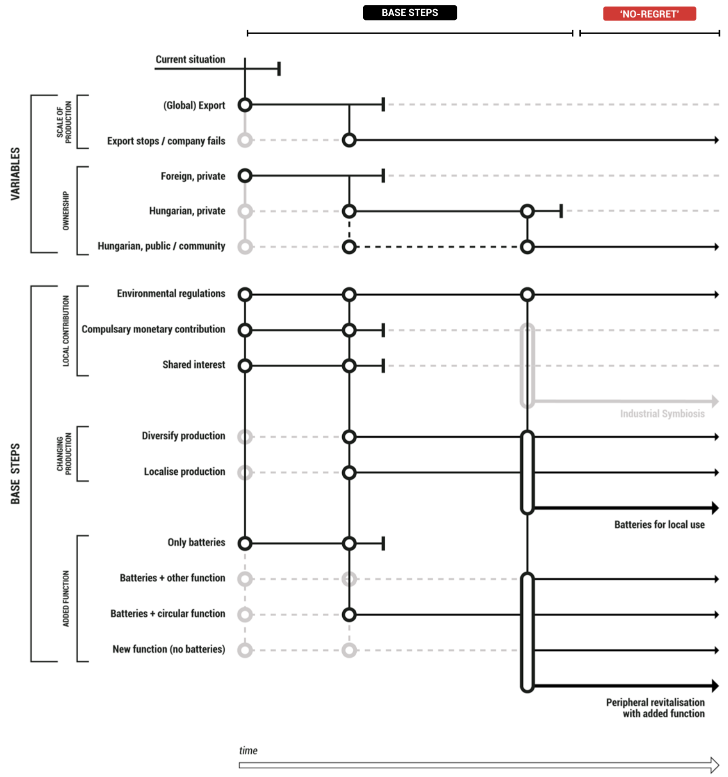
Glimpse into the Future: Community

In pathway global export stops, therefore the foreign company leaves as it is not worth it for them to remain in the region. For a while a Hungarian private company takes over and starts producing batteries for domestic use, diversifying the end products. A **circular hub with repair facilities and a material bank** is established at the factory site for the settlement to use.

As time passes, the private company also leaves, and the **factory becomes community-owned**. This step requires re-education and re-skilling of community members, and a significant societal change towards a community-oriented way of life. On the other hand, it opens up the possibility to introduce new, diverse functions based on local needs, and to start social programs in order to help the peripheries by using circular initiatives.

Although an appealing path, based on current trends and the history of industrial activities in the country, this is a not likely option, as it requires a significant shift in values and governance systems.

<u>Stakeholders who would prefer this path</u>: local citizens, marginalised groups



transfer station to new action

adaptation tipping point

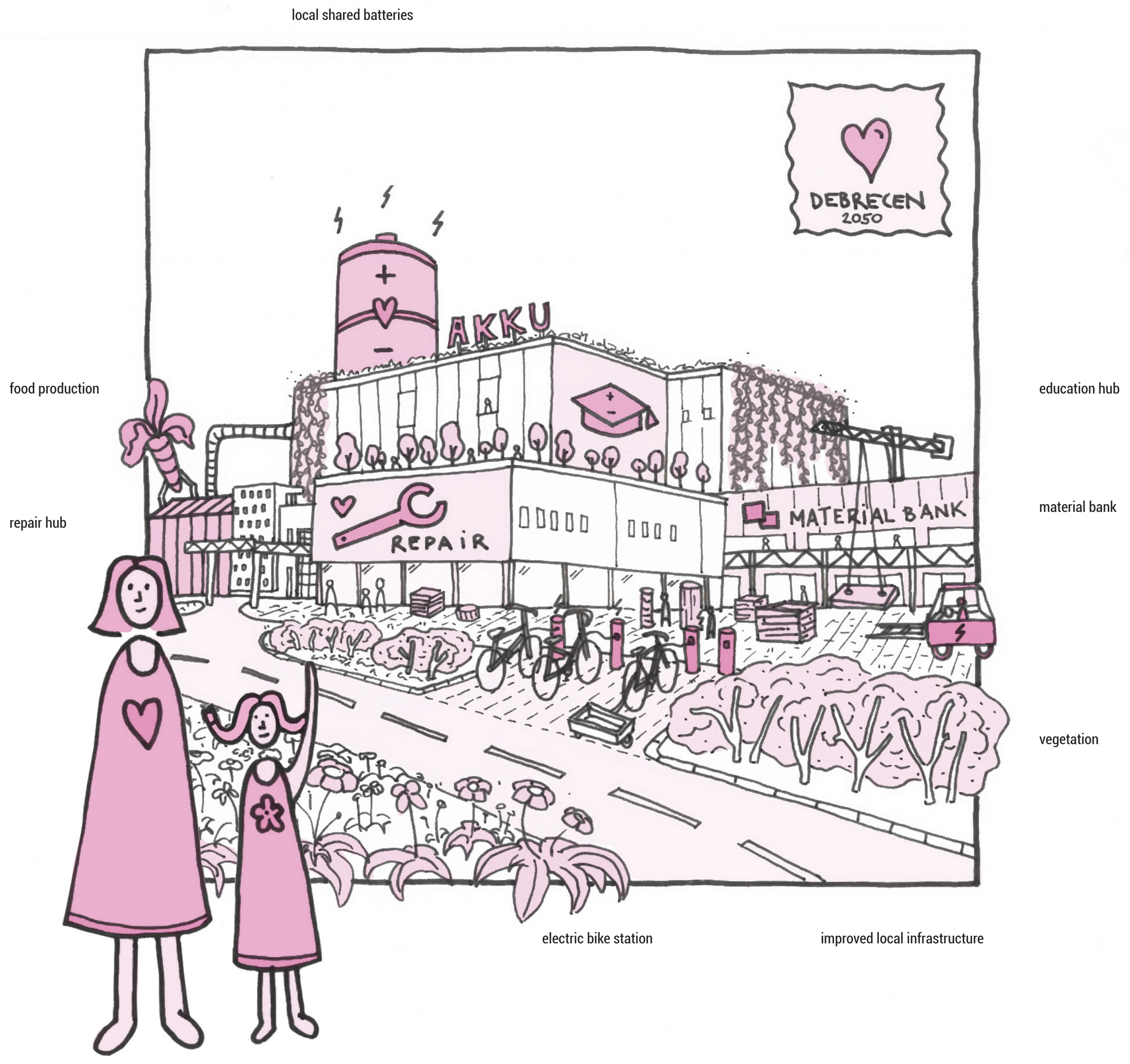
adaptation (transformation) pathways

Fig. 8.15 (left): Pathways in case of a community-oriented approach

source: author

Fig. 8.16 (right): Postcard from a community-oriented near-future

source: author



Exploring Uncertainties

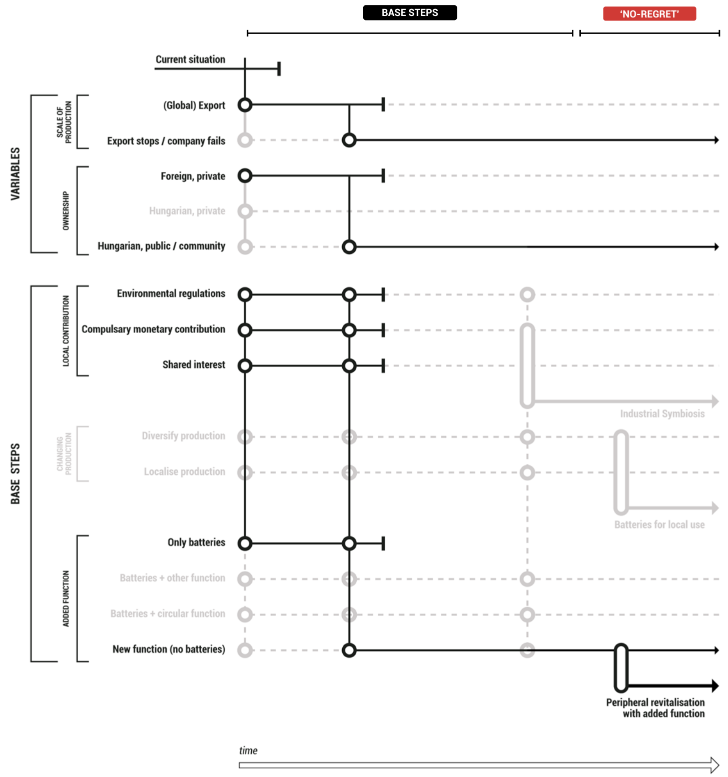
Glimpse into the Future: No Battery Production

Due to external factors (geopolitical conflicts, disruptions in the global value chain) **all production stops,** therefore the foreign company leaves. Private Hungarian companies are not interested in taking over, thus the **factory becomes publicly owned by the municipality.**

Even though battery production stopped, the **community over time transforms the site** by introducing natural pollution reduction measures and new functions that are compatible with the industrial atmosphere and are beneficial for the settlement and the region (on the postcard: transformation to an agroecological hub).

Despite the current trends, it is not likely that battery production will completely stop due to path-dependencies. Exploring options like this can help evoke imagination and widen perspectives.

Stakeholders who would prefer this path: municipalities, non-humans



transfer station to new action

adaptation tipping point

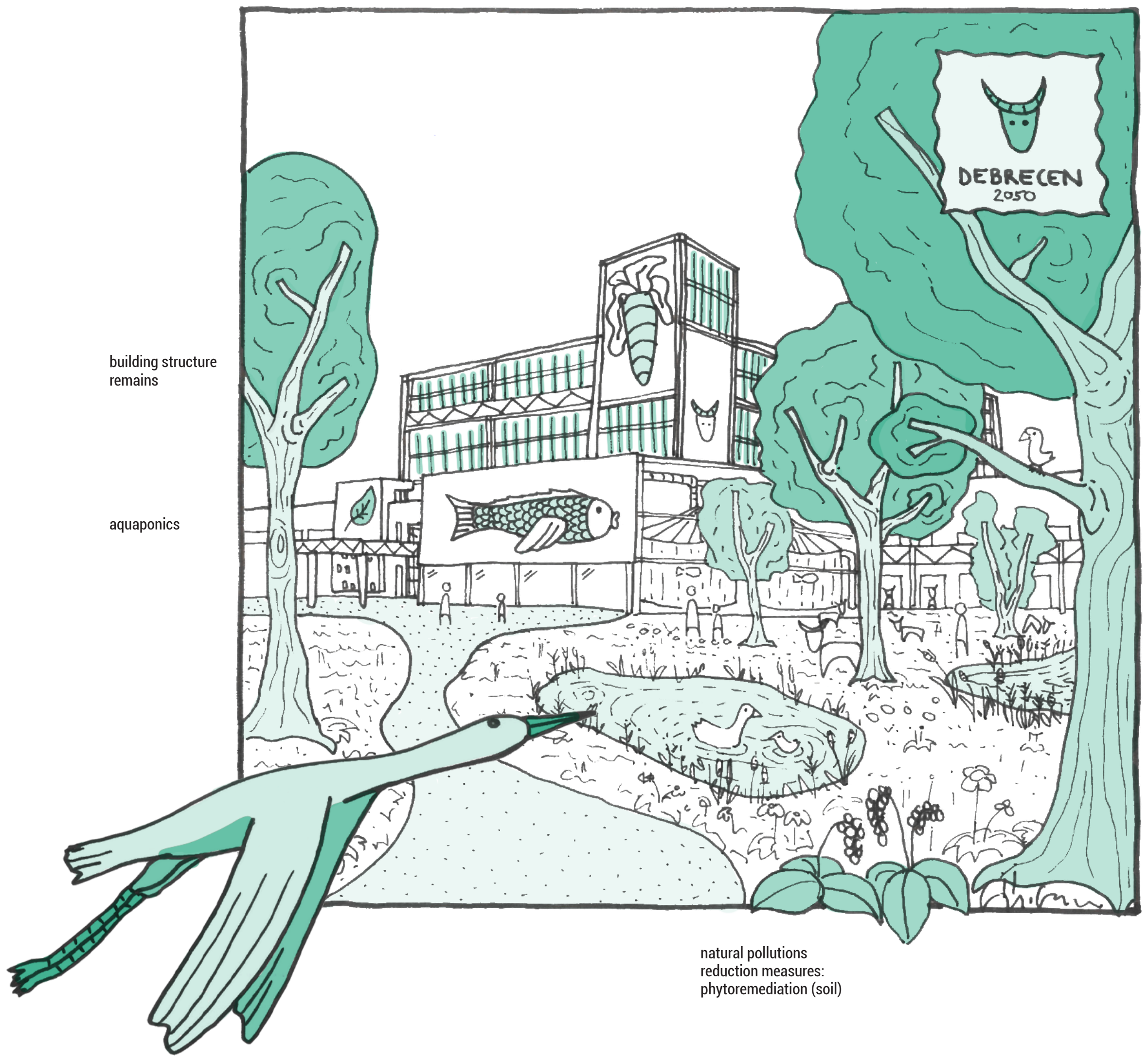
adaptation (transformation) pathways

Fig. 8.17 (left): Pathways in case of no battery production in the near-future

source: author

Fig. 8.18 (right): Postcard from a near-future without battery production

source: author



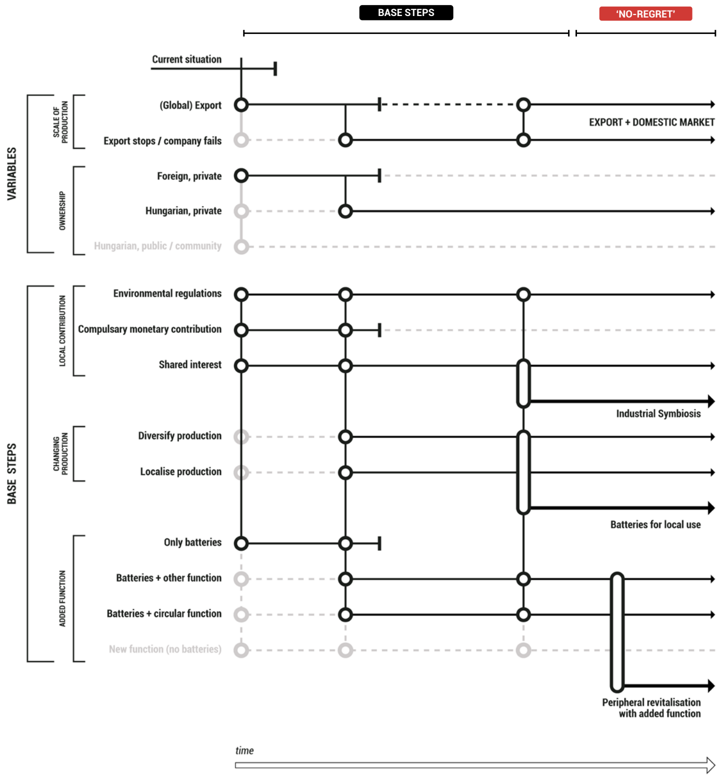
Glimpse into the Future: Export and Domestic Use

After a shorter period of time where it was not worth it to produce for export, the foreign company leaves. A Hungarian private company takes over and start to produce for the domestic market, diversifying their products. Soon there is a novel demand for batteries abroad, therefore they recontinue the production for export.

This is a balanced scenario, as this way all 'no regret' measures can be reached relatively fast. Due to high demand, there are enough resources for industrial symbiosis, changing ownership allows for diversified, local production, while by adding functions, the company has interest in helping the periphery.

Based on current trends this is a relatively likely option, accommodating for both high and low demands for batteries, bridging the global-local differences.

Stakeholders who would prefer this path:
academia, researchers, R+D companies, municipalities



transfer station to new action

adaptation tipping point

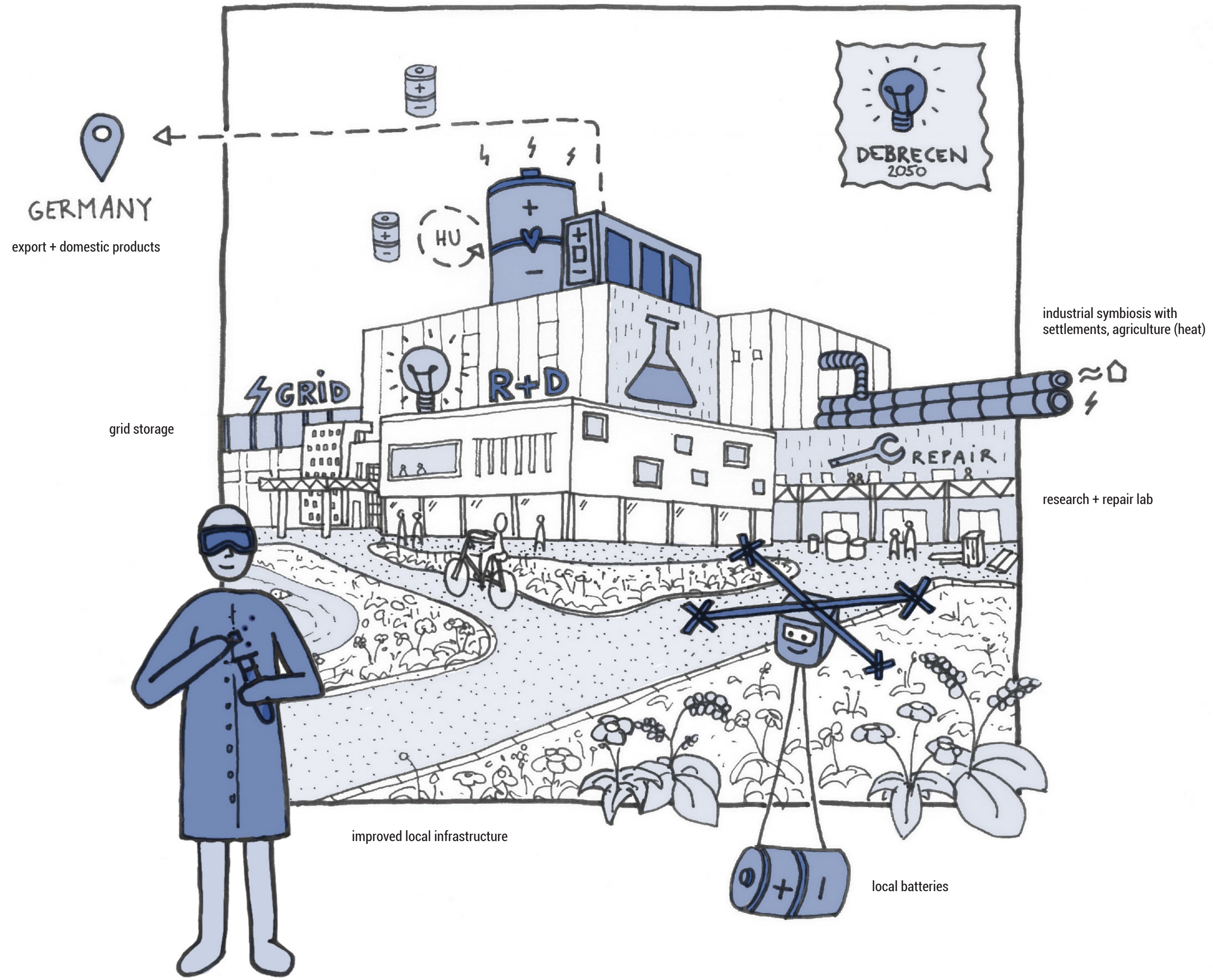
adaptation (transformation) pathways

Fig. 8.19 (left): Pathways in case of balanced export and domestic battery production

source: author

Fig. 8.20 (right): Postcard from a near-future with balanced export and domestic battery production

source: author



Concluding on the Operationalisation Chapter

In this chapter, transformation pathways and a governance framework were introduced, providing a bridge from the long-term vision to answers to the current battery crisis. Spatial and temporal aspects of the pathways and proposed interventions were discussed, and four pathway examples based on possible futures and stakeholder preferences were presented alongside postcards depicting a 'glimpse into the future'.

<u>The main lessons include</u>:

- Transformation (adaptation) pathways contribute to a holistic, flexible way of constructing strategies for the region.
- As the battery industry reshapes the country, and there are no other leading industries to rely on, it is crucial to come up with contextual and sustainable solutions to the current problems, which also have a long-term perspectives.
- There is not one correct path. There are 'no regret' measures and choices that need to be made ultimately to achieve the goals of the vision and a flexible spatial framework, but these are based on different externalities, uncertainties and stakeholders.
- On the reversibility of decisions: non-linear approaches, recursive paths and constant feedback loops help steering the region towards transformability, thus avoiding (future) lock-ins
- Without a governance framework that combines bottom-up and top-down approaches, adaptive governance cannot be reached, thus transformation is not possible.
- The most important aspect is raising awareness and realising the need for change.
- To make the method of transformation pathways more realistic, next steps could include workshops with actual stakeholders. A first effort towards this step are the postcards.

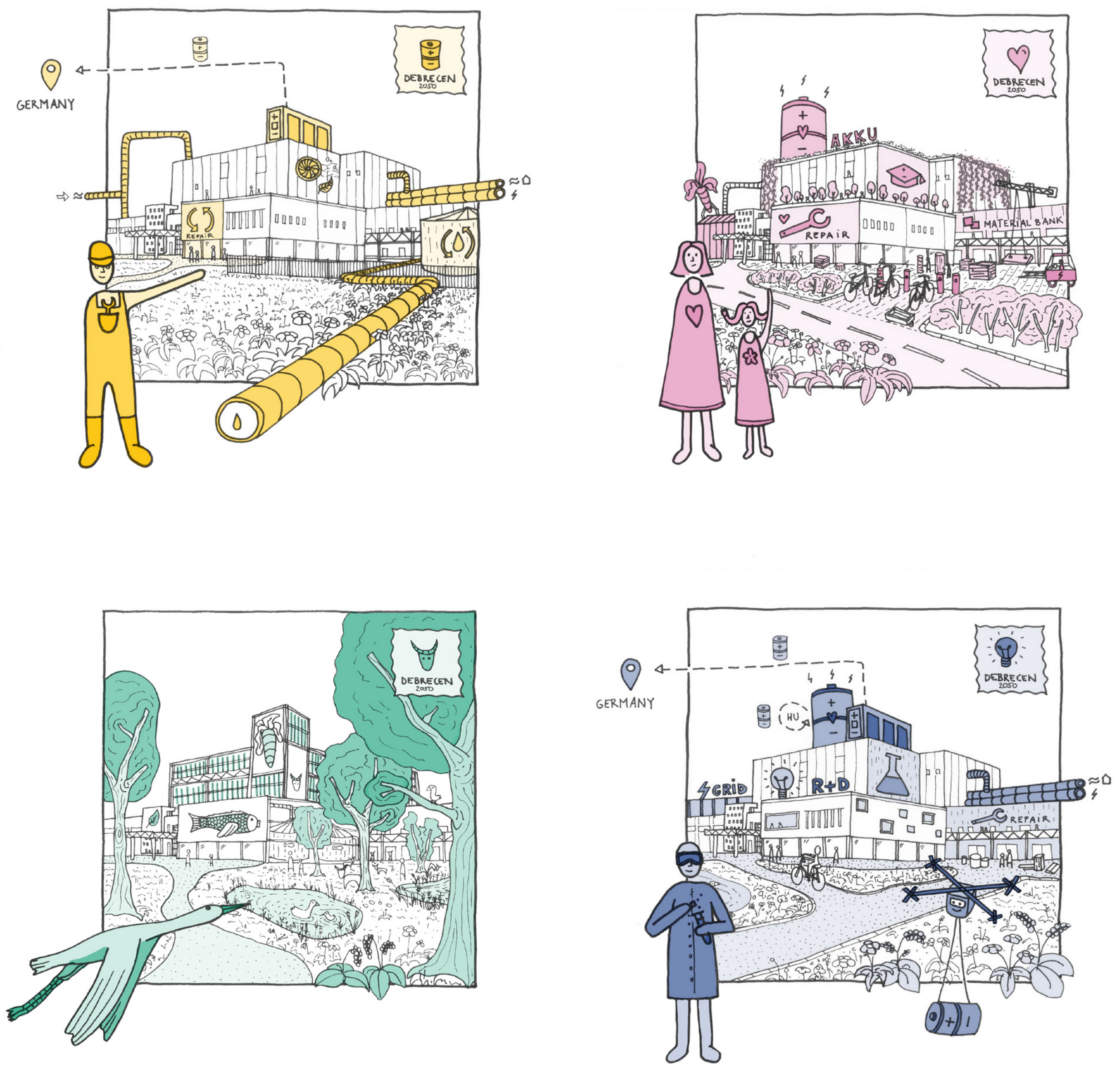
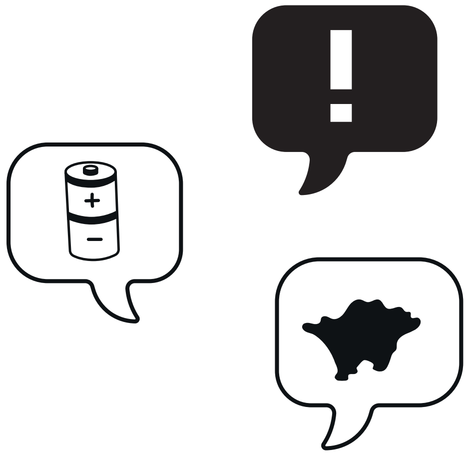


Fig. 8.21: The four postcards

source: author

CONCLUSION



Conclusion

In order to answer the main research question, the sub-questions have to be discussed first.

1 What are the **spatial, social and economic dimensions of industrial development** in the region through time, and how does the **battery industry** fit into this picture?

The spatial dimension of industrial development in Hungary has historically mirrored the country's shifting geopolitical alignments. Industrial activity has repeatedly reoriented with changes in regime. Under the Austro-Hungarian Monarchy, a centrum-periphery relation was established with Budapest at the core; during communist era the direction changed towards the Soviet Union, following main infrastructural corridors. After 1990, a reorientation towards Western-Europe, particularly Germany, can be observed, with industrial expansion largely concentrated in the western part of the country. While the battery industry partially follows these recent patterns, it deters from it in the case of North-East Hungary. In this region a rapid reindustrialisation process is happening, as well as the novel industrialisation of cities with different economic profiles, like Debrecen.

Parallels to earlier industrialisation efforts are evident, particularly in the lack of integrated spatial planning, lacking contextual considerations and future vision, leading to forced industrialisation at resource-scarce or otherwise ill-suited areas. As recent developments are driven by technical requirements – such as access to high-voltage lines, highways and rail – local ecosystems and the subsurface are neglected.

Economically, the battery industry, together with the earlier expansion of the automotive sector in the 2000s, has become Hungary's dominant industrial driver. Without other competitive options, this tendency leaves the country exposed and creates structural vulnerabilities. The sector is highly export-oriented and controlled by foreign companies (East-Asian, German firms), who cater to the Western-European market. As a result, the country is dependent on the global value chain and the regional industry is not resilient to fluctuations in supply and demand, manifesting in the current stagnation of production.

These dynamics reinforce existing path dependencies. The continuous announcement of new factories shapes future development trajectories and resource allocations, resulting in sociospatial disparities in North-East Hungary. This makes future transformation challenging, as shifting toward alternative, more resilient economic models becomes increasingly difficult due to the path-dependent relations.

Socially, foreign dominance in industrial development has long been a feature of Hungary's economy. However, while earlier foreign companies often maintained some degree of social responsibility, this is seemingly not the case with the battery industry. There is a lack of participation, social engagement and local contribution, combined with secrecy and non-transparent practices. Due to high degrees of automatization, less and less jobs are provided. There is a shortage of skilled workforce, contrary to the unemployment issues of the past decades. This leads to the trend of inviting migrant workers to the region, who are in need of housing and social infrastructure. Although working conditions changed compared to previous eras, it did not necessary improve, and both workers and local citizens are subjected to toxic materials emitted by the battery factories.

To conclude, despite its challenges and future consequences, it is possible to identify transformation potentials of the battery industry, which include changing ownership, diversifying production, adding circular functions, local contribution and industrial symbiosis. Such interventions are necessary towards a more contextual and sustainable development path.

2 What is the **territorial capital and transformative potential** of North-East Hungary, and how is it affected by the pace of change?

Sustainable and context-specific development is crucial; therefore, identifying the territorial capital of the region is necessary. This method yields spatial and social insights, but overlooks the temporal dimension. **In order to assess the transformability potential of territorial elements, understanding the nature and pace of change is of core importance, as transformation is inherently linked to change.** Consequently, a frequency of change analysis was conducted by observing past and present shifts, resulting in the classification of elements as either static or dynamic in nature. This approach is not straightforward, as the function, physical form, or the role in the overarching system of an element influences the interpretation of change. Therefore, the analysis leads to multiple understandings, and requires an additional, project-specific step of interpretation to derive meaningful conclusions.

In general, dynamic elements – such as rivers, centres of knowledge, economic activities, and not well-connected or renewable infrastructures - require urgent action, as they change frequently and in an unpredictable manner. This also implies that they hold greater transformability potential in the near-future. These include buffering capacities, flexible, mixed and layered uses that can accommodate frequent shifts. By contrast, static elements are characterised by a slow-moving, constant nature, making them more predictable. These include landscape and protected areas, major infrastructure corridors, peripheral settlements, monofunctional spaces and sociospatial disparities. Due to their stability, they are the characteristic, identity-defining aspects of North-East Hungary, shaping the region across past, present and future. **While they have low frequencies of change and limited transformability, this does not imply they are not in need of transformation - on the contrary, they might demand long-term, complex interventions.** In consequence, both dynamic and static elements must be considered when pursuing long-term regional sustainability and transformative resilience.

Nature and its diverse landscapes represent the primary territorial capitals of North-East Hungary. In the future, landscape and subsurface-based development, alongside a restored balance of human and nature are key aspects towards sustainable and contextual development. **Landscape, geomorphology,**

topography and soil have historically shaped, and will continue to shape, the region. Therefore, embracing these characteristics and using them to steer the region holds significant transformative potential towards deeper change, when combined with community, cultural and heritage values.

Additionally, turning the current crisis of battery development and lack of human capital to an opportunity through transformation can act as the catalyst towards long-term sustainability.

3 **What spatial organisation allows for transformation at points of crisis?** How could that be translated into a long-term future vision and spatial framework for the region?

To answer this question, first a vision is created, formulating goals, means and values towards long-term transformation. It is based on the principles of contextuality, 'response-ability' and the six enablers of transformability. Given the seemingly conflicting nature of the six enablers, two scenarios can be developed, leading to two options on how a transformative future can manifest spatially: (1) efficient – hierarchic and optimised, and (2) redundant – decentralised and diverse. Both configurations allow for a certain degree of transformation and crisis 'response-ability', but they perform differently when assessed against the values of sustainability transformation.

Efficient structures are suited for monitoring and preventing crisis, but disturbance can spread with ease due to high degrees of connectivity and lack of reserves. Additionally, this option lacks sufficient social consideration. On the other hand, redundant systems can compartmentalise disruptions, and have built-in reserves to cope with shocks. However, they heavily rely on community-based structures and score low on economic viability and scalability.

A spatial organisation that strategically integrates both efficient and redundant principles in a balanced manner has the potential to allow for transformation at points of crisis. This means focusing on main nodes and corridors that connect the region to its surroundings, while encouraging local, landscape-based, community-led development paths at the same time. This approach forms the foundation of the proposed long-term transformative framework.

However, a transformative framework requires more than balanced spatial organisation – it must have enough flexibility to deal with future uncertainties, such as economic shifts, climate events and population dynamics. Therefore, instead of creating a fixed spatial design, the framework defines priorities and quality-based objectives that are based on the transformability principles and potentials concluded following the territorial capital analysis, touching upon multiple scales. These goals lead to the means means of adaptive resource management, adaptive governance and adaptive land, through which it is possible to thrive for the desired values (overall goals) of development within the planetary boundaries, just society and resilient biosphere.

4 How could the **contradiction between short-term responses to the battery crisis and the pursuit of long-term territorial transformation** be addressed?

To address the contradiction between short-term responses to the battery crisis and the pursuit of long-term territorial transformation, the method of backcasting via transformation (adaptation) pathways offers a flexible and integral approach.

With long-term goals and a spatial framework already defined, it becomes possible to work retrospectively, and construct viable paths starting from the crisis of the current battery system towards the desired future. This approach enables the identification of immediate actions that generate long-lasting, transformative effects.

Base steps - key decisions that can influence the battery system – are defined, starting from the variables of the uncertainty of battery production and ownership. Based on their different configurations, various pathways of solution measures can be generated leading towards 'no regret' measures – interventions beneficial across multiple future scenarios. Since the pathways are designed to bridge the gap between battery crisis and regional transformation, the initial interventions focus on industrial and economic dimensions, followed by interventions with social and ecological values.

After the base steps, attention must first be given to dynamic elements, due to their rapidly changing nature. On the long run, interventions targeting the slow-paced elements ensure that the region shifts to sustainable, transformative paths.

The transformation pathways can also serve as tools to engage various stakeholders, providing a basis for co-creation and shared decision-making. The engagement strategy and the proposed governance framework attempts to set the base for this step. Spatialising alternative paths and interventions, as well as creating the postcards helps showing desired qualities, building a collective vision and fostering spatial imagination, contributing to the transformation process.

Conclusion

? How could the **current battery crisis be leveraged** to enable **long-term spatial, transformative change** in **North-East Hungary?**

The current battery industry crisis, while exposing North-East Hungary to deep structural vulnerabilities, presents a unique opportunity. Moving beyond the current sustainability transition paradigm and its path-dependent strategies is essential to shift to a just, circular and flexible development path. Reframing the battery crisis as a catalyst for transformation is a crucial first step in this process.

Using transformation (adaptation) pathways operationalises the leverage point, and bridges the gap between short-term crisis responses and long-term transformation goals. It allows for the anticipation of urgencies through flexible and adaptable pathway configurations informed by local needs, and encourages participation and co-creation. In addition, forming a shared vision that evokes spatial imagination is necessary to engage stakeholders of both industry and region, as the first step in every transformation should be to recognise the need of change, and to show its potential benefits.

Understanding the context through territorial capitals and promoting landscape-based development is key to achieve a sustainable transformation. Measures grounded in this approach serve as the foundation for all future interventions. Observing the frequency and nature of change helps setting priorities by identifying dynamic and static elements, thus revealing where urgencies lie, when moving from battery-related measures towards the desired transformability goals.

A balanced spatial organisation, combining efficient (hierarchical, optimised) and redundant (decentralised, diverse) principles, is necessary for building regional crisis 'response-ability'. This leads to a contextual, sustainable and resilient long-term spatial framework for the region.

By leveraging the current battery crisis through an adaptive, flexible and contextual approach, long-term transformative change can be achieved in the region of North-East Hungary. Success depends not on halting battery development, but on strategically redirecting its trajectory toward a transformative future.

REFLECTION

Reflection

Relation Between the Project, Master Track and Faculty

The thesis investigates a rather peripheral topic in the field of urbanism, yet the way of interpretation clearly connects to the studio topic and the master program. Dealing with spatial, territorial issues regarding the battery industry might seem unexpected from an urbanism graduation project, yet battery-related development is a phenomenon that will radically shape all aspects of Hungary – including economy, society, environment and space - in the upcoming decades. The thesis identifies, and takes a stance against the ongoing uncontextual and unsustainable industrial electrification transition, and proposes a transformability-based spatial exploration towards a sustainable socio-economic transformation, aligning with the goals and values of the Metropolitan Ecologies of Places studio. The project also combines theory with exploration, and investigates both the problems and the proposed solutions on multiple scales.

The main focus of the thesis revolves around regional spatial transformation, from the perspective of spatial planning and systems-thinking, as it is part of the Urbanism track. Proposing adaptive, flexible and sustainable solutions on a territorial scale requires social, environmental and economic perspectives, while the nature of the Hungarian governance makes it unavoidable to take a political stance. This integrated approach aligns well with the goals of the Urbanism track.

The relation between this project and the overall master programme - MSc Architecture, Urbanism and Building Sciences – lies in the fact that I use the methodology and knowledge learned during the two-year program, and apply them in the Hungarian context.

Reiteration Moments

Both the research and design process induced multiple reiteration moments, therefore they inherently influenced each other throughout the project, leading to a circular, rather than linear approach.

For a long time, it was not clear whether I wanted to focus on the problems created by the battery industry or take the region of North-East Hungary as a base. I found the answer after the P1 feedback, when a revelation moment was provided by theoretical research: transformative resilience. This stirred the project in a novel direction, combining the industrial and territorial lenses, and setting the goal of leveraging the battery crisis in order to achieve long-term transformability.

After conducting the territorial capital analysis, I attempted to test new battery economies through the process of scenario-building. Due to too many externalities and uncertainties, this approach did not work out, and I had to go back to research and theory to find a method that can bridge intermediate actions regarding the battery industry with long-term transformability goals. After mentor feedback and reading, I got to the conclusion that backcasting with adaptation pathways could be a viable solution for the given paradox. This lead to a great iteration moment that completely reshaped the course of the thesis. In consequence, the base of the scenario-construction is informed by theory instead of the battery industry. This made it possible to design a spatial framework for transformation, then use backcasting to suggest immediate action and interventions.
Additionally, conducting expert interviews helped with widening my knowledge regarding the core issues of the battery industry, and based on their expertise I gained valuable feedback on the preliminary scenarios, that lead to realisations and reiteration moments.

A Flexible Approach

In a world where change is accelerating and the geopolitical situation is increasingly uncertain, it is crucial to find flexible and adaptable approaches to planning and design. With my thesis, I tested a methodology that is based on this premise, formulating a statement against rigid, one-way design solutions.

The methodology focuses on incorporating uncertainties by offering multiple future possibilities, starting from the current crisis. The proposed transformation (adaptation) pathways allow for connecting future with present through backcasting, and can be used to engage stakeholders.

The title of the project reflects this approach, by emphasizing (with italics) that the region could take on different roles, not only that of a battery region. Possible other compatible functions that could coexist with, or take over the factories are listed in the Exploration chapter, as well as depicted with the four postcards, presenting transformations on a smaller scale.

Reflection

Rapidly Changing Battery Industry

At the start of the academic year, the battery industry presented itself as a booming economic sector in Hungary. Various gigafactories were being built and new facilities were announced, further pushing the image of a 'battery boom' described in the contextualisation chapter.

Around November, articles about sectorial struggles started to surface. At the end of 2023, the demand for electric cars dropped in Europe (Weiler, 2025b), meaning that production had to halt in multiple battery factories. Since the middle of 2024, thousands of workers were let go from multiple big assembly centres (Weiler, 2025b). **From a success story of a rapidly developing dynamic industry, the trajectory switched towards stagnation and waiting. This shows how quickly supply and demand fluctuates only during ten months' time, and how exposed the industry really is to such changes.**

It was a challenging experience to work with the above described conditions, resulting in the necessity of multiple reiterations. On the other hand, it made me strive for flexible approaches that can handle these kind of unpredictabilities due to global, external dependencies, which led to the focus on transformability and the use of transformation (adaptation) pathways.

'The municipal assembly has voted: starting next year, the Göd battery factory will have to pay twice as much local tax.'

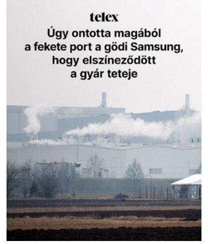
'They sent away the external contractors, then started firing colleagues over every little thing. Now they've announced that we're next.'

'The production lines shut down one after another.'

'Orbán, returning from the Indian jungle, did not dream of a takeoff (economic performance at the start of 2025) like this.'

'They announced the 900-person Chinese factory in Hatvan, a town of 20,000, without informing the mayor.'

'We want to bring hundreds of thousands of guest workers to Hungary, while we don't even trust each other.'



'The Samsung plant in Göd emitted so much black dust that the roof of the factory became discolored.'

Fig. 9.1: collection of articles about the battery industry and economy throughout the past 10 months

source: Telex.hu

Academic Relevance

As global critical raw materials (CRM) based supply chains are defining the economy of the 21th century, it is crucial to research their spatial and environmental consequences in order to uphold sustainability goals. This project delves into the disparities between the North-East Hungarian territory and the CRM-based battery industry.

As the battery industry is a rapidly evolving and relatively novel sector, almost no spatial studies have been done on this topic. In order to offer a sustainable solution, the project aims to explore the spatial dimension of transformability - or transformative resilience - on a territorial scale. In this sense, the thesis tests a novel understanding of space, based on flexibility and the pace and nature of change.

The main scientific relevance of the project lies in connecting the current crisis with the long-term goals using adaptation pathways, towards territorial transformation. This is an approach that is not widely tested on the regional scale or in a spatial manner, which this thesis sets out to do.

Societal Relevance

Globally, the project aims to improve the well-being of humans and ecosystems, by shifting the paradigm to a sustainability transformation, instead of the current, unsustainable electrification transition in North-East Hungary. This leads to the three values of the thesis, adapted from Folke (2016), which are: (1) just society, (2) development within planetary boundaries, and (3) a resilient biosphere for humanity and ecosystems. These three values also connect to the Sustainable Development Goals of the United Nations (2015).

Even though industrial electrification and the Lithium-ion supply chain are global phenomena, they have very local consequences spatially and socially. The government of Hungary disregards local communities and makes spatial decisions in a centralised, authoritarian way, without participatory processes (Czirfusz, 2022). Moreover, the chosen region of North-East Hungary is one of the most left-behind areas of the country, with issues of shrinking population and deep poverty, as well as climate vulnerability threats. The project addresses these challenges by providing a vision, and creating a spatial framework for the region towards long-term regional transformation in order to avoid future lock-ins. It is based on local characteristics offering a just, sustainable and resilient future for the area, that hopefully fosters bottom-up initiatives, and presents an alternative to the current practices, improving the life of the inhabitants of the region.

Reflection

Ethical Considerations

The project takes place in Hungary, a country with a sensitive geopolitical situation and a centralised, illiberal governance, which cannot be overlooked by the thesis. Although I have a clear stand regarding this issue that could lead to biased decisions, I strive to avoid that by looking at the project from the viewpoint of all stakeholders, considering economic viability as well as ecological and societal aspects. It is important to make informed decisions and balance values and burdens for all actors.

Since this project does not tackle a classical urbanism topic, experts in the field of battery industry-related research and spatial planning in the Hungarian context were consulted, and a data management plan was created. Throughout the project I worked with open data, which was collected and analysed ethically.

Limitations

At the beginning of the graduation process, I set out to do a complex, multiscalar project. Due to the vast size of the region and the lack of time, I ended up with staying on the regional scale for the most part of the project, partially loosing the multiscalarity, which I attempted to balance with the axonometric drawings and potentials on factory, building and sub-region scales. For the same reasons, more time, research and local participation would be needed to make truly well-informed decisions, therefore sometimes estimations were used.

Ideally, identifying territorial capitals and potentials, as well as constructing and deciding on preferred pathways should be done in a participatory, co-creative manner, by always involving different affected actors. Due to the limitations of lack of time and resources (as it was the very end of the thesis process), I was not able to realise this step. Nevertheless, to further test the approach, organising a workshop with locals would be an interesting opportunity.

Transferability

The approach towards understanding the pace and nature of change to inform design, as well as using adaptation pathways to bridge short-term needs with long-term goals are transferable for other projects. I would like to encourage future designers to use them when dealing with complex problems that need to answer both immediate and future needs, and that have multiple uncertainties and actors.

Due to the context-specific nature of the thesis, the (spatial) interventions, strategies and vision have to be reevaluated and tailor-made for other projects or regions in case they would like to use the same approach, as they are influenced by governance, culture and geographic conditions among others.

Personal Reflection: Lessons, Complexity, Roles

Starting from a personal fascination of complexity, combined with the urgency of the battery crisis in North-East Hungary, I set out to do a project based on systems-thinking and imagination, which is not common practice in Hungary.

I believe that without being able to think in complex ways, it is impossible to solve the wicked problems we face in our changing world. I wanted to experiment with a thesis where I can delve into complex problems, and have the freedom to try and fail. Finding an approach, suitable scales and presentation methods to tame the project was not an easy task. Focusing on transformability helped guiding the process, as well as connecting it to theory, which I did not have much prior experience with.

Finally, this ten-month journey made me realise the future direction I would like to take as an urbanist, focusing on advocating for flexible approaches based on complexity and uncertainties, that have the potential to stir development towards contextual and sustainable solutions.

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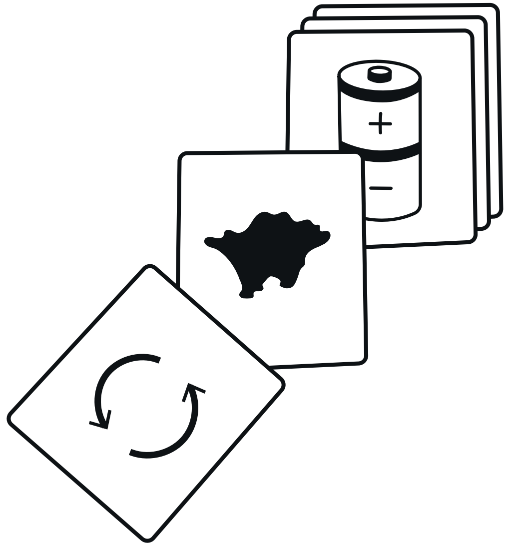

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Fig. 2.7: The cathode material manufacturing factory of EcoPro Global Hungary Zrt. in Debrecen

@own image

Fig. 2.8: The already operational battery assembly factory of Göd – Samsung SDI

@Bődey János / Telex

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Fig. 2.9: Buildup of a Lithium-ion battery cell, with the required critical raw materials, based on the JRC Foresight study (Carrara et al., 2023)

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3. PROBLEM FIELD

Fig. 3.1: The summary of the problem field: multiscalar disparities and dependencies

Icons: Donata Bologna @the Noun Project; ilCactusBlu @the Noun Project; Alexander Skowalsky @the Noun Project

Fig. 3.2: Geographical distribution of global processes of the Li-ion battery supply chain: mining, manufacturing and recycling

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Fig. 3.4: The map of European dependencies: import of critical raw materials, energy dependency and geopolitical conflicts

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Fig. 3.5: The simplified lithium-ion battery supply chain highlighting the Hungarian processes

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Fig. 3.6: The system of friend-shoring, a parallel development path

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Fig. 3.9: Uncontextual battery development - spatial disparities

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Geofabrik download server. (n.d.). https://download.geofabrik.de/europe/hungary.html

Icons: Rank Sol @the Noun Project

Fig. 3.11: Reindustrialisation of North-East Hungary: The battery triangle

Akarteis. (2025, February 21). *Térképen mutatjuk a több mint 40 akkumulátoripari üzemet Magyarországon [We show more than 40 battery industry plants in Hungary on a map]. akarteis.hu*. https://akarteis.hu/terkepen-mutatjuk-a-tobb-mint-40-akkumulatoripari-uzemet-magyarorszagon/?

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Geofabrik download server. (n.d.). https://download.geofabrik.de/europe/hungary.html

Fig. 3.12: Regional vulnerabilities

Climate vulnerability:

Kocsis, K. (Ed.). (2024). *Magyarország Nemzeti Atlasza – Természeti környezet* (2nd ed.) [National Atlas of Hungary – Natural Environment (2nd ed.)]. Budapest: HUN-REN CSFK Földrajztudományi Intézet.

Poverty:

Kolosi, T., Szelényi, I., & Tóth, I. G. (2022). Magyarország szegénységi térképe [Poverty map of Hungary]. In *Társadalmi riport 2022* (pp. 261–282). TÁRKI

Shrinking:

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Unemployment:

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For all:

Geofabrik download server. (n.d.). https://download.geofabrik.de/europe/hungary.html

Fig. 3.13: North-East Hungarian reality – battery-hotspots and the systems that serve them

4. THEORIES AND CONCEPTS

Fig. 4.1: Theoretical framework

Author's own drawing.

Fig. 4.2: The wedding cake of SDGs aligned with transformability values

Folke, C. (2016). Resilience (Republished). *Ecology and Society*, *21*(4). http://www.jstor.org/stable/26269991

The SDGs wedding cake. (2016, June 14). Stockholm Resilience Centre. https://www.stockholmresilience.org/research/research-news/2016-06-14-the-sdgs-wedding-cake.html

Icons: Richard @the Noun Project; Adrien Coquet @the Noun Project

Fig. 4.3: Cascading change between Panarchies

Gunderson, L. H., & Holling, C. S. (Eds.). (2002). *Panarchy: Understanding transformations in human and natural systems.* Island Press.

Fig. 4.4: The relation between enablers of transformability

Feliciotti, A. & Romice, O. & Porta, S. (2016). Design for Change: Five Proxies for Resilience in the Urban Form. *Open House International*. 41. 23-30. 10.1108/OHI-04-2016-B0004.

5. RESEARCH DESIGN AND METHODS

Fig. 5.1: The research approach of the thesis

Fig. 5.2: The theoretical taxonomy of territorial capital

Camagni, R. (2017). Regional competitiveness: towards a concept of territorial capital. In *Springer eBooks* (pp. 115–131). https://doi.org/10.1007/978-3-319-57807-1_6

Fig. 5.3: Territorial capital layers based on Orsi et al. (2024), with the added layers of landscape and governance

Fig. 5.4: Frequencies of change (for urban environments)

Urhahn. (2021, February 15). *Het begint met een goede straat* [It begins with a good street]. https://www.urhahn.com/goede-straat/

Fig. 5.5: Adaptation pathways map

Haasnoot, M., Kwakkel, J. H., Walker, W. E., & Ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change*, *23*(2), 485–498.

Fig. 5.6: Analytical framework

Fig. 5.7: Backcasting scheme

Fig. 5.8: Graduation timeline

6. UNDERSTANDING

Fig. 6.1: Diachronic Analysis

@ Fortepan / Gergely Ötvös [Image]. *Lenin Kohászati Művek, 1956* [The Lenin Metallurgical Works, 1956]. Retrieved from https://fortepan.hu/hu/photos

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@ István Babai. [Image]. Retrieved from: https://www.telepaks.net/2022/12/28/tercier-szabalyozas-a-paksi-atomeromuben/

@ Author's own image.

Kiss, É. (2002). *A magyar ipari térszerkezet változásai* [Changes in the spatial structure of Hungarian industry]. *Földrajzi Értesítő 2002 LI. évf. 3-4. füzet*, pp. 347-367.

Fig. 6.2: The pre-World War I. situation of industrialisation - centre and peripheries of Greater Hungary

Kiss, É. (2002). *A magyar ipari térszerkezet változásai* [Changes in the spatial structure of Hungarian industry]. *Földrajzi Értesítő 2002 LI. évf. 3-4. füzet*, pp. 347-367.

Fig. 6.3: Synthesis of the shifting industrial axes through time

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Előd, F. (2023a, February 6). *Miért ennyire fontos Orbánéknak, hogy akkumulátorgyárak országa legyünk?* [Why is it so important to Orbán and his associates that we become a country of battery factories?]. *Telex*. https://telex.hu/komplex/2023/02/06/akkumulatorgyarak-orban-god-debrecen-catl-beruhazas

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Kiss, É. (2002). *A magyar ipari térszerkezet változásai* [Changes in the spatial structure of Hungarian industry]. *Földrajzi Értesítő 2002 LI. évf. 3-4. füzet*, pp. 347-367.

Fig. 6.4: Electricity generation sources in Hungary, 2023

International Energy Agency [IEA]. (n.d.-a). *Hungary - Countries & Regions*. https://www.iea.org/countries/hungary/electricity

@ István Babai. [Image]. Retrieved from: https://www.telepaks.net/2022/12/28/tercier-szabalyozas-a-paksi-atomeromuben/

Fig. 6.5: Hungarian battery industry and the related systems

Akarteis. (2025, February 21). *Térképen mutatjuk a több mint 40 akkumulátoripari üzemet Magyarországon [We show more than 40 battery industry plants in Hungary on a map]. akarteis.hu.* https://akarteis.hu/terkepen-mutatjuk-a-tobb-mint-40-akkumulatoripari-uzemet-magyarorszagon/?

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Fig. 6.6: Path-dependencies of the battery industry

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Éltető, A. [Interview]. (2025). Expert interview with Andrea Éltető about the Hungarian battery industry development trends and scenarios. January, 2025.

Fig. 6.7: General characteristics of battery factories

Czirfusz, M. [Interview]. (2025). Expert interview with Márton Czirfusz about the Hungarian battery industry development trends and scenarios. January, 2025.

Éltető, A. [Interview]. (2025). Expert interview with Andrea Éltető about the Hungarian battery industry development trends and scenarios. January, 2025.

Fig. 6.8: The Workflow of the Understanding chapter

Fig. 6.9: From transformability to static and dynamic elements

Fig. 6.10: The different scales of the frequency of change in relation to the Territorial Capital layers

Fig. 6.11: The land use typologies of the territory (for legends and bigger maps: see appendix)

Basemap:

Google Earth. (n.d.). https://earth.google.com/web

Industry:

Czirfusz, M. (2022). *Akkumulátoripari Fellendülés Magyarországon: az Értéklánc Szereplői, Dolgozói és Szakszervezeti Perspektívák* [Battery Industry Boom in Hungary: Perspectives of Value Chain Actors, Workers, and Trade Unions]. Friedrich Ebert Stiftung. https://library.fes.de/pdf-files/bueros/budapest/19980-20230301.pdf

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Water:

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Nature:

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Agriculture:

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Settlement:

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Transportation:

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Fig. 6.12: Topography, soil types and geomorphology

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Soil Atlas of Europe - ESDAC - European Commission. (n.d.). https://esdac.jrc.ec.europa.eu/content/soil-atlas-europe

Fig. 6.13: Section of the territory

Kocsis, K. (Ed.). (2024). *Magyarország Nemzeti Atlasza – Természeti környezet* (2nd ed.) [National Atlas of Hungary – Natural Environment (2nd ed.)]. Budapest: HUN-REN CSFK Földrajztudományi Intézet.

Soil Atlas of Europe - ESDAC - European Commission. (n.d.). https://esdac.jrc.ec.europa.eu/content/soil-atlas-europe

Fig. 6.14: Surface water, groundwater, flooding and droughts

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European Environment Agency [EEA]. (2019). *EU-Hydro River Network Database 2006-2012 (vector), Europe* [Dataset]. https://land.copernicus.eu/en/products/eu-hydro/eu-hydro-river-network-database?tab=metadata

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Fig. 6.15: The hydrology of the region before regulating the system

Kocsis, K. (Ed.). (2024). *Magyarország Nemzeti Atlasza – Természeti környezet* (2nd ed.) [National Atlas of Hungary – Natural Environment (2nd ed.)]. Budapest: HUN-REN CSFK Földrajztudományi Intézet.

Fig. 6.16: The remnants of the old water system

Google Earth. (n.d.). https://earth.google.com/web

Fig. 6.17: Protected nature, vegetation and the battery factories

Czirfusz, M. (2022). *Akkumulátoripari Fellendülés Magyarországon: az Értéklánc Szereplői, Dolgozói és Szakszervezeti Perspektívák* [Battery Industry Boom in Hungary: Perspectives of Value Chain Actors, Workers, and Trade Unions]. Friedrich Ebert Stiftung. https://library.fes.de/pdf-files/bueros/budapest/19980-20230301.pdf

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Icons: Adrien Coquet @the Noun Project; Paulo Volkova @the Noun Project

Fig. 6.18: Diverse national parks and world heritage sites

(1) @ *Józse Litványi / National Geographic* [Image]. Retrieved from: Natgeo-Admin, & Natgeo-Admin. (2021, July 13). A nap képe: A Bükk-fennsík peremén | National Geographic. *National Geographic | National Geographic - Magyarország*. https://ng.24.hu/foto/a-nap-kepe/2021/08/01/a-bukk-fennsik-peremen/)

(2) @ *Székely, K. (2005)* [Image]. *Időutazás a cseppkövek birodalmában: Baradla-barlang. ANPI, Jósvafő. ISBN 963-218-486-6*

(3) @ *László Lisztes / Hortobágy National Park Directorate* [Image]. Retrieved from: UNESCO World Heritage Centre. (n.d.). *Hortobágy National Park - the Puszta*. https://whc.unesco.org/en/list/474/gallery/

(4) @ *Tibor Hanák / latnivalokmagyarorszagon.hu* [Image]. Latnivalokmagyarorszagon. (n.d.). *Tokaj | Látnivalók Magyarországon*. https://latnivalok-magyarorszagon.hu/tokaj/

Fig. 6.19: The four landscape-types

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

Geofabrik download server. (n.d.). https://download.geofabrik.de/europe/hungary.html

Fig. 6.20: Natural capital: frequency of change

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Fig. 6.21: Settlement sizes

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Fig. 6.22: The static nature of Hungarian villages and settlement form

(1) @ *Fortepan / Csaba László örökösei* [Image]. Retrieved from https://fortepan.hu/hu/photos/?q=Csaba%20L%C3%A1szl%C3%B3%20%C3%B6r%C3%B6k%C3%B6sei,%20Holl%C3%B3k%C5%91

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Fig. 6.23: Settlement identities

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Icons: Hilmy Abiyyu Asad @the Noun Project; Paulo Volkova @the Noun Project

Fig. 6.24: Four examples of the different settlement identities

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Icons: Lucas Rathgeb @the Noun Project; NeMaria @the Noun Project; Alvida @the Noun Project; Adrien Coquet @the Noun Project; Graphic Nehar @ the Noun Project

Fig. 6.25: Transformability potentials and the relation of identity and morphology

Bátorfy, A. (2023, March 8). Utak, épületek, hálózatok [Roads, buildings, networks]. *Atlo. https://atlo.team/utak-epuletek-halozatok/*

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Icons: Lucas Rathgeb @the Noun Project; NeMaria @the Noun Project

Fig. 6.26: Settlement capital: frequency of change

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Icons: Paulo Volkova @the Noun Project

Fig. 6.27: Networks of transportation: hierarchies and use

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Icons: trang5000 @the Noun Project

Fig. 6.28: The morphology of transport infrastructure in the region

(1) *MTI Fotó / László Lehotka* (K, L. (2024, November 1). *Dugó dugót ér az M3-as autópályán, és már dugul az M7-es is*. Economx.hu. https://www.economx.hu/belfold/kozlekedes-m3-m7-autopalya-torlodas.798872.html)

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(4) @ hovamegyavonat.blog.hu [Image]. Retrieved from: *Ügynök, L. (2016, June 2). Dupla nyolcas - állva, vagy fekve? Az elveszett mezőcsáti vonal nyomában. . . Hova Megy Ez a Vonat? https://hovamegyavonat.blog.hu/2016/06/02/dupla_nyolcas_allva_vagy_fekve_az_elveszett_mezocsati_vonal_nyomaban*

Fig. 6.29: Angular Integration (r = 50 km) connectivity analysis: corridors and periphery

European Environment Agency [EEA]. (2019). *EU-Hydro River Network Database 2006-2012 (vector), Europe* [Dataset]. https://land.copernicus.eu/en/products/eu-hydro/eu-hydro-river-network-database?tab=metadata

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Fig. 6.30: Energy infrastructure: electricity, oil and gas

European Environment Agency [EEA]. (2019). *EU-Hydro River Network Database 2006-2012 (vector), Europe* [Dataset]. https://land.copernicus.eu/en/products/eu-hydro/eu-hydro-river-network-database?tab=metadata

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Fig. 6.31: Tiszaújváros: the main 'node' of energy

European Environment Agency [EEA]. (2019). *EU-Hydro River Network Database 2006-2012 (vector), Europe* [Dataset]. https://land.copernicus.eu/en/products/eu-hydro/eu-hydro-river-network-database?tab=metadata

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Icons: Adrien Coquet @the Noun Project

Fig. 6.32: Morphology of energy infrastructure in the region

(1) @ own image

(2) *@ Google Earth* [Image]. Retrieved from: https://earth.google.com/

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Fig. 6.33: Geothermal energy potential

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Fig. 6.34: Solar energy potential

A napenergia kimeríthetetlen, tiszta és ingyenes. (n.d.). https://www.naplopo.hu/miert-napenergia

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Fig. 6.35: Biomass energy potential

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Fig. 6.36: Hydro energy potential

European Environment Agency [EEA]. (2019). *EU-Hydro River Network Database 2006-2012 (vector), Europe* [Dataset]. https://land.copernicus.eu/en/products/eu-hydro/eu-hydro-river-network-database?tab=metadata

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Fig. 6.37: Hydrogen energy potential

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Fig. 6.38: Infrastructural and relational capital: frequency of change

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Icons: trang5000 @the Noun Project

Fig. 6.39: Primary, secondary and tertiary sector activities in the region

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Icons: Adrien Coquet @the Noun Project; Alvida @the Noun Project

Fig. 6.40: Leading economic sectors in the region

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(2) *@ Wikipedia* [Image]. Retrieved from: Wikipedia-Autoren. (n.d.). *DateI:Matra Mining Plant.JPG – Wikipedia*. https://de.m.wikipedia.org/wiki/Datei:Matra_Mining_Plant.JPG

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Fig. 6.41: Systemic sections of the two most characteristic supply-chains: food

European Environment Agency [EEA]. (2023). *Industrial Reporting under the Industrial Emissions Directive 2010/75/EU and European Pollutant Release and Transfer Register Regulation (EC) No 166/2006* [Dataset]. Retrieved from: https://www.eea.europa.eu/en/datahub/datahubitem-view/9405f714-8015-4b5b-a63c-280b82861b3d?activeAccordion=1089405

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Icons: Akbar @the Noun Project; Alvida @the Noun Project; QualityIcons @the Noun Project; Ruben Semedo @the Noun Project; Ghost Itemku @the Noun Project; Mila Karmila @the Noun Project; Alvida @the Noun Project;

Fig. 6.42: Systemic sections of the two most characteristic supply-chains: heavy industry

European Environment Agency [EEA]. (2023). *Industrial Reporting under the Industrial Emissions Directive 2010/75/EU and European Pollutant Release and Transfer Register Regulation (EC) No 166/2006* [Dataset]. Retrieved from: https://www.eea.europa.eu/en/datahub/datahubitem-view/9405f714-8015-4b5b-a63c-280b82861b3d?activeAccordion=1089405

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Icons: Adrien Coquet @the Noun Project; Andi Nur Abdillah @the Noun Project; Akbar @the Noun Project; Sebastiaan van Veen @the Noun Project; Cho Nix @the Noun Project

Fig. 6.43: Density and diversity of functions (services, industry) in the region

European Environment Agency [EEA]. (2019). *EU-Hydro River Network Database 2006-2012 (vector), Europe* [Dataset]. https://land.copernicus.eu/en/products/eu-hydro/eu-hydro-river-network-database?tab=metadata

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Fig. 6.44: Economic capital: frequency of change (heatmap)

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Fig. 6.45: Knowledge, research and development

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Icons: Adrien Coquet @the Noun Project; Akbar @the Noun Project; Sebastiaan van Veen @the Noun Project; Rikas Dzihab @the Noun Project; Mia Elysia @the Noun Project

Fig. 6.46: Vulnerable areas of the territory

European Environment Agency [EEA]. (2019). *EU-Hydro River Network Database 2006-2012 (vector), Europe* [Dataset]. https://land.copernicus.eu/en/products/eu-hydro/eu-hydro-river-network-database?tab=metadata

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Fig. 6.47: Sociospatial disparities of the region

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Fig. 6.48: Human capital: frequency of change

Berkes, J., & Dusek, T. (2023). The socio-economic performance of the Hungarian NUTS3 regions between 2010–2020. *DETUROPE – The Central European Journal of Tourism and Regional Development, 15*, 85–108. https://doi.org/10.32725/det.2023.014

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Fig. 6.49: Scales of governance and planning

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Fig. 6.50: Stakeholder relations: onion diagram

Icons: Adrien Coquet @the Noun Project; metami septimna @the Noun Project

Fig. 6.51: Power-interest matrix, current situation

Icons: Adrien Coquet @the Noun Project; metami septimna @the Noun Project

Fig. 6.52: Map of elements of low frequencies of change in the region

European Environment Agency [EEA]. (2019). *EU-Hydro River Network Database 2006-2012 (vector), Europe* [Dataset]. https://land.copernicus.eu/en/products/eu-hydro/eu-hydro-river-network-database?tab=metadata

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Icons: Adrien Coquet @the Noun Project; Paulo Volkova @the Noun Project

Fig. 6.53: Map of elements of high frequencies of change in the region

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Icons: trang5000 @the Noun Project

Fig. 6.54: Summary of territorial transformability potentials

7. EXPLORATION

Fig. 7.1: Values, means and principles of the vision

Icons: Richard @the Noun Project; Adrien Coquet @the Noun Project

Fig. 7.2: Scenario construction: efficient and redundant cases

Fig. 7.3: Efficient scenario - simplified scheme

Fig. 7.4: Multi-scale strategies in hierarchical organisation around the main node

Fig. 7.5: The separate layers of the efficient scenario

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Icons: trang5000 @the Noun Project; Sebastiaan van Veen @the Noun Project; Rutmer Zijlstra @the Noun Project; Lucas Rathgeb @the Noun Project; Rikas Dzihab @the Noun Project; Mia Elysia @the Noun Project

Fig. 7.6: Spatial organisation of an efficient North-East Hungary

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Icons: trang5000 @the Noun Project; Sebastiaan van Veen @the Noun Project; Rutmer Zijlstra @the Noun Project; Lucas Rathgeb @the Noun Project; Rikas Dzihab @the Noun Project; Mia Elysia @the Noun Project

Fig. 7.7: Redundant scenario - simplified scheme

Fig. 7.8: Battery communities: the new way of living - abstract relations: horizontal organisation

Fig. 7.9: Landscape-based strategies and differences

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Icons: Adrien Coquet @the Noun Project; dh park @the Noun Project; Rikas Dzihab @the Noun Project; Alvida @the Noun Project; Arif Arisandi @the Noun Project; Sebastiaan van Veen @the Noun Project; Neil @the Noun Project

Fig. 7.10: The separate layers of the redundant scenario

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Icons: Adrien Coquet @the Noun Project; Sebastiaan van Veen @the Noun Project; Alvida @the Noun Project; dh park @the Noun Project; Mike Zuidgeest @the Noun Project

Fig. 7.11: Spatial organisation of a redundant North-East Hungary

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Icons: Adrien Coquet @the Noun Project; Sebastiaan van Veen @the Noun Project; Alvida @the Noun Project; dh park @the Noun Project; Mike Zuidgeest @the Noun Project

Fig. 7.12: Transformative framework - simplified scheme

Fig. 7.13: Scenario evaluation framework

Icons: Richard @the Noun Project; Adrien Coquet @the Noun Project

Fig. 7.14: The vision is a combination of strategies from the redundant and efficient scenarios

Fig. 7.15: Long-term transformative goals of the vision

Icons: Rikas Dzihab @the Noun Project; Mia Elysia @the Noun Project; Rutmer Zijlstra @the Noun Project; Merlin @the Noun Project; iconlabs @the Noun Project

Fig. 7.16: The future ecosystem of the region of combined efficient and redundant measures, based on the four landscape-types.

Fig. 7.17: The separate layers of the vision

European Environment Agency [EEA]. (2018). *CORINE Land Cover 2018 (vector), Europe, 6-yearly - version 2020_20u1, May 2020*. EEA Geospatial Data Catalogue. https://land.copernicus.eu/en/products/corine-land-cover/clc2018

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Icons: trang5000 @the Noun Project; Sebastiaan van Veen @the Noun Project; Rutmer Zijlstra @the Noun Project; Lucas Rathgeb @the Noun Project; Rikas Dzihab @the Noun Project; Mia Elysia @the Noun Project; Adrien Coquet @the Noun Project; Alvida @the Noun Project; dh park @the Noun Project; Mike Zuidgeest @the Noun Project; Leonardo Henrique Martini @the Noun Project

Fig. 7.18: The long-term transformative framework of North-East Hungary: efficient and redundant elements

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Icons: trang5000 @the Noun Project; Sebastiaan van Veen @the Noun Project; Rutmer Zijlstra @the Noun Project; Lucas Rathgeb @the Noun Project; Rikas Dzihab @the Noun Project; Mia Elysia @the Noun Project; Adrien Coquet @the Noun Project; Alvida @the Noun Project; dh park @the Noun Project; Mike Zuidgeest @the Noun Project; Leonardo Henrique Martini @the Noun Project

Fig. 7.19: Possible functions that can coexist with or exchange the battery industry

Fig. 7.20: Scheme of the changing regional economy

Fig. 7.21: Understanding transformability in the scope of the project

Icons: INA @the Noun Project

8. OPERATIONALISATION

Fig. 8.1: Explanation of the workings of the adaptation (transformation) pathways in this thesis

Fig. 8.2: From battery crisis to a transformative future

Icons: Rikas Dzihab @the Noun Project; Mia Elysia @the Noun Project; Rutmer Zijlstra @the Noun Project; Merlin @the Noun Project; iconlabs @the Noun Project; brose lealky @the Noun Project; Adrien Coquet @the Noun Project; Sebastiaan van Veen @the Noun Project

Fig. 8.3: Pathways leading to main milestones, in relation to European sustainability goals

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Icons: Rikas Dzihab @the Noun Project; Mia Elysia @the Noun Project; Rutmer Zijlstra @the Noun Project; Merlin @the Noun Project; iconlabs @the Noun Project; brose lealky @the Noun Project; Adrien Coquet @the Noun Project; Sebastiaan van Veen @the Noun Project

Fig. 8.4: Parallel pathways: variables and base steps

Fig. 8.5: The sequence of setting variables and choosing solutions

Fig. 8.6: The spatial translation of adaptation pathways

Fig. 8.7: Engagement strategy

Icons: Rikas Dzihab @the Noun Project; I Putu Dicky Adi Pranatha @the Noun Project; Hadi Mulyono @the Noun Project

Fig. 8.8: Possible process of the engagement

Fig. 8.9: The new framework of governance

Varjú, V. [Interview]. (2025). Expert interview with Viktor Varjú about the Hungarian spatial planning system. March, 2025.

Fig. 810: Natural-cultural landscape formations as the base of future governance

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Fig. 8.11: Possible pathways based on different production, ownership patterns and stakeholders

Fig. 8.12: The base photo for the postcards: EcoPro factory now

@ Author's own image.

Fig. 8.13: Pathways in case of an export-oriented approach

Fig. 8.14: Postcard from an export-oriented near-future

Fig. 8.15: Pathways in case of a community-oriented approach

Fig. 8.16: Postcard from a community-oriented near-future

Fig. 8.17: Pathways in case of no battery production in the near-future

Fig. 8.18: Postcard from a near-future without battery production

Fig. 8.19: Pathways in case of balanced export and domestic battery production

Fig. 8.20: Postcard from a near-future with balanced export and domestic battery production

Fig. 8.21: The four postcards

9. REFLECTION

Fig. 9.1: collection of articles about the battery industry and economy throughout the past 10 months

@ Telex.hu [images and articles]

APPENDIX

Appendix 1

Battery Industry in Hungary - Data

	BATTERY INDUSTRY-RELATED FACILITIES IN HUNGARY	COUNTRY OF ORIGIN	LAT	LON	REGION	CITY	MAIN SECTOR	PRECISE ACTIVITY	STAGE OF REALISATION	WORKPLACES CREATED	GOVERNMENT FUNDING (Million €)	VALUE OF INVESTMENT (Million €)	YEAR of production
1	Amphenol Sincere Industrial Product Kft.	China	46.06402	18.13474	Southern Transdanubia	Cserkút	Other components	components	active	160 employees in 2023	0	?	2019
2	Andrada Group Kft.	Slovenia	47.40656	18.8239	Pest	Sóskút	Recycling	battery recycling	active	160	17 million €	33 million €	2024
3	Audi Hungaria Zrt.	Germany	47.69994	17.68012	Western Transdanubia	Győr	EV	electric car	active, transformation	500	19,4 million €	400 million €	2023
4	BMW Manufacturing Hungary Kft.	Germany	47.56759	21.52513	Northern Great Plain	Debrecen	EV	electric car	in construction	1500	65,3 million €	2000 million €	2025
5	Boysen Battery Components Hungary Kft.	Germany	47.8920127	21.7340979	Northern Great Plain	Nyíregyháza	Other components	metal cover-plate	in construction	400	13,86 million €	150 million €	2025
6	Bumchun Precision Hungary Kft.	South Korea	48.044136	19.791403	Northern Hungary	Salgótarján	Other components	battery component	active	600	7,4 million €	97 million €	2020
7	BYD Electric Bus & Truck Hungary Kft.	China	47.74526	18.08266	Central Transdanubia	Komárom	EV	electric bus and truck	active	300	3 million €	20 million €	2017
8	BYD Szeged	China	46.28693	20.09315	Southern Great Plain	Szeged	EV	electric bus and truck	planned	10000	?	5000 million €	2025
9	CATL	China	47.4679375	21.623437	Northern Great Plain	Debrecen	Cell manufacturer	battery cell	in construction	9000	800 million €	7340 million €	2025
10	CK EM Solution HUN Kft	South Korea	47.6046621	20.2980585	Northern Hungary	Heves	Sub-component manufacturing	adhesive	active	8	1 million €	10 million €	2024
11	Dana Hungary Kft.	USA	47.6970193	17.6785784	Western Transdanubia	Győr	Other components	EV components	active	1300	?	89 million €	2019
12	Dongwha Electrolyte	South Korea	47.3831604	18.8292237	Pest	Sóskút	Sub-component manufacturing	electrolyte, solvent recycling	active	90	0	32 million €	2022
13	EcoPro Global Hungary Zrt.	South Korea	47.4789148	21.6193782	Northern Great Plain	Debrecen	Sub-component manufacturing	cathode material	active	631	0	725 million €	2025
14	Enchem Hungary Kft.	South Korea	47.74061	18.07122	Central Transdanubia	Komárom	Sub-component manufacturing	electrolyte, solvent recycling	active	7 (average from 2023)	1.8 million €	23 million €	2023
15	EVE Power Hungary Kft.	China	47.5782942	21.5109138	Northern Great Plain	Debrecen	Cell manufacturer	battery cell	in construction	1000	?	1000 million €	2026
16	GS Yuasa Magyarország Kft.	Japan	48.0538981	20.811065	Northern Hungary	Miskolc	Cell manufacturer	battery cell	active	51	2,2 million €	29 million €	2019
17	Halms Hungary Kft.	China	47.4849371	21.6283193	Northern Great Plain	Debrecen	Other components	battery component	active	300	4,2 million €	43 million €	2022
18	Hangke Technology Hungary Kft.	China	?	?	?	?	Other components	Battery production machinery	planned	0	0	?	?
19	Iljin Materials	South Korea	47.60851	19.33118	Pest	Gödöllő	Other components	Elecfoil	planned	?	1.8 million €	10,7 million €	2024
20	INZI CONTROLS HUNGARY Kft	South Korea	47.7447793	18.0864242	Central Transdanubia	Komárom	Other components	battery component	active	122	4,7 million €	45 million €	2020
21	JWH Kft. (Jaewon)	South Korea	47.7373415	18.0674828	Central Transdanubia	Komárom	Recycling	additives recycler	active	41	?	16 million €	2017
22	Kedali Hungary Kft.	China	47.6101962	19.3306422	Pest	Gödöllő	Other components	battery component	active	330	3,2 million €	40 million €	2024
23	LOTTE ALUMINIUM Hungary Kft.	South Korea	47.5847833	18.3395612	Central Transdanubia	Tatabánya	Sub-component manufacturing	aluminium foil	active	107	3 million €	133 million €	2022
24	Magyar Suzuki Zrt.	Japan	47.76857	18.74707	Central Transdanubia	Esztergom	EV	electric car	no EV yet	-	0	-	after 2025
25	Mektec Manufacturing Corporation Europe HU Kft.	Japan	47.4902745	19.3197346	Pest	Pécel	Other components	battery component	active	251	1,8 million €	21 million €	2020
26	Mercedes-Benz Manufacturing Hungary Kft.	Germany	46.86803	19.71451	Southern Great Plain	Kecskemét	EV	electric car	active, transformation	2500	31 million €	1000 million €	2021
27	NICE LMS	South Korea	47.7626301	19.1518546	Pest	Vác	Other components	aluminium battery casing	active	60	1,2 million €	144 million €	2023
28	NIO Power Manufacturing Technology Center	China	47.4757068	18.86791	Pest	Biatorbágy	Recycling	battery cell exchange stations	active	several 100	4,2 million €	15 million €	2022
29	Nippon Paper Industry	Japan	47.7350206	19.2127545	Pest	Vácrátót	Other components	carboxymethyl cellulose	active	60	5,7 million €	40 million €	2024
30	Opel Magyarország (Stellantis Szentgotthárd Kft.)	Germany	46.96253	16.28149	Western Transdanubia	Szentgotthárd	EV	electric car	no EV yet	-	0	-	-
31	SAMSUNG SDI Magyarország Zrt.	South Korea	47.6767387	19.1674948	Pest	Göd	Cell manufacturer	battery cell	active	1800	126 million €	1200 million €	2018
32	Sang-A Frontec EU Kft.	South Korea	47.6140858	19.3084961	Pest	Szada	Other components	battery component	active	55	3,5 million €	25 million €	2023
33	Sangsin Hungary Kft.	South Korea	47.5005884	19.8715688	Northern Great Plain	Jászberény	Other components	aluminium battery casing	active	150	8,6 million €	28 million €	2018
34	Semcorp Hungary Kft.	China	47.4737892	21.6209389	Northern Great Plain	Debrecen	Sub-component manufacturing	separator foil	active	440	32,2 million €	183 million €	2023
35	ShinHeung SEC EU Kft.	South Korea	47.3518991	19.4228462	Pest	Monor	Other components	battery component	active	435	2,3 million €	24 million €	2017
36	SK Battery Manufacturing	South Korea	47.7393908	18.0680191	Central Transdanubia	Komárom	Cell manufacturer	battery cell	active	410	102,6 million €	313 million €	2020
37	SK ON Hungary Kft.	South Korea	47.1417083	18.8107456	Central Transdanubia	Iváncsa	Cell manufacturer	battery cell	active	2500	190,9 million €	1623 million €	2023
38	SK ON Hungary Kft.	South Korea	47.73884	18.06437	Central Transdanubia	Komárom	Cell manufacturer	battery cell	active	1000		756 million €	2022
39	Soulbrain HU	South Korea	47.5796167	18.34426	Central Transdanubia	Tatabánya	Sub-component manufacturing	electrolyte	active	45	1 million €	22 million €	2021
40	SungEel HiTech Hungary Kft.	South Korea	47.9959489	19.8194645	Northern Hungary	Bátonyterenye	Recycling	battery waste recycler	active	100	7 million €	26 million €	2019
41	SungEel HiTech Hungary Kft.	South Korea	47.32945	19.01898	Pest	Szigetszentmiklós	Recycling	battery waste recycler	active	50		5 million €	2019
42	Sunwoda (Hungary Sunwoda Automotive Energy Technology Kft.)	China	47.8954959	21.7380934	Northern Great Plain	Nyíregyháza	Cell manufacturer	battery cell	in construction	1000	?	1500 million €	2025
43	Toray Industries Hungary Kft.	Japan	47.7617648	18.5808202	Central Transdanubia	Nyergesújfalu	Sub-component manufacturing	separator foil	active	188	12,2 million €	408 million €	2021
44	ToyoInk Hungary Kft.	Japan	47.221346	19.4117295	Pest	Újhartyán	Sub-component manufacturing	CNT dispersion (cathode)	active	45	1,7 million €	14 million €	2022
45	Volta Energy Solutions Hungary Kft.	South Korea	47.5895487	18.3410847	Central Transdanubia	Tatabánya	Sub-component manufacturing	copper foil	active	281	35,8 million €	300 million €	2021
46	W-Scope Hungary Plant Kft.	South Korea	47.8817385	21.7520581	Northern Great Plain	Nyíregyháza	Sub-component manufacturing	separator foil	active	1200	?	720 million €	2025
47	Xinzhi	China	47.67181	19.64499	Northern Great Plain	Hatvan	Other components	components for EV motors	announced	900	?	121-133 million €	after 2025
48	Zhejiang Huayou Cobalt (Bamo Technology Hungary Kft.)	China	47.6775242	17.9632907	Central Transdanubia	Ács	Sub-component manufacturing	cathode material	active	900	0	1278 million €	2026
49	Zhejiang Shuanghuan	China	47.57155	19.72348	Northern Great Plain	Jászfényszaru	Other components	EV parts: gears and shafts	planned	450	18 million €	103 million €	2026
50	Zhenyu Technológia Magyarország Kft.	China	47.47987	21.62383	Northern Great Plain	Debrecen	Other components	EV components	planned	?	?	59 million €	2027

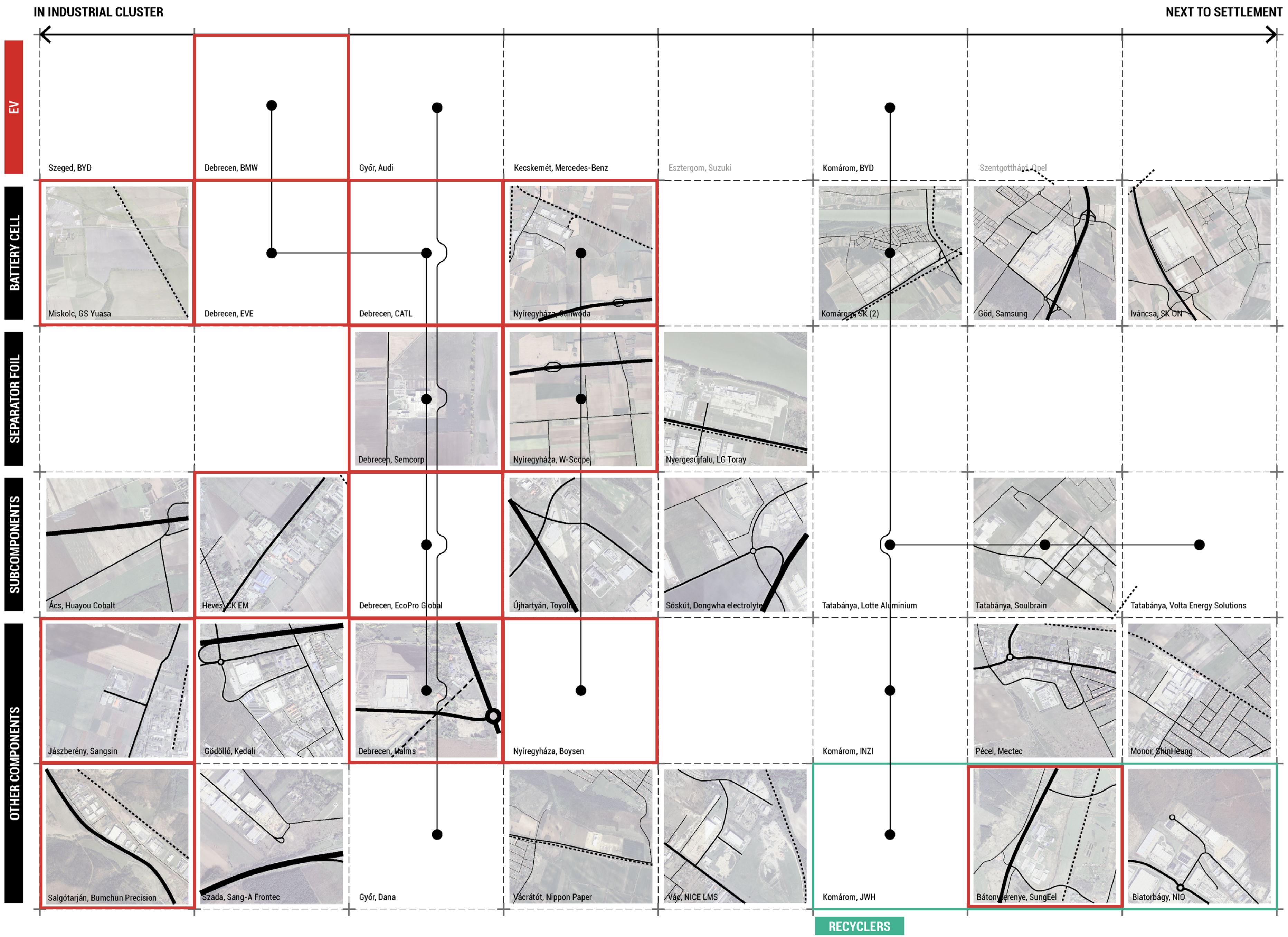
	ILLEGAL BATTERY-WASTE DUMPSITES		LAT	LON	REGION	CITY	MAIN SECTOR	PRECISE ACTIVITY
1	Mocsa	-	47.66913	18.18244	Central Transdanubia	Mocsa	End of life	Illegal battery-waste dumpsite
2	Sárbogárd	-	46.8791	18.62133	Central Transdanubia	Sárbogárd	End of life	Illegal battery-waste dumpsite
3	Mohora	-	47.99383	19.34062	Northern Hungary	Mohora	End of life	Illegal battery-waste dumpsite
4	Salgótarján	-	48.03431	19.80831	Northern Hungary	Salgótarján	End of life	Illegal battery-waste dumpsite
5	Abasár	-	47.7989	20.00367	Northern Hungary	Abasár	End of life	Illegal battery-waste dumpsite
6	Iklad	-	47.66282	19.44218	Pest	Iklad	End of life	Illegal battery-waste dumpsite

Spreadsheet compiled by the author.

sources: Akarteis (2025); Czirfusz (2022); Czirfusz (2024); Éltető (2024)

Appendix 1

Battery Matrix



Factories in North-East Hungary

roads

rail

Battery matrix - different factory sites with connected infrastructure

source: author; Google Earth (satellite images)

Appendix 2

Elements of Industry

Battery Industry

The battery industry forms the Miskolc - Debrecen - Nyíregyháza reindustrialised triangle, while there are smaller clusters around Slagótarján with the SungEel recycling company and around Jászberény with smaller sub-component producers.

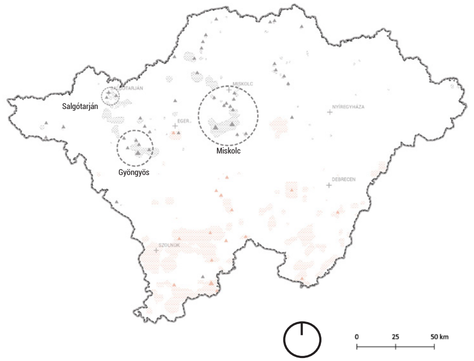
● active / ○ planned or being built

- EV Electric vehicles
- C Cell manufacturers
- S Sub-component manufacturers
- O Other components
- R Recycling companies
- Value chain connections

Chemicals and Metals

The biggest industrial cluster of chemicals and metals is around Miskolc. Tiszaújváros is an important chemical node, while there is a bigger concentration of factories around Debrecen as well.

- Chemical industry - main
- Chemical industry
- Metals - main
- Metals



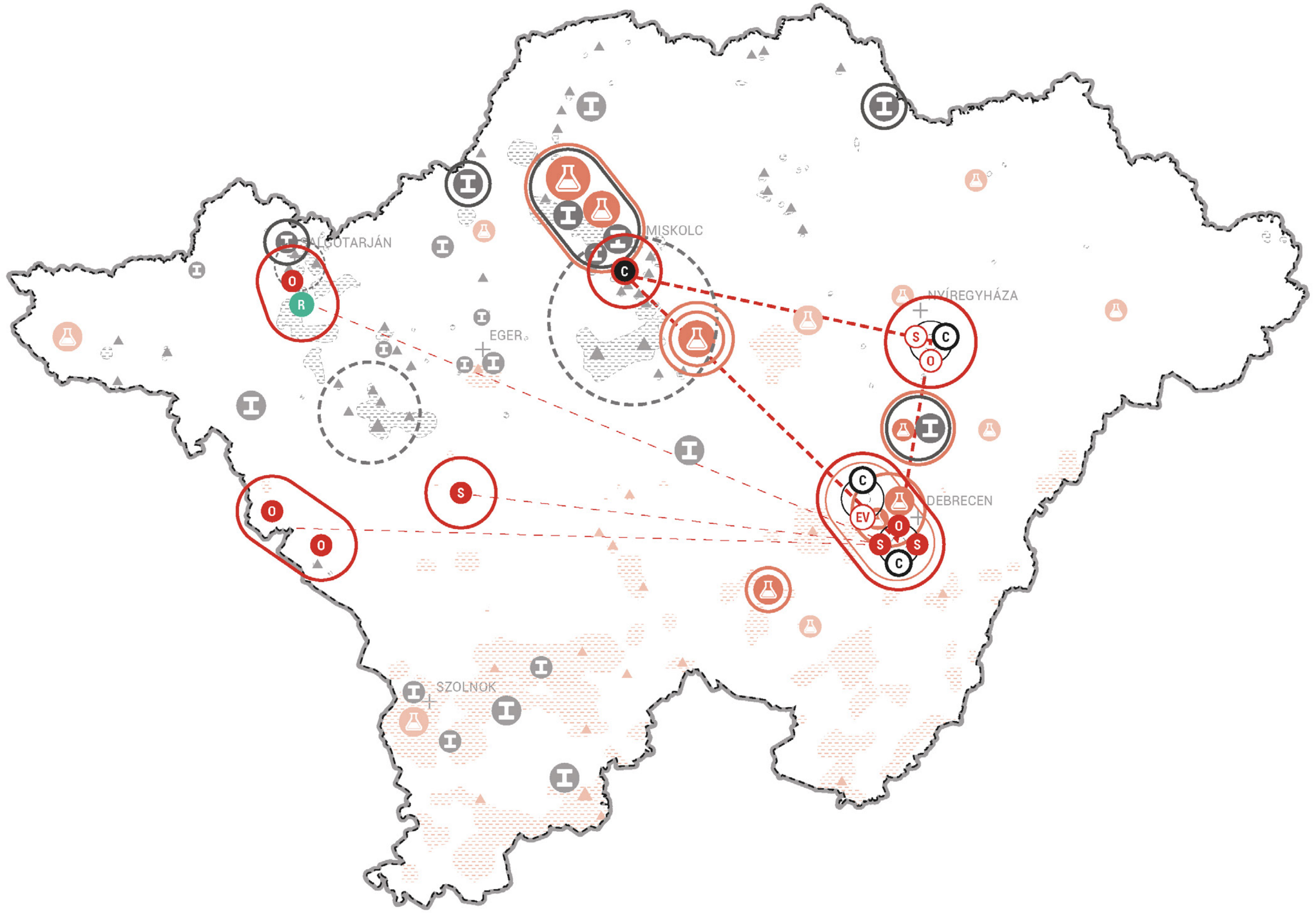
Mining and Minerals

Traditionally, the Northern mountain range has a history of lignite and coal mining, with bigger extraction sites concentrated around Miskolc, Gyöngyös and Sátoraljaújhely. On the other hand, there is natural gas and oil extraction in Southern, flat areas.

- Mineral extraction
- Mineral mines
- Natural oil and gas extraction
- Natural oil and gas fields
- Bigger clusters

Elements of industry by layers (left) and combined (right)
(data based on Czirfusz, 2022; EEA, 2023; Előd, 2023a; Geofabrik, n.d.; TEIR, n.d.)

source: author

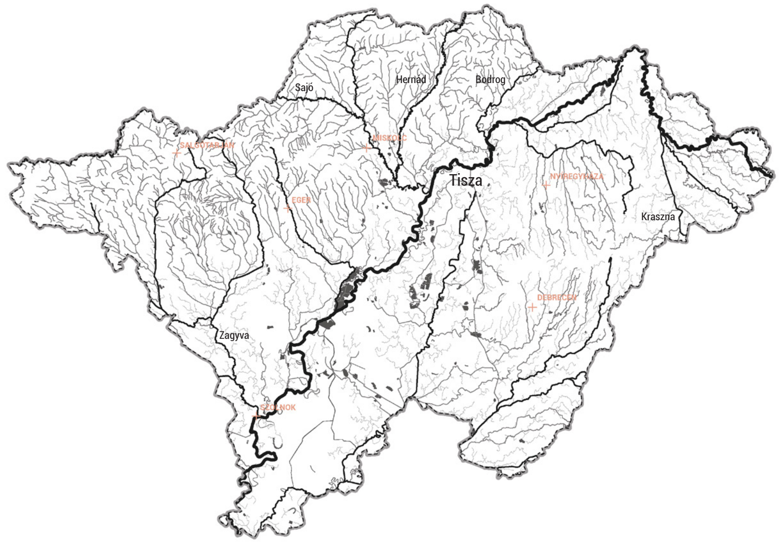


Elements of Industry
This map synthesises the main layers of predominant industries in the area, highlighting the main clusters. An important conclusion is that the battery-triangle encompasses main hotspots of other industrial clusters too, making future symbiosis a possibility.

0 25 50 km

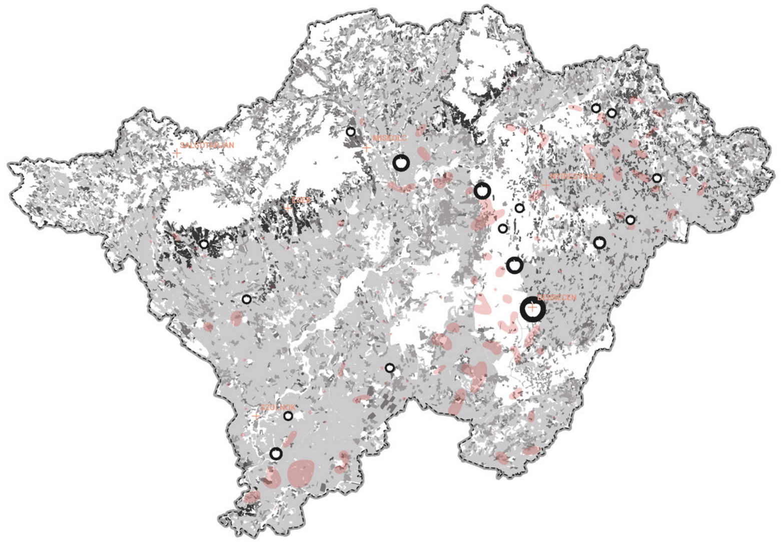
Appendix 2

Elements of Territory



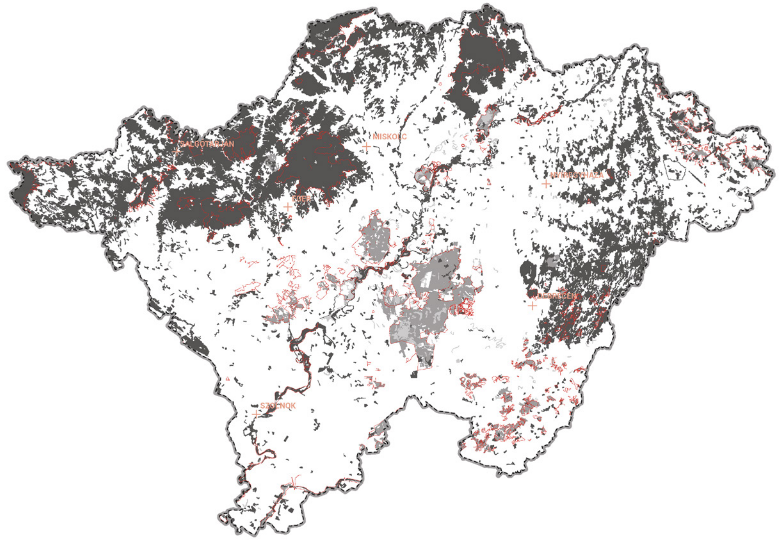
Water

- rivers
- smaller streams
- creeks
- waterbodies



Agriculture

- intensive agriculture
- food and beverage sector
- vineyards
- fruit trees and berries
- complex cultivation patterns, ricefields, agriculture with nature
- pastures
- non-irrigated arable land



Nature

- protected areas
- forests
- natural grasslands
- wetlands

0 25 50 km

Elements of territory: water, nature, agriculture, settlement

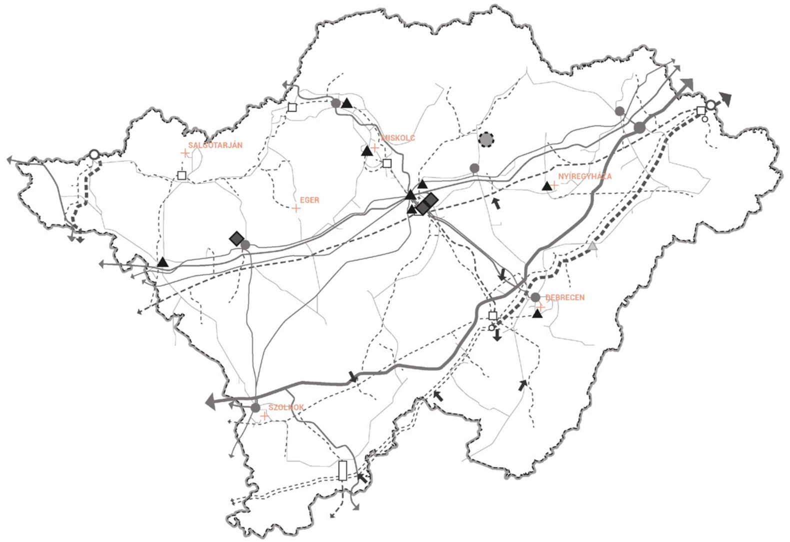
source: author

Settlement

- continuous and discontinuous urban fabric
- big cities
- settlement administrative borders

Appendix 2

Elements of Territory



Infrastructure

Energy

- coal plant
- hydropower plant (planned)
- 750 kv power-line
- 400 kv power-line
- 220 kv power-line
- electricity substations
- oil / gas plant
- >1000 D gas pipeline
- 600<D<800 gas pipeline
- 300<D<500 gas pipeline
- gas nodes
- domestic production entry point

Infrastructure

Transportation

- airports
- highways
- main roads
- small roads
- train tracks
- train stations
- train stops

0 25 50 km

Elements of territory:
transportation and energy

source: author

Appendix 3
Social capital - stakeholder analysis

The chart on the right summarises the most important stakeholders in relation to the region (North-East Hungary) and the industrial electrification process. They are sorted into three sectors: public, private and civic. To understand their motives and roles, I identified their interests, problem perception, goals, resources and dependency to the strategy, and then stated whether they are critical to the project. With red I highlighted the underlying interests and goals. It is important to note that Hungary has a highly centralised, illiberal government structure, so one always have to be mindful of the lack of transparency and miscommunication that often occurs. By stating underlying interests, I tried to show these disparities. The resources are represented by Bourdieu's capitals (economic, cultural, symbolic, social) (Harvey et al., 2008).

	ACTORS	INTEREST	PROBLEM PERCEPTION	GOALS	RESOURCES	DEPENDENCY	CRITICAL?
PUBLIC	**European Union**	Regulating battery-related developments	Fear of falling behind in electrification transition *(+ HU relations with China)*	Independent European battery supply chain	Economic, Cultural, Symbolic	high	X
PUBLIC	**National Government**	Becoming a battery 'middle-power' in Europe	Social tension - otherwise it is an opportunity	Executing economic vision: battery-manufacturing lead	Economic, Cultural, Symbolic, Social	low	X
PUBLIC	**Ministries** ***(Technology and Industry, Energy)***	Executing the vision of the government	Not enough Research and Development, lack of energy to power factories	Innovation, finding new sources of energy (nuclear)	Economic, Cultural, Symbolic	mid	
PUBLIC	**HIPA**	Providing (fake) proof that Hungary benefits from the transition	There is a gap between the industry and locals that is not addressed by the government	Connecting battery-related industry with local actors	Symbolic	mid	
PUBLIC	**Counties**	Executing the vision of the government	No real power, local problems and pollution	Gaining fiscal stability (from local business tax)	Economic, Cultural, Symbolic	mid	(x)
PUBLIC	**Municipalities**	Local prosperity, representing the view of the citizens	No gain from factories, liveability of settlements is decreasing, citizen protests	Gaining fiscal profit from presence of industry, territorial preservation	Economic, Cultural, Symbolic	high	X
PUBLIC	**National Parks**	Preserving protected nature	Industry is polluting nature: water, air and soil	More strict environmental regulations for the factories, buffers	Cultural	low	
PRIVATE	**Battery industry** *(China, South-Korea, Japan)*	Staying close to the European market, friend-shoring, cheap labour and loose regulations	EU is pushing for independent market, regulations	Being able to sell batteries to European buyers, profit	Economic	high	X
PRIVATE	**Car industry**	Keeping leading position in Europe, mitigating crisis	Not being able to compete with cheap Chinese EV import, no buyers	Transforming factories to manufacture electric vehicles, finding cheaper methods	Economic, Symbolic	mid	(x)
PRIVATE	**Energy and electricity providers**	Finding new energy sources, providing electricity to all sectors and inhabitants	Battery factories need a lot of electricity, which Hungary does not have	Building Paks II nuclear power plant, finding ways to provide enough energy	Economic, Symbolic	high	(x)
PRIVATE	**Waste management companies**	Recycling, storage of hazardous materials	Loose regulations about hazardous waste storage, leaks and pollution	Safer storage of hazardous waste materials, joining the battery recycling industry	Economic	mid	(x)
PRIVATE	**Chemical industry**	Potential to work together with battery industry	Shrinking market, not enough profit and innovation	Joining the battery supply chain to prosper again	Economic, Cultural	mid	
PRIVATE	**Transport companies** ***(train, road)***	Improving infrastructure in the country	The current road- and train infrastructure does not have enough capacity	Better road and train connections for battery transport	Economic	mid	(x)
PRIVATE	**Local car-related businesses**	Keeping up with the electrification transition	Shrinking market, outdated component manufacturing, not ready for transition	Keeping existing business with the big car manufacturers, transforming to EV-parts	Economic	low	
CIVIC	**Independent media**	Truthfully informing people about the ongoing transition	Misinformation and lack of transparency from governmental platforms	Shedding light on causes, effects and consequences of battery manufacturing	Cultural, Symbolic	mid	(x)
CIVIC	**Environmental protection groups, NGOs**	Protecting and preserving natural areas	Pollution from battery industry (water, air and soil) leads to ecological degradation and habitat loss	Advocating for strict environmental regulations concerning battery manufacturing	Cultural, Social	mid	(x)
CIVIC	**Charity organisations**	Representing the most vulnerable groups affected by the transition	Battery manufacturing reduces the liveability of the most vulnerable even more	Providing safety net for most vulnerable communities affected by transition	Cultural, Social	low	
CIVIC	**Church**	none	none	none	Symbolic, Social	low	
CIVIC	**Roma ethnic groups**	Liveability getting worse	Pollution and spatial claims of the industry, unemployment	Meeting daily needs	Social	mid	X
CIVIC	**(Affected) Citizens**	Better spatial development of factories, participation	Placement of factories disregard local conditions, pollution, liveability	Having a say in decision-making, more regulations	Social	high	X
CIVIC	**Non-humans**	Habitat, ecosystem preservation in the region	Pollution from battery industry (water, air and soil) leads to ecological degradation	Protecting habitats, stricter environmental regulations around battery factories	Social	mid	(x)
CIVIC	**Migrant workers**	Improving working conditions	Health risk in factories, cultural differences from Hungarians	Better liveability, local safety net	—	mid	(x)
CIVIC	**Academia** ***(universities, technical colleges)***	Innovation, collaborating with industries to do Research and Development	Only manufacturing factories in Hungary, no R+D	Transparency, who could join R+D projects and collaborate with the industry	Cultural, Symbolic, Social	high	X

Capitals:
- ● Economic
- ○ Cultural
- Symbolic
- Social

Identifying stakeholders

source: author

Appendix 3

Social capital - stakeholder analysis

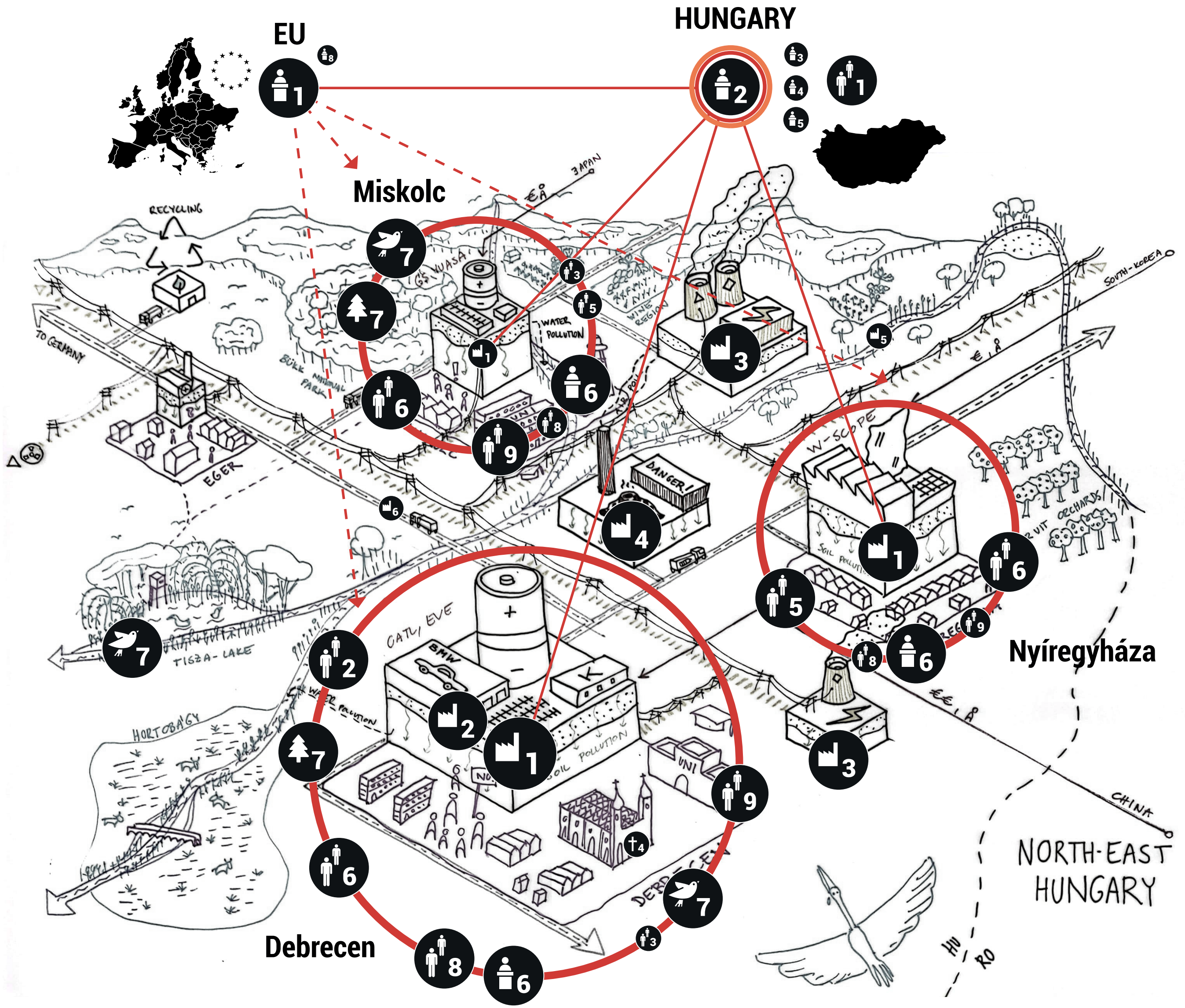
Stakeholder Spatial Relations

As the last step of the stakeholder analysis, the actors are connected to the spatial realm, depicted using an abstract axonometry of the region. They cluster around the three main cities, Debrecen, Nyíregyháza and Miskolc, as well as the related battery-manufacturing facilities in the centre, with infrastructural, energy and natural networks in-between. Hungary and the European Union are shown above the region, emphasizing again the influence of the government and the possible effect of the involvement of the European Union.

PUBLIC
- European Union
- Hungarian National Government
- Ministries
  (Ministry of Technology and Innovation, Energy)
- HIPA (Hungarian Investment Promotion Agency)
- Counties of North-East Hungary
- Settlements of North-East Hungary
- National Parks (Aggtelek, Hortobágy, Bükk)
- European Battery Association

PRIVATE
- Battery industry (CATL, EVE Power)
- Car industry (BMW)
- Energy and electricity providers (MVM, MOL)
- Waste management companies (MOHU)
- Chemical industry (e.g. BorsodChem)
- Transport companies (MÁV, Magyar Közút)
  (train, road)

CIVIC
- Independent media
- Environmental protection groups, NGOs
- Charity organisations (e.g. Hungarian Red Cross)
- Church (catholic, reformat)
- Roma ethnic groups
- (Affected) Citizens
- Non-humans
- Migrant workers
- Academia (University of Debrecen, Miskolc)
  (universities, technical colleges)



Abstract spatial relations of the stakeholders in the region

source: author

Appendix 4

Data Management Plan

Plan Overview

A Data Management Plan created using DMPonline

Title: BK Master Thesis - Towards a Transformative Battery Territory

Creator: Fruzsina Kovács

Contributor: Alexander Wandl

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2025)

Project abstract:

This research investigates the relation of the battery manufacturing industry and spatial territorial development in North-East Hungary, with a special focus on achieving future transformability and flexibility with regional design.

The study addresses the lack of spatial and social context regarding this ongoing “sustainability transition” towards carbon-free industrial processes in Hungary that is represented by the rapid expansion of battery manufacturing facilities, and proposes a paradigm shift towards sustainability transformation. Based on this theoretical stand, the study aims to explore the future relationship of the battery industry and territorial development by understanding, testing and operationalising transformability based on the degree of flexibility and regional characteristics.

Expert interviews will be conducted to gather reliable and up-to-date data to understand the underlying relationships, trends, and possibilities of battery manufacturing and the region, as this is a relatively new and still evolving subject. Audio recordings will be made during the interviews, which will be stored on the TU Delft OneDrive (and will be destroyed at the end of the project), then are manually transcribed, and the aggregated pseudonymised data will be part of the body of the Master Thesis, which is made available in the TU Delft Education repository after the completion of the project (27. 06. 2025.).

The interview participants are experts on the relation of battery manufacturing industry and territorial development in Hungary. All were contacted through recommendations from the academic network of the Responsible Researcher.

The ultimate goal of the interviews is to understand further the main effect of the rapid development of battery manufacturing on the Hungarian spatial (and social) fabric and to see what are the feasible future pathways to integrate this industry on a regional scale, with an emphasis on flexibility and transformability.

ID: 166866

Start date: 02-09-2024

End date: 27-06-2025

Last modified: 29-01-2025

BK Master Thesis - Towards a Transformative Battery Territory

0. Adminstrative questions

1. Provide the name of the data management support staff consulted during the preparation of this plan and the date of consultation. Please also mention if you consulted any other support staff.

The DMP has been shared with my supervisors Alexander Wandl and Francesca Rizzetto via DMPonline, and the data and DMP for this project has been discused on 03. 01. 2025. (before the feedback of the data steward) and 14. 01. 2025. (after the feedback of the data steward) with them.

Janine Strandberg, Data Steward at the Faculty of Architecture & the Built Environment, has reviewed this DMP on 10. 01. 2025.

2. Is TU Delft the lead institution for this project?

- Yes, the only institution involved

I. Data/code description and collection or re-use

3. Provide a general description of the types of data/code you will be working with, including any re-used data/code.

Type of data/code	File format(s)	How will data/code be collected/generated? *For re-used data/code: what are the sources and terms of use?*	Purpose of processing	Storage location	Who will have access to the data/code?
Personally Identifiable Information (PII): participants' names, email adresses, name of institution	.xlsx	Contact information for participants taking part in interviews, received through project mentor (professional network). Informed consent forms are signed digitally and contain participants' name + email + name of institution.	For administrative purposes: obtaining informed consent and communicating with participants.	TU Delft OneDrive	Fruzsina Kovács (master student) + supervisors: Alexander Wandl and Francesca Rizzetto
Expertise (PIRD)	.xlsx	The expertise of the participants taking part in interviews is asked during the interview process.	To be able to see the relation between the research questions and the field of expertise of the interviewee.	TU Delft OneDrive	Fruzsina Kovács (master student) + supervisors: Alexander Wandl and Francesca Rizzetto
Audio-recordings of interviews with experts (PIRD)	.mp3	Interviews are conducted during online expert meetings. Audio-recordings are made on an external device, before being moved to TU Delft OneDrive. Recordings are deleted after transcription.	Capturing the opinions on the relation of battery manufacturing industry and territorial development in Hungary from participants who are experts on this topic.	External recording device (temporary storage) + TU Delft OneDrive (primary storage)	Fruzsina Kovács (master student) + supervisors: Alexander Wandl and Francesca Rizzetto
Informed consent forms	.pdf	Informed consent forms signed digitally.	To obtain and document informed consent.	TU Delft OneDrive	Fruzsina Kovács (master student) + supervisors: Alexander Wandl and Francesca Rizzetto
Pseudonymous transcriptions of interviews	.txt .pdf	Pseudonymised transcriptions created manually based on audio-recordings. Participants are asked to review the transcriptions of their interview before the transcript is finalised, which is also made clear in a separate point in the consent form.	Privacy-preserving data on the relation of battery manufacturing industry and territorial development in Hungary from participants who are experts on this topic.	TU Delft OneDrive	Fruzsina Kovács (master student) + supervisors: Alexander Wandl and Francesca Rizzetto
Pseudonymous data on opinion on the relation of battery manufacturing industry and territorial development in Hungary (PIRD)	.csv	Data obtained from pseudonymised transcriptions.	Privacy-preserving data on the relation of battery manufacturing industry and territorial development in Hungary from participants who are experts on this topic.	TU Delft OneDrive	Fruzsina Kovács (master student) + supervisors: Alexander Wandl and Francesca Rizzetto
Master Thesis	.pdf	Serves as record of the process as well as documentation.	Long-term documentation	TU Delft OneDrive	Fruzsina Kovács (master student) + supervisors: Alexander Wandl and Francesca Rizzetto

II. Storage and backup during the research process

4. How much data/code storage will you require during the project lifetime?

- 250 GB – 5 TB

Appendix 4
Data Management Plan

5. Where will the data/code be stored and backed-up during the project lifetime? (Select all that apply.)

- Another storage system – please explain below, including provided security measures
- TU Delft OneDrive

OneDrive: Primary research data storage. Only TU Delft team members (Master student and supervisors) have access. Survey and interview data will be stored in separate folders, and within the interview folder, there are separate folders for audio-recordings and transcripts. Informed consent forms and contact information are encrypted separately from research data to minimise risk of re-identification.

External recording device: Used as a temporary storage location for recorded online interviews. Interviews will be deleted from device as soon as they are moved to OneDrive.

III. Data/code documentation

6. What documentation will accompany data/code? (Select all that apply.)

- Data – Methodology of data collection

The dataset will not be shared in a data repository, but the methodology of data collection will be explained in the MSc thesis, which is made available in the TU Delft Education repository.

IV. Legal and ethical requirements, code of conducts

7. Does your research involve human subjects or third-party datasets collected from human participants?

If you are working with a human subject(s), you will need to obtain the HREC approval for your research project.

- Yes – please provide details in the additional information box below

I intend to apply for ethical approval from the Human Research Ethics Committee, but have not yet done so. As a student, I am the Corresponding Researcher, but my supervisor is the Responsible Researcher for the HREC application.

8. Will you work with personal data? (This is information about an identified or identifiable natural person, either for research or project administration purposes.)

- Yes

The research data collected in the project will be pseudonymised, but processing of personal data is required for conducting the research project.

9. Will you work with any other types of confidential or classified data or code as listed below? (Select all that apply and provide additional details below.)

If you are not sure which option to select, ask yourFaculty Data Steward for advice.

- No, I will not work with any other types of confidential or classified data/code

10. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of yourFaculty Contract Manager when answering this question

This is an internal TUD MSc thesis project.
The student conducts the research independently, and is the owner of the interview. The pseudonymised, transcribed data from the interviews will be part of the body of the Master Thesis, which is made publicly available in the TU Delft Education repository after the completion of the project (27. 06. 2025.).

11. Which personal data or data from human participants do you work with? (Select all that apply.)

- Telephone number, email addresses and/or other addresses as contact details for administrative purposes
- Proof of consent (such as signed consent materials which contain name and signature)
- Other types of personal data or other data from human participants – please provide details below
- Audio recordings
- Names as contact details for administrative purposes

Personally Identifiable Information (PII): interviewee name, name of the institution, and email address are processed for administrative reasons (to obtain informed consent and communicate with participants).
Personally Identifiable Research Data (PIRD): Personal research data processed for interview participants:

- audio-recordings
- professional opinion on the relation of battery manufacturing industry and territorial development in Hungary
- expertise

Participant data for interviewees is anonymised when recordings are transcribed.

12. Please list the categories of data subjects and their geographical location.

Interview participants are experts on the topic of the relation of the battery manufacturing industry and territorial development in the country of Hungary.

13. Will you be receiving personal data from or transferring personal data to third parties (groups of individuals or organisations)?

- No

16. What are the legal grounds for personal data processing?

- Informed consent

The HREC informed consent guide and template will be used to create the informed consent forms for the interviewees (template 1 (participant information) - and template 2 (Explicit Consent points) in the HREC guide).

17. Please describe the informed consent procedure you will follow below.

The researcher will inform the potential participants about the goals and procedures of the research project. The researcher will also inform them about the personal data that are being processed and for what purpose. A digital copy of the information will be emailed to participants before the interview, and all participants will be asked for their consent for taking part in the study and for data processing by signing a digital informed consent form before the start of the interview.
Participants are asked to review the transcriptions of their interview before the transcript is finalised (it will be sent to them privately via e--mail), which is also made clear in the consent form as a separate point of consent.

18. Where will you store the physical/digital signed consent forms or other types of proof of consent (such as recording of verbal consent)?

Digital informed consent forms and contact information are stored in the TU Delft OneDrive and encrypted separately from research data to minimise risk of re-identification.

19. Does the processing of the personal data result in a high risk to the data subjects? (Select all that apply.)

If the processing of the personal data results in a high risk to the data subjects, it is required to perform aData Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data in your research project.

If any category applies, please provide additional information in the box below. Likewise, if you collect other type of potentially sensitive data, or if you have any additional comments, include these in the box below.

If one or more options listed below apply, your project might need a DPIA. Please get in touch with the Privacy team (privacy-tud@tudelft.nl) to get advice as to whether DPIA is necessary.

- None of the above apply

23. What will happen with the personal data used in the research after the end of the research project?

- Anonymised or aggregated data will be shared with others

The research data consists of pseudonymised interview transcripts. This data will be used in the body of the Master Thesis, but will not be shared in a data repository.

24. For how long will personal research data (including pseudonymised data) be stored?

- Other – please state the duration and explain the rationale below
- Personal data will be deleted at the end of the research project

Audio-recordings of interviews are destroyed after completion of the pseudonymised interview transcriptions. All other personal research data will be destroyed at the latest 1 month after the end of the project.

25. How will your study participants be asked for their consent for data sharing?

- Other – please explain below (see guidance for additional options)

All participants will be asked for their consent for the data from the interviews to be part of the body of the Master Thesis, which is made publicly available in the TU Delft Education repository after the completion of the project (27. 06. 2025.). Participants who do not consent to data sharing will not be included in the research project. There will be a separate consent point indicated in the Informed Consent Form where the interview participants can state whether their names can be used for quotes in the thesis or not. In case they do not agree, the data will be pseudonymised, which will only be shared with restricted access (on the TU Delft Onedrive - only the corresponding researcher and responsible researcher will have access). Participants can exercise their right to be forgotten and for their personal data to be removed anytime during the process.

V. Data sharing and long term preservation

27. Apart from personal data mentioned in question 23, will any other data be publicly shared?

Please provide a list of data/code you are going to share under 'Additional Information'.

- I do not work with any data other than personal data

Appendix 4
Data Management Plan

29. How will you share research data/code, including those mentioned in question 23?

- I am a Bachelor’s/Master’s student at TU Delft and I will share the data/code in the body and/or appendices of my thesis/report in the Education Repository

Psudonymised data collected during the project will be included in the body of the MSc thesis (in correspondance with the informed consents), made available in the TU Delft Education Repository.
The dataset is not shared in a data repository.

31. When will the data/code be shared?

- As soon as corresponding results (papers, theses, reports) are published

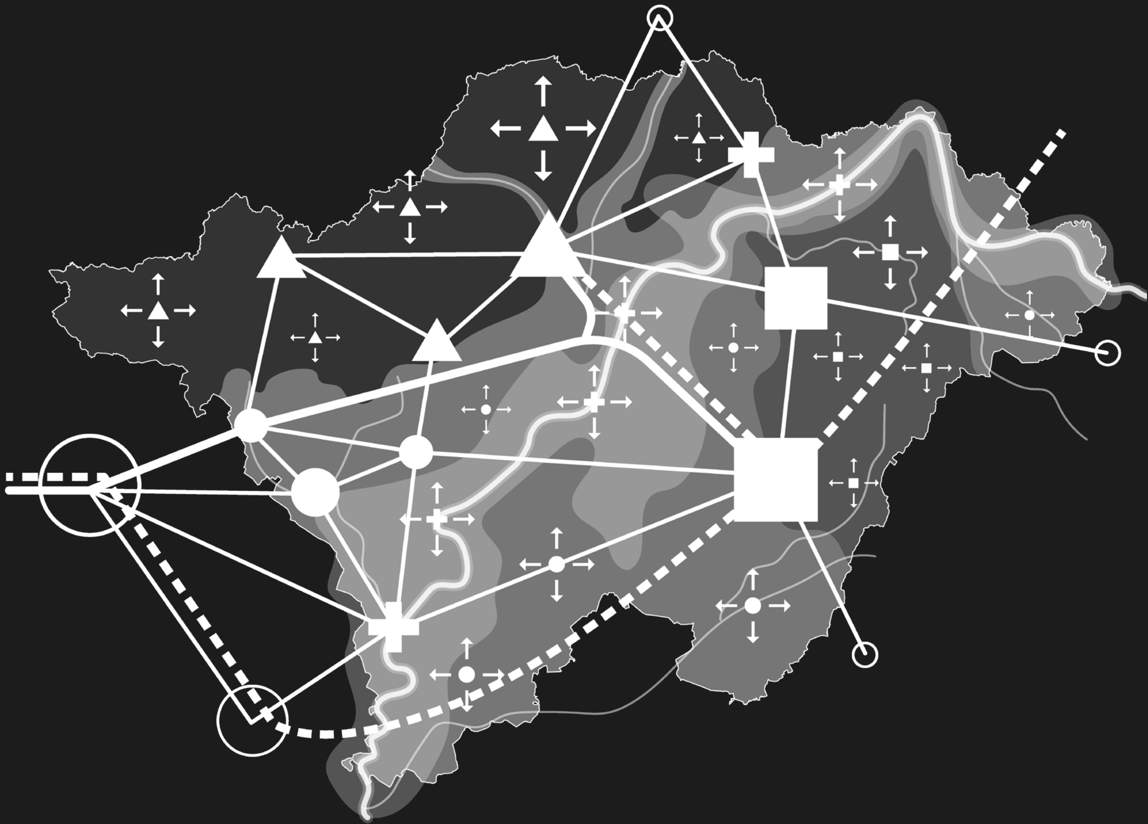
VI. Data management responsibilities and resources

33. If you leave TU Delft (or are unavailable), who is going to be responsible for the data/code resulting from this project?

Thesis supervisor, Alexander Wandl, associate professor of the department of Urbanism, with the email address: A.Wandl@tudelft.nl

34. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

Research data are only shared within the MSc thesis: no additional resources are required.



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