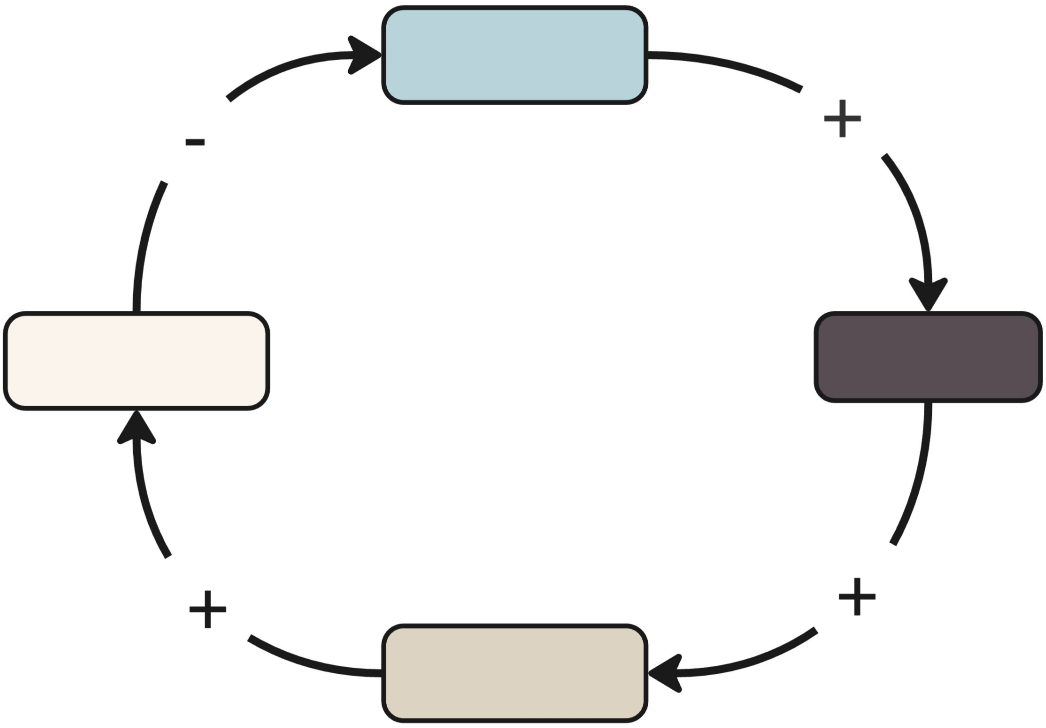

Navigating the Green Transition:

An analysis of EU policy trajectories and their implications for Gothenburg's industrial future.

Master's thesis in Industrial Ecology

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Cover: A casual loop digram showing a circular system

Gothenburg, Sweden 2026

Abstract

Gothenburg is an industrial city with a multitude of industries, some of which are heavily dependent on fossil fuels. With the European Union (EU) signalling a phase-out of fossil fuels, there is a need to expand net-zero-emission energy sources. For Gothenburg to transition, there is a need for reliable net-zero-emission energy. From the EU, there is a push to deploy net-zero technologies (NZTs), which are different technologies with the purpose of phasing out fossil fuels or mitigating emissions. Hence, the aim of this study is to propose policy recommendations based on leverage points for Gothenburg's transition towards a net-zero energy sector, in alignment with the Green Deal Industrial Plan. To achieve this, the following research questions have been established:

1. What are the policy signals from the EU conveyed in the Green Deal Industry Plan (GDIP) and Net-Zero Industry Act (NZIA), on how to implement NZTs?
2. What enablers and barriers influence the effective implementation of NZTs in Gothenburg, considering industrial, infrastructural and geographical conditions?
3. Which NZTs are most viable in a Gothenburg context?

The analysis of policy signals showed that the EU frameworks focus on implementing NZTs overall, without favouring any specific technologies. Based on the analysis of the Gothenburg conditions, the city is viable for solar power, wind power, biofuels and batteries. Based on the findings in this report, we propose the following policy recommendations for the city:

(a) Address permitting times and work to improve the permitting process to accelerate the deployment rate of NTZs.
(b) Sustainability requirements for public procurement.
(c) Utilise the high density of Science, Technology, Engineering & Mathematics (STEM) personnel in the population.
(d) Keep producing biofuels for city-owned companies and support the transition to biofuels at the refineries.
(e) Facilitate collaboration within the industry.
(f) Technologies to invest in: Solar and wind power, biofuels, and batteries. Explore the feasibility of e-fuels further.

This thesis has identified multiple areas of further research, for example, broadening the scope of policies and technologies. By increasing the scope, it is possible to better understand the energy system and the future of NZTs in Gothenburg.

Keywords: the European Green Deal, Net-zero technologies, Gothenburg, Energy sector, EU policy

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Lastly, we would like to thank our family and friends for their support throughout this journey. Special thanks to Sebastian and Ida, who took the brunt of our anxieties. Thank you for listening to our extensive worries and for giving us pep talks to remind us that we can do hard things. You have been invaluable!

Linnéa Aminoff & Signe Steindahl, Gothenburg, June 2026

List of Abbreviation

Below is the list of abbreviations that have been used throughout this thesis listed in alphabetical order:

CLD	Causal loop diagrams
CCS	Carbon capture and storage
CCU	Carbon capture and utilisation
EGD	the European Green Deal
EU	European Union
GDIP	Green Deal Industrial Plan
GHG	Greenhouse gas
NZIA	Net-Zero Industry Act
NZT	Net-zero technology
QCA	Qualitative content analysis
RQ	Research question
STEM	Science, Technology, Engineering & Mathematics

List of Definitions

Below is the list of definitions that have been used throughout this thesis:

Net-zero technology (NZT)
Technologies that help to achieve net-zero emissions, either by eliminating emissions, such as wind power, or by balancing emissions, where unavoidable emissions are equal to the carbon they absorb, such as biofuels. In the case of biofuels, the biomass absorbs CO_2 while growing and releases it back into the atmosphere when combusted, resulting in net-zero emissions.

The following list is derived from Article 4 in "Regulation (EU) 2024/1735 of the European Parliament and of the Council of 13 June 2024 on establishing a framework of measures for strengthening Europe's net-zero technology manufacturing ecosystem and amending Regulation (EU) 2018/1724".

(a) solar technologies, including PV, solar thermal electric and solar thermal technologies
(b) onshore wind and offshore renewable technologies
(c) battery and energy storage technologies
(d) heat pumps and geothermal energy technologies
(e) hydrogen technologies, including electrolysers and fuel cells
(f) sustainable biogas and biomethane technologies
(g) CCS technologies
(h) electricity grid technologies, including electric charging technologies for transport and technologies to digitalise the grid
(i) nuclear fission energy technologies, including nuclear fuel cycle technologies
(j) sustainable alternative fuels technologies
(k) hydropower technologies
(l) renewable energy technologies, not covered under the previous categories
(m) energy system-related energy efficiency technologies, including heat grid technologies
(n) renewable fuels of non-biological origin technologies
(o) biotech climate and energy solutions
(p) transformative industrial technologies for decarbonisation not covered under the previous categories
(q) CO 2 transport and utilisation technologies

(r) wind propulsion and electric propulsion technologies for transport
(s) nuclear technologies not covered under previous categories.

Alternative Fuels
This definition is derived from Article 2 in "Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU".

(a) alternative fuels for zero-emission vehicles, trains, vessels or aircraft:
- electricity
- hydrogen
- ammonia

(b) renewable fuels:
- biomass fuels, including biogas, and biofuels as defined in Article 2, points (27), (28) and (33), respectively, of Directive (EU) 2018/2001
- synthetic and paraffinic fuels, including ammonia, produced from renewable energy

(c) non-renewable alternative fuels and transitional fossil fuels:
- natural gas in gaseous form (compressed natural gas (CNG)) and liquefied form (liquefied natural gas (LNG))
- liquefied petroleum gas (LPG)
- synthetic and paraffinic fuels produced from non-renewable energy

Leverage point
A leverage point is a point in a system which can create a big change in the system with a relative small action. Therefor a small action in a leverage point can magnify the change beyond the small action. (Meadows, 1999)

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1 Introduction

With rising levels of CO_2 in the atmosphere and rising temperatures, there is a need for societal change (European Commission, n.d.-a). Climate change puts pressure on industries to reduce fossil fuel use, as fossil fuels release CO_2 into the atmosphere. By replacing fossil technologies with new solutions that reduce emissions, it is possible to mitigate the consequences of climate change (Ritchie et al., 2023). Because of this, the European Union (EU) has made a significant effort and invested in the green transition to pave a unified path forward for the EU. One of the major policy frameworks is the EU Green Deal, an overarching framework that sets the direction for the EU's green transition (European Commission, n.d.-c). It is both an organisation with laws and a big economy with a large industry and emissions. The EU's ambition is to be the world's leading market for green technology and to compete with superpowers like China and the USA by offering the best technology.

One sector that is heavily dependent on fossil fuels is the energy sector (Ritchie & Rosado, 2020). In recent years, the expansion of renewable energy sources has significantly influenced how energy is produced, but the energy sector has not fully transitioned (Ritchie et al., 2023). Achieving this transition requires further action to implement solutions to phase out fossil fuels. NZTs are technologies that aim to support the transition to net-zero CO_2 emissions and have the potential for rapid scale-up (European Commission, n.d.-e). The specific technologies are defined in section List of Definitions and are derived from the EU's list of NZTs (European Parliament and Council of the European Union, 2024). The idea is that by introducing and adapting these technologies, greenhouse gas (GHG) emissions can be phased out. This involves using alternative fuels and technologies that are free from fossil fuels or mitigating emissions when phase-out is not possible.

Gothenburg is an industrial city that relies on fossil fuels for many of its industries, specifically refineries and port activities (Göteborgs Hamn AB, 2025; Preem, 2024). With the EU signalling a phase-out of fossil fuels, the city's reliance on fossil fuels presents significant challenges (Business Region Göteborg, 2024b; European Commission, n.d.-d). This situation underscores the importance of understanding how EU directives will impact Gothenburg's future (Naturvårdsverket, 2026). Adopting a proactive approach will better equip the city to navigate the challenges posed by climate change and evolving climate policies (The world bank group, 2011). To facilitate the city's development, there is a critical need to develop a vision that supports decision-makers and local industry in shaping Gothenburg's future. As we move toward substitution of fossil fuels, new opportunities arise that shape what is competitive on the market, which need to be adapted to the specific strengths Gothenburg possesses (COP30, 2026). A change that is important for a trade city like Gothenburg to be actively involved in, to maintain its position as an industrial city. That is why it is important to utilise the leverage points of Gothenburg for an efficient transition toward a more sustainable future.

1.1 Aim and scope

1.1.1 Aim and research questions

The aim of this study is to propose policy recommendations based on leverage points for Gothenburg's transition towards a net-zero energy sector, in alignment with the Green Deal Industrial Plan (GDIP). To achieve this, the following research questions (RQs) will be addressed:

RQ1: What are the policy signals from the EU conveyed in the GDIP and Net-Zero Industry Act (NZIA), on how to implement net-zero technologies?

RQ2: What enablers and barriers influence the effective implementation of net-zero technologies in Gothenburg, considering industrial, infrastructural and geographical conditions?

RQ3: Which net-zero technologies are most viable in a Gothenburg context?

1.1.2 Scope

The aim of this study is to focus on the transition of the energy sector to NZTs in Gothenburg, in alignment with the European Green Deal (EGD). The GDIP was chosen because it is a part of the EGD that focuses on the implementation of NZTs. The NZIA provide a regulatory perspective to the GDIP, which is used to understand the specific actions that can be taken based on the overarching strategy provided by the GDIP. Together, GDIP and NZIA provide an understanding of the ambition and trajectory for the sustainability transition of industries in the EU. There are other policies that might address the implementation of NZTs in the energy sector, but they will not be considered in this report. NZIA is the document addressing implementation of NZTs in general. (European Commission, 2023b)

This study will focus on how EU policy will affect the current energy sector in Gothenburg, as well as which industries might be affected by this shift. This will include an analysis of the characteristics of the city and NZTs, and how future changes might affect them. This means studying what Gothenburg looks like today and finding strengths and opportunities that might be utilised. However, it will not include a detailed review of the city's existing policy documents.

To achieve net-zero emissions, fossil fuels will have to be phased out to a large extent, hence, the main focus of this study will be the implementation of NZTs as a substitute for fossil fuels. In this study, the energy sector is defined by its primary energy carriers: fuels, electricity, and heat. However, the study is delimited to only fuels and electricity, as these represent the most critical transition points for the phasing out of fossil fuels. While heating is a significant energy carrier in Gothenburg, the city's main heating source, district heating, derives largely from waste-to-energy and industrial surplus heat; only 0.6% comes from fossil fuels. (Göteborg Energi, n.d.-c) Hence, the primary challenges for phasing out fossil fuels in Gothenburg industry lie within the transport and industrial sectors. This study will explore how policy might affect fossil fuels and their possible substitutes as energy carriers: biofuels, e-fuels, and electricity. E-fuels are fuels made with hydrogen and CO_2, preferably from Carbon capture and utilisation (CCU), and can be used in existing refinery infrastructure with some adjustments (Ravi & Aziz, 2022).

This study delimits its scope to energy carriers and their direct production inputs. Hence, Carbon capture and storage (CCS), grid technologies, and energy efficiency technologies are excluded from this report. Although CCS is a vital tool for offsetting emissions to achieve net-zero emissions, it functions as a means of mitigating emissions rather than a contributor to energy production. In contrast, CCU is included, as it serves as a direct feedstock for producing alternative energy carriers, specifically e-fuels. Furthermore, while grid and energy efficiency technologies are important pillars for achieving the overarching net-zero targets, they are excluded from this study. Grid technologies are excluded because they focus on transmission and distribution infrastructure rather than on the core production inputs for energy carriers. Similarly, energy-efficiency technologies are excluded because this study focuses on energy-source substitution rather than on reducing consumption volumes.

Within the scope of this study, the technology categories are adopted from the NZIA categorisation outlined in List of Definitions. However, for the analytical purposes of this report, "Biotech climate and energy solutions" is interpreted strictly from an energy perspective, focusing on the production of liquid and gaseous fuels. Although this category can include biomaterials, those are excluded here. Since these solutions are considered alongside "sustainable alternative fuels" and 'renewable fuels of non-biological origin', collectively referred to as biofuels and e-fuels. Biofuels are fuels derived from biomass and can take various forms. In this report, biofuels are defined as fuels utilised in vehicles, specifically biogas, ethanol, and biodiesel (WWF, n.d.).

The focus on energy carriers also means that "transformative industrial technologies for decarbonisation not covered under the previous categories" and "wind propulsion and electric propulsion technologies for transport" are also excluded.

Nuclear power is excluded from the scope of this study. Even if nuclear power can contribute to phasing out fossil fuels, it will not be considered, as it is a national question rather than a regional one, and there are no current plans for a nuclear site in the region. Current laws prohibit the exploitation of the coastline for new nuclear reactors, except in areas already exploited (SFS 1998:808, 1998). Although policy proposals to lift these legal restrictions are currently under evaluation (Swedish Government, 2026), the combined regulatory uncertainty and lack of local initiatives lead to the exclusion of nuclear power from this study.

Hydrogen is a critical feedstock for e-fuels and CCU, but to maintain a distinct focus on the regional energy carriers utilised by the industry, this study delimits the scope of hydrogen to its use in e-fuel production and does not evaluate hydrogen sourcing.

In the causal loop diagrams in section 4.3, we have chosen to simplify the competition between different energy sources by assuming that total energy consumption remains constant; that is, if the production of one increases, another decreases. This is a simplification of reality, as numerous mechanisms influence the consumption of various energy sources. For example, there are feedback loops in which replacing fossil fuels with biofuels in one context leads to a drop in fossil fuel prices, so the reduced consumption is simply offset by consumption elsewhere (Rajagopal, 2013).

Social aspects have not been included due to the added complexity of understanding human behaviour, hence the consumer's role has been summarised as "consumer demand" to show the side of the consumers, which includes consumer demand from both the public and private sectors. Factors such as preference or acceptance for change have therefore been removed. On a similar note, the competitiveness in the workforce has not been included. Instead, only the competence and education of the workforce are included.

Lastly, end-of-life and recycling have not been included because the studied policies address production and use rather than end-of-life. CO_2 emissions are acknowledged, but the effect of those is not taken into consideration.

2
Background/Research context

This chapter presents the background of the study. The first section provides an overview of the case study subject: Gothenburg. Following that, a description of relevant EU policy is presented, with a primary focus on the GDIP and NZIA.

2.1 Gothenburg

The city of Gothenburg was founded in the 1600s, and evolved into a trading and shipping hub with the rise of the *Svenska Ostindiska Kompaniet (Swedish East India Company)*, and later industries took advantage of the favourable location close to the harbour (Göteborgs Stad, n.d.-a). The strategic location makes it an ideal hub for trade and a vital connection point between cities throughout the Nordic region (Business Region Göteborg, n.d.-a). 20% of the Swedish foreign trade passes through the port of Gothenburg (Port of Gothenburg, n.d.). The location allows for transport by railway, air, and sea, enabling logistics and making it suitable for companies engaged in cooperation and trade with other countries. The city is still considered an industrial trading city, but there has been a shift towards innovation (Business Region Göteborg, n.d.-a).

As the industry shifts towards net-zero industries, there is also a shift from carbon-based to renewable energy, and the required competencies change. The most common areas of work in the Gothenburg region are engineering and IT, and about 10% of the workforce has an education in a technical or scientific field. (Business Region Göteborg, n.d.-a). In the EU, Gothenburg ranks 29th out of 234 in terms of technological skill and innovation potential (Business Region Göteborg, n.d.-a). Furthermore, Gothenburg have good opportunities for research and development since there are many sandboxes, which are isolated, safe environments to test out new technologies or ideas used to test products, and the number of different industries also contributes to niche knowledge (Business Region Göteborg, n.d.-c, 2024a; Invest in Gothenburg, n.d.).

When it comes to sustainability, both businesses, public actors and academia are collaborating to reduce emissions. (Business Region Göteborg, n.d.-b) Industries in the Gothenburg region are working toward more sustainable operations through initiatives such as clustering and cooperation among companies (Business Region Göteborg, n.d.-b). Gothenburg has set additional goals as it aims to become a climate-neutral city by 2030, which presents a relatively short timeframe for achieving these objectives. In the years leading up to this target, there are essential actions that need to be completed. (Göteborgs Stad, n.d.-b). Gothenburg has also selected to be a mentor for other cities in the EU to guide sustainable development through the Intelligent Cities Challenge (Business Region Göteborg, 2023).

The energy sector in Gothenburg comprises large-emission industries across multiple areas, infrastructure interconnects district heating and cooling, electricity, transport, gas, and waste (Göteborgs Stad, 2022). It also has connections to national, European, and global energy systems, with large-scale energy production for export and import of electricity. Waste incineration and the production at the refineries provide district heating (Göteborgs Stad, 2022). Combined heat and power plants also contribute to district heating while producing electricity. Sludge and waste are used to produce biogas in the city's biogas plant, which is then used as fuel in the transport sector. According to Gothenburg's energy plan (Göteborgs Stad, 2022), changes in refinery production from fossil to bio-based might negatively affect the district heating system.

2.2 The Green Deal Industrial Plan

In 2019, the EU launched the EGD to address the challenges posed by climate change (European Commission, 2019). This strategy aims to achieve net-zero GHG emissions by 2050 while ensuring that Europe remains a competitive economy. The goal of the deal is to facilitate the transformation towards a sustainable society that decouples resource use from economic growth. Additionally, the deal emphasises that this transition must be just and inclusive (European Commission, 2019). Alongside EGD, there is a roadmap outlining the key actions and the timeline for their execution. This includes proposals for a Climate Law, comprehensive plans to achieve the EGD targets, strategies, action plans, and the like. (European Commission, 2019).

The GDIP is part of the EGD and aims to accelerate the transition towards climate neutrality while ensuring the EU's competitiveness (European Commission, 2023a). The EU wants to lead the clean tech transition, and the Plan outlines four key pillars for doing so: *predictable and simplified regulatory environment, faster access to funding, enhancing skills, and open trade for resilient supply chains.* (European Commission, 2023a)

To address the first pillar, *a predictable and simplified regulatory environment*, the European Commission proposes the NZIA, the Critical Raw Material Act as well as reform of the electric market design. These interventions aim to simplify, streamline and stabilise the framework, while ensuring demand for raw materials is met, and that consumer prices for renewables remain low. (European Commission, 2023a)

The second pillar is intended to facilitate financing and investment in the production of clean technology in the EU by streamlining these processes (European Commission, 2023a). This also means addressing subsidies implemented abroad that, according to the European Commission, create an uneven playing field. To address this, they propose the Temporary State Aid Crisis and Transition Framework to simplify and accelerate the granting of aid (European Commission, 2023a). Normally, there are strict caps on how much a state can subsidise industries to ensure fair competition within the EU, but under the Temporary State Aid Crisis and Transition Framework and the General Block Exemption Regulation, the framework allows for increased aid intensities and faster approval processes for strategic green sectors (European Commission, 2023a). The European Commission suggests using existing funds such as the REPowerEU, InvestEU, and the Innovation Fund.

The third pillar, *enhancing the necessary skills*, addresses the need for new skills and skilled workers in the green technologies industry (European Commission, n.d.-g). To meet this demand, the European Commission has launched the Net-Zero Industry Academies to help develop the necessary skills needed for net-zero industries (European Commission, n.d.-g). The European Commission also suggests applying a 'skill-first' approach, recognising actual skills and qualifications of both EU and third-country nationals (European Commission, n.d.-g).

The fourth pillar, *facilitating open and fair trade*, aims to encourage global cooperation and trade within the clean transition (European Commission, n.d.-g). Here, the European Commission raises concerns about interventions, such as subsidies, in China, which it says jeopardise fair competition and open trade. Expressing how they will use the trade defence instruments to *"[...] defend the Single Market, and rules-based international trade, from unfair trade practices like dumping and distortive subsidies."* (European Commission, 2023a).

2.3 Net-Zero Industry Act

Regulation (EU) 2024/1735, also known as the NZIA, is legislation intended to address the first pillar of the GDIP: *a predictable and simplified regulatory environment* (European Commission, n.d.-g). The intention is to simplify the regulatory framework in order to support and scale up the EU's manufacturing of NZTs. (European Commission, 2023a) Through a simplified regulatory framework, the act aims to attract investment to increase manufacturing capacity for NZTs within the EU (European Parliament and Council of the European Union, 2024). To meet the target of producing 40% of the EU's annual NZTs deployment needs by 2030, the NZIA focuses on creating favourable conditions for their production (European Parliament and Council of the European Union, 2024).

3
Method

This chapter outlines the methods employed in this report to address the aim and RQs. Figure 3.1 provides an overview of how the aim and RQs connect to the methods used in this report. To address RQ1, a qualitative content analysis (QCA) was conducted to categorise policies in themes and understand how policies from the GDIP steer the sustainability transition. To address RQ2, a literature review (LR) was conducted to understand the industrial, geographical and infrastructural conditions of Gothenburg. Finally, to address RQ3, causal loop diagrams (CLDs) were used to better understand the effects on the NZTs and a literature review was conducted to further examine the enablers and barriers of implementing NZTs in Gothenburg. The findings were synthesised to propose policy recommendations for the city towards a net-zero energy sector.

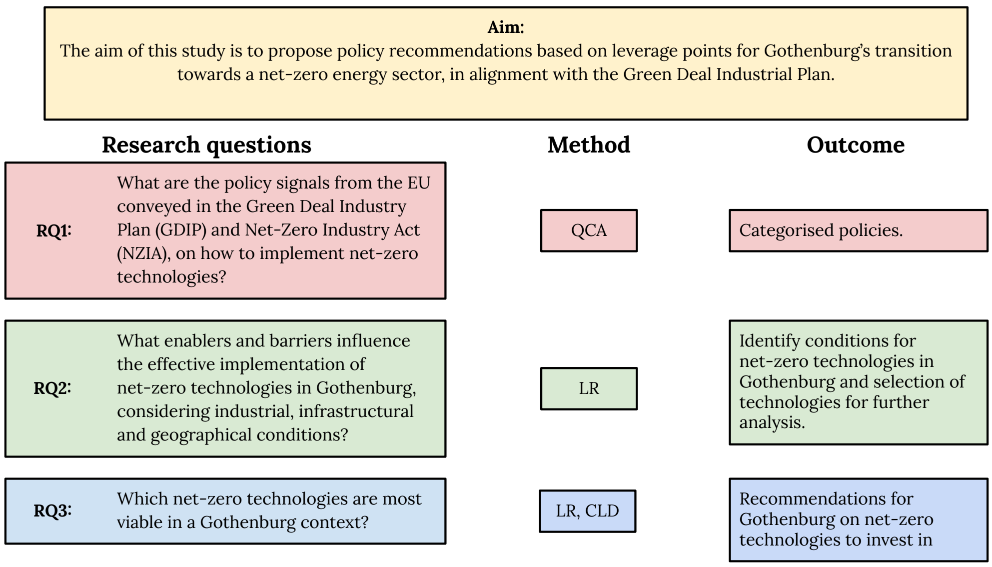

Figure 3.1: Overview of how the aim and research question connect to the methods used in the report. The methods are qualitative content analysis (QCA), literature review (LR) and causal loop diagram (CLD).

3.1 RQ1: Policy signals from EU Green Deal

To derive the signals and understand how the EU intends to implement NZTs a QCA was conducted. For this, the GDIP and the NZIA were analysed.

The method employed is based on a QCA, as described by Bohm and Sundqvist (2025), but uses a mixed deductive and inductive approach to identify themes. Initially, the anticipated policy instruments were outlined and divided into themes. Due to some overlap in the themes, Google's large language model, Gemini 3.5 Flash, was utilised to help clarify and refine them. For example, the large language model helped refine the themes and avoid mixing regulatory policy instruments with specific laws. The prompt, including the coding and the answer, is provided in Appendix B.1. The inductive phase of the analysis occurred during the coding phase, as additional themes were identified and incorporated into the coding as they appeared in the coded statements.

Once the statements were extracted, they were coded in accordance with the method described in Bohm and Sundqvist (2025). The criteria for including statements were that they should suggest or legislate policy affecting any NZTs, including those not currently used in Gothenburg, since they might be of interest in the future. The statements are organised into categories and subthemes, with each subtheme providing more specific definitions in the coding. The coding manual can be found in appendix A.0.1. After the QCA were completed, a few of the deducted subthemes were removed because they were not found in the analysis. One example of this is permits. The themes can be found in table 4.1. The statement corresponds to policies that can affect the implementation of NZTs in Gothenburg. A list of NZTs (see table 3.1) was compiled from the EU list of NZTs in List of Definitions, excluding those outside the scope. The difference between general/unspecific and net-zero technologies is that for net-zero technologies, two or more technologies are mentioned in the statement, alternatively, NZTs are specifically mentioned.

Table 3.1: Industries coded in the qualitative content analysis.

Net-zero technology
General/Unspecific
Net-Zero technologies (Cross-Sectorial)
Solar
Wind
Battery and storage
Biogas/biomethane

3.1.1 Example of coding QCA:

This is an example to show how the QCA was conducted. In table 3.2, an example of a statement from the Green Deal Industry Plan is presented.

Table 3.2: Example of coding in the qualitative content analysis

Statement: The Act [The Net-Zero Industry Act] could enable the Commission to request **European standards promoting the fast roll-out of key technologies**			
Code	**Theme**	**Subtheme**	**Net-zero technology**
European standard	Regulatory	Standard	General

First, the statement was retrieved from the document. Then the statement was coded to derive the meaning. From this, the themes can be derived. The main theme in this case is *Regulatory* and the subtheme is *Standards*. Since no specific technology or industry is mentioned, the net-zero technology is selected as *General*.

3.2 RQ2: Enablers and barriers for implementation of net-zero technologies in Gothenburg

To evaluate the feasibility of the NZTs, within the context of Gothenburg, a case-study approach was utilised.

Initially, a baseline of the energy and industrial landscape of Gothenburg was established by reviewing strategic documents from the municipality, primarily grey literature. Key documents for the baseline include the *Energy Plan for the City of Gothenburg 2022-2030* (Göteborgs Stad, 2022) and *the City of Gothenburg's Environment and Climate Programme 2021-2030*(Göteborgs Stad, 2024).

To map out the city's specific preconditions, a targeted literature search was conducted. The search started with ”Business Region Gothenburg” and was expanded using a snowballing approach, which led to ”Svenskt Näringsliv företagsklimat”, ”Invest in Gothenburg”, and ”Port of Gothenburg”. Additionally, a targeted search was conducted using the following search strings to deepen the understanding of current industrial strengths in Gothenburg, using the following terms (with English translations provided in parentheses where applicable):

- Göteborgs stad styrkor (Strengths Gothenburg)
- Göteborgs industri (Gothenburg industry)
- Green City Zone
- Gothenburg Green City Zone

This approach helped gain insights into the local relevance and potential of the NZTs included in the study.

Following the baseline assessment, Table (4.2) was constructed to evaluate each NZT based on the Gothenburg context. The technologies were organised along the rows, while the columns represented three predefined dimensions for localised technology deployment: industrial landscape, infrastructure, and geographical and natural assets. To validate the table, a targeted literature search was conducted for each NZT.

Based on the results of the previous step, technologies were selected for further analysis based on their opportunity and feasibility of development in Gothenburg. First, technologies were evaluated based on their potential in the Gothenburg context, leading to the exclusion of non-scalable options such as hydropower. Second, pathways with less established implementation paths were prioritised, leading to the exclusion of solar power. Finally, the scope of the technological complication was assessed, and if deemed too extensive, the technology was removed. This led to the exclusion of e-fuels, since they require a comprehensive value chain analysis, including detailed mapping of point-source emissions and hydrogen sourcing, that exceeds the resources of this paper. Instead, these are highlighted as critical areas for future research.

3.3 RQ3: Viability of NZTs in Gothenburg

To study the viability of the different NZTs in Gothenburg, Causal Loop Diagrams (CLD) were used. The method used for the CLDs is based on *Business Dynamics: Systems Thinking and Modeling for a Complex World* (Sterman, 2000)

CLDs were created in two parts. Part one consisted of two steps and was used to gain a technical understanding of the NZT. First, a conceptualised model was developed based on the authors' knowledge of the subject, followed by an empirical validation process. This created an iterative process as new connections were formed during the validation. The second part integrated policies and the local context around Gothenburg.

Initially, the empirical validation was attempted through an exploratory manual search. However, this proved to be an unsystematic and time-consuming approach. To address these limitations and create a more organised and reproducible validation process, a structured, AI-assisted methodology for identifying relevant literature was developed.

To validate the CLDs, Google Search AI Mode, Gemini 2.5, was used with a standardised prompt to find relevant literature to either confirm, deny, or nuance the statement. This prompt was tested and improved using Google's large language model, Gemini 3.5 Flash. The standardised prompt is presented below.

Standardised large language model Prompt

Role: Evidence-Based Research Auditor specialising in System Dynamics.

Task: Fact-check a specific causal assumption from a Causal Loop Diagram (CLD) using real-time web search. Your goal is to find empirical evidence that confirms, nuances, or debunks the proposed relationship between the variables.

Statement to verify: *"[Insert statement to be verified here]"*

Context/System: *[Insert context/system here]*

Instructions (Strict compliance required):

1. **Live Search:** You MUST use the search tool to find scientific papers, official industry reports, or academic articles.
2. **Verbatim Quotes:** For every source, you MUST provide a direct, word-for-word quote from the text that supports or disproves the statement. The quote must be long enough to be searchable via Ctrl+F.
3. **Validation:** Do not invent DOIs or links. Provide direct URLs to the source or the PDF document.
4. **Identify Mechanisms:** Focus on identifying the underlying causal mechanism (the "why") described in the literature.
5. **No Speculation:** If no reliable sources are found that directly address the link, state this clearly instead of speculating.

Format: Present the results in a Markdown table: | Source (Author, Year, Title) | URL | Status (Confirms/Denies/Nuanced) | Verbatim Quote (for Ctrl+F) | Key Mechanism Explained |

From this, a table was retrieved containing literature that either confirmed, denied, or nuanced the statement. The large language model was used to find sources, but after that, each source was carefully evaluated to assess its usefulness in confirming, denying, or nuancing the statement. The large language model served as a search engine for identifying relevant sources. However, the final synthesis and critical evaluation of each source were performed manually to ensure relevance. This was done by looking at the source in terms of credibility and deciding if the source itself is reliable. For example, sources with a marketing objective were avoided because of the risk of biased information. Then the statement itself was evaluated in the context of the text. This was, for example, to determine whether the link is relevant only in a niche setting or in more general cases.

By instructing the large language model to either confirm, nuance or deny the statement, confirmation bias was avoided. Using role prompting, which involves instructing the large language model to take on the role, in this case, the role of a researcher, helps to frame the type of responses the model provides. (B. Chen et al., 2025)

The CLDs for each technology will be divided into three parts. The first will be a systems view of how the technology develops in general. Here, the diagram will be explained in detail to provide information about the technology. The next part included the policy described in 4.1. By adding the policies to the technological diagram, it is possible to analyse the development of the technology. Lastly, the specific preconditions for Gothenburg will be added as described in 4.2. This will provide a fuller perspective of how the adaptation of the technologies might look at the local level. An increase/decrease in industry in this context means production capacity. When the policies and Gothenburg preconditions were not that extensive, they were added in the same step.

Figure 3.2 is an example of how the CLDs are designed in this report.

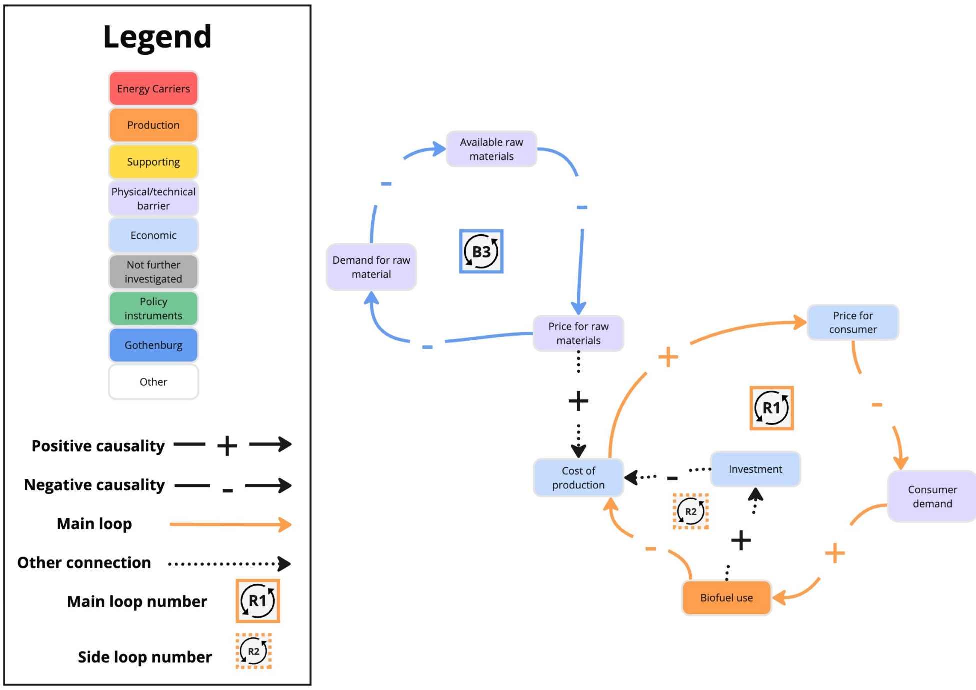

Figure 3.2: Example of a causal loop diagram. Main loops are presented by different colours to make them distinguishable.

Each CLD is made up of factors which represent aspects of the system. In the orange loop [R1], the main loop has a reinforcing effect, marked by the R in front of the number. In the blue loop [B3], the main loop is balanced, marked with the letter B in front of the number.

3.4 Limitations and assumptions

Misinterpretations of causal loops can occur because their connections lack weighting, making all links appear equally important. This can create false leverage points. There is also a risk of links being missed due to system boundaries. A similar risk exists regarding the conditions of Gothenburg. To mitigate the impact of this, each loop is also described in text, this might not solve the limitation, but it helps further explain the connections.

By using a large language model to assist in validating causality, there is a risk of not understanding the depth of the technologies since they are not analysed through a systematic literature review. This could possibly lead to missed leverage points. However, without using a large language model, the report would not cover as many technologies. Furthermore, the chosen large language model, Google Search AI Mode using Gemini 2.5, is not specifically designed for scientific research, which may affect the sources provided.

The literature review in this report is a mix of academic and grey literature. Grey literature has the disadvantage of not being peer-reviewed and therefore has the risk of being biased. This can lead to missing out on barriers for the implementation of NZTs. To mitigate this risk, multiple sources have been read from different angles to gain a fuller picture.

4

Results and discussion

This chapter presents the findings of the study, following the order of the RQs. First, section 4.1 outlines the policy signals from the EU regarding the implementation of NZTs. This is followed by an analysis of the viability of different NZTs within the specific industrial, infrastructural, and geographical context of Gothenburg in section 4.2. The next section, 4.3, synthesises the findings from sections 4.1 and 4.2 into causal loop diagrams to understand the viability of these technologies in Gothenburg. Furthermore, the leverage points and policy recommendations are presented. Finally, the research scope and further research are discussed.

4.1 Policy

In this section, the policy instruments will be presented in the five themes identified in the QCA: regulatory, financial instruments, education & skill, cooperation, and pilots. Table 4.1 presents the identified subthemes.

Table 4.1: The categories and subcategorise used in the qualitative content analysis, inducted subcategories are written in italic

Theme	Subtheme
Not relevant/No instrument mentioned	-
Other	-
Regulatory	Standards Mandates Targets *Streamlining* *Competitiveness* *Requirements*
Financial instruments	R&D funding Subsidies Grants Loans Taxes *Public procurement* *Investment* *Aid*
Education & Skill	Education & competence provision *Advice*
Cooperation	-
Pilots	-

Section 4.1.1 to 4.1.4 will present policy instruments regarding unspecified NZTs and more general policies. Then, section 4.1.5 will present policy instruments targeted toward specific NZTs. Finally, a summary of the policy signals will be presented. All policies in these sections are drawn from GDIP (European Commission, 2023a) and NZIA (European Parliament and Council of the European Union, 2024) and summarise the findings in the QCA. The coding can be found in Appendix A.0.2.

4.1.1 Regulatory

In the QCA, six subthemes were identified in the theme regulatory policy instruments: standards, mandates, targets, streamlining, competitiveness, and requirements.

The overarching aim of the EGD is net-zero emissions across the EU, but the GDIP and NZIA include more specific targets for the deployment of NZT. These targets focus on increasing the manufacturing of NZTs within the EU, as well as promoting education and skills development in these areas. A significant part of regulatory policy instruments aims to streamline processes, particularly the permitting process, which seems to be a key barrier to the implementation of NZTs. The aim is to reduce administrative bottlenecks and make financial application procedures easier.

This will be accomplished by establishing time limits for permit and assessment processes, improving information accessibility, providing single points of contact, and introducing a code of good practice to facilitate streamlined assessments. In this theme, there are also policy instruments addressing competitiveness and how to ensure the EU can remain competitive with non-EU countries. It involves assessing how new regulations could impact this competitiveness. Additionally, competitiveness is supported through interventions in the later stages of the value chain, which include export credits and international procurement instruments.

There are also requirements and standards in place. The requirements are used to increase the demand for NZTs through sustainability requirements for public procurement. This also plays a part in increasing education and skills, as well as economic objectives, through risk sharing and aid. Another regulatory policy instrument is mandates, which assign specific statuses to projects that promote the deployment of NZTs. By receiving a status such as ”net-zero strategic project,” these initiatives can benefit from priority in permitting processes, access to funding, and additional support, including cooperation and exemptions.

4.1.2 Financial instruments

In the QCA, nine subthemes were identified in the theme financial policy instruments: R&D funding, subsidies, grants, loans, taxes, public procurement, investment and aid. The goal of the financial instruments is to reduce economic barriers to the industry’s implementation of NZTs. Funding for R&D and investment policies helps improve technical development and has an effect early on in the value chain. Investment policies and aid are used to increase funding for industry transition and to increase education and skills in relevant subjects. These are actions that would otherwise be expensive for the companies themselves to fund. Loans are utilised to support and finance the industry, with a greater emphasis on industrial development than on education.

Subsidies, taxes and public procurement are used to promote the demand for NZTs. Policy instruments for NZTs regarding taxes aim to reduce prices through tax breaks and tax credits. Subsidies also target prices but from a consumer side, where tax incentives in this case mostly target producers. Grants are used as a general financial tool to fund NZTs, but also as a targeted tool for energy-intensive production through REPowerEU. There are multiple grant initiatives for NZTs across different funds within the EU.

4.1.3 Education & Skill

In the QCA, two subthemes were identified in the theme education and skill: education & competence provision, and advice. Education and competence provision are used to provide the necessary skills in areas important for NZTs. It is promoted through investments and recognition of skills. There are also education and cooperation initiatives. Advice is used to promote education, technical development and cooperation.

4.1.4 Cooperation and Pilots

In the QCA, no subtheme was identified in the themes cooperation and pilots. Cooperation is used to promote multiple different areas of interest. It is used to collaborate on education and the sourcing of raw materials, while also stimulating investments, coordinating energy and increasing demand for NZTs. This, therefore, affects multiple points in the value chain. The signals are that the EU wants to promote cooperation across member states, but some policy instruments also promote cooperation with partners outside of the EU. For pilots, there is only one policy: regulatory sandboxes used to accelerate technical development.

4.1.5 Policy for specific technologies

There are two policies related to a specific technology that are within the scope of this report, one for battery & storage and one for wind. For battery & storage, there is a regulatory framework that aims to secure competitiveness and a resilient value chain. Wind is approached through a partnership for onshore renewable energy, which aims to expand wind power through collaboration. All NZTs are also positively affected by the policies for NZTs and general.

4.1.6 Summary of policy signals

The signals from policies in the GDIP and NZIA are quite clear: the intention is to phase out fossil fuels while accelerating the adoption of NZTs. A substantial effort is being directed toward regulatory policies, with a focus on streamlining processes and setting targets. These targets include general emissions-reduction goals as well as specific objectives to increase the production of NZTs within the EU. Additionally, a strong emphasis is placed on education and the provision of competence, which is reflected across multiple themes. Finally, there are also substantial financial commitments from the EU to help accelerate the transition to NZTz.

The signals from the EU are rather technology-neutral, focusing more on general NZTs than specific NZTs. There are other policies than those studied in this report that might further address specific technologies. However, the aim of the GDIP and NZIA is the transition toward a net-zero future, rather than which specific technologies are used to achieve it. Hence, the technologies implemented can be adapted to the local context.

4.2 Gothenburg's conditions

In this chapter, the opportunities for NZTs in Gothenburg will be presented in table 4.2. Here, the preconditions of each NZT are evaluated in three different dimensions: industrial landscape, infrastructure, and geographical and natural assets. If a dimension was not found for an NZT in Gothenburg, the box is left empty.

Table 4.2: Net-zero technologies in a Gothenburg context

Net-zero technology	**Industrial landscape**	**Infrastructure**	**Geographical and natural assets**	**Other**
Solar energy	Electrification of industries will require more electricity (F. Johansson et al., 2025).	The City of Gothenburg's Energy Plan (2022) requires municipal committees to establish solar energy plans for all their building projects, both new and existing, to actively promote the deployment of solar cells.	Gothenburg is suitable for solar panels with an average annual yield of 950 kWh per installed kW (Göteborg Energi, n.d.-b).	

Continued on next page

Table 4.2: Net-zero technologies in a Gothenburg context (Continued)

Net-zero technology	Industrial landscape	Infrastructure	Geographical and natural assets	Other
Wind power	Electrification of industries will require more electricity (F. Johansson et al., 2025).		The sea outside of Gothenburg seems suitable for offshore wind, as evidenced by establishment projects like Västvind, where a direct connection to Gothenburg's electricity grid is being investigated (Eolus, 2024). There are no suitable areas within the city to establish new onshore wind power (Göteborg Energi AB, 2024). Most wind power plants owned by Göteborgs Energi (a municipally owned company) are in other municipalities.	There are already plans to build offshore wind turbines on the coast outside of Gothenburg. However, the permit processes are taking time, but there is one project that has been approved (Länsstyrelsen Västra Götaland, n.d.).

Continued on next page

Table 4.2: Net-zero technologies in a Gothenburg context (Continued)

Net-zero technology	**Industrial landscape**	**Infrastructure**	**Geographical and natural assets**	**Other**
Battery and storage	With Volvo Cars committing to shift their production to 100% electrical cars by 2040, (Volvo Cars, 2026), there will be a significant increase in demand for car batteries. With more renewable, variable energy sources such as wind and solar, more energy storage could help balance the grid (Region Västra Götaland, 2025).	There is currently a battery factory established through a collaboration between Volvo and Northvolt, called Novo (Novo energy, n.d.). However, since Northvolt shut down, Volvo is seeking a new partner. The operations at the Novo factory were shut down in January 2026(Junkala, 2026).		The investments in the battery factory have created investments in education and skill supply (Business Region Göteborg, 2025).

Continued on next page

Table 4.2: Net-zero technologies in a Gothenburg context (Continued)

Net-zero technology	**Industrial landscape**	**Infrastructure**	**Geographical and natural assets**	**Other**
Biofuel & e-fuel	The two refineries in the city already have the necessary market and network in place. There is already some biofuel production in Gothenburg, for example, Gyraab uses sewage sludge to produce biogas (Gyraab, n.d.). This is then sold to Göteborgs Energi, which is turning it into biofuel.	The refineries already have much of the necessary logistics and storage infrastructure in place. While transitioning to a biorefinery or an e-fuel hub requires substantial investments in new processing units, such as hydrogen electrolysers and specialised reactors, existing sites could be rebuilt to produce biofuel or e-fuels (Transport & Environment, 2023).	The geographical location of Gothenburg is favourable due to its proximity to transport infrastructure, such as the port and railroads (Business Region Göteborg, n.d.-c).	Note that the production of e-fuels requires large quantities of hydrogen (eFuel Alliance, n.d.).
Hydropower	Electrification of industry will require more electricity (F. Johansson et al., 2025).		There are some small-scale hydropower plants in the Gothenburg region, but within the city, hydropower is not an option (Göteborg Energi AB, 2024).	Note that hydropower is part of the energy mix, but that is from import of energy (Göteborg Energi AB, 2024).

Continued on next page

Table 4.2: Net-zero technologies in a Gothenburg context (Continued)

Net-zero technology	**Industrial landscape**	**Infrastructure**	**Geographical and natural assets**	**Other**
CCU for fuel production	High-emission industries, such as the chemical industry, produce significant CO_2 point emissions that could be utilised for this purpose (Green Fuel Journal, 2026).			Note that this requires a lot of energy in the form of electricity and hydrogen (Green Fuel Journal, 2026).

Based on the findings and initial screening presented in Table 4.2, some of the NZTs will be further investigated in the Gothenburg context. Other NZTs will be excluded from further analysis in the next step. Since hydropower is not a scalable option for the city, it will not be further investigated in the next section.

The industry will require more net-zero electricity, even though it does not necessarily need to be produced in Gothenburg, doing so could speed up the electrification. If electricity production is to be expanded within the region/municipality, wind and solar power are the available options based on the findings in Table 4.2. There is already a well-defined plan for expanding solar within the city (Berndtsson, n.d.; Göteborgs Stad, 2022, 2024). Given indications of increased electricity demand for the transition to a net-zero future (F. Johansson et al., 2025), this path of expansion of solar power should be continued. However, based on the findings in Table 4.2, this study will conclude its investigation of solar power here. While the recommendation is to continue with current solar initiatives, further analysis will prioritise technologies with less established implementation pathways.

Biofuels and e-fuels are both relevant options to investigate in a Gothenburg context. However, because assessing e-fuels requires a comprehensive value chain analysis, including point-source emissions, hydrogen supply, and large electricity demand, a full evaluation is not feasible within the resource constraints of this report. Therefore, e-fuels are excluded from further investigation and recommended for future research.

4.3 Causal loop diagrams

The technologies are divided into different levels since they are dependent on each other, see figure 4.1. The overarching level is the big picture 4.3.1. This symbolises the energy sector and describes the relationships between the different technologies. Each technology will be presented in steps: first, technological specifics, then policy and Gothenburg.

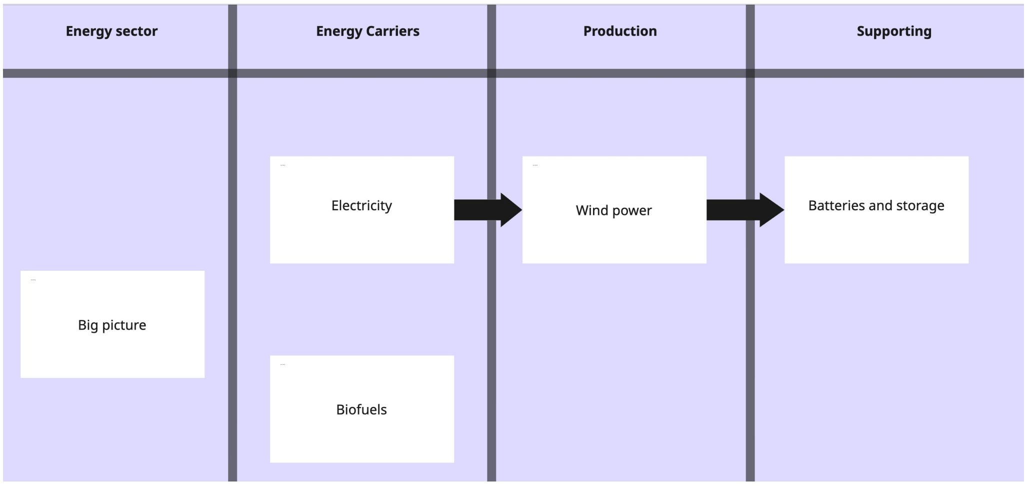

Figure 4.1: Overview of technologies studied in the causal loop diagrams

The energy carriers are the main substitutes for fossil fuels: electricity (see 4.3.2) and biofuels (see 4.3.3). The production level describes some methods for producing the energy carriers. In this report, this is wind power (see 4.3.4). At the supporting level, there is battery & storage, which is a necessary part of renewable energy since it is variable and requires storage to maintain a continuous energy supply (see 4.3.5).

4.3.1 Big Picture

This chapter will present a systems map of the NZTs deemed relevant for Gothenburg. Figure 4.2 shows how they are connected and dependent on one another.

4.3.1.1 Big Picture - Technical focus

Big picture technical, figure 4.2, describes the technological side of the NTZ and how the technical circumstances affect the technologies in a big picture.

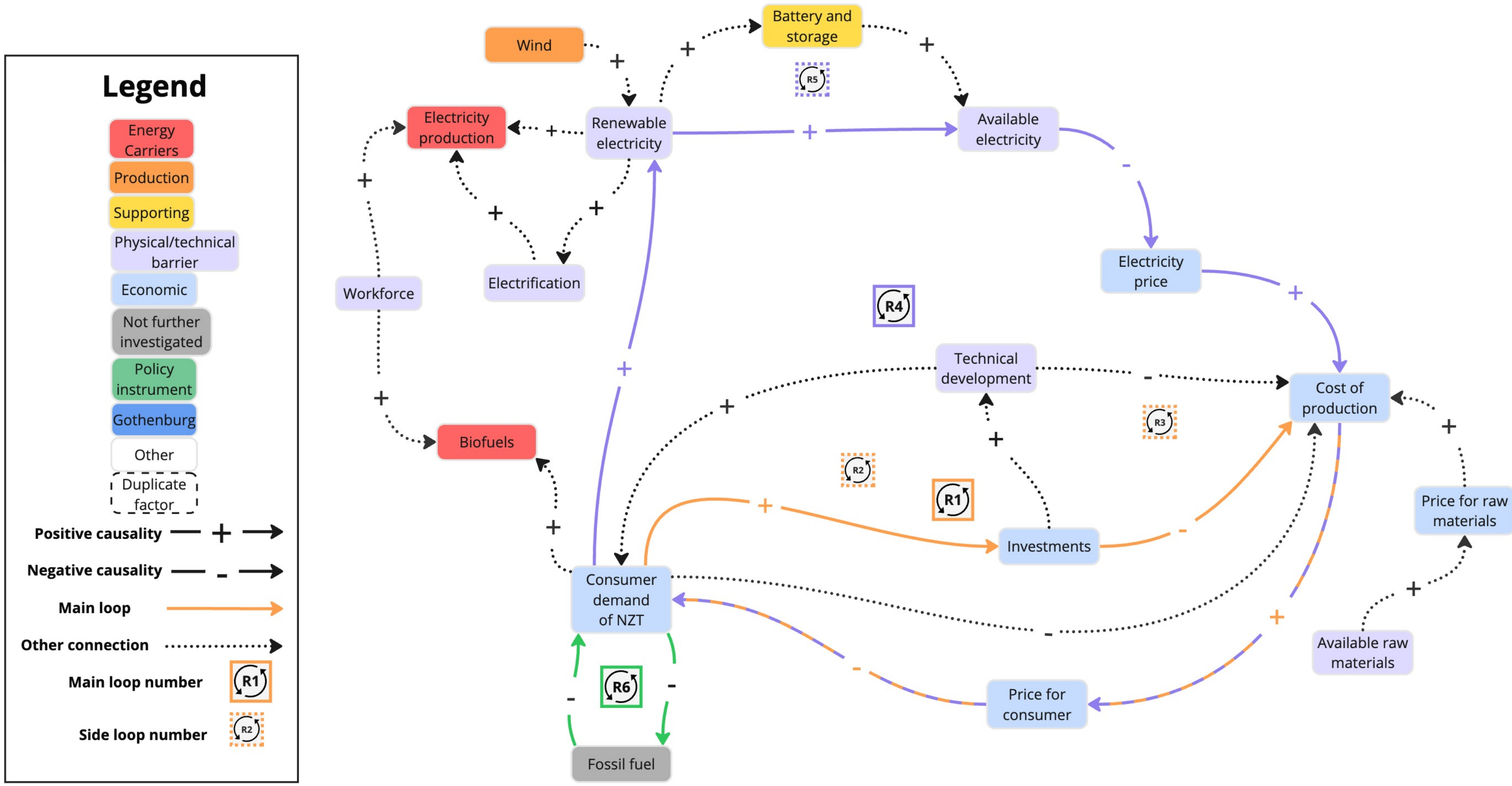

Figure 4.2: Causal loop diagram of the big picture with a focus on technologies

A central part of the system is consumer demand, since it drives the adoption of technologies. As consumer demand increases, it stimulates the investment in the technology (Yu & Zeng, 2024), which has the ability to decrease the cost of production and thereby lower the price for the consumer, which leads back to an increase in consumer demand [R1] (IEA, 2025a). The effect varies by technology: for example, EVs are more sensitive to consumer demand than other technologies, driving the demand for batteries (IEA, 2025b). Production also has a direct link to the cost of production due to scaling effects (UN environment programme, 2023).

Investments also stimulate technical development, which by itself can lead to an increase in consumer demand due to new market opportunities [R2] or lead to a decrease in the cost of production [R3] (Han et al., 2025; Huang, 2024; IEA, 2026; IRENA, 2025a). Another thing that affects the cost of production is the price for raw materials (IEA, 2021b; Lisauskas et al., 2025). The price of raw materials depends on the availability of material and its rarity, and is driven up by high demand (IEA, 2025a).

The cost of production can also be connected to the price of electricity (Merkus & Board of Trade Sweden, 2024). This is, however, dependent on the technology since energy-intensive technologies are more sensitive to changes than, for example, the production of wind power plants (Elia et al., 2020; Wharton et al., 2025). As the demand for NZTs increases, there is a need to expand on renewable electricity, which in turn increases the available electricity (Fulghum et al., 2026). Since the price of electricity is highly dependent on the amount of available electricity, this affects the price, which in turn affects the cost of production [R4] (Gasparella et al., 2023). Since some renewable electricity sources are weather dependent, they are variable and unpredictable and therefore require batteries and storage in order to have more capacity [R5] (Fulghum et al., 2026; van Gendt et al., 2026).

Renewable electricity sources, like wind and solar power, lead to more electricity being produced (Fulghum & Mishra, 2025; IRENA, 2025b), which in turn leads to increased electrification (IRENA, 2025b). This in turn leads to more electricity being produced (Gao et al., 2025). Lastly, as the consumer demand for NZTs increases, the consumer demand for fossil fuels decreases and vice versa [R6] (IEA, 2021a).

4.3.1.2 Big Picture - Policy focus

In this step of the big-picture map, the policies from section 4.1 are integrated into the technology map shown in figure 4.2. To make it comprehensible, the policies will be presented in groups based on their placement in the map. The results will be organised by starting with education and skills, highlighting the relevant policy instruments tied to these areas. Following that, permits and streamlining processes will be covered, along with cooperation, competitiveness, and financing for NZTs. Lastly, policy instruments related to technical development, price and consumer demand are presented. All policies in these sections are from the QCA, which means they come from the GDIP (European Commission, 2023a) and NZIA (European Parliament and Council of the European Union, 2024). The QCA coding can be found in Appendix A.0.2.

Many of the identified policy instruments are cross-sectoral, meaning they are designed to support the entire net-zero sector rather than focusing on specific technologies. To illustrate this concept, these instruments are connected to a broader NZT factor, which represents how these general policy measures influence the overall landscape for NZTs.

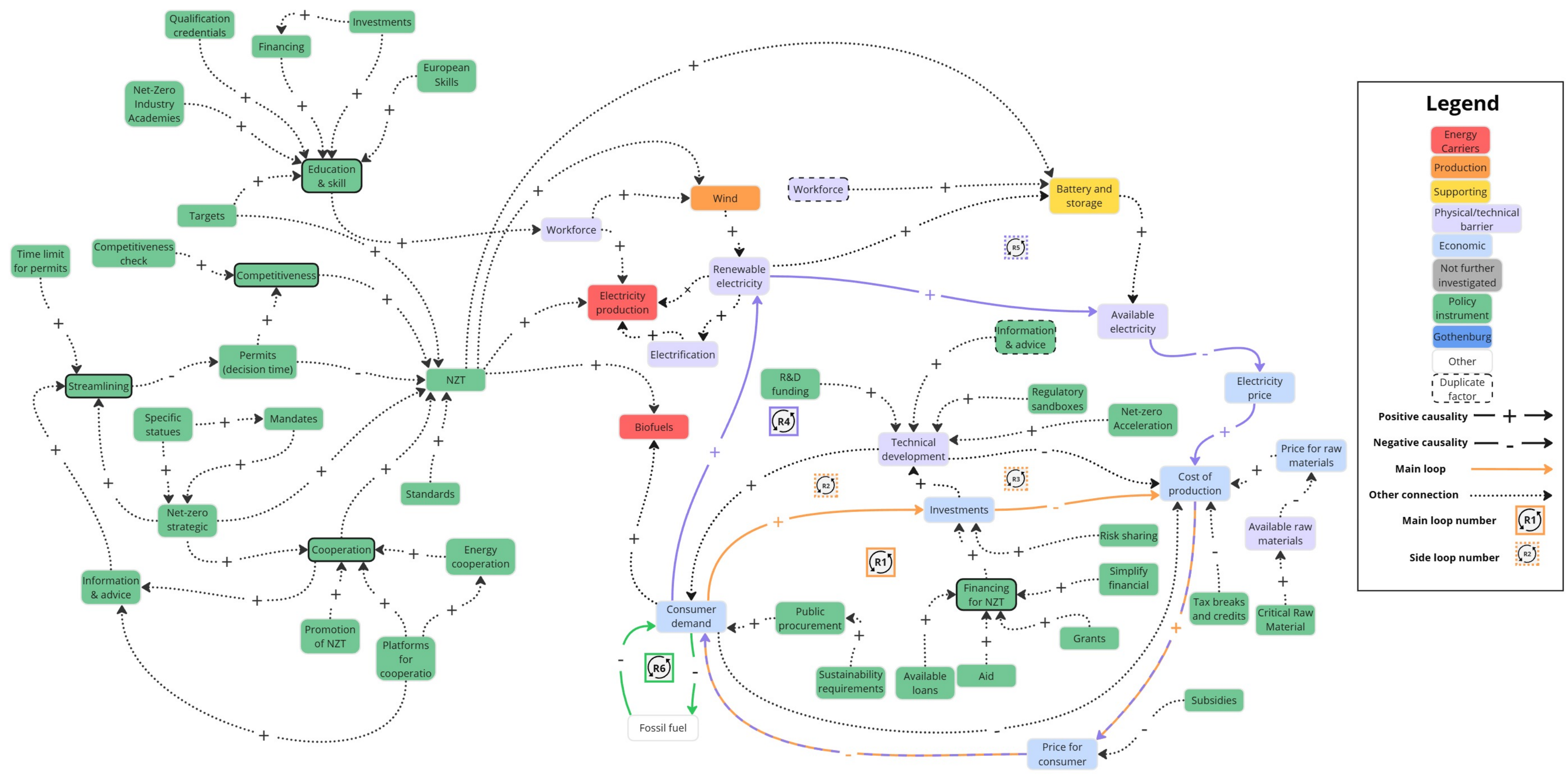

Figure 4.3: Causal loop diagram of the big picture with a focus on policy

The GDIP and NZIA highlight the importance of a skilled workforce for the effective implementation of NZTs. With the emergence of new technologies, there is a pressing need for workers to acquire knowledge and skills about these technologies. Education and skill are necessary drivers for strengthening the enabling landscape for the deployment of NZTs. The Net-Zero Industry Academies and the European Skills Agenda act as drivers that increase the stock of skilled human capital in the workforce. Qualification credentials are used to leverage existing competence. Financing provides positive feedback to education & skills by supplying the necessary capital to support education.

Long permit decision times are a bottleneck to the deployment of NZTs. Many of the policy instruments in the GDIP and NZIA aim to reduce permit decision times by streamlining the permit process. There are several drivers for the streamlining. First, there are time limits on NZTs permits, which are even more rigid for projects subject to specific statutes or mandates, such as net-zero strategic projects. By reducing the time businesses must wait for their permits, the deployment of NZTs can be accelerated. Information and advice for businesses are also important drivers for streamlining the deployment of NZTs.

Streamlining improves competitiveness by accelerating permit processes. Competitiveness checks are implemented, meaning that new regulations are assessed for their potential impact on companies in the EU. This mechanism aims to improve or mitigate the effects of policy on competitiveness, thereby enhancing the landscape for NZTs.

Statutes such as net-zero strategic projects promote cooperation, which in turn strengthens the enabling landscape for the deployment of NZTs. The multiple initiatives for platforms for cooperation, both within the EU and with other collaborators, aim to have a positive impact on cooperation and also help provide information and advice among actors, which in turn drives streamlining.

Technical development is an important driver for deploying more NZTs. Several policy instruments are available to promote the technical development of NZTs. Regulatory sandboxes and net-zero acceleration valleys work as risk mitigation. By allowing experimentation in protected markets, these instruments lower barriers for Small and Medium-sized Enterprises, thereby increasing the level of technical development. Furthermore, R&D funding serves as a direct positive impact, driving innovation by providing capital. As technical development increases, it triggers a negative causality with production costs, which in turn reinforces the investment loops R1 and R3, driving technical development even further.

Investments in NZTs are crucial for driving technological development, reducing production costs, and increasing consumer demand for NZTs, as shown in R1-R3. There are three main ways in which the GDIP and NZIA intend to increase investments in NZTs, by providing incentives to invest, risk sharing, and financing. While financing for NZTs itself increases the incentives to invest in NZTs, there are additional incentives such as sustainability requirements for public procurement. This indirectly affects investments in NZTs as it positively impacts consumer demand, which in turn incentivises investments. Risk sharing plays a critical role in fostering investment by alleviating the risk burden on individual companies, thereby positively impacting investment.

There are several ways in which the EU policies positively affect the financing of NZTs. By making aids, grants and loans available for investment in NZTs, the EU provides financing for NZTs and increases the investments. Additionally, by simplifying the financial application process, the EU streamlines access to financing, reducing obstacles that might hinder secure funding.

There are also policy instruments that specifically target production costs and consumer prices, which influence the dynamics in R1-R3. For instance, tax breaks and tax credits for businesses can lower their costs, while subsidies can directly reduce costs for consumers.

4.3.1.3 Big Picture - Gothenburg focus

In figure 4.4, the conditions of the Gothenburg section 4.2 have been added to the technical system of the big pic from figure 4.3. This provides an overview of how the precondition in Gothenburg affects NZTs.

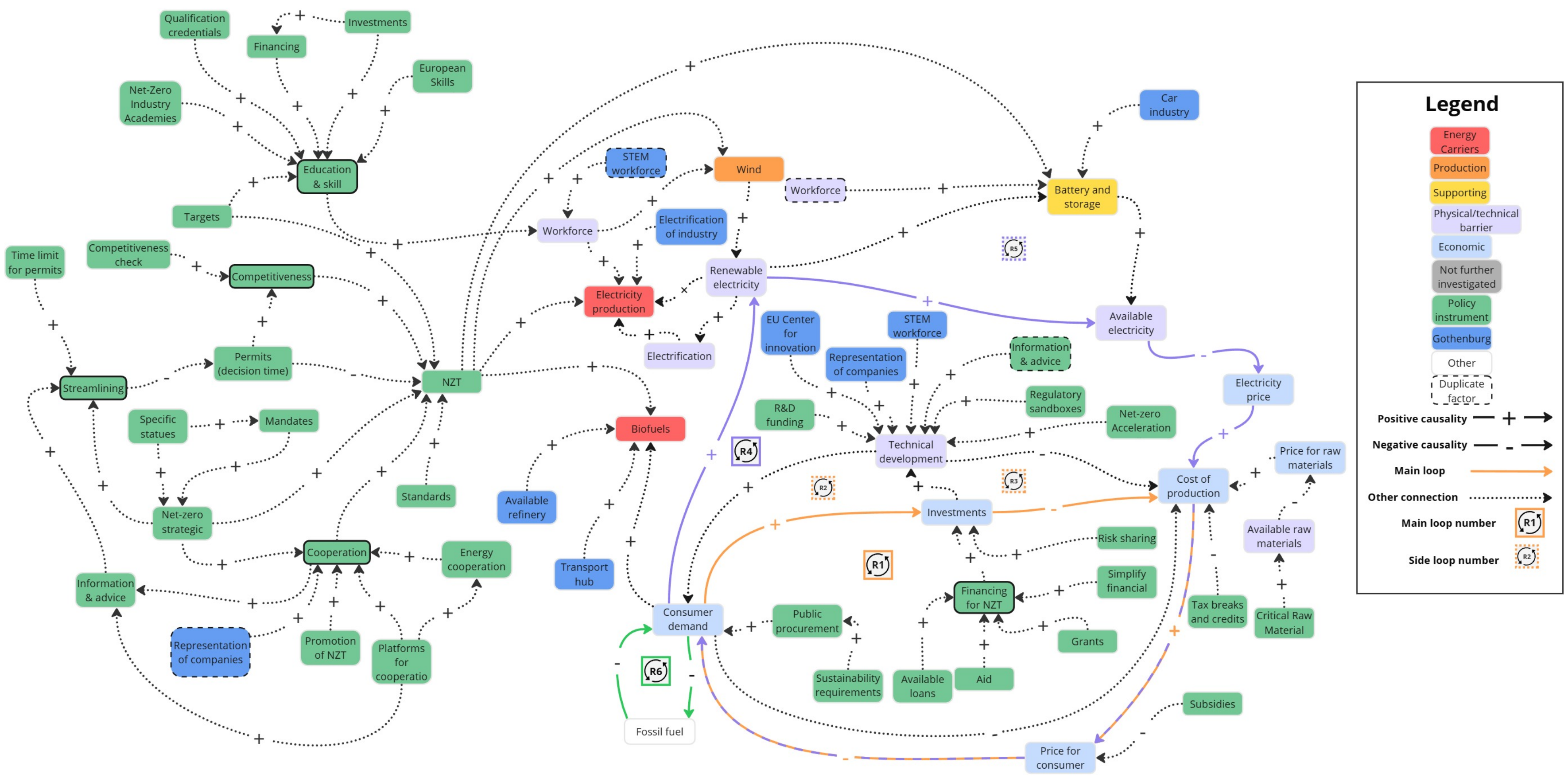

Figure 4.4: Causal loop diagram of the big picture with a focus on Gothenburg

Gothenburg provides many beneficial aspects for the implementation of NZTs, much due to its multiple and diverse industries, coastal location and its status as a transport hub (Business Region Göteborg, n.d.-a). Technical development benefits from the presence of many companies in Gothenburg, as it provides diverse knowledge (Business Region Göteborg, n.d.-a). This provides an opportunity for cross-sectoral cooperation. There are large investments in innovation in Gothenburg and it also has a high Science, Technology, Engineering & Mathematics (STEM) workforce density. (Business Region Göteborg, n.d.-a)

Having a large automotive industry with ambitious targets for EV production (Volvo Cars, 2026) motivates the expansion of the battery and storage industry. Gothenburg has a large industrial sector, and as industries become more electrified (F. Johansson et al., 2025) it is reasonable to invest in expanding electricity production. Furthermore, Gothenburg's location and role as a transport hub create a need for sustainable fuel (Business Region Göteborg, n.d.-c). This, together with the existing refineries and biofuel production locations (Transport & Environment, 2023), provides an opportunity to invest in biofuels, as there is already a market and the necessary infrastructure for production.

4.3.2 Electricity

Electricity production is a big part of NZTs with a special focus on renewable energy sources.

4.3.2.1 Electricity - Technical focus

Figure 4.5 presents the CLD for electricity.

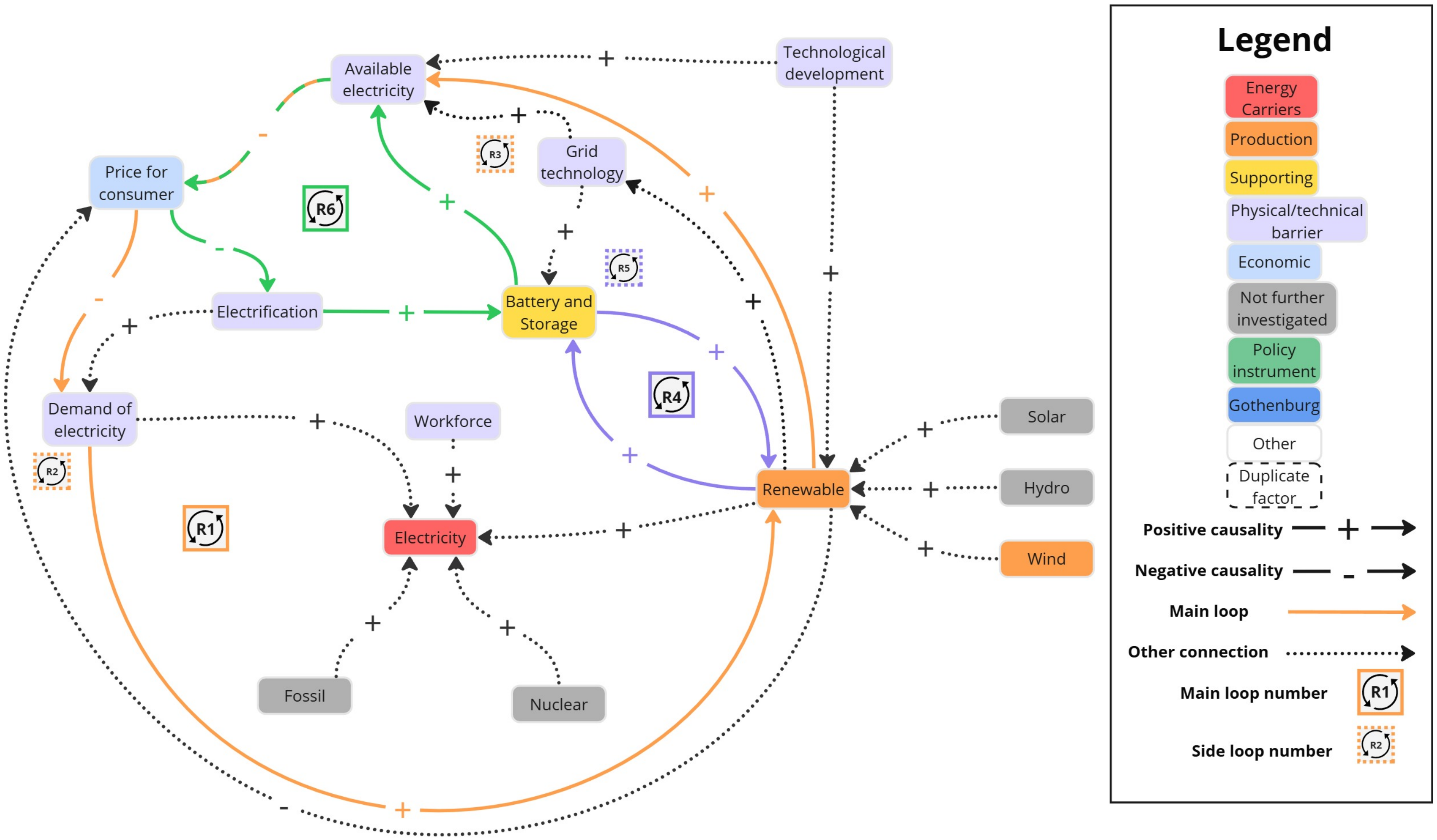

Figure 4.5: Causal loop diagram of electricity with a focus on technical aspects

Electricity can be generated through three primary sources: renewable energy, nuclear power, and fossil fuels (EIA, n.d.). Increasing the use of non-fossil energy sources reduces the need for fossil fuels.

As the production of renewable electricity increases, the total amount of available electricity increases, which decreases the price for consumers and increases the demand (Huntington, 2025) and creates a reinforcing feedback loop [R1]. There is also a connection between the increased level of renewable electricity and the decrease in price [R2], due to low production costs (Cevik et al., 2022). With the increase of renewable electricity in the grid, there is a need to develop the grid technology in order to handle the variations in production capacity [R3] (IEA, n.d.-b). Technical development has the ability to lead to more available electricity by increasing the places where it is possible to place power plants or by increasing the efficiency (Han et al., 2025; IRENA, 2022).

As society transitions away from fossil fuels, electrification is one alternative for some sectors. The electrification of industry and transport is a major driver of electricity demand (IEA, n.d.-a; F. Johansson et al., 2025). This requires increased electricity production, leading to an expansion of the renewable energy sector (EMBER, n.d.). Since wind and solar power are variable and weather-dependent, batteries and storage are needed to increase production and available electricity and to balance demand with production [R4]. (IEA, n.d.-b; IRENA, 2025c; MIT Energy Initiative, 2022) This can also be supported with grid technology [R5]. The increased available electricity due to the use of batteries and storage affects the price for consumers, which pushes for electrification and again increases the need for batteries and storage [R6].

There are no specific policies addressing electricity specifically, the Gothenburg preconditions for the relevant technologies in electricity will be presented in section 4.3.4 (European Commission, 2023a; European Parliament and Council of the European Union, 2024).

4.3.3 Biofuels

Biofuels are fuels derived from biomass and can take various forms. In this report, biofuels are defined as fuels utilised in vehicles, specifically biogas, ethanol, and biodiesel.(WWF, n.d.).

4.3.3.1 Biofuels - Technical Focus

Figure 4.6 shows the CLD for the technical aspects of biofuels.

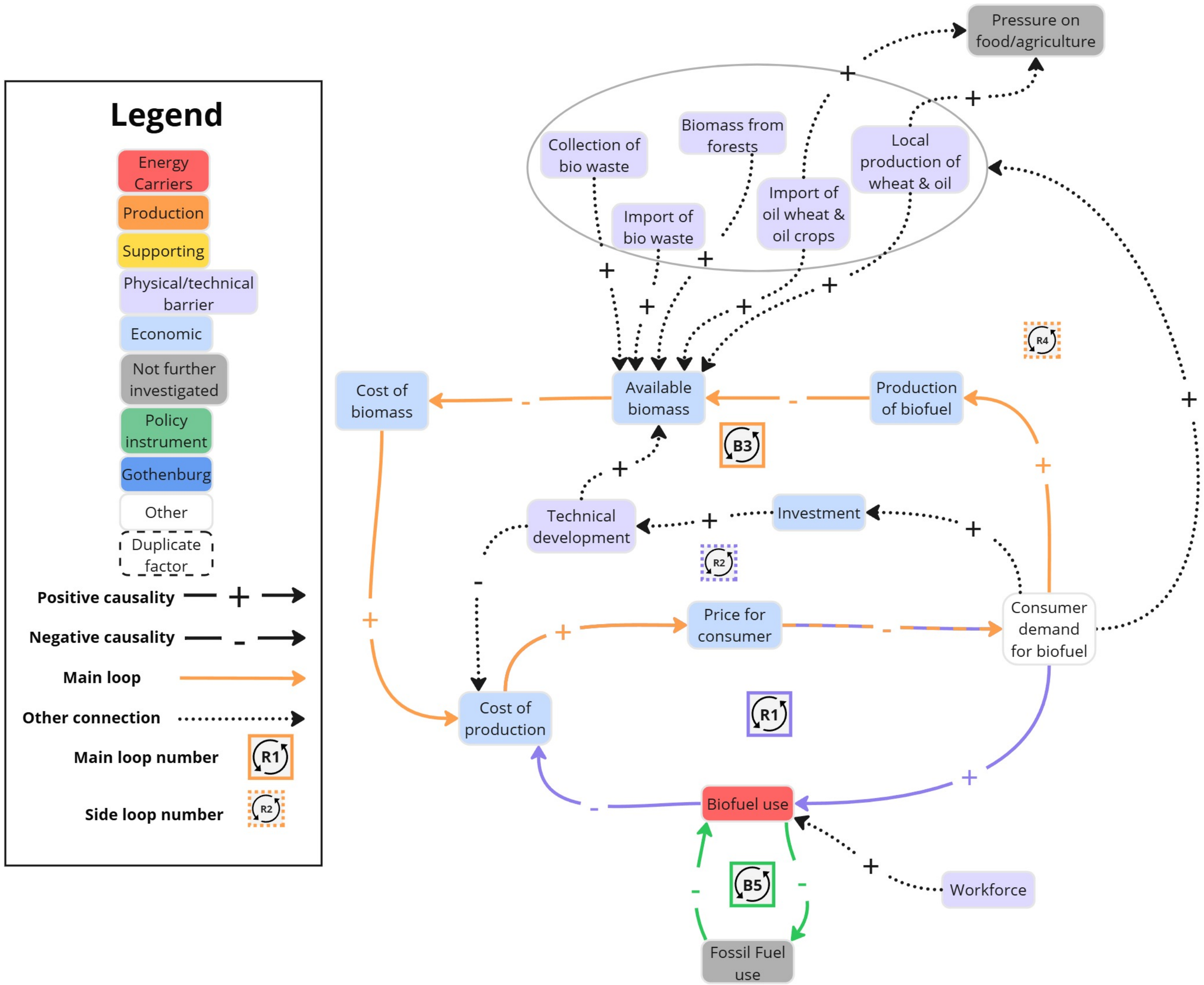

Figure 4.6: Causal loop diagram of biofuels with a focus on technical aspects

When the production of biofuel increases, there is a possibility of reducing the cost of production, this cost reduction is limited by the cost of biomass (Jacobson & Jeffers, 2013). This is due to the ability to optimise production and decrease the production time of each unit. A decrease in production costs can lower consumer prices, which in turn increases consumer demand and, ultimately, increases biofuel use (L. Chen et al., 2021; Millinger et al., 2022) [R1]. Several additional factors can influence these developments. As production volumes increase, the potential for technological development increases and has the ability to decrease the cost of production and increase the available biomass (Jacobson & Jeffers, 2013; Kessler & Sperling, 2016). With the consumer demand increasing, so does the willingness to invest in the technology. This investment increases the availability for technological development even more (Nelson et al., 2022) [R2].

Consumer demand motivates the increase in the production of a good, which in this case leads to an increase in biofuel production (Lundberg et al., 2023). By increasing the production, the available biomass decreases since it is a finite product (IEA, 2022) and contributes to a change in the cost of biomass, which affects the cost of production as a whole (Haas et al., 2006; Material Economics & Energy Transitions Commission, 2021) [B3].

This increase in consumer demand for biofuel can also necessitate expanding biomass production and collection (Svebio, 2020). The biofuel industry in Sweden is today already largely dependent on the import of biomass (Suzan, 2023). This biomass is in the form of animal fats, wheat & oil cops or biomass from the forest, depending on the type of biofuel (Naturskyddsföreningen, 2021). Both import and local production of biomass increase the available biomass but put pressure on the food/agriculture system (Bergsma et al., 2007; Kampman et al., 2010) [R4].

But there is an alternative to biofuels, namely fossil fuels. Biofuels have the ability to substitute fossil fuels and decrease the use [B5].

4.3.3.2 Biofuels - Political and Gothenburg focus

In figure 4.7, the policies from section 4.1 and 4.2 have been added to the technical system of biofuels from figure 4.6.

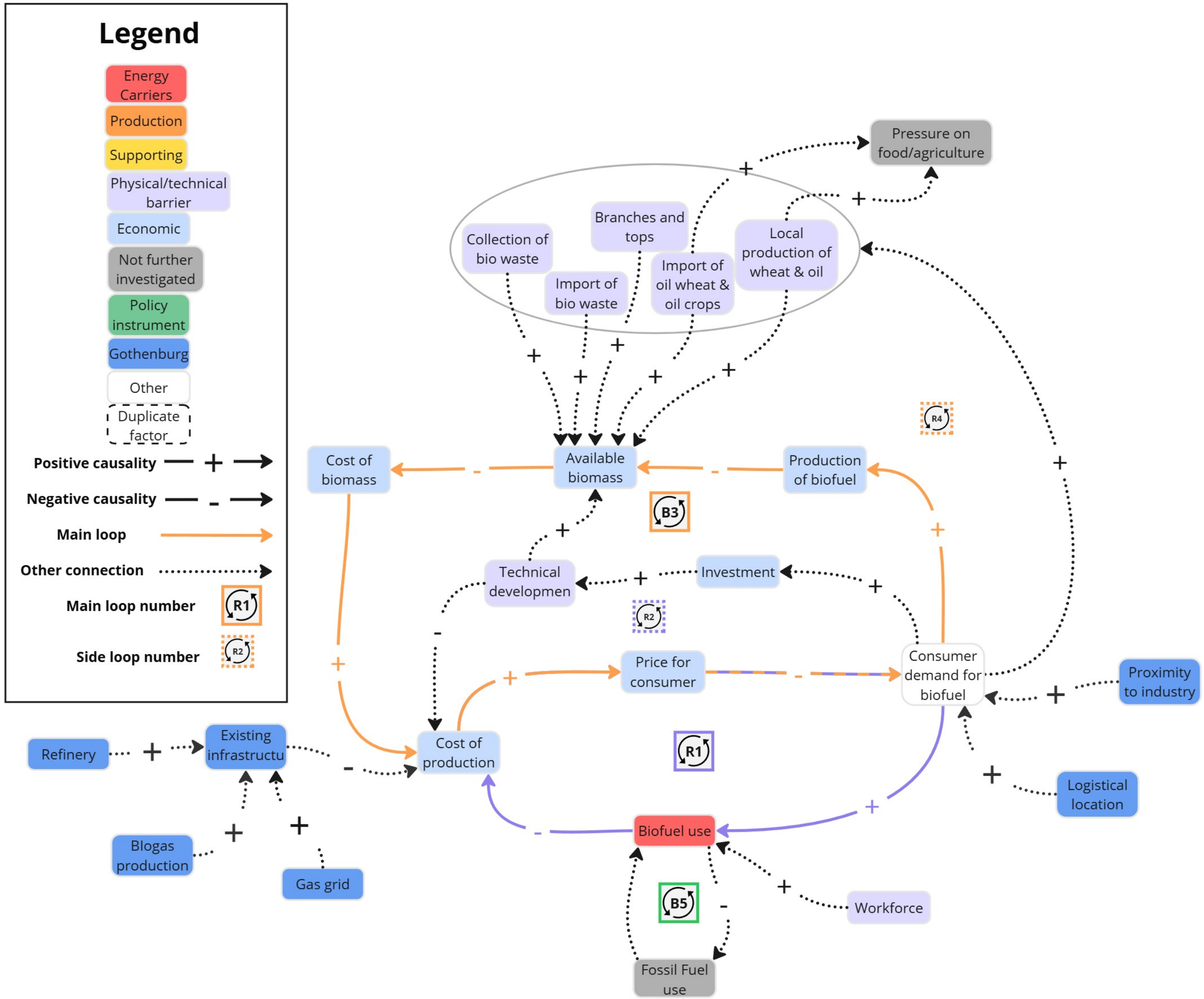

Figure 4.7: Causal loop diagram of biofuels with a focus on policy and Gothenburg aspects

There are no specific policies addressing biofuels specifically, however, biofuels will be affected by the general policy instruments addressing NTZs (European Commission, 2023a; European Parliament and Council of the European Union, 2024).

There are some specific preconditions for biofuel in Gothenburg. The current biofuel production in Gothenburg is quite small, Gryaab produces about 70 GWh of biogas per year (Gyraab, n.d.). The existing infrastructure, in the form of refineries and production sites for biofuels and fossil fuels, provides an opportunity to produce more biofuels, since much of the infrastructure is already in place, reducing construction costs (Invest in Gothenburg, 2023). Furthermore, the gas grid provides infrastructure that makes adaptation to biofuels easier (Göteborg Energi, n.d.-a). The location of Gothenburg also provides an opportunity to export biofuel, thereby expanding the range of possible consumers (Biofuels international, 2023).

All of this is limited by the available biomass, which can only be increased so much sustainably (Energy Transitions Commission, 2021). With the world's consumption of fossil fuels reaching about 500 EJ/year (IEA, 2021c), it will not be possible to replace all fossil fuels with biofuels (S. Johansson, 2013).

Even if the primary scope focuses on EU policy, it is worth noting the recent developments in Sweden regarding the reduction obligation. It was cut from 7,8% for petrol and 30,5% for diesel to 6% for both in 2024 to reduce consumer prices, and then adjusted to 10% in 2025 (Sajtos, 2025), creating regulatory uncertainty. This uncertainty complicates the industry's ability to predict, adjust, and plan its transition without long-term commitments from policymakers.

4.3.4 Wind power

Wind power is a renewable energy source that can be deployed both onshore and offshore.

4.3.4.1 Wind power - Technical focus

This is the technical system of wind, see figure 4.8.

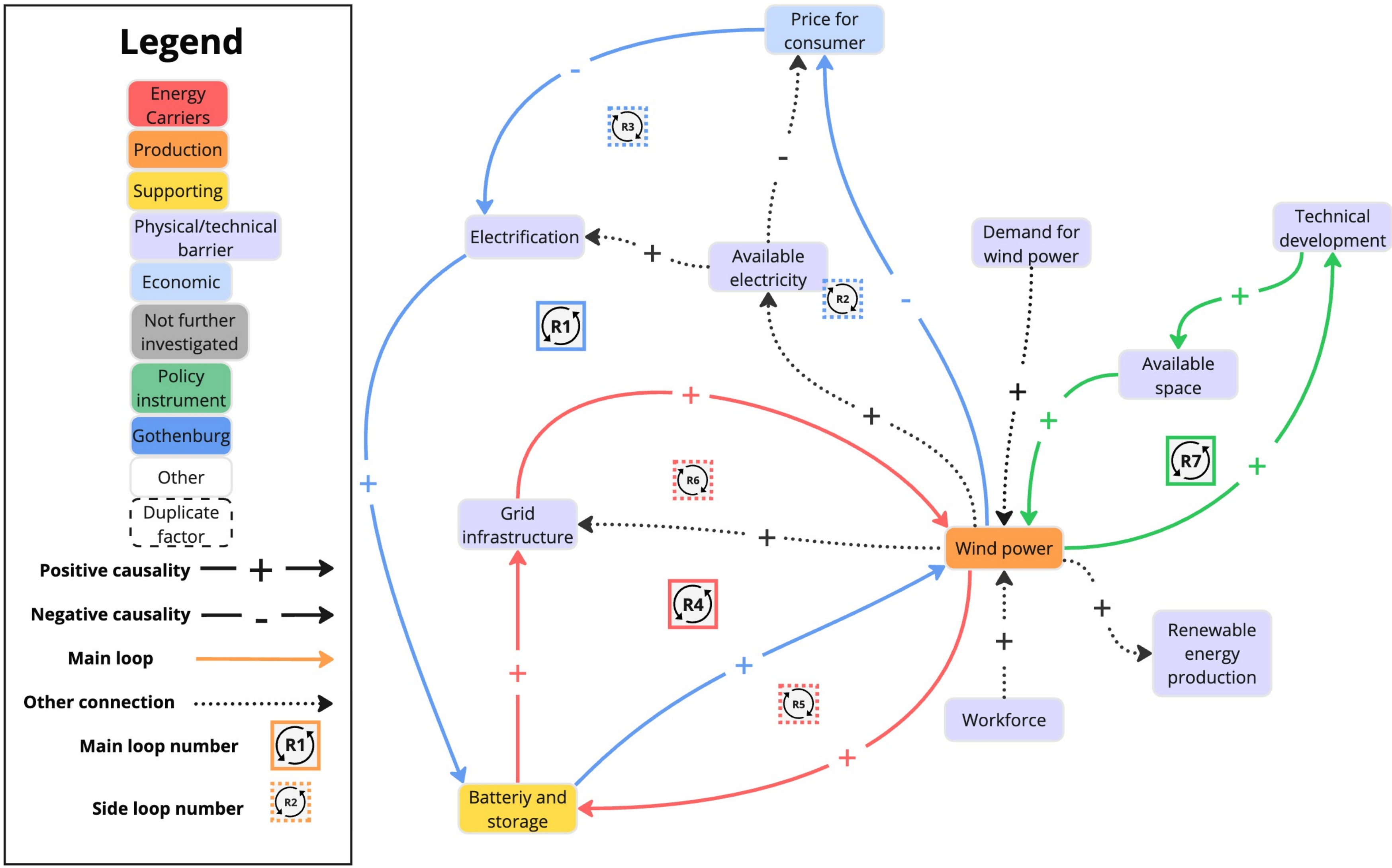

Figure 4.8: Causal loop diagram of wind power with a focus on technical aspects

Wind power increases renewable energy production (Matuszewska-Janica et al., 2021). The cost of producing electricity from wind power is not included, since there is next to no cost beyond the power plant's construction and occasional maintenance (Byers et al., 2018).

More wind in the energy mix lowers the price for the consumer due to the small cost of producing electricity through wind power (Cevik et al., 2022; EAI, 2026). These lower prices increase the motivation to electrify industries, which increases the demand for batteries and storage (Huntington, 2025; IEA, n.d.-b) [R1]. Furthermore, batteries and storage enable greater wind power deployment by storing electricity during non-windy periods (Amarapala et al., 2023). With more electricity available, electricity prices decrease, thereby facilitating the electrification of industries. (Dansk Industri, 2025; Naturskyddsföreningen, 2026) [R2, R3].

Since wind is dependent on the weather, the production is variable and unpredictable, and therefore dependent on battery and storage as well as grid infrastructure in order to have a continuous supply of electricity (Bertsch et al., 2017; Eroğlu & Kurtuluş, 2025) [R4]. More batteries and storage create an opportunity for more wind in the energy mix [R5]. Batteries and storage play a crucial role in enhancing grid infrastructure and, in turn, facilitate more wind power in the energy system [R6]. (IEA, n.d.-b; Jorgenson et al., 2015).

As more wind power is produced, the technical development is improving, and as the technology continues to improve, previously unsuitable areas for wind power may become viable for development. (Wiesenthal et al., 2012). For example, advancements in offshore wind energy have enabled floating wind turbines, allowing installation in locations previously considered impractical (Cappellari et al., 2026). More available space enables greater deployment of wind power (Moutinho et al., 2025) [R7].

Furthermore, wind power requires skilled personnel who are obtained through competence provision and education.

4.3.4.2 Wind power - Political and Gothenburg focus

In figure 4.9 the policies from section 4.1 and 4.2 have been added to the technical system of wind from figure 4.8.

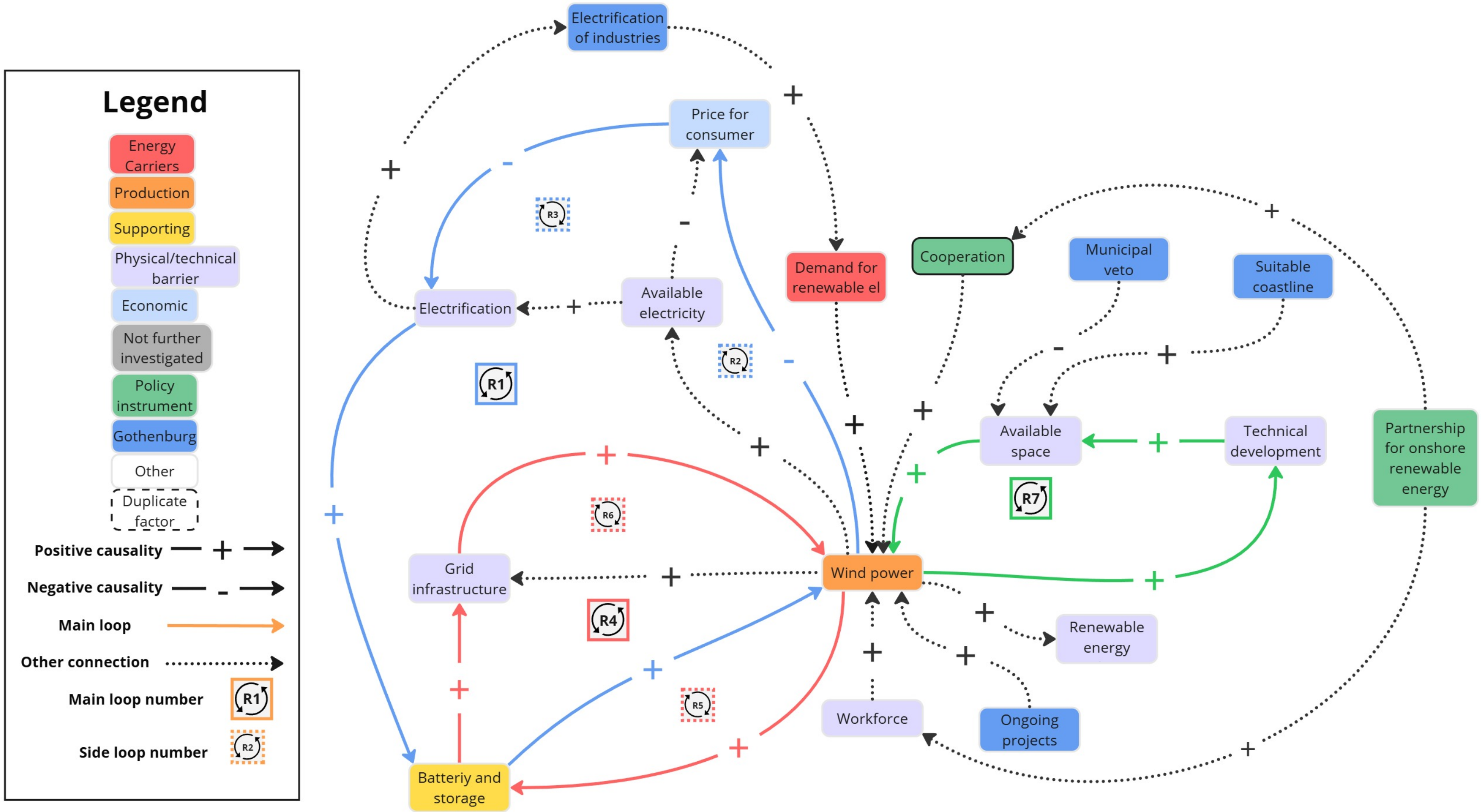

Figure 4.9: Causal loop diagram of wind power with a focus on policy and Gothenburg aspects

There is only one specific policy addressing wind power: cooperation through partnership for onshore renewable energy, intended to support the *pact of skill* (European Commission, 2023a), an initiative to promote education and training (European Commission, n.d.-f). This affects both the workforce and cooperation, which in turn positively impacts the deployment of wind power. Wind power will also be affected by the general policy instruments addressing NTZs (European Commission, 2023a; European Parliament and Council of the European Union, 2024).

Based on the findings in chapter 4.2, the electrification of industry in Gothenburg will increase the need for electricity (F. Johansson et al., 2025). As the coastline outside of Gothenburg is suitable for offshore wind, this provides an opportunity to deploy offshore wind power (Eolus, 2024). However, limited land availability discourages further expansion of onshore wind power (Göteborg Energi AB, 2024).

There are ongoing offshore wind projects outside the coast of Gothenburg that have the potential to pave the way for future initiatives (Eolus, 2024). These initial projects are crucial for adapting offshore wind power to the local context and serve as learning grounds for adapting the technology by refining installation methods and establishing what works in Gothenburg (Wiesenthal et al., 2012). Furthermore, the authorities learn from early permitting processes, and subsequently, approval processes might become more efficient with time. Shipping traffic heading for the port is a limiting factor in the expansion of offshore wind in the immediate coastal areas. (Ahlström et al., 2023) Also, the municipal veto has a negative effect on the expansion (F. Johansson et al., 2021). This, along with lengthy permit processes, creates uncertainty for potential investors.

4.3.5 Battery and storage

There are many parameters influencing the battery and storage industry. In figure 4.10 the technical system is presented.

4.3.5.1 Battery and storage - Technical focus

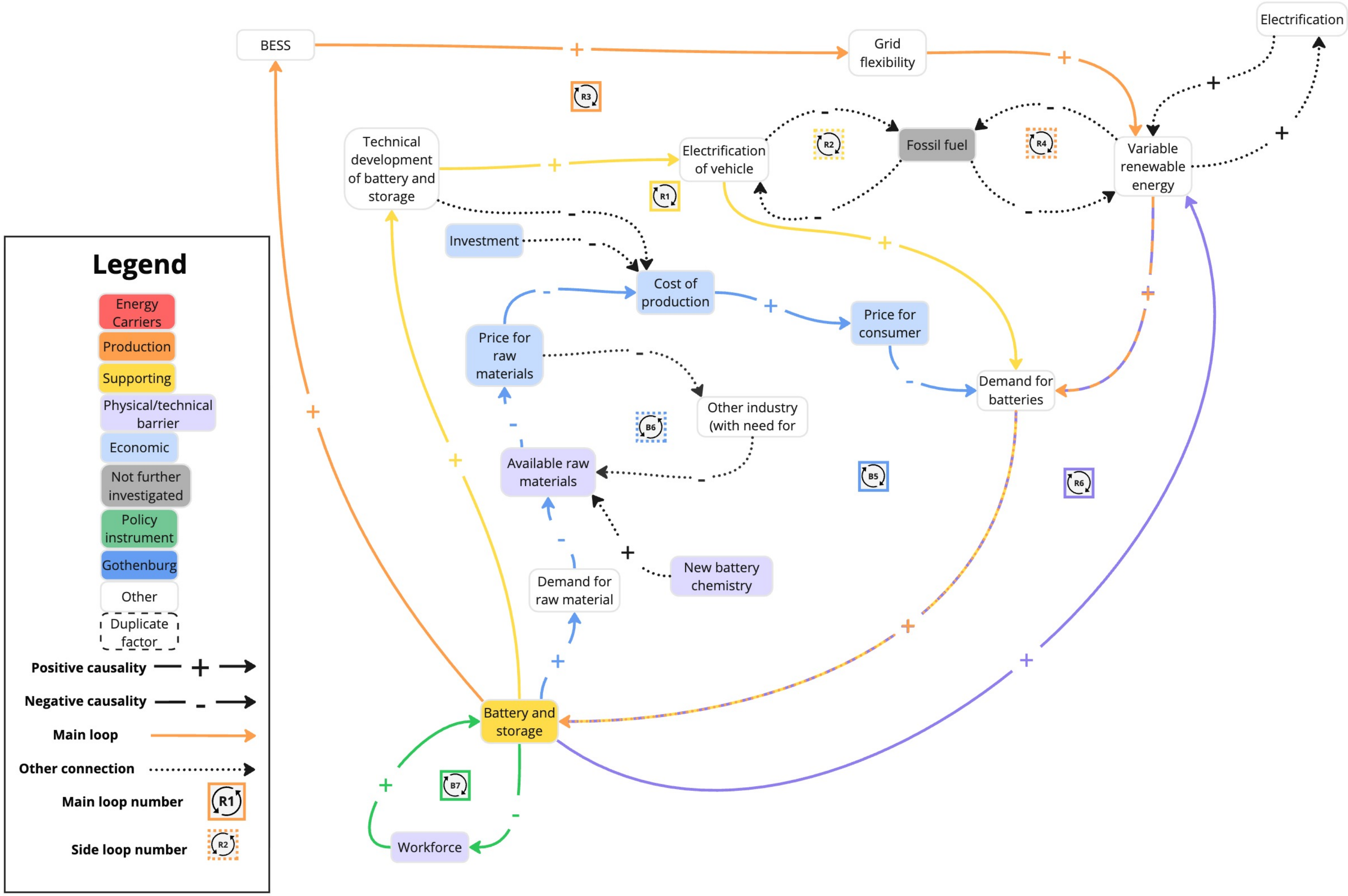

Figure 4.10: Causal loop diagram of battery and storage with a focus on technical aspects

The battery and storage industry is closely coupled with the renewable energy industry. In order to reach its full potential, renewable energy generation is dependent on batteries and energy storage. As many renewable electricity sources are variable and unpredictable, in order to increase production, the energy storage capacity needs to be expanded [R8]. (European Commission, 2021)

The generation and use of electricity need to be balanced on the grid; batteries and storage provide the flexibility to meet this demand. (European Commission, 2021) This reinforcing loop, [R4], illustrates how the development of the battery and storage industry is positively causally linked to the battery energy storage system (BESS) and, in turn, grid flexibility. (IRENA, 2025c) Increased grid flexibility allows for more variable renewable energy in the system, which increases the demand for batteries and storage. (European Commission, 2021; IRENA, 2025c) The EU intends to replace fossil fuels with renewable energy, which, together with the assumption that the total energy demand is constant, makes a reinforcing loop of negative causation between fossil fuels and renewable energy [R5]. (European Commission, n.d.-b) This loop shows that the battery and storage industry is closely coupled with electrification and the technical development of batteries and storage, as mentioned in 4.3.4.1.

The electrification of vehicles has been a major driver of the battery industry, demanding lighter, longer-range batteries. As the battery and storage industry develops the technical advancements of batteries and storage increase. As battery technology advances, so does the electrification of vehicles.(IEA, 2024) This becomes a positive feedback loop, including the demand for batteries [R1]. As the automotive industry shifts towards electric cars, the need for fossil fuels decreases [R2]. (European Commission, 2021) The technical development of batteries and storage can reduce production costs (IRENA, 2025a), which indirectly affects demand by lowering consumer prices (IEA, 2024) and improving the range of electric cars. [R3]

Today, lithium-ion batteries are the leading battery technology, but new battery chemistries are being developed. Lithium-ion batteries require some critical raw materials, specifically lithium, nickel, cobalt, copper, graphite, and manganese. (IEA, 2024) There are concerns about supply chain risk and price volatility [B6, B7]. (IEA, 2025a) Historically, the price has been highly volatile, peaking in 2022, raising concerns for the supply chain (IEA, 2025a). This can cause an increase in the cost of production.

4.3.5.2 Battery and storage - Political and Gothenburg focus

In figure 4.11, the policies from section 4.1 and 4.2 have been added to the technical system of battery and storage from figure 4.10.

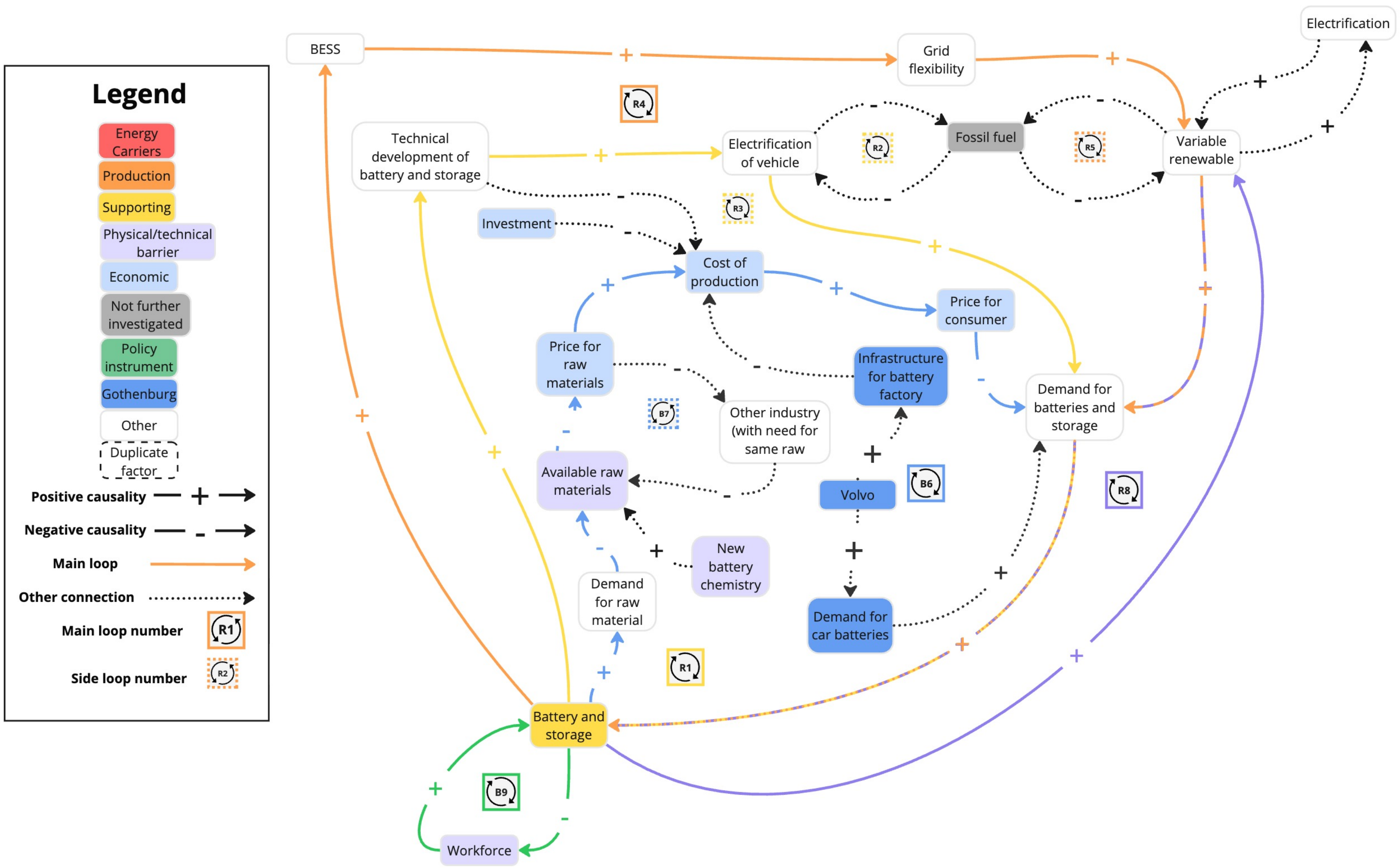

Figure 4.11: Causal loop diagram of battery and storage with a focus on policy and Gothenburg aspects

From the EU policies, there is one specific policy related to batteries and storage, a regulatory framework for batteries, with the ambition to increase the competitiveness of batteries (European Commission, 2023a; European Parliament and Council of the European Union, 2024). Battery and storage will also be affected by the general policy instruments addressing NTZs. In a wider sense, if the share of renewable electricity increases in Gothenburg, batteries and storage would be required to secure a balanced grid (Region Västra Götaland, 2025).

Based on the findings in chapter 4.2, the work with the battery factory is an important precondition in Gothenburg. The direct effect lies in the battery factory established through a partnership between Volvo and Northvolt (Novo energy, n.d.). Due to Northvolt's bankruptcy, Volvo is now the sole owner of the factory and needs a partner to continue operations at the battery factory (Junkala, 2026). As Volvo Cars has committed to produce only EVs by 2040 (Volvo Cars, 2026), there is a clear market for batteries in the city. With all the work and money already invested in the battery factory, there is an opportunity to restart using the existing infrastructure, thereby lowering upfront investment costs.

4.4 Leverage points and policy recommendations

In this chapter, the leverage points identified from previous chapters will be presented, followed by the policy recommendations for the city of Gothenburg.

Considering the industrial, infrastructural and geographical conditions in Gothenburg, some things are becoming clear. For Gothenburg, it is all about the interconnection of the energy sector/system (Göteborgs Stad, 2022). To summarise the findings in Table 4.2, electrifying the industry requires an increased supply of net-zero electricity. While this electricity does not have to be produced in Gothenburg, enhancing local production would be advantageous to prevent grid constraints, such as congestion (Göteborg Energi, n.d.-d). Table 4.2 shows that the best options for Gothenburg to increase its production of net-zero electricity are wind and solar power. Expanding these variable energy sources would, in turn, require more energy storage. The investment already made in the battery factory in the city could be a stepping stone not only for supplying the automotive industry but also for working with BESS. The battery factory, while closely linked to the automotive industry, could also significantly enhance energy storage expansion in the area by attracting essential expertise and talent to the city.

The prolonged permitting processes are an issue that, if addressed, could help deploy NZTs faster. It is still necessary to ensure that legal processes are followed, but by speeding up the permitting processes, for example, with more resources, NZTs can be deployed more quickly. For example, within the County Administrative Board of Västra Götaland, three project proposals for offshore wind power are awaiting government approval after being assessed by the local authorities (Länsstyrelsen Västra Götaland, n.d.).

Another leverage point would be to use the existing infrastructure in the refineries to shift the production towards biofuels. This would require investments to adapt to a new kind of production (Transport & Environment, 2023) but since much of the infrastructure is already in place, the changes would be incremental.

Based on the signals from the GDIP and NZIA, combined with the analysis on enablers and barriers for the studied NZTs, we propose the following policy recommendations for the city. While these recommendations are based on the analysed EU policies and the specific technological needs, a detailed review of the city's existing policy documents is beyond the scope of this study. Consequently, some of these measures might already be in place, under development, or partially addressed locally.

(a) As the GDIP and NZIA addresses permitting times, the city needs to address this issue as well. Even though it might be a matter not only at the local level but also at the national level, it also needs to be addressed by the city.
(b) Some aspects of development are beyond the city's control, but public procurement is a powerful tool to help stimulate the market. Requesting sustainable solutions, favouring NZTs, in the city's procurement, creates a market. The EU also mandates this type of procurement.
(c) Gothenburg has a great opportunity to invest in innovation, given its high density of STEM personnel in the population, which provide opportunities for the transition toward a net-zero energy sector. Our recommendation is to utilise that asset and keep Gothenburg's industry as a frontrunner and innovation hub.
(d) Continue on the path of biofuel production for the city-owned companies and help facilitate and encourage the transition to biofuels at the refineries. Here, possible cooperation should be investigated. Maybe the actors can specialise in handling different types of biomass, or create a joint biomass import.
(e) The city should facilitate cooperation, both by bridging the public and private sectors and by fostering collaboration among businesses. Specifically, the city should work to facilitate platforms for cooperation in NZTs, both within the energy sector and across industries. Utilising the broad technical competence within the city and working cross-sectoral to create symbioses within the industry clusters.
(f) We recommend that Gothenburg continue the deployment of solar power, intensify the efforts for offshore wind power, support the transition to biofuels within the refinery industry, and promote the battery industry in the city. Additionally, the city should explore the feasibility of e-fuels to utilise point-source emissions via CCU and examine the resulting hydrogen sourcing requirements.

4.5 Limitations and further research

In this chapter, the limitations and further research will be discussed.

The sustainability transition is a big and multifaceted process which has a multitude of levels. This report has limited the scope to the GDIP and NZIA, which provides one perspective on the implementation of NZTs. This is, however, not a complete picture of all actions. There are actions in other EU strategies as well as local in Gothenburg and in Sweden that affect the transition and have not been taken into consideration due to the limited time of this report. The main objective of the GDIP and NZIA is on NZTs in general, which increases the risk of the report missing nuance and specific actions related to specific technologies. On a similar note, policies can be interpreted differently due to vagueness. This has been addressed by checking the interpretation between the authors, but there is still a possibility of misinterpretations.

One of the big industries in Gothenburg today is the refinery industry with VARO-Preem and St1. Phasing out fossil fuels will be challenging for these companies, since their entire business models are built on fossil fuels. However, there are some initiatives to phase out fossil fuels from these industries and replace them with E-fuels and biofuels. These fuels will have to be the future for these industries to reach net-zero emissions, otherwise, these industries will be replaced by other forms of energy. Since not all fossil fuels can be easily replaced by electrification, for example, heavy transport and maritime transport, there is and will be a need for renewable fuels. We think that if these industries are to stay relevant in a future scenario with a phase out of fossil fuels, renewable fuels are the way to go.

Worth noting is that the assumption that replacing fossil fuels reduces their use is a simplification of the system. In reality, decreasing the use of fossil fuels causes prices to fall, which increases demand for them, creating a balancing loop (Rajagopal, 2013). It is therefore not enough to invest in biofuels, there also have to be incentives against fossil fuels. This is where the policies such as carbon taxes, the EU emission trading system and so on make a difference. These dynamics should be further researched and applied to the system.

Due to the limitations of this study, some important leverage points may be missing. While many of the NZTs could have been further explored regarding their specific technical requirements, cost-efficiency and so on, to deepen the systemic understanding, such an expansion would have come at the expense of the study's depth in other critical areas. Further research should include the topics left out of this report, such as e-fuels, hydrogen, and CCU, to capture the whole system and identify additional leverage points. Given the proposal to change Swedish law on nuclear (Swedish Government, 2026), that option should also be further investigated. The limited scope, which excludes some technologies, has a limited understanding of the interconnections within the whole system. For example, the energy plan for the city of Gothenburg (Göteborgs Stad, 2022) notes that a shift away from fossil fuels in the refineries could negatively affect the district heating system, as the output is likely to be at a lower temperature. Based on this, further research should examine how these technologies fit within the system and conduct a more technical analysis of the technologies included in this study. Furthermore, it proved difficult to fully capture the complexity of the energy sector in Gothenburg within the time frame of this project. This report is the first step to understanding what the net-zero energy sector in Gothenburg might look like, but other factors affecting this should be added to the analysis to complete the picture. This report is therefore an initial study which can be further elaborated through further studies.

4.6 Navigating the research scope

One of the issues in writing this report was that we did not set clear system boundaries from the beginning. Due to the time frame of this project and the inherently complex nature of systems analysis, establishing suitable system boundaries has been a significant challenge. Although it was not explicitly intended from the start, the approach followed the Double Diamond design framework. Initially, approaching Gothenburg and EU policy in an explorative, divergent manner, which was subsequently narrowed down to establish the scope and system boundaries. Once the boundaries were set, the second diamond was opened by exploring the specific problem areas. Based on these findings, the possible paths for Gothenburg were explored, and finally, recommendations for the city were made based on this. The inherently complex nature of systems analysis makes the boundaries and scope important parts of the project, but keeping them exploratory at the beginning allows space to identify the right approach. However, while there are advantages to this kind of open boundaries when starting out the project, it is also a more time-consuming approach, leading to some interesting aspects being excluded from the scope due to resource constraints, such as e-fuels. Consequently, it affects the final results. This also means that some of the subjects researched during the process did not make it into the final report. Here, we will discuss some parts that were not included in the final scope.

Initially, the report focused more on specific industries in the Gothenburg region. For this, we mapped the types of producing industries present in Gothenburg and divided them into different groups with the aim of being able to map their connection. However, the connections were never mapped due to the shift in focus.

To understand what the industry requests of policy and policymakers, and what they view as the key needs for transitioning their industry, sustainability reports from one company in each group were read. To complement the sustainability reports and gain a circular economy perspective, the preparatory work for the Circular Economy Act was reviewed ("Call for evidence"). This preparatory work includes gathering input from stakeholders on their concerns regarding the upcoming act, scheduled for 2026. This included statements from Swedish companies on what they considered important for the coming act. Six companies from different industries were selected to provide a range of perspectives.

This industry focus was shifted towards the energy sector because it expanded the scope beyond what was feasible within this time frame. Furthermore, the boundaries of the studied system were hard to define with the industry focus, which once again broadened the scope of the report.

Lastly, a Swedish and Gothenburg perspective on policies was included from the beginning. Klimatpolitiska rådets [The climate policy council's] report (Klimatpolitiska rådet, 2025) and *The climate plan for the City of Gothenburg's Environment and Climate Programme 2021-2030* Göteborgs Stad (2024) were read and coded along with the GDIP and NZIA in the QCA. These were, however, removed due to it not giving a comprehensive view of how the Swedish and Gothenburg policy looks.

5

Conclusion

The aim of this study is to propose policy recommendations based on leverage points for Gothenburg's transition towards a net-zero energy sector, in alignment with the Green Deal Industrial Plan (GDIP). The transition to fossil-free energy production is a necessary step in combating climate change. By introducing NZTs, the effects of climate change can be mitigated, and GHG emissions to the atmosphere can be reduced. The EU is working towards net-zero emissions and has therefore implemented policies towards that goal, which will affect the future of Gothenburg. To find a path forward for Gothenburg in this transition and propose policy recommendations, the following RQs have been answered:

1. What are the policy signals from the EU conveyed in the Green Deal Industry Plan (GDIP) and Net-Zero Industry Act (NZIA), on how to implement net-zero technologies
2. What enablers and barriers influence the effective implementation of net-zero technologies in Gothenburg, considering industrial, infrastructural and geographical conditions?
3. Which net-zero technologies are most viable in a Gothenburg context?

To answer these questions a QCA, literature review and CLDs have been used. The scope of this thesis is NZTs with a focus on biofuels, wind power and battery & storage.

The EU policy documents that are the main focus of this report are cross-sectoral and refer to NZTs in general rather than specifying the technologies. Hence, based only on the EU policy, it has proven difficult to give Gothenburg specific recommendations on which of the NZTs to invest in for the future. The conclusions from the analysis of the EU policy are that the EU want to deploy more NZTs and they take many different actions to increase the deployment of NZTs. By synthesising this with the preconditions in Gothenburg, it is posible to conclude that some technologies have no scalable potential in Gothenburg, like hydropower. Some are already well on their way with extensive plans, such as solar power, and others are possible but require the deployment of new technologies and larger changes, such as biofuels.

The policy recommendations are the following (these are elaborated in 4.4):

(a) Address permitting times and work to improve the permitting process to accelerate the deployment rate of NTZs.
(b) Sustainability requirements for public procurement.

(c) Utilise the high density of STEM personnel in the population.
(d) Keep producing biofuels for city-owned companies and support the transition to biofuels at the refineries.
(e) Facilitate collaboration within the industry.
(f) Technologies to invest in: Solar and wind power, biofuels, and batteries. Explore the feasibility of e-fuels further.

To summarise, the electrification of industry will require more electricity in the city, the primary ways of increasing the electricity production in the city are solar and wind power. Since variable electricity will require more energy storage, the suggestion is to resume the work with the battery factory to promote the development of the battery industry in the city. The refineries should further investigate how to transition their production from fossil fuels to net-zero fuels, primarily focusing on biofuels, while also exploring the possibilities for e-fuels.

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A

Appendix A: QCA Coding

A.0.1 Coding manual

Table A.1: Coding manual

Subtheme	More nuanced description of the themes. Subthemes in italics are added with inductive method
2.2) Standards	2.2) Create a level of uniformity that has to be achieved
2.3) Mandates	2.3) Give authority to act in a certain way, could include specific status.
2.4) Targets	2.4) A level of achievement that should be met
2.5) Streamlining	2.5) Improving efficiency in different administrative processes
2.6) Competitiveness	2.6) Different interventions to address competitiveness on the market
2.8) Requirements	2.8) An action that should be done but not defined in law
3.0) R&D funding	3.0) Providing economic means for the research/development of a concept
3.1) Subsidies	3.1) A decrease in the cost of industry, i.g. reduce the cost of loans
3.2) Grants	3.2) Money given for a particular purpose
3.3) Loans	3.3) Lending money
3.4) Taxes	3.4) Instruments related to taxes
3.7) Public procurement	3.7) - 'public procurement procedure' means either of the following: - (a) any type of award procedure covered by Directive 2014/24/EU for the conclusion of a public contract or Directive 2014/25/EU for the conclusion of a supply, works and service contract; - (b) a procedure for the award of works or a service concession covered by Directive 2014/23/EU;
3.8) Investment	3.8) Financing project with the hope of getting an return in the future
3.9) Aid	3.9) Money given to organisation or project from public funding.
4.1) Education & Competence provision	4.1) Providing the opportunity to learn (longer perspective)
4.3) Advice	4.3) Providing a contact for support and guidance
5) Cooperation	Working together towards a common goal
6.2) Pilots	6.2) Provide opportunity to test ideas/hypotheses/new concepts

A.0.2 Excel file

QCA coding

Note: To access and open the attached Excel file, please download this PDF and open it using a dedicated PDF reader, such as Adobe Acrobat Reader

B

Appendix B: AI declaration

During the writing of this report, Grammarly, an AI writing assistant, was used to help improve the writing by proofreading and grammatical corrections. Gemini 3.5 Flash was used to assist with some LaTeX coding and to suggest linguistic improvements. The analysis and all final writing decisions were made by the authors. The specific use of generative AI for data categorisation is detailed in the section below. The prompt used for fact-checking the CLDs can be found in 3.3.

B.1 Prompt for refining categories

Below is a description of the interaction with AI (Gemini 3.5 Flash (Thinking Mode)) to help with the coding categories.
The following instructions were given to the AI model.

Prompt 1

Vi försöker göra en kodning inom ramarna för "content analysis" enligt Bell et al. 2022 (Business research methods). Vi är lite osäker på våra kategorier och hade velat ha hjälp att göra bättre (tydligare och mer omfattande) indelningar inom kategorierna. Skulle du kunna hjälpa oss med att ge förslag på indelningar inom kategorierna för att förbättra kodningen?

Input Data from excel sheet:

```
Age it was written (0 if unknown)0) Not relevant 1) Other 2)
General/Unspecific 3) Nextgeneration EU 4) REPower EU 5) InvestEU
"Just transition" scheme 6) The Climate Law 7) Fit for 55 8)
CBAM 9) The green deal industry plan 10) The Net-Zero Industry
act 11) Zero pollution action plan 12) EU-ETS0) No action 1)
Action0) Not relevant 1) Generall/Unspecific 2) Other 3) solar
photovoltaic and solar thermal technologies 4) onshore wind
and offshore renewable energy 5) batteries and storage 6) heat
pumps and geothermal energy 7) electrolysers and fuel cells 8)
biogas/biomethane 9) carbon capture and storage (CCS) 10) grid
technologies (which also include electric vehicles smart and fast
charging) 11) Fossil fuels 0) Not relevant 1) Other 2) Signals
3) Setting enabling conditions 4) Accelerating CO2 capture and
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storage 5) Facilitating access to markets 6) Enhancing skills
7) Fostering innovation 8) Building Industrial Partnerships 9)
Legislation0) Not relevant 1) Other 2) General/Unspecific 3)
Nextgeneration EU 4) REPower EU 5) InvestEU "Just transition"
scheme 6) The Climate Law 7) Fit for 55 8) CBAM 9) The green deal
industry plan 10) The Net-Zero Industry act 11) Zero pollution
action plan 12) EU-ETSAge to implement it (if not applicable 0)0)
Not relevant 1) Other 2) General/Unspecific 3) Increase 4) Decrese
5) Remove 6) Monitor 7) Improve 8) SimplifyNumber in % (9999 if not
applicable)0) Not relevant 1) Other 2) General/Unspecific 3) Taxes
4) EU-ETS 5) Funding 6) Education 7) Cooperation 8) Technological
development StatementsAgeDocumentActionIndustryInstrument"Name of
action?"Age of implementationChangeValue of action?  (If action
is not remove)FactorThe starting point for the Plan is the need
to massively increase the technological development, manufacturing
production and installation of net-zero products and energy supply
in the next decade, and the value added of an EU-wide approach
to meet this challenge together.20239012 390399998It [Green Deal
Industrial Plan] also seeks to avert the risk of replacing our
reliance on Russian fossil fuels with other strategic dependencies
that could impede our access to key technologies and inputs for
the green transition, through a mix of diversification and own
development and production.20239011290299998This is why this year
the Commission has introduced an additional 'competitiveness check'
on all new regulation to ensure that all potential competitiveness
impacts are addressed and unnecessary burdens avoided.  A simple,
predictable and clear regulatory environment is key to promoting
investment.2023911592023699997First, as part of the Green Deal
Industrial Plan, the Commission proposes to put forward a
Net-Zero Industry Act to underpin industrial manufacturing of
key technologies in the EU.20239119100099990The act [Net-Zero
Industry Act] would provide a simplified regulatory framework for
production capacity of products that are key to meet our climate
neutrality goals, such as batteries, windmills, heat pumps, solar,
electrolysers, carbon capture and storage technologies 4 .2023911
4 5 6 7 9210089999Following sector-specific analysis, identify
goals for industrial capacity by 2030 where necessary to ensure
that strategic dependencies do not put the green transition at
risk.  It will consider the whole supply and value chain across
borders, so that supplies do not become a bottleneck;2023Reduce the
length and enhance the predictability of permitting processes by
defining specific time limits for different stages of permitting,
and significantly reinforce Member States' administrative capacity,
e.g.  by introducing a 'one-stop-shop' - a sole point of contact
for investors and industrial stakeholders during the entire
```

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administrative process.2023The Act could enable the Commission
to request European standards promoting the fast roll-out of key
technologies2023
```

B.1.1 AI-generated answer

Response from Gemini 3 (Thinking Mode) -Verbatim

Det här är ett spännande projekt! Att tillämpa innehållsanalys (content analysis) enligt Bell et al. (2022) kräver precis det ni arbetar med nu: **ömsesidigt uteslutande** (mutually exclusive) och **uttömmande** (exhaustive) kategorier. Just nu ser jag en del överlappningar, särskilt mellan policyinstrument, åtgärder och faktorer. För att öka reliabiliteten (så att två personer kodar samma sak på samma sätt) behöver vi strama upp definitionerna.
Här är mina förslag på hur ni kan förfina och strukturera era kategorier:

1. Förfining av befintliga kategorier

- **Kategori: Industry / Technology (Branscher & Teknik):** Ni har en bra lista baserad på Net-Zero Industry Act, men den kan grupperas för att fånga upp bredare uttalanden.
  - *12) Cross-sectoral/Multiple technologies:* När texten nämner "key technologies" utan att specificera vilka.
  - *13) Raw Materials / Supply Chain:* Eftersom ni nämner "strategic dependencies" i ert exempel, behövs en kategori för råmaterial (t.ex. litium, sällsynta jordartsmetaller).
- **Kategori: Instrument (Policyverktyg):** Här blandas specifika lagar (CBAM) med generella metoder (Legislation). Det är bättre att separera vad det är från vilket specifikt initiativ det tillhör.
  - *Regulatory:* Lagstiftning, standarder, tillståndsprocesser (Permitting).
  - *Economic/Financial:* Skatter, subventioner, EU-ETS, finansiering (Funding).
  - *Soft Law/Support:* Vägledning, samarbete, nätverksbyggande.
  - *R&D/Innovation:* Stöd till forskning och teknikutveckling.
- **Kategori: Change (Typ av förändring):** För att göra detta mer omfattande bör ni även fånga riktningen på styrningen.
  - *9) Streamline/Accelerate:* Används ofta i texten (t.ex. "fast roll-out" eller "predictability").
  - *10) Harmonize:* När man pratar om gemensamma EU-standarder istället för nationella.

2. Förslag på ny kodningsstruktur (Kodschema)

För att undvika förvirring rekommenderar jag att ni delar upp kodningen i tydliga dimensioner:

Dimension	Beskrivning	Exempel på koder
A. Policy Arena	Vilket specifikt EU-ramverk?	1. Green Deal, 2. NZIA, 3. REPowerEU
B. Mechanism	Hur ska målet nås?	1. Finansiellt stöd, 2. Regulatorisk förenkling
C. Target Sector	Vad påverkas?	1. Vindkraft, 2. Batterier, 3. Generell industri
D. Objective	Vad är syftet?	1. Minska beroende, 2. Nå klimatmål

3. Justering av era exempel (Pilot-testning)

Citat: *"Reduce the length and enhance the predictability of permitting processes..."*
Bättre kodning:

- **Instrument:** Regulatory (Permitting)
- **Change:** Improve/Simplify (7/8)
- **Factor:** Setting enabling conditions (3)

Tips för att öka reliabiliteten (enligt Bell et al.)

- **Skapa en kodningsmanual:** Skriv ner en kort definition för varje siffra. Exempel: "Kod 8 (Simplify) används när texten nämner minskad administrativ börda".
- **Exklusivitet:** Bestäm om ni kodar flera rader om en mening innehåller både "batteries" och "wind".
- **Residualkategorin "Other":** Använd denna sparsamt. Om den når över 10% behöver ni analysera dessa och skapa en ny kategori.

Vill ni att jag hjälper er att skriva korta definitioner för de nya kategorierna (en mini-kodningsmanual) så att ni och eventuella medkodare tolkar dem likadant?

Prompt 2

Vad skiljer ditt förslag på cross-sectoral/multiple technologies från general? Kan du för varje kategori (på engelska) skriva ut vilka koder som borde/kan ingå?

Response from Gemini 3 (Thinking Mode) - Verbatim

Bra fråga! Skillnaden är subtil men avgörande för att din data ska bli reliabel (tillförlitlig) enligt **Bell et al. (2022)**.

General/Unspecific: Används när texten pratar om "industrin", "ekonomin" eller "den gröna omställningen" i breda ordalag utan att nämna teknik överhuvudtaget.

Cross-sectoral/Multiple technologies: Används när texten är specifik men nämner flera tekniker samtidigt (t.ex. "batteries and wind") eller refererar till gruppen "net-zero technologies". Om du kodar detta som "General" tappar du informationen om att det faktiskt handlar om teknik.

Här är ett förslag på en mer omfattande och professionell kodningsmanual (Coding Manual) på engelska, strukturerad för att minimera överlappning.

1. Policy Framework (The Context)

Identifies which overarching EU initiative the statement belongs to.

1) Not relevant
2) General/Unspecific EU Policy (Broad mentions of EU goals)
3) The European Green Deal (The broad umbrella)
4) Green Deal Industrial Plan (The specific 2023 strategy)
5) Net-Zero Industry Act (NZIA)
6) REPowerEU (Energy focus/Russian gas dependency)
7) Fit for 55 / The Climate Law (Legislative targets)
8) NextGenerationEU / InvestEU (Funding frameworks)
9) CBAM (Carbon Border Adjustment Mechanism)
10) Other (Specific acts like the Critical Raw Materials Act)

2. Industry & Technology Focus (The Target)

What specific sector or technology is being discussed?

1) Not relevant
2) General Industry (No specific technology mentioned)
3) Cross-sectoral / Multiple Technologies (e.g., "Strategic net-zero technologies")
4) Solar (Photovoltaic and thermal)
5) Wind (Onshore and offshore)
6) Batteries & Storage
7) Heat Pumps & Geothermal
8) Hydrogen (Electrolysers and fuel cells)
9) Sustainable Biogas/Biomethane
10) Carbon Capture & Storage (CCS)
11) Grid Technologies (Including EV-charging infrastructure)
12) Raw Materials (Mining, refining, and recycling of critical minerals)
13) Fossil Fuels (Coal, oil, natural gas)
14) Other (Nuclear, biotech, etc.)

3. Policy Instrument (The Tool)

How is the policy being implemented?
1) Not relevant / No instrument mentioned
2) Regulatory/Legislative (Permitting, standards, mandates, “checks”)
3) Economic/Financial Support (Subsidies, grants, funding, state aid)
4) Market-based Instruments (Taxes, EU-ETS, carbon pricing)
5) Soft Power / Cooperation (Partnerships, dialogue, networking)
6) Research & Innovation (R&I) (R&D funding, pilots, labs)
7) Education & Skills (Training, “Net-Zero Academies”)
8) Other

4. Type of Action/Change (The Direction)

What is the intended movement or effect?
1) Not relevant
2) Increase/Expand (More production, more funding, more deployment)
3) Decrease/Reduce (Lowering emissions, less dependency, cutting red tape)
4) Remove/Phase out (Ending fossil fuel use, removing barriers)
5) Simplify/Streamline (Faster permitting, “one-stop-shops”, predictability)
6) Improve/Enhance (Better efficiency, higher standards, more skills)
7) Monitor/Analyze (Tracking progress, reporting, transparency)
8) Other

5. Strategic Factor/Objective (The Why)

What is the underlying goal or driver of the statement?
1) Not relevant
2) Competitiveness (Global market share, protecting EU industry)
3) Resilience & Security of Supply (Reducing dependencies on China/Russia)
4) Climate Neutrality (Decarbonization, hitting 2030/2050 targets)
5) Innovation Leadership (Being at the “forefront” of tech)
6) Social Fairness (Just transition, job creation)
7) Market Integration (Internal market, EU-wide approach)
8) Other

Illustration av kodningsprocessen

När ni kodar en mening, bör ni gå igenom varje kategori steg för steg för att skapa en “sträng” av koder.
Exempel på tillämpning med det nya schemat:
“The Act [NZIA] would provide a simplified regulatory framework for produc-

tion capacity of products... such as batteries and windmills."
Framework: 5 (NZIA)
Industry: 3 (Cross-sectoral)
Instrument: 2 (Regulatory)
Action: 5 (Simplify)
Factor: 2 (Competitiveness) eller 7 (Market Integration)

Nästa steg:

Skulle ni vilja att jag tar fram en inter-coder reliability checklist? Det är ett verktyg ni kan använda för att testa om ni kodar likadant innan ni sätter igång med hela materialet, vilket är ett krav för en högkvalitativ uppsats enligt Bell et al.

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