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Environmental, Social and Governance (ESG) scoring system: Towards net-zero city targets

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Title

Environmental, Social and Governance (ESG) scoring system: towards net-zero city targets

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Abstract:

The Environmental, Social, and Governance (ESG) framework is a critical tool for promoting sustainable urban development, especially as cities strive to achieve climate change adaptation, mitigation, and net-zero targets. However, there is a notable gap in city-specific ESG scoring systems that show cities' management capacity of the ESG factors and identify areas for improvement. Enhancing the ESG performance of cities can attract essential investments for financing climate initiatives and achieving sustainability goals. Despite extensive research on corporate ESG frameworks and urban sustainability indices, there remains a need for a tailored ESG framework for cities. This thesis aims to fill this gap by developing a comprehensive ESG scoring system tailored to cities.

This study's research question is: How can a city-specific ESG scoring system be developed to measure and enhance cities' sustainability performance? The study aims to define a set of city-level ESG indicators and a scoring system to address this.

The methodology includes a critical review of existing sustainability frameworks and standards, followed by a double materiality assessment. The indicators and scoring framework are applied to two case study cities: Lahti and Glasgow. Data is collected from open-access public sources and geospatial analysis using Google Earth Engine.

The key message of this research is the development of a city-specific ESG scoring system that provides a quantifiable framework for assessing cities' ESG risk management capacity. This system helps cities attract ESG-oriented investments, facilitate the financing of climate initiatives, improve transparency in line with the SDGs, and achieve net-zero targets.

Key findings reveal distinct sustainability profiles for Lahti and Glasgow. Lahti excels in environmental performance but faces social inclusivity and safety issues, while Glasgow excels in social infrastructure but faces significant environmental challenges. These insights highlight the effectiveness of the ESG scoring system in identifying areas for improvement and guiding investments.

This research provides a practical and tailored approach to developing city-specific ESG frameworks, offering valuable tools for policymakers and investors to improve urban sustainability performance and support global efforts to promote sustainable urban development and climate resilience.

Keywords

City ESG, ESG Scoring, urban sustainability, net zero cities, sustainable investment

Originality statement: I hereby declare that this Master's dissertation is my own original work, does not contain other people's work without this being stated, cited and referenced, has not been submitted elsewhere in fulfilment of the requirements of this or any other award.	**Signature**

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ABBREVIATIONS

BREEAM	Building Research Establishment Environmental Assessment Method
CDP	Carbon Disclosure Project
ICLEI	International Council for Local Environmental Initiatives
CH4	Methane
CO	Carbon monoxide
CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
CSI	City Sustainability Index
CSRD	Corporate Sustainability Reporting Directive
EBA	European Banking Authority
EEA	European Environment Agency
EFRAG	European Financial Reporting Advisory Group
EGCA	European Green Capital Award
EGLA	European Green Leaf Award
EN	European Norm
ERSA	European Regional Science Association
ESG	Environmental, Social and Governance
ESRS	European Sustainability Reporting Standards
EU	European Union
FI	Financial Institution
GBP	Green Bond Principles
GCIF	Global City Indicators Facility
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIS	Geographic Information System
GRI	Global Reporting Initiative
ICMA	International Capital Market Association
IEA	International Energy Agency
IFC	International Finance Corporation
IPCC	The Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
KPIs	Key Performance Indicators
LEED	Leadership in Energy and Environmental Design
NDCI	Normalized Difference Chlorophyll Index
NGOs	Non-Governmental Organizations
NHS	National Health Service
NI	Normalized Impact
NO_2	Nitrogen dioxide
OECD	Organisation for Economic Co-operation and Development
PM_{10}	Particulate Matter less than 10 micrometers
PM_2	Particulate Matter less than 2.5 micrometers
PPPs	Pprocurement, and public-private partnerships
PRI	Principles for Responsible Investment
SASB	Sustainability Accounting Standards Board
SBP	Social Bond Principles
SDG	Sustainable Development Goals

SLLB	Sustainability-Linked Loan financing Bonds
SO_2	Sulphur dioxide
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
USIFs	Urban Sustainability Indicator Frameworks
W_B	Weight for Biodiversity
W_C	Weight for Climate
W_D	Weight for Development
W_E	Weight for Engagement
W_G	Weight for Governance
W_H	Weight for Hydrology
W_I	Weight for Inclusion
W_L	Weight for Leadership
W_P	Weight for Pollution
W_Q	Weight for Quality
W_S	Weight for Safety
WHO	World Health Organization
WRI	World Resources Institute

CHAPTER 1: INTRODUCTION

The acronym ESG stands for Environmental, Social, and Governance first introduced by a United Nations (UN) report in 2004, emphasizing the integration of these factors into financial analysis, asset management, and security brokerage to guide investments towards sustainability and responsible practices (The Global Compact, 2004). It is a comprehensive and useful method to define positive and negative impacts both on financial performance of an entity, sovereign or individual. The environmental factors under the ESG concept include air, water, and solid emission factors such as greenhouse gas (GHG) emissions, biodiversity, and ecology. Social factors encompass workforce and labor conditions, occupational health and safety, discrimination, diversity, equal opportunity, child labor, value chain management, and community impacts. Governance factors involve codes of conduct and business principles like accountability, transparency, executive pay, board diversity and structure, bribery and corruption, stakeholder engagement, and shareholder rights. (Li et al., 2021).

In 2006, The United Nations Environment Programme Finance Initiative (UNEP FI) and UN Global Compact launched Six Principles for Responsible Investment (PRI) to encourage institutional investors to consider ESG objectives for their investment decisions (UN Global Compact, 2006).Considering ESG-oriented investors focus on both financial and nonfinancial ESG aspects, it is crucial to define, score, and disclose their ESG performance, especially when increasing financing for the city's net-zero initiatives.

1.1. Rationale

Cities are contributing to almost 80% of the global GDP and producing more than 60% of global greenhouse gas (GHG) emissions (Khatri et al., 2022). As of 2023, according to Net Zero Stocktake, 252 cities globally have pledged to achieve net-zero emissions by 2050, which cover approximately 2.120 million of the world's population. The projected cost to reduce carbon emissions and increase the resilience of urban infrastructure is anticipated to be between USD 4.3–5.4 trillion annually until 2030, but climate finance flows to the cities is around USD 2.5-3 trillion per year (The State of Cities Climate Finance, 2021). To achieve the city’s goal of net zero carbon emissions and enhance cities climate resilience, there is a pressing need to double investments in climate initiatives for urban areas (UNFCCC, 2019). It is essential to increase climate investments in cities to close the gap between expected expenditures and present financial flows. Insufficient funding is a substantial obstacle to achieving net-zero emissions and developing climate resilience in urban areas.

Investments prioritising ethics, the environment, social responsibility, and good governance are essential for sustainable prosperity and societal advancement (Puaschunder, 2017). The ESG performance is positively related to the entity’s economic sustainability. Increasing ESG performance has the potential to help organizations reduce their carbon emissions, generate

positive social impact, and achieve sustainable development goals (SDGs) ((Chipalkatti, Le and Rishi, 2021), (Alsayegh, Rahman and Homayoun, 2020) (Kräussl, Oladiran and Stefanova, 2023) (Cheng et al., 2016)).

ESG disclosure and scorings are important ways for cities to demonstrate their commitment to sustainability and to attract investors interested in financing sustainable initiatives. Cities may enhance their prospects of obtaining essential funding for critical infrastructure improvements by offering transparent and accurate information on environmental, social, and governance standards. Cities can utilize municipal revenues and grants, debt financing as municipal bonds and loans, and hybrid mechanisms as public-private partnerships for financing their climate-related investments (Diez Martinez and Short Gianotti, 2024). Especially innovative financing instruments such as sustainability-linked bonds, green, social and transition bonds, green lending which aligns with environmental and social risk management principles, green procurement, and public-private partnerships (PPPs) can help to mobilise capital to sustainability-oriented projects (ICAD, 2007; OECD, 2021). The utilization of green bonds plays a pivotal role in promoting ecological, low-carbon expansion while facilitating the realization of carbon neutrality goals for cities and fosters profitability and growth potential (Dan and Tiron-Tudor, 2021; Zheng et al., 2023; D'Amato, D'Ecclesia and Levantesi, 2021).

According to a survey conducted within "*The European Mission on 100 Climate-Neutral and Smart Cities*" programme, which includes over 100 participating cities, it was found that out of the 350 cities surveyed, a substantial 77.1% lacked any prior engagement with innovative financing mechanisms. Only 51 of them stated that they have the experience to utilise social impact and green bonds. Additionally, 169 cities stated their intention to use innovative financing possibilities (Ulpiani et al., 2023). This highlights the increasing interest in using financial instruments for climate mitigation investments but also emphasizes a significant lack of understanding and access to resources. Addressing this gap by creating customized guidance, tools, and support tailored to cities' specific needs has the potential to not only promote social impact and green bonds and accelerate urban transformation to achieve their net zero commitments.

Considering innovative financing instruments and ESG-oriented investors supporting green and social bonds, defining, scoring, and disclosing the borrowers' ESG performance is crucial. The literature lacks research on city or municipality-specific ESG risk scoring to provide comprehensive indicators specifically related to the urban environment. Developing a city-specific ESG risk assessment can be an initial step before creating a unified ESG scoring framework for cities, considering the challenges posed by the diverse specialities of different cities in developing a common ESG analysis method. By conducting a city-specific ESG risk assessment, cities can better understand their unique challenges and opportunities in terms of sustainability. This information can then be used to develop an initial ESG scoring

framework that can be applied across different cities, ultimately leading to more informed, impact-oriented investment decisions and a more sustainable urban environment overall.

1.2. Aims and Objectives

The primary aim of this academic study is to define (synthesise) city-level ESG indicators, and a scoring system tailored to cities with a focus on their ability to facilitate climate change adaptation, mitigation efforts, and potential net-zero strategies. This will help enhance the ESG performance and transparency levels of these cities. The study's indirect goal is to help close the climate investment gap that cities need to reach their net-zero goals by making cities better at ESG performance and making it easier for them to use ESG impact-focused investment instruments.

The main objectives of the study are:

i. Conduct a critical review of existing indicators and methodologies used in ESG scoring, particularly emphasising those relevant to European cities.
ii. Identify the ESG indicators for cities, considering their potential to contribute to climate change adaptation and mitigation, as well as potential net-zero strategies. Utilize a double materiality analysis to assess the significance of these indicators in both environmental and financial impact contexts and perform a weighted analysis of the selected indicators.
iii. Develop a numerical scoring model for the final individual environmental score, social score and governance score
iv. Assess the effectiveness of the new ESG scoring system using a case study approach.

1.3. Outlines of the methodology

This study uses a mixed method approach that integrates qualitative and quantitative analysis and a pragmatic research philosophy to develop synthesised ESG indicators tailored to cities and an associated scoring system. Qualitative methods entail a literature review and conducting reviews of existing city sustainability frameworks and guidelines. Quantitative analysis includes double materiality analysis in line with the EFRAG Double Materiality Assessment Guidelines, which was used to understand the ESG implications and weighting of the selected indicators. Scoring ranges were distributed arithmetically, by considering the average values of the European cities, including best and worst values of the relevant indicator data. After determining the city ESG indicators, the scoring system was used in the comparative case study for the cities of Lahti and Glasgow. ESG indicator selection was finalised based on the lessons learned and experiences of the scoring system on real cases. The data was analysed from open-access public sources such as statistical databases, city reports and publications. The environmental pollution score of the ESG data was created using GIS data and Google Earth Engine. Finally, a set of ESG indicators and associated scoring

ranges were defined and final environmental, social and governance scores were calculated by using Microsoft Excel sheet.

1.4. Structure of this thesis

This master thesis is composed of five chapters as follows:

Chapter 1: Introduction
This section underscores the critical importance of ESG indicators in promoting urban sustainability, attracting more investments to realize climate change mitigation and adaptation goals, and achieving cities' net-zero targets. It explains the need to focus on city-specific ESG scoring, outlines the study's primary aims and objectives, and provides an overview of the thesis structure.

Chapter 2: Literature Review
This chapter thoroughly examines existing global ESG frameworks and the diverse methodologies used in urban sustainability studies. It also evaluates ISO 37120 sustainable cities standards and various global initiatives guiding cities toward sustainability.

Chapter 3: Methodology
This section details the mixed-methods approach integrating qualitative and quantitative analyses, the research philosophy, and the specific methods used, such as the selection of ESG indicators, double materiality assessment, and the selection of case studies for in-depth analysis.

Chapter 4: Results and discussion
This chapter validates and presents the chosen ESG indicators, discusses the findings from the double materiality assessment, and examines the application of the ESG scoring system in selected cities using detailed case study results.

Chapter 5: Conclusion
This section explores the broader implications of the study for urban policy, investment, and sustainability practices, summarizes the contributions of the study, and suggests future research directions.

CHAPTER 2: LITERATURE REVIEW

2.1 Global ESG Frameworks

In recent years, there has been an increased recognition of the importance of non-financial elements related to ESG metrics. Several news sources discussed the potential consequences of negative information related to the ESG area on companies' financial position. These consequences include the loss of strategic clients, decreased business activity due to environmental risks, a negative perception of the company, and increased reputational risk (Chodnicka-Jaworska, 2021). Consequently, ESG factors and related risks started to be evaluated as their consequences can cause serious negative financial implications also. Finance professionals have developed many scoring models to assess ESG data and transform it into ESG scores, aiding investment decisions alongside financial analysis. Multiple ESG rankings and standards have been adopted to conduct these analyses (Glavas, 2023). The general structure of these ESG ranking systems consists of environmental, social and governance pillars, related indicators and raw metrics (Figure 1).

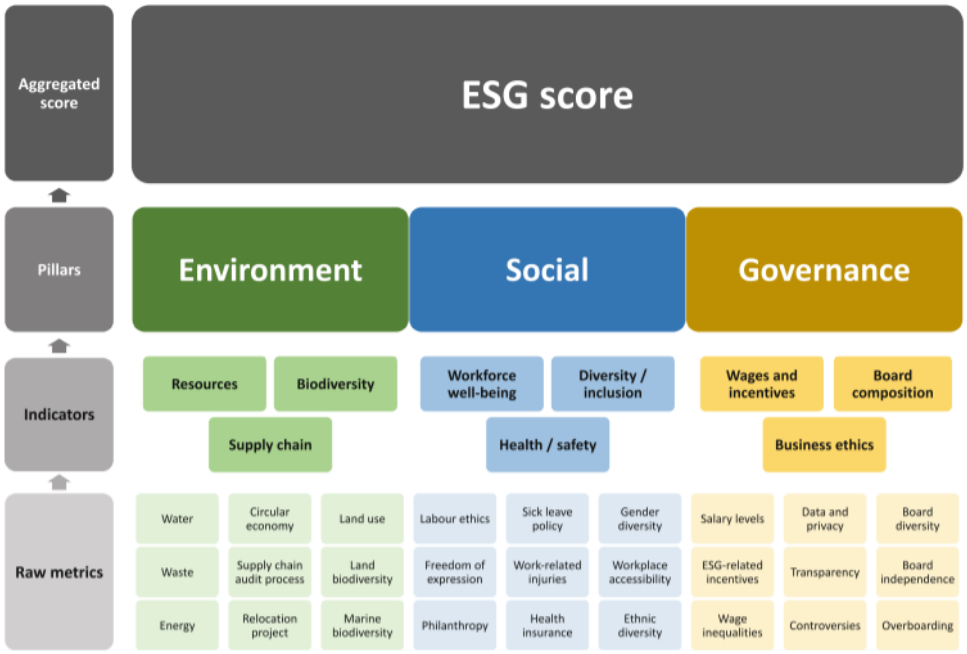

Figure 1 General concept of ESG scoring frameworks (Glavas, 2023)

There are estimated to be approximately 500 ESG rankings, 170 indices, and 120 voluntary ESG standards, with conceptual and methodological distinctions. (Eccles, Lee and Stroehle, 2020). The United Nations Sustainable Development Goals (SDGs), The Global Sustainability Standards Board Global Reporting Initiative (GRI), The Equator Principles, The International Finance Corporation Environmental and Social Performance Standards (IFC Performance Standards), The OECD Due Diligence Guidance for Responsible Business Conduct, The Sustainability Accounting Standards Board (SASB) Standards are some examples of international frameworks addressing the problem of defining common ESG factors (EBA, 2021). The SDGs can be assumed to be the most comprehensive framework among the

existing ESG frameworks after being approved by 193 UN member states in 2015. The SDGs define global goals for cities and human settlements to make them more inclusive, safe, resilient, and sustainable by 2030. SDG 11 Sustainable Cities and Communities aims to transform urban spaces into inclusive, safe, resilient, and sustainable environments. It emphasizes the importance of access to affordable housing, basic services, and sustainable transport systems. Participatory planning, cultural and natural heritage protection, disaster reduction, environmental sustainability, green spaces, economic ties, and climate resilience are integral components of SDG 11 (United Nations, 2015).

2.2. Urban Sustainability Measuring studies

The exploration of ESG and sustainability in the context of urban development is crucial and intricate. Although ESG and sustainability are often used interchangeably, they encompass distinct yet interrelated areas. (Garcia, Mendes-Da-Silva and Orsato, 2017). Sustainability is a broader concept encompassing environmental, economic, and social dimensions. On the other hand, ESG, as a concept, is explicitly being used as criteria guiding investment decisions related to environmental, social, and governance factors. Nonetheless, due to the significant overlaps, it is important to examine the existing sustainability frameworks to create ESG frameworks for cities.

2.2.1. Review of examples of existing urban sustainability indices and assessment framework studies

Several studies have suggested approaches for assessing the sustainability of cities, emphasizing the incorporation of environmental, economic, and social indices. In their study, González-García et al., 2019) proposed a system that utilized 38 parameters to determine the significance of municipal size concerning sustainability. According to their system, the indicator selection process has four steps. First, several indications from specialist organizations and databases are compiled. Second, redundant indications are deleted. Next, a Leopold matrix is defined to reduce the number of indicators and choose an optimal subset based on city-level data availability and data source frequency. A sustainability index is calculated by normalizing, aggregating, and weighting the indicators. Accordingly, (Rama et al., 2020) assess the sustainability of Spanish cities using a three-letter code as social, economic and environmental and apply the technique established by González-García et al. (2019) to examine sustainability in municipalities, focusing on Spanish cities. Key social indicators encompass education levels, gender-based violence cases, unemployment rates, poverty risk, household size, electoral participation, age demographics, population growth, immigrant population, population density, availability of leisure facilities, proximity to hospitals, and social service expenses. Economic indicators include GDP per capita, unemployment rates, household income, types of employment contracts, number of businesses, budget metrics, surplus/deficit, debt, and investment. Environmental indicators encompass vehicle ratios, air quality measures (ozone, NO_2, PM_{10}), water and electricity

consumption, availability of green and pedestrian areas, and municipal waste collection. These indicators form a framework for evaluating municipal sustainability across social, economic, and environmental domains.

The reference Mori and Christodoulou, (2012) identifies several indicators for city sustainability, including ecological footprint, environmental sustainability index, dashboard of sustainability, welfare index, genuine progress indicator, index of sustainable economic welfare, city development index, human development index, environmental vulnerability index, environmental policy index, living planet index, environmentally adjusted domestic product, and genuine saving. The authors' argument centred on the lack of an existing index that fully aligns with the four essential criteria for an ideal City Sustainability Index (CSI). These criteria include incorporating the triple bottom line, comprehensive assessment of environmental impacts, focus on city sustainability and equitable evaluation of world cities. They emphasized that no current index adequately addresses all these aspects. On the other hand, in the study of Merino-Saum *et al*., (2020) they examined 2847 variables from 67 measuring efforts, highlighting the significance of social concerns such as quality of life, access to services, consumer behaviour, and employment in assessments of urban sustainability and underlining the importance of community engagement and participatory approaches in developing indicators for urban sustainability assessments.

In addition, there are many review studies to evaluate the existing urban sustainability framework and indices. Michalina *et al* (2021) analysed selected global and European urban sustainability indicator frameworks (USIFs) based on their commonalities and differences, sustainability dimensions, thematic categories, and categorized indicators. The selection process involved criteria such as usability in various urban environments, real application in cities, alignment with sustainable development principles, and the existence of indicators. The study identified the most frequently used thematic categories and key indicators within the four main dimensions of sustainable development: environmental, social, economic, and institutional. It highlighted the inconsistencies in the representation of these dimensions and the need for a balanced approach.

Cohen (2017) conducted a systematic review of urban sustainability assessment literature with the date range 2001–2017 to identify common methods, framings, and categories for organising indicators. The review focused on the most frequently used methods and the alignment of these assessments with common sustainability principles, urban sustainability dimensions and categories identified in the literature (Table 1). A common practice is to select and categorise indicators to assess cities' environmental, economic, and social performance. However, governance is often treated separately as an institutional aspect, with limited frequency. The study suggests that urban sustainability assessments would benefit from a more unified framework and recommends using mixed-methods research to enhance the reliability of future assessments.

Table 1 Urban sustainability categories in the literature (Cohen, 2017).

Category	Total Number of Instances in the Literature	Number of Unique Elements in the Literature	Number of Sources Referencing
Air Quality	19	2	16
Arts, Culture and Recreation	40	15	22
Buildings	49	19	18
Built Environment	30	9	17
Climate Change	18	3	14
Community	22	9	15
Economy	104	41	40
Education	16	6	12
Energy	45	12	33
Equity	73	28	30
Food Systems	14	8	11
Governance	124	32	34
Growth and development	8	5	8
Housing	29	9	20
Infrastructure	29	11	16
Land Use	84	13	36
Management	16	7	10
Manufacturing	6	4	6
Material Use	33	15	22
Mobility and transportation	76	19	32
Natural Environment	99	29	49
Natural Resources	41	18	27
Pollution	15	4	10
Public Health	32	14	16
Quality of Life	23	9	16
Safety	42	12	20
Technology	15	4	13
Waste	32	12	23
Water	64	19	29

Gavaldà, Gibbs and Eicker, (2023) evaluate and analyse various urban sustainability and liveability frameworks, including LEED, BREEAM Communities, ENVISION, UN Urban Indicators Guidelines, European Green Capital Award, European Green City Tool, European Green Leaf Index, Global City Indicators Programme, SGDs for cities, Covenant of Mayors, ISO 37120 and OECD Green Cities Programme and analyse them from an epistemological perspective to propose KPIs for an integral sustainability-liveability framework. As a result, the study proposes a new set of KPIs for an integral sustainability-liveability framework divided into environmental sustainability, liveability-local conditions and liveability-equality categories. Environmental sustainability covers energy, GHG, resources, water, air quality, resilience, land use, biodiversity and transportation. Liveability-local conditions cover place and environmental indicators, mental and physical health, education and learning, work and local economy, people and community. Liveability and equality cover health, income, gender, social and ethnicity. As a result, the study provides valuable insight into developing the urban sustainability framework.

By leveraging the approaches and methodologies outlined in these studies, a multidimensional urban framework that incorporates the ESG indices can be adopted.

2.2.2. ISO 37120 Sustainable City Standards series

ISO 37120 Indicators for Sustainable Cities, ISO 37122 Indicators for Smart Cities, and ISO 37123 Indicators for Resilient Cities define methods for a set of indicators to steer and measure city services, quality of life, smart city development, and resilience planning. ISO 37120 includes indicators for monitoring smart city development and risk assessments for

developing smart, resilient, and sustainable cities (ISO 37120:2018, Sustainable Cities and Communities — Indicators for City Services and Quality of Life, 2018). ISO 37120:2018 indicators encompass 18 categories, including economy, education, energy, environment, finance, governance, health, housing, population, recreation, safety, solid waste, sport, culture, telecommunication, transportation, urban agriculture, urban planning, wastewater, and water, with a total of 111 indicators. The ISO 37120:2018 city sustainability indicators are summarized in Figure 2.

The ISO 37120 metrics are arranged based on themes specific to the sectors and services offered by the city (Melo, Dantas and Camargo, 2020) and the major concern of the indicators is assessing and guiding the management and performance of city services. On the other hand, ISO 37123 indicators for resilient cities focus on the smart city planning and monitoring for a city and cover the various city kinds of climate mitigation and mainly monitoring indicators such as "*percentage of buildings built or refurbished within the last 5 years in conformity with green building principles, Number of bicycles available through municipally provided bicycle sharing services per 100 000 population, percentage of households with smart energy meters*". ISO 37120 standards have only one criterion directly connected with climate mitigation: "*Amount of greenhouse gas emission*".

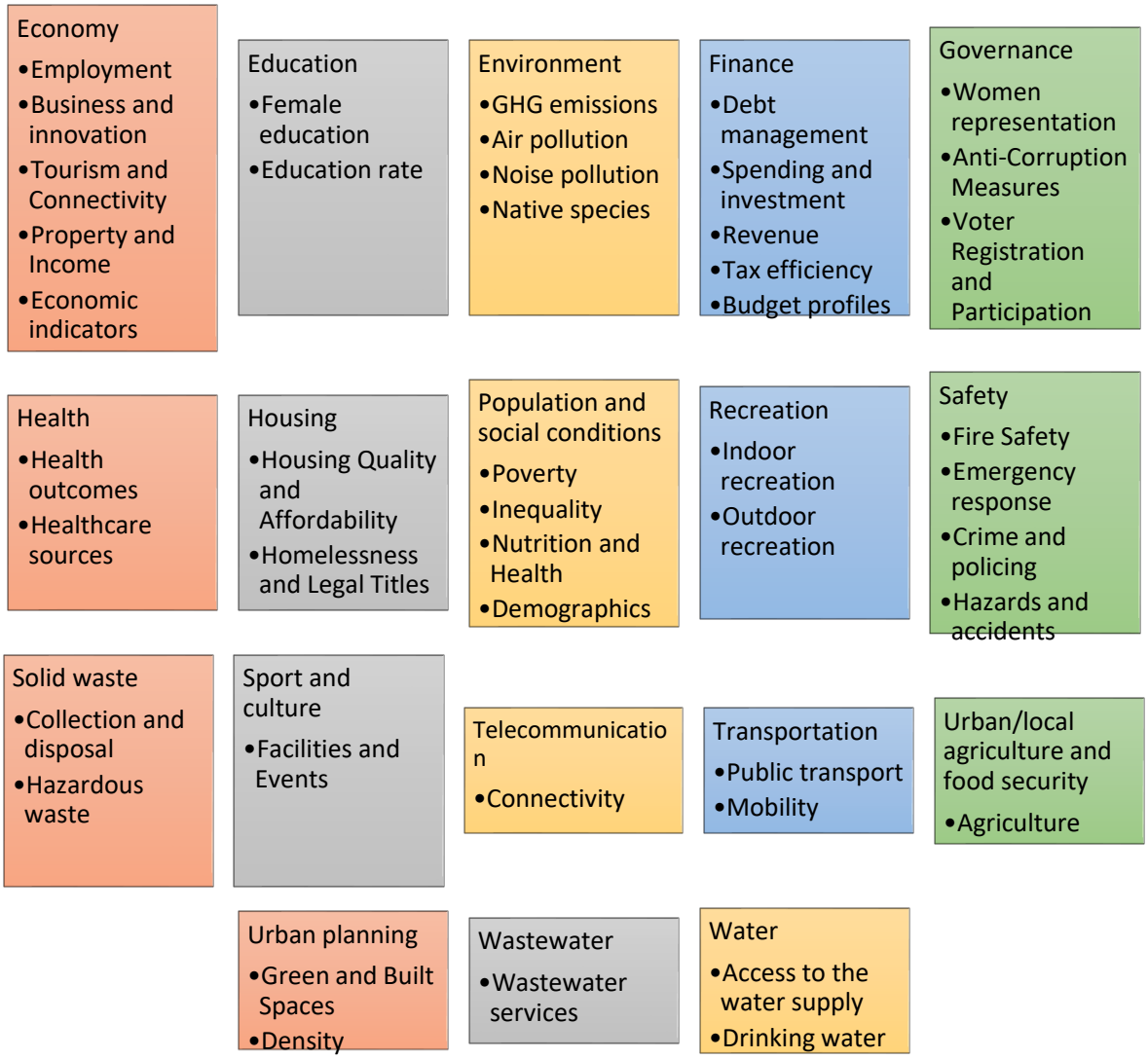

Figure 2 ISO 37120:2018 Sustainable cities and communities standard indicator groups (BSI, 2018)

2.2.3. Initiatives for city sustainability assessment and guidances

When we look beyond the academic literature, there are several frameworks, systems and standards to define city sustainability such as C40 cities, The World Bank's The Global City Indicators, CDP Cities Programme, Sustainalytics Sub-Sovereign Risk Ratings, SASB indicators. A brief description of the main frameworks follows:

- **C40 Cities Programme**

C40 Cities is a global network of major urban centres launched in 2005 that aims to guide cities to reduce greenhouse gas emissions, improve environmental sustainability, and boost economic development while prioritizing environmental and social responsibility. All participating cities commit to the Paris Agreement's objective to the global mean temperature increase below 1.5°C. The program provides a collaboration platform among cities to exchange knowledge, implement city climate policies, and make measurable strides

in reducing greenhouse gas emissions. Research shows the effectiveness of the C40 Cities framework in driving reductions in city emissions, e.g., New York City's "*OneNYC*" strategy, developed with the support of C40, has resulted in a 15% decrease in greenhouse gas emissions from 2005 levels (NYC Mayor's Office of Sustainability, 2019). Similarly, London's Climate Action Plan, guided by C40's directives, aims to achieve carbon neutrality by 2050 through comprehensive measures across various sectors, including transportation, energy, and waste management (Greater London Authority, 2018).

On the other hand, The World Bank's Global City Indicators Facility (GCIF) is another initiative that aims to provide standardized indicators for cities to measure, report, and enhance their performance and quality of life and includes 63 indicators under the categories of competitiveness, creativity, greenhouse gas governance, recreation & culture, social capital, subjective well-being, total energy use, urban accessibility, and water quality (Bhada and Hoornweg, 2009).

- **Carbon Disclosure Project Cities Programme**

The Carbon Disclosure Project (CDP) is a non-profit organization that deals explicitly with the consequences of climate change. CDP cities invite municipalities to complete an annual questionnaire using an online platform. The CDP questionnaire gathers qualitative and quantitative data on governance, climate hazards, adaptation, city-wide emissions, emissions reduction, and opportunities. The survey covers local government emissions, energy usage, buildings, transport, urban planning, food, waste, and water security (CDP-ICLEI, 2023). By including climate-related data, the questionnaire aims to enhance the understanding of urban greenhouse gas (GHG) emissions and underscore potential hazards and benefits arising from climate change (Groth, Brück and Oberascher, 2016)Nonetheless, the responses to the CDP questionnaire are based on subjective self-assessment, which may raise concerns about the objectivity of the conclusions obtained.

- **Net Zero Cities programme**

The NetZeroCities[1] initiative is part of the Horizon 2020 initiative and aligns with the European Union's objective of "*100 Climate-Neutral and Smart Cities 2030*" as well as The European Green Deal. Its goal is to provide tools, resources, expertise, and a platform for collaborative knowledge sharing to support *mission cities* and *pilot cities* in their efforts to achieve climate neutrality(Mondal, Bresciani and Rizzo, 2024). The NetZeroCities programme provides a structured framework for cities to develop, implement, and monitor comprehensive climate action plans aimed at reducing emissions across all sectors, including energy, transportation, waste management, and buildings (C40 Cities, 2020). The program emphasizes making decisions based on data. It uses standardized indicators and reliable data collection methods to monitor the progress of cities towards achieving net-zero goals (Global Covenant of Mayors

[1] https://netzerocities.eu/

for Climate & Energy, 2017). This approach enables cities to identify key areas for intervention, to allocate resources efficiently, and to measure the impact of their climate actions. Case studies from cities participating in the Net Zero Cities programme highlight the effectiveness of this approach. For instance, Copenhagen aims to become the world's first carbon-neutral capital by 2025. The city has implemented a range of measures, including expanding its district heating system, increasing the use of renewable energy, and promoting cycling as a primary mode of transportation (City of Copenhagen, 2017). These initiatives, guided by the Net Zero Cities framework, have resulted in significant emissions reductions and positioned Copenhagen as a global leader in urban sustainability. Despite these successes, cities face challenges in achieving net-zero emissions, including technical, financial, and political barriers. Ensuring consistent and high-quality data collection, securing funding for large-scale projects, and navigating complex regulatory environments are among the key obstacles (Puppim De Oliveira et al., 2013). Through the use of standardized data, fostering collaboration, and prioritizing equity, the program establishes a strong foundation for cities to reach their net-zero objectives and play a part in global climate initiatives.

- **Arcadis Sustainable Cities Index**

The Arcadis Sustainable Cities[2] Index, first published in 2015, ranks 100 global cities based on three pillars of sustainability: Planet (environmental), People (social), and Profit (economic). Environmental indicators include air pollution, green spaces, waste management, public policy, energy consumption, greenhouse gas emissions, and investment in low-carbon infrastructure such as renewable energy and sustainable transport. Social performance indicators include health, education, crime, income inequality, work-life balance, reliability of public transport infrastructure, broadband, and Wi-Fi availability. Economic performance indicators include affordability, commercial transport infrastructure, economic performance (ease of doing business, economic development, employment), and business infrastructure (access to reliable electricity and connectivity). According to the Arcadis Sustainable Cities Index, the city of Oslo is considered the most sustainable city, followed by Stockholm, Tokyo, Copenhagen, Berlin and London. However, the results can be questioned when considering the overpopulation problem in Tokyo, and housing problems in Copenhagen, Berlin and London.

- **City ESG rating systems**

Sustainalytics[3], MSCI[4] Inc, and ISS[5] (Institutional Shareholder Services) are some of the prominent ESG risk rating providers that evaluate companies' long-term ESG risk exposure. Among these providers, Sustainalytics utilizes a method to assess municipalities' long-term ESG risk ratings through the Sub-Sovereign Risk Ratings methodology. Sustainalytics claims

[2] https://www.arcadis.com/
[3] https://www.sustainalytics.com/
[4] https://www.msci.com/
[5] https://www.issgovernance.com/

this methodology can be applied to any municipality in any geography, although its primary focus is on the United States municipality market. The municipality's sub-sovereign risk rating assesses the wealth of regions, including natural, generated, human, and institutional capital. It evaluates the vulnerability of this wealth to socioeconomic and environmental, social, and governance variables. (Sub-Sovereign Risk Ratings, 2023).

2.3. Importance of ESG Disclosure and Scoring for Cities

Cities rely on ESG disclosure to show their commitment including practice and principles that are sustainable into their activities. Through ESG disclosure and scoring, cities can effectively communicate their efforts to mitigate environmental impact, promote social equity, and ensure transparent and effective governance. ESG transparency could then attract investors who are specifically interested in funding projects that align with sustainable and responsible practices. Institutional investors make their ESG practices known as part of their commitment to the Principles for Responsible Investment (PRI), and the PRI evaluates and scores their annual ESG reports. Investors are inclined to allocate more assets to institutions with higher ESG disclosure scores. This disclosure's effectiveness is further bolstered when it is supported by third-party ESG fund ratings and is associated with more sustainable equity holdings. Ceccarelli *et al*., (2023) and Nazarova and Lavrova (2022) find in their studies that higher ESG disclosure scores are associated with have higher allocation of assets and increased investment attractiveness by institutional investors and asset managers.

It is important to note that accurate ESG disclosures and ratings can help cities to obtain funding for their transition to net zero. For instance, green bonds, as a sustainable financial tool, can help cities advance their low-carbon initiatives. In 2013, the city of Gothenburg, in Sweden, procured USD 500 million through the issuance of green bonds. The purpose of these funds was to finance projects aimed at reducing city’s carbon emissions, including the implementation of district heating systems, switching to electric vehicles in public transportation, and a biogas project. Similarly, Mexico City issued green bonds totalling close to USD 100 million in 2016, 2017, and 2018, with the allocated funds directed toward climate-focused projects such as clean transportation, sustainable building initiatives, improving energy efficiency, and the promotion of renewable energy sources.(International Energy Agency, 2021).

The Green Bond Principles (GBP) and Social Bond Principles (SBP) published by the International Capital Market Association (ICMA) provide guidelines for a transparent, accurate, and integral process of sustainable bond issuance. In 2023, the global sustainable bond issuance rose to USD 863 billion, and 98% of these issuances followed the ICMA Principles (ICMA, 2024). While having an ESG rating is not a mandatory requirement for issuing green and social bonds according to the ICMA GBP and SBP, most issuers prefer to obtain ESG ratings or second-party opinions to bolster their bond offerings in response to market expectations and investor interest. By considering the potential of green bonds to

finance city's net zero targeted investment projects, providing accurate ESG disclosure and ratings can enhance municipalities' ability to secure funding for critical infrastructure upgrades necessary for their transition to a net-zero economy.

2.4. Double Materiality in ESG Assessment

Materiality refers to the relevance of information in the context of stakeholder analysis and decision-making. (Madison and Schiehll, 2021). The concept of double materiality was first introduced by the European Commission as part of the Non-Financial Reporting Directive in 2019 (Adams *et al., 2021)*. The term "*financial materiality*" refers to the impact that a company's development, performance, and position have on its overall worth. Investors are often most interested in this perspective.

The mention of impact materiality refers to the significance of environmental and social factors. This viewpoint is of primary concern to citizens, consumers, employees, business partners, communities, and civil society organisations (European Commission, 2019). Overall, double materiality merges both concepts: financial and impact materiality. A sustainability topic or information is considered to fulfil the requirements of double materiality if it is significant in terms of financial or impact materiality or both (European Financial Reporting Advisory Group, 2022a). The European Commission's *Corporate Sustainability Reporting Directive* (CSRD) requires entities to report on information from the impact and financial perspective as well as information from only one perspective. Accordingly, the European Financial Reporting Advisory Group (EFRAG) publishes conceptual guidance to conduct a double materiality assessment to be used for the CSRD reporting (EFRAG, 2022a). EFRAG Double Materiality guidelines provide a systematic approach to evaluate the materiality of sustainability subjects or sub-topics for all sectors and specific sectors.

The EFRAG Double Materiality Guidelines provide a comprehensive framework for assessing and reporting the materiality of ESG factors. These guidelines are designed to help organizations understand and disclose their activities' impacts and dependencies from financial and non-financial perspectives. For the present research, double materiality analysis was used to scale the financial implications as well as the impact materiality of the selected ESG indicators from the city perspective. According to the European Commission's guidelines on non-financial reporting, impact materiality is defined as: "*The materiality of non-financial information from the perspective of the impact of an entity's activities on society and the environment. It considers how an organization's operations affect external stakeholders, including environmental and social aspects*" (European Commission, 2019). On the other hand, financial materiality, as per the EFRAG, is defined as: "*The significance of sustainability-related risks and opportunities on the entity's cash flows, financial position, and financial performance. This includes the evaluation of ESG factors that can influence the economic value of the company and its capacity to generate future economic benefits*" (EFRAG, 2022b).

These two perspectives were used to identify and justify the selected indicators and to evidence how sustainability topics can pose potential financial risks.

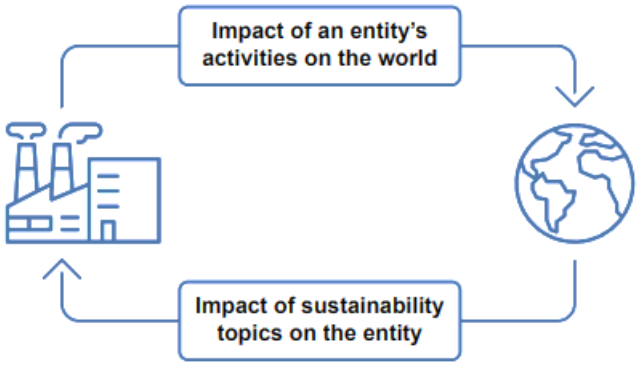

Figure 3 Double materiality concept (Global Reporting Initiative (GRI), 2024)

Double materiality assessments can be used as guidance by entities to identify relevant ESG key performance indicators. As the nature of the ESG scoring models was developed by finance professionals to consider raw ESG scores that can support investment decisions along with a financial analysis (Glavas, 2023); there are many crosscuts between double materiality and ESG scoring.

Nielsen, 2023 Investigates the relationships between double materiality and ESG metrics using qualitative research methods, such as interviews with experts and business models. A business model canvas was created for a case study company and a double materiality analysis was conducted by defining material impacts and financial materiality. A REGS (Resilience, Emissions, Governance, Sharing) model was used to identify ESG metrics from the double materiality analysis results, and ESG metrics were identified.

2.5. Gaps and Challenges in Existing Frameworks

Current urban sustainability frameworks focus on the impact materiality. Common city rating tools are categorised into themes such as site (location, linkage, planning, sustainability), resources (energy, water, material), infrastructure, waste management, transportation, land use planning, social & economic well-being, and innovation (design, technology) to assess the sustainability of development (Kaur and Garg, 2019). These tools are designed to measure the environmental and social impacts of the indicators however, they do not consider the financial impact of such indicators on cities. The double materiality concept, which merges financial and impacts materiality, can help to overcome this situation. By incorporating double materiality in the ESG scoring, cities can now evaluate how their sustainability efforts not only pose a financial risk but also offer an opportunity where environmental and economic performances are in tandem. This will empower decision-makers in a much more holistic manner and ultimately have significant effects in the actual impact of urban sustainability.

Most city sustainability rating systems use a 100-point scale with equal or varying weights. Some systems also use percentages, but these can differ. The selection of categories, criteria, and weights is based on subjective factors, leading to a lack of objectivity (Retzlaff, 2008). Double materiality assessment results can provide quantitative input to decide on the criteria and weights despite the subjective factors.

ESG disclosure and scoring are powerful tools to attract investment to cities by demonstrating their commitment to sustainability and responsible governance. An in-house ESG scoring mechanism can provide clear and reliable data on a city's sustainability performance, raise investor confidence, and unlock access to new sustainable finance instruments, such as green bonds, social bonds, and sustainability-linked loans (Diez Martinez and Short Gianotti, 2024).

Policy and governance enhancements are very central towards sustainable urbanization. A tailor-made scoring system on ESG should be able to highlight the salient features of governance, such as transparency, stakeholder engagement, and accountability, which would build trust for the successful implementation of initiatives on sustainability. Through the systematic and rigorous assessment of governance practices, the scoring model would enable cities to pinpoint areas where they need to get better at following best practices and ultimately enhance their overall governance effectiveness (OECD, 2021).

Developing a tailor-made ESG scoring framework for cities is crucial to addressing the city-centric sustainability challenges that cities face today. A city-specific ESG scoring system can provide a holistic approach to urban sustainability, ease access to sustainable financing, and support policy and governance improvements. This would enable cities to achieve their net-zero objectives while fostering a more sustainable and resilient future.

2.6. Enablers, Barriers, and Outcomes for City ESG Criteria development

Efficient and open governance frameworks are crucial for promoting sustainability efforts in urban areas. It is essential for city leaders and legislators to demonstrate a strong dedication to sustainability and distribute resources accordingly (Bovaird & Löffler, 2003). Governance enablers encompass the creation of unambiguous policies, efficient regulatory structures, and robust determination from political entities to execute and maintain ESG standards (OECD, 2016).

The involvement of all stakeholders, including citizens, companies, and community organisations, is crucial for achieving inclusive participation (Freeman, 1984). Regular consultation, feedback, and cooperation mechanisms guarantee that a wide range of opinions are considered, resulting in more complete and widely supported sustainability initiatives (Reed et al., 2009). Engaging stakeholders in decision-making processes promotes cooperation and ensures the involvement of all relevant parties. Efficient interaction platforms guarantee the inclusion and consideration of all perspectives (Freeman, 1984).

Enabling laws and regulations promote the implementation of sustainable practices (EU, 2020). The establishment and execution of sustainability-oriented policies foster an environment that is favourable for the integration of ESG practices. This not only ensures adherence to regulations but also promotes the adoption of exemplary approaches in all industries (World Bank, 2020). Inconsistent policies and laws can cause ambiguity and inefficiencies, impeding the execution of sustainability initiatives (North, 1990). Aligning policies across several tiers of government guarantees a consistent and enabling regulatory framework for ESG activities (OECD, 2016).

2.7. Different perspectives and different expectations of stakeholders from the cities

Each of the different city stakeholders has different expectations and perspectives on the city environment. These expectations can be categorized as follows:

Table 2 Expectations of different stakeholders of cities

Public servants in positions of authority within the government.	Inhabitants and Social Groups	Enterprises and Investors	Non-Governmental Organisations (NGOs)
•Government officials prioritise regulatory compliance, public policy, and resource allocation. Their viewpoint influences the legal and legislative structure for ESG activities (OECD, 2016).	•Residents and communities express apprehension on the standard of living, well-being, and the promotion of diversity and equality. Their endorsement and input are important for the triumph of sustainability initiatives (UN-Habitat, 2020).	•Businesses and investors are attracted to economic expansion, investment prospects, and the mitigation of risks. They spearhead economic efforts and allocate funds for ESG projects (Freeman, 1984).	•Non-governmental organisations (NGOs) promote and support initiatives aimed at safeguarding the environment, ensuring fairness and equality in society, and fostering the growth and progress of communities. They have a vital role in advocating for inclusive and fair sustainability policies (Betsill & Bulkeley, 2006).

2.1. Conceptual Framework for City-Specific ESG Scoring

The ESG approach focuses on risk management and mitigation, rather than just sustainability frameworks (Sütterlin, 2024). It is important to understand the major challenges faced by cities, particularly in Europe. The present research specifically examines the main problems and thematic areas of European cities from an ESG perspective. According to the European Environment Agency, the primary environmental challenges for European cities include emissions, air and noise pollution, high energy consumption, water and resources use, land use, and habitat fragmentation (European Environment Agency, 2021). Other challenges and related issues with potential environmental impacts are also summarized in Table 3. When

developing ESG indicators, it's crucial to consider a city's major challenges and concerns, as well as its capacity for management and monitoring.

Table 3 EEA Examples of potential challenges facing cities (Eales et al., 2021)

Environmental challenges	**Other challenges with environmental implications or that can increase vulnerability to environmental challenges**
Heat waves	Urban sprawl
Sea level rise	Overcrowding and population density
Severe storms and flooding	Inadequate or absent infrastructure
Water consumption and shortages/droughts	Community severance (a physical and
Forest fires	psychological barrier created by, for example,
Air pollution	roads or rail infrastructure)
Water pollution	Road congestion
Ground contamination	Social exclusion and inequality
Noise pollution	Unemployment rates
Light pollution	Lack of affordable housing
Energy consumption and shortages	Insufficient public services
Clean drinking water	Non-communicable diseases (e.g. heart
Timber, mineral and other natural resources and material	disease, cancer, asthma, diabetes)
consumption and shortages	Poor mental health
Land/soil erosion	Demographic change
Food shortages/access to food	Health pandemics
Solid waste processing	
Solid waste disposal	
Sewage treatment and disposal	
Stormwater management	
Habitat fragmentation	
Decline of native species/natural habitats	
Land take	
Lack/loss of green space	
Lack/loss of ecologically productive land	

2.2. Objectives and factors for the selection of the city ESG indicators

Cities are crucial actors in addressing climate change, with over 252 cities worldwide pledging to transition to net-zero emissions (Net Zero Stocktake 2023 | Net Zero Tracker, 2023). This transition is not only helpful in mitigating climate change but also offers opportunities for improved air quality, health benefits, and sustainable development (O'Regan and Nyhan, 2023). Study shows that reaching '*net zero*' greenhouse gas emissions globally would lead to a considerable reduction in air pollution with the benefit of a substantial decreases in childhood asthma incidence and adverse birth outcomes (Milner et al., 2022).

Urban green spaces and nature-based solutions are important in achieving net-zero city targets. They have several positive impacts on the city's air quality and climate adaptation by reducing the urban heat island effect and collaborating through mitigation with carbon sequestration and increased biodiversity. Indirectly, they help to improve public health. In addition, studies indicate that urban green spaces have direct impacts on several Sustainable Development Goals (SDGs) such as SDG11 Sustainable cities and communities, SDG15 Life on

land and SDG13 Climate Action (Lorenzo-Sáez et al., 2021).From this aspect, it is crucial to integrate green solutions while setting net zero city policies.

Net zero emissions on a worldwide scale is a complicated target that can only be accomplished via the collective efforts of society rather than by individual entities working in isolation (Net Zero Tracker, 2023). Effective climate measures must be taken by accompanied by empowering the city governance and stakeholder engagement.

On the other hand, promoting gender equality and diversity is another key component for cities. Cities need to undergo significant transformation to achieve net zero targets, such as retrofitting buildings, improving transportation systems, and enhancing urban greens by planning more open public green spaces. All these actions are connected to the development of new urban planning thinking. For these new urban planning practices, it is important to consider promoting gender equality and inclusivity and including different gender components in the decision-making.

In the light of the literature review, objectives for the city ESG indicator development were selected as given in Figure 4:

Figure 4 City ESG indicator objectives

During the determination of city ESG indicators, the Sustainable cities and communities - Indicators for city services and quality of life indicators in ISO 37120 sustainable cities standards were taken as a basis. The set of indicators in this ISO standard was selected by taking into consideration the prioritised challenges of European cities in the current situation, which was defined by Eales et al., 2021. Indicators that can encourage climate resilience and adaptation to climate change in terms of the environmental and social nexus were selected. Indicator areas were reviewed depending on the identified objectives, and the environmental, social, and governance indicator sets were decided based on other relevant guides and guidelines.

An important factor in indicator selection was data availability and quantifiability since monitoring and comparability of city performances were one of the key objectives of this study. However, it was also important to select indicators that could contribute to the development of city policies and push city authorities to address major city challenges rather than just monitor the existing issues. In addition, indicators were chosen based on their practicality and actionability to ensure that cities can adopt and act upon the findings.

Inclusivity was another concern that was handled from two perspectives: stakeholder inclusivity and social equality and inclusivity. For stakeholder inclusivity, different expectations from different stakeholders, including residents, businesses, government, and NGOs, were considered. By incorporating measures specifically targeting social fairness and inclusivity, sustainability initiatives are designed to benefit every community section.

2.3. Selection of the case study- Lahti and Glasgow cities

The City of Glasgow is located in west central Scotland with a population of 635,130 people and a 175 km^2 spanning area (Glasgow City Council, 2021). Glasgow emerged as a global industrial leader during the Industrial Revolution, particularly renowned for its shipbuilding prowess along the Clyde River. This period marked Glasgow as the "*Second City of the British Empire*," underscoring its significance in global trade and industry. However, the late 20th century witnessed a profound decline in heavy industries, precipitating economic and social challenges for the city (BBC News, 2011).

In response to these challenges, Glasgow embarked on a remarkable journey of recovery and regeneration. The city has transitioned towards a service-oriented economy, with significant growth in finance, tourism, education, and the creative industries. Many of the city's cultural sites were celebrated in 1990 when Glasgow was designated European Capital of Culture (Williams, 2020).

The second selected case study is the city of Lahti. Lahti is located in southern Finland, with a population of approximately 120,000 and a 54 km^2 area. Following World War II, Lahti experienced rapid industrialization, resulting in population and economic growth as well as environmental challenges. But during 1987-1994, the city started a recovery project to improve the environmental quality, and this movement continued with several sustainability projects and resulted in the award of the *European Green Capital* label in 2021 (Eko Diena, 2021; The City of Lahti, 2023).

Even though the two cities selected have different demographic, economic, and social structures, they share similarities in industrial development and pollution backgrounds, resulting in successful sustainable recoveries. The City of Lahti has a climate neutrality commitment by 2025, while the city of Glasgow has a net-zero commitment by 2030 (The City of Lahti, 2023; Glasgow City Council, 2024).

The scoring model was applied to each city to evaluate their ESG scores and compare their ESG performance. Finally, the insights and experiences from the case studies were used to analyse the applicability of the proposed ESG scoring methodology and assess the areas for its development.

2.4. Summary and Research Gaps

Cities need more investment to achieve their net-zero targets. The actual financing gap is estimated to be almost USD 1.8-2.4 trillion annually until 2030 (The State of Cities Climate Finance, 2021). ESG scores significantly influence asset allocation, with higher scores indicating higher investment attractiveness and sustainable equity holdings, as supported by third-party ESG fund ratings. However, there is a research gap in existing ESG literature regarding ESG scoring tailored specifically for cities and municipalities.

Accurate ESG disclosures and ratings can help cities provide funding for their transition to net zero. Although several urban sustainability frameworks and corporate ESG scoring systems exist, a city-tailored ESG score framework is essential for tackling cities' specific sustainability difficulties. A city-tailored ESG rating system can offer a comprehensive approach to urban sustainability, facilitate the availability of sustainable funding, and assist in enhancing policy and governance. This would allow communities to accomplish their net-zero goals while promoting a more sustainable and resilient future.

In this context, this study will focus on developing a city-specific integrated ESG framework, focusing on the cities' net-zero achievements to fill the literature gap.

Overall, key questions will be addressed by this study:

- How can a city-specific ESG scoring system developed to measure the environmental, social and governance risk management performance of the urban environments?
- What are the key sustainability indicators that should be included in a city-specific ESG scoring system?
- What are the challenges and barriers for cities to implement an ESG scoring system?

CHAPTER 3: METHODOLOGY

3.1. Research overview

This chapter outlines the methodology adopted to pursue the present research objectives, followed by a critical review of the existing urban sustainability framework, an explanation of the double materiality assessment and the city ESG indicator selection, a brief explanation of two case study cities, an explanation on the data used and methods applied for the data processing and the definition of an ESG score calculation method. Google Earth Engine[6], the very well-known cloud-based geospatial analysis platform, was used to obtain environmental data.

3.2. Research Philosophy, Approach and Framework

This study aims to develop a specific ESG indicator set and scoring system tailored to be applied to cities. For the city-specific ESG indicator development, a mixed method approach that integrates qualitative and quantitative analysis and pragmatic research philosophy was employed. This aligns with the mixed-methods research strategy advocated by (Saunders, Lewis and Thornhill, 2019), facilitating data triangulation to enhance validity and reliability. The study's design includes the following key stages:

i. Qualitative analysis of existing sustainability frameworks and ESG indicator selection
ii. Quantitative double materiality assessment for ESG indicators weighting analysis
iii. Development of a synthesized scoring methodology and framework to calculate final scores
iv. Data collection and analysis for the application of the framework
v. Evaluation and validation of the framework through comparative case studies

The study design is summarized in a research onion given in Figure 5, to provide an overview to the strategy, methods and approaches. This study follows an abductive approach, moving between theory and data to develop a set of possible ESG indicators and scoring systems tailored for cities. A multi-method strategy was adopted, incorporating archival research and comparative case studies. Archival research critically reviewed well-known and widely recognized city sustainability frameworks, such as ISO 37120 Sustainable Cities Standards, CDP Cities Programme, C40 Cities Guidelines, WHO Urban Health Index and UN Sustainable Development Goals.

The double materiality analysis was conducted in line with the European Financial Reporting Advisory Group (EFRAG) Double Materiality Guidelines to assess the potential material positive and negative impact of the selected city ESG indicators on the environment and society, as well as their financial consequences.

[6] https://earthengine.google.com/

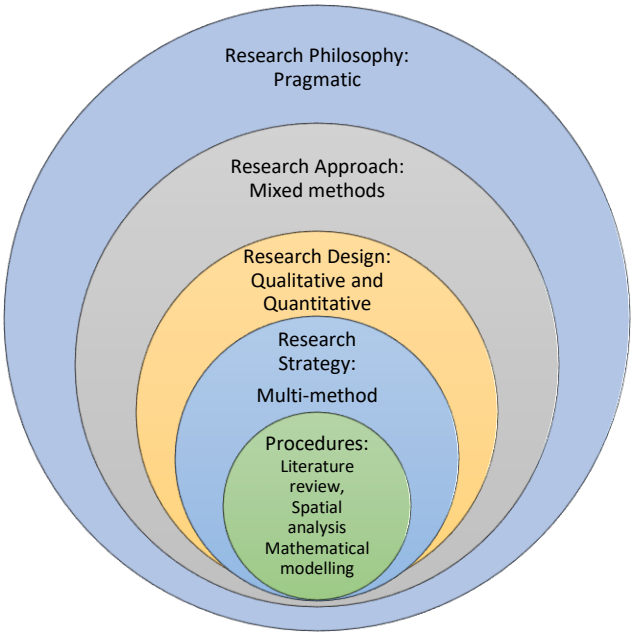

Figure 5 Research onion ((Saunders, Lewis and Thornhill, 2019)

The numerical scoring model was created using the framework proposed by Rossi et al. (2024). The framework emphasized including geospatial data to enhance the accuracy and relevance of ESG ratings. The existing environmental score structure was retained, and a climate score was added. Furthermore, methodologies for social score and governance score were formulated, leading to comprehensive ESG scoring frameworks.

3.3. Indicator selection

This thesis combines several urban sustainability frameworks to develop a comprehensive composite indicator set for urban ESG assessment. Composite indicators can help transform the available complex information into a single measure, thereby helping policymakers, researchers, and stakeholders. Nardo et al., 2008 further add that the indicators capture wide socio-economic phenomena, facilitating comprehensive assessments, comparisons across countries, and evidence-based decision-making. For the selection of the city ESG indicators, a literature review was conducted on urban sustainability and a critical review of the existing frameworks. The process enabled the identification of the most suitable urban sustainability frameworks to develop ESG indicators. Additionally, a double materiality analysis was performed to demonstrate the financial and impact materiality of the indicators and calculate the weightings of the indicators for deriving the ESG scores.

Initially, each of the frameworks was reviewed, and the relevant indicators and recommendations are listed in Table 4. The criteria for the selection were considered as follows:

- Having a negative and/or positive financial risk and/or implication of the impact
- Data availability and accessibility of the open public data

- Quantifiability and comparability of the city ESG
- Practicality and actionability

Table 4 Selected ESG indicators for cities

	Sub-topic	Indicator	Indicator source	Unit
ENVIRONMENTAL	E-Hydrology	Water stress level	Rossi et al, 2024	%
		Water pollution levels	Rossi et al, 2024	-
	E-Biodiversity	Proximity to natural protection area	Rossi et al, 2024	-
		Interaction with the Biodiversity Hotspot	Rossi et al, 2024	-
	E-Pollution	NO_2 emissions	Rossi et al, 2024	mol/ m^2
		SO_2 emissions	Rossi et al, 2024	mol/ m^2
		CO emissions	Rossi et al, 2024	mol/ m^2
		CH_4 emissions	Rossi et al, 2024	ppb
		Normalized Difference Chlorophyll Index (NDCI)	Rossi et al, 2024	
	E-Climate change mitigation	GHG Emissions	ISO 37120:2018 - Sustainable cities and communities	tCO_2/ capita
		Net Zero City Strategy	NetZeroCities	-
		Climate Change Mitigation Policy	CDP Cities 2024 Questionnaire	-
		Science-based emission reduction target	CDP Cities 2024 Questionnaire	-
		Net zero target for the city	NetZeroCities	-
		Baseline year for the interim emission reduction target	CDP Cities 2024 Questionnaire	year
		Percentage of renewable energy use in the current energy mix	CDP Cities 2024 Questionnaire	%
		Target to increase renewable energy production capacity	CDP Cities 2024 Questionnaire	-
		Waste landfilling rate of the city	CDP Cities 2024 Questionnaire ISO 37120:2018 - Sustainable cities and communities	%
		Share of CO_2-free city buses in the fleet	CDP Cities 2024 Questionnaire	%
		Green and Healthy Streets Acceleration or equivalent initiative participation	C40 Cities Green & Healthy Streets Accelerator	-
	E-Climate Change Adaptation	Climate Risk Assessments	CDP Cities 2024 Questionnaire	-
		Climate Adaptation Policy	CDP Cities 2024 Questionnaire	-
		Policy or target to enhance green infrastructures	CDP Cities 2024 Questionnaire	-

		Access to public green space (at least 0.5-1ha of public green space within 300m of each residential)		%
		Policy or program to increase urban green cover	CDP Cities 2024 Questionnaire	-
		Green infrastructures or nature-based solutions for stormwater management	CDP Cities 2024 Questionnaire	-
		Cooling and/or heating centers	Own	-
		Food Policy	C40 Good Food Cities	-
		Policy or target to enhance biodiversity and natural ecosystems	Key performance indicators for smart sustainable cities. *U4SSC*	-
		Policy to enhance health and wellbeing of citizens	Own	-
		Emergency plan against to climate hazard, i.e, extreme weather conditions, flooding, forest fires, droughts etc?	NetZeroCities	-
		Membership to climate adaptation initiatives (i.e ; Signatories to Covenant of Mayors[7]: - EU Life Programme[8] - Climate-ADAPT[9] - Participants in 100 Resilient Cities[10] - C40 Cities[11] - Making Cities Resilient Campaign[12] - Europen Green Capital[13]	Own	-
SOCIAL	S-Inclusion	Unemployment rate	ISO 37120:2018 - Sustainable cities and communities	%
	S- Gender Equality	City policies to promote gender equality initiatives and programs	URBACT- Gender Equal Cities	-
		Training for city officials on gender equality	URBACT- Gender Equal Cities	-
		City public authority gender pay gap	Key performance indicators for smart sustainable cities. *U4SSC*	%

[7] https://www.covenantofmayors.eu/about/covenant-community/signatories.html
[8] https://ec.europa.eu/easme/en/life
[9] https://climate-adapt.eea.europa.eu/
[10] http://www.100resilientcities.org
[11] https://www.c40.org/
[12] https://www.unisdr.org/campaign/resilientcities/home/cities
[13] http://ec.europa.eu/environment/europeangreencapital)

	Family-related leave and flexible working arrangements for city public authority employees	URBACT- Gender Equal Cities	-
	Programs to increase the availability of quality childcare	URBACT- Gender Equal Cities	-
	Program to strengthen women in disaster management	URBACT- Gender Equal Cities	-
S-Development	Tertiary education level	SDG 4.3	%
S-Mobility	Sustainable Transport Rate	Own	%
	Access to the internet	Key performance indicators for smart sustainable cities. *U4SSC*	-
S- Engagement	Efficient feedback mechanism	Own	-
	Citizen involvement in decision-making	Own	-
S- Health	Waiting time for the access to the healthcare	Own	Min/capita
	Number of physicians per 1000 population	ISO 37120:2018 - Sustainable cities and communities	Number/capita
	Mortality rates from preventable diseases among persons less than 75 years (per 100,000 inhabitants)	ISO 37120:2018 - Sustainable cities and communities	Number/ 100,000 inhabitants
	Average life expectancy	ISO 37120:2018 - Sustainable cities and communities	Years
	Rates of chronic diseases (e.g., diabetes, hypertension)	ISO 37120:2018 - Sustainable cities and communities	%
S-Quality	Persons having cost overburden rate (%)	ISO 37120:2018 - Sustainable cities and communities	%
	Number of homeless % population	ISO 37120:2018 - Sustainable cities and communities	%
	Residential rental dwelling units as a percentage of total dwelling units	ISO 37120:2018 - Sustainable cities and communities	%
S-Safety	Number of violent crimes against women per 1000 population	ISO 37120:2018 - Sustainable cities and communities	Number/1000
	Crimes against property per 1000 population	ISO 37120:2018 - Sustainable cities and communities	Number/1000

	S- Culture	Number of cultural institutions and sporting facilities per 1000 population	ISO 37120:2018 - Sustainable cities and communities	Number/1000
		Percentage of municipal budget allocated to cultural and sporting facilities	ISO 37120:2018 - Sustainable cities and communities	%
		Annual number of cultural events per 1000 population (e.g. exhibitions, festivals, concerts)	ISO 37120:2018 - Sustainable cities and communities	Number/1000
		Protection policies for cultural heritage sites	Key performance indicators for smart sustainable cities. *U4SSC*	-
GOVERNANCE	G-Representation	Non-men (Women) mayors or other leaders and members as a percentage of total elected to city-level office	ISO 37120:2018 - Sustainable cities and communities	%
	G-Integrity and Accountability	Number of convictions for corruption and/or bribery by city officials per 1000 population	ISO 37120:2018 - Sustainable cities and communities	Number/1000
	G-Digital Governance	Electronic governance services	Key performance indicators for smart sustainable cities. U4SSC	-
	G-Citizen Engagement	Grievance mechanism	Own	-
		Voter turnout rate (Voter participation in last municipal election (as a percentage of registered voters)	ISO 37120:2018 - Sustainable cities and communities	%

3.3.1. Environmental indicators

3.3.1.1. Hydrology indicators

Water stress appears when there is an increase in demand for water within a specific time frame or when low water quality makes it difficult to use (EEA, 1999). The worldwide urban population confronting water shortage is expected to grow by 121.3% (81.5–154.4%) to 2.065 (1.693–2.373) billion by 2050. 840 (476–905) million people anticipated perennial water scarcity, and 1.225 (0.902–1.647) billion anticipated seasonal water scarcity. By investing in infrastructure, two-thirds of water-scarce communities may alleviate their water shortage (He et al., 2021). This alarming increase underscores the need for cities to address water stress proactively. In addition, water stress directly affects public health and quality of life and can severely impact economic activities. Industries that rely on water use, such as agriculture and manufacturing, can suffer significant losses during water stress. Climate change can worsen water stress, impeding economic growth, triggering migration, and inciting violence. By incorporating water stress as a city ESG indicator, cities can better manage water resources, ensuring the continuity of economic activities and reducing the risk of economic downturns (World Bank Group, 2016).

Water pollution is a significant indicator of the public's and the environment's health. The normalized difference chlorophyll index (NDCI) parameter to simulate the chlorophyll-a (chl-a) concentration was used from remote sensing data; Sentinel-2 images. Chlorophyll-a concentration is an indicator to measure the amount of algae growing in water, which is related to the nutrient concentrations in water bodies. Increases in nitrogen levels brought on by pollution can cause algae and other aquatic plants to overgrow in contaminated water bodies. This may increase the amount of chlorophyll-a in the water, which may be identified by setting a NDCI threshold accordingly. Water contamination is detected at a threshold of 0.1, as suggested in the study by (Rossi, Byrne and Christiaen, 2024).

3.3.1.2. Biodiversity indicators

Habitat loss due to urban development is one of the most significant causes of biodiversity loss. It is projected that urban land expansion by 2050 is a significant threat to biodiversity (Simkin et al., 2022). As a biodiversity indicator, only the proximity and possible negative interaction with natural protection areas were evaluated. It was assumed that urban interactions and possible growth can threaten biodiversity components and lead to habitat loss.

3.3.1.3. Pollution indicators

This study focuses on the concentration of nitrogen dioxide, sulphur dioxide, carbon monoxide and methane in the atmosphere as the pollution indicators as suggested by the study from (Rossi, Byrne and Christiaen, 2024). Remote sensing monitoring tools were selected to assess these gas concentrations rather than recording the emissions of a single point in time since they give access to the temporal average concentration of these pollutants.

NO_2, CO and CH_4 are greenhouse gases that significantly negatively impact the environment and health. NO_2 is a significant pollutant that contributes to the formation of ground-level ozone and fine particulate matter, and its long-term exposures can lead to respiratory problems. It also has a negative effect on the vegetation and soil, leading to ecosystem damage (Dise et al., 2011).

CO is a fossil fuel combustion-sourced air contaminant gas; high levels of CO are not expected for outdoor urban areas, but they can still have several negative health impacts. While CO has a small direct global warming potential and an indirect GHG, it directly contributes to climate change by influencing the levels of methane and tropospheric ozone, both potent GHGs (Intergovernmental Panel on Climate Change, 2001).

CH_4, or methane, is a potent greenhouse gas with a global warming potential 28 times greater than that of CO_2. It significantly contributes to climate change, affecting weather patterns and

biodiversity (Dellenbaugh-Losse and Dreyer, 2022). Monitoring CH_4 emissions is critical for cities aiming to achieve net zero emissions.

SO_2 is a precursor of acid rain and is associated with respiratory disease. SO_2 main sources can be natural processes as well as the combustion of sulphur-containing fossil fuels (Department for Environment Food & Rural Affairs, 2024).

3.3.1.4. Climate change indicators

Climate change adaptation and mitigation indicators are critical for assessing a city's resilience and climate-related risks and efforts. These indicators can help cities understand and improve their strategies to tackle the challenges posed by climate change, ensure sustainable urban development, and monitor their progress toward achieving net zero city targets.

A net zero target for a city is vital for limiting global temperature rise well below 1.5° C as outlined in the Paris Agreement. It is critical to monitor city's greenhouse gas emissions and their reduction in time to monitor cities' commitment towards net-zero targets. Science-based targets provide a clear and credible path to reduce emissions in line with the scientific targets defined by the IPCC. Both climate change adaptation and mitigation policies are crucial to achieving zero emissions. For developing climate strategies and policies, climate risk assessment can help cities understand their vulnerabilities, assess the most relevant actions to prioritize and ensure that the cities are prepared for and can effectively respond to climate-related hazards.

To achieve the net zero and to improve cities' climate adaptation green infrastructures and nature-based solutions have multiple benefits, reducing urban heat islands, managing stormwater and improving air quality, enhancing biodiversity, and improving the aesthetics of cities. Therefore, policies that promote green infrastructure enhance a cities resilience to climate impacts and contribute to the overall environmental sustainability.

3.3.2. Social indicators

3.3.2.1. Inclusion indicators

The unemployment rate was selected as an inclusion indicator to measure the ratio of the labour force that is unemployed and seeking employment. High unemployment rates can lead to increased poverty, social unrest, and economic instability, therefore this indicator is one of the major components of the city's ESG scoring.

3.3.2.2. Gender equality indicators

City policies promoting gender equality initiatives, programmes, and training for city officials on gender equality and disclosing the gender pay gap for the city public authorities are

selected as city ESG gender equality indicators. Implementing municipal initiatives that enhance the accessibility of high-quality childcare, especially for economically disadvantaged families, tackles socio-economic disparities and promotes women's economic autonomy and engagement in the workforce. Childcare solutions facilitate parental engagement in the workforce and promote children's growth and progress (Dellenbaugh-Losse and Dreyer, 2022).

3.3.2.3. Development indicators

As a development indicator, only the tertiary education level indicator could be selected by considering the availability of the data and time constraints. This indicator measures the ratio of the population that has attained all formal post-secondary education, including public and private universities, colleges, technical training institutes, and vocational schools (World Bank Group, 2024). Better employment opportunities, higher incomes and improved social mobility have been linked to higher education levels. Economic growth is promoted by investing in education while also reducing social inequalities (Barro and Lee, 2013).

3.3.2.4. Mobility indicators

The sustainable transport rate was selected as a mobility indicator based on the cities' net-zero targets. International Energy Agency (IEA) has several climate scenarios, and their net zero scenarios require transport emissions from the transport sector to fall by more than 3% per year by 2030 (IEA, 2023).This situation makes sustainable and low-emission transport one of the key levers for achieving net zero emissions.

3.3.2.5. Engagement indicators

The availability of an efficient feedback mechanism and citizen involvement in decision-making were selected as engagement indicators. Timely engagement of people in the decision-making process is essential for effective participation. To tackle urban crises and enhance to democracy, experts suggest enhancing inclusivity in policy-making institutions, implementing advocacy planning for marginalised communities, and promoting the formation of stable neighbourhood interest groups.

Public engagement enhances the link between a government and the public through efficient communication and collaborative dispute resolution (UN-Habitat, 2018). Public consultations and participatory budgeting are examples of citizen involvement in decision-making. It uses local knowledge to innovate and to ensure that policies meet community needs. This builds civic responsibility and gives inhabitants a say in their city's development (Lijphart, 1997). It supports SDG 11 and 16 by promoting social fairness and good governance (United Nations, 2015). Participation strengthens communities and improves sustainability and governance.

3.3.2.6. Health indicators

Waiting times to health care access and average life expectancy for males and females were selected as city health indicators. These indicators can help to understand the healthcare system performance and indirect impacts of the environmental conditions of the cities.

Life expectancy measures population mortality. Life expectancy is intimately linked to health circumstances, which are crucial for development. Mortality rates influence population size and growth potential. Life expectancy at birth in a nation measures overall quality of life and includes death rates across all ages. This metric suggests the possible return on investment in human capital and is essential for calculating actuarial metrics.

Average walking time to the nearest healthcare has also been defined as an indicator; shorter travel times indicate better accessibility and convenience of healthcare services. Geospatial distribution tools could measure this indicator, but due to time limitations and a lack of data for the city of Glasgow, to make possible the comparison between the two cities, it was decided to remove this indicator. In addition, "Number of physicians per 1000 population and Mortality rates from preventable diseases among persons less than 75 years (per 100,000 inhabitants)" as ISO 37120 indicators were selected as ESG indicators. However, during the case study, no data was available for neither Lahti nor Glasgow, and it was decided that these indicators should be removed.

3.3.2.7. Quality indicators

Persons having cost overburden rate, the number of homeless as a percentage of the population, and residential rental dwelling units as a percentage of total dwelling units were selected as quality indicators.

The housing cost overload rate refers to the proportion of the population that lives in households where the total housing expenses (excluding housing allowances) exceed 40% of the disposable income (excluding housing allowances) (Eurostat, 2024). High housing cost burdens can lead to financial stress and housing instability. Addressing housing affordability is important for promoting social equity and well-being. A lower cost overburden rate in cities implies a higher ability to provide affordable housing for their residents, thus minimizing the risk of homelessness and financial difficulties. The security that comes with affordable housing ensures economic stability and quality of living, avoiding financial problems and redirecting these resources to other essential needs like health, education, and transport.

The proportion of residential rental dwelling units to total dwelling units is also significant. It measures the ratio of rental housing against the total housing stock. A balanced housing market gives opportunities for different types of housing, including rentals. When well balanced, the market helps foster social mobility through increased affordability and greater

stability in housing situations. Cities with a higher percentage of rental dwelling units are more diversified: young professionals, low-income families, and transient workers can live in them (OECD, 2011).

Another key indicator is the homelessness rate as a proportion of the population. Homelessness is a very serious social problem that has core effects on personal health, safety, and dignity. Preventing homelessness is essential in ensuring social inclusion and quality of life.

3.3.2.8. Safety indicators

The percentage of women who have experienced violence and crimes against property per 1000 population were selected as safety indicators. Reducing the violence rates against women is important to provide gender equality as well, and it can be an effective tool to empower women in city environments, encourage them to work and participate in urban life without fear of violence and support them in full and productive employment (UN-Habitat, 2020).

3.3.2.9. Culture indicators

The percentage of the municipal budget allocated to cultural and sporting facilities (supporting indicator) and protection policies for cultural heritage sites were selected as cultural indicators. The percentage of the municipal budget allocated to cultural and sporting facilities measures the financial commitment of the city management to these areas and allows for a comparison of different cities' approaches to the issue. This indicator is important as it reflects the city's dedication to fostering a vibrant cultural life and promoting physical activity, which is crucial for mental and physical health.

3.3.3. Governance indicators

3.3.3.1. Representation indicators

Ensuring equitable participation of all genders in local governance is essential for democracy and leads to improved urban policies and more involved communities (Dellenbaugh-Losse and Dreyer, 2022). ISO 37120 Sustainable Cities standards suggest that "*Women as a percentage of total elected to city-level office*" is a core indicator for sustainable cities under the governance category. This indicator was modified as a "non-men" percentage of the total elected to city-level office to use more inclusive language and align with SDG 16.7 to ensure responsive, inclusive, participatory and representative decision-making at all levels. However, no data was available for both case study cities and women as percentage of total elected city level office was used as a leadership and representation indicator under the Governance category.

3.3.3.2. Integrity and Accountability Indicators

The number of convictions for corruption and/or bribery among city officials per 100,000 population is a supporting indicator derived from the ISO 37120 standards. The governance principles include selflessness, objectivity, accountability, transparency, integrity, and leadership. The number of convictions for corruption/bribery may serve as an indicator of the degree to which the government upholds these fundamental ideals and ensures that city officials adhere to high ethical standards.

Moreover, addressing corruption and bribery is aligned with SDG 16.5, whose goal is to substantially reduce corruption and bribery in all its forms, and SDG 16.6, that implies developing effective, accountable and transparent institutions at all levels.

There was no available data regarding the number of local governance corruption and/or bribery cases in Lahti and Glasgow. Although both cities publish annual sustainability report disclosures, there was no information about this issue.

3.3.3.3. Digital Governance indicators

The availability of electronic governance services was selected as a governance indicator. Electronic governance refers to the use of digital technology to facilitate communication and interaction between the government and its citizens, improve service provision and foster transparency. In addition, electronic governance guarantees that government services are readily available to all citizens, including individuals who may encounter obstacles in conventional forms of engagement, such as individuals with disabilities and those residing in rural regions.

3.3.3.4. Citizen Engagement Indicators

Citizen engagement metrics are crucial for measuring public involvement and democratic processes in municipal administration. These metrics show residents' engagement in decision-making and how effectively local officials listen to them.

The voter turnout rate measures civic involvement and democracy health, as well as the proportion of registered voters who voted in the previous municipal election. High voter turnout suggests city inhabitants are involved in voting and local government. It shows individuals believe their votes may affect local leadership and policy (Solijonov, 2016). However, low voter participation may suggest indifference, disenfranchisement, or unhappiness with politics, indicating a need for civic engagement.

An effective grievance procedure is also important. A grievance process lets residents communicate their issues, complaints, and opinions on local government and services. This method gives people a formal way to resolve grievances, improving government openness

and accountability. A successful grievance system shows the city's commitment to listening to and resolving people's demands, which builds confidence between citizens and the government. It also offers useful data for improving public services and policy. A successful grievance mechanism can contribute to achieving SDG 16.7, ensuring responsive, inclusive, participatory, and representative decision-making at all levels.

3.4. Double materiality assessment

The double materiality analysis was performed independently, utilizing expert judgment and qualitative assessment techniques in alignment with the EFRAG Double Materiality Guidelines. While recognizing the value of structured, multi-stakeholder approaches, this analysis leverages expertise and context-specific knowledge.

The following steps were followed for the double materiality assessment as given in EFRAG Double Materiality Guidelines:

Step 1: Specify the definition of the assessed sustainability topic: The sustainability topics and subtopics are determined according to the ISO 37120 Sustainable cities and communities standard issues and themes.
Step 2: Assess parameters of impact materiality of the sustainability topic
Step 2A: Determine the scale of impact: The scale and scope of impacts were analysed according to the following intensity scale:

Table 5 Scale and scope of impact

Scale of impact		**Scope of impact**	
5	Absolute	5	Global/total
4	High	4	Widespread
3	Medium	3	Medium
2	Low	2	Concentrated
1	Minimal	1	Limited
0	none	0	None

Remediability was measured on the following scale:

Table 6 Remediability scale of impact

Remediability of impact	
5	non-remediable/irreversible
4	very difficult to remedy or long-term
3	difficult to remedy or mid-term
2	remediable with effort (time & cost)
1	relatively easy to remedy short-term
0	very easy to remedy

Step 3: Determine the preliminary impact materiality of the analysed topic: A proxy indicator of preliminary overall impact materiality, the following formula was used:

$$Preliminary\ Impact\ Materiality = Scale\ of\ Impact + Scope\ of\ Impact + Remediability\ (1)$$

Preliminary impact materiality was described using the following table:

Table 7 Scale of preliminary impact materiality

Preliminary impact materiality	
≥ 12 critical	Critical
[10,12)	Significant
[8,10)	important
[5,8)	informative
< 5	minimal

Step 4: A judgemental analysis was performed by following the steps 2 and 3 to assessed the impact materiality for each city sustainability topic and sub-topic. EFRAG, 2022 suggest conducting a judgemental analysis by considering both the existing situation and the anticipated progression in the likelihood of the materiality at both a general and specific level throughout all relevant time frames for the effect. It was stated that assessing the likelihood of expected implications is crucial for making informed judgements by considering factors such as magnitude, scope, and remediability. Table 8 shows the assessment results of the impact materiality.

Materiality heatmap visualises sub-sub-topics derived from ISO 37120 Sustainable cities and communities against three different materiality types, negative and positive, and evaluates their impacts' remediability potential. The colour gradient in the heatmap ranges from blue (lower scores) to red (higher scores), indicating the material scores assigned to each sub-sub-topic under different materiality types. The highest scores among all materiality types belonged to emergency preparedness. The high “remediability” score indicates the difficulty of addressing these issues once they arise by requiring significant resources, time, planning, and infrastructure improvements. The high score shows that failures in this area can have significant consequences, potentially affecting the entire community or city. In summary, any serious negative situation in this area could lead to catastrophic outcomes. From these aspects, it can be assumed that the sub-topic can be linked to high environmental and social risks. Besides, when considering the high risks, strong emergency preparedness can be a critical governance issue with important implications for public safety and municipal stability.

Employment is another critical area where negative impacts can damage society with a domino effect and be linked to poor living standards. High unemployment rates can lead to social unrest, increased poverty, and reduced economic growth, affecting the municipality’s overall ESG performance. Poor living standards can result in social instability, economic decline, and health risks. High materiality in areas like public transport and affordable housing indicates their importance in mitigating these risks.

Table 8 Double materiality assessment - impact analysis

Sustainability Topic	Sub-topic	Sub-sub topic	SCALE-NEGATIVE	SCOPE NEGATIVE	REMEDIABILITY	SCALE-POSITIVE	SCOPE POSITIVE
Governance, empowerment and engagement	Governance	Non-discrimination and Representation	3	2	1	4	2
		Transparency and Accountability	3	2	1	2	1
		Engagement	3	2	2	3	2
Education and capacity building	Education Access and Quality	Educational Quality	4	2	3	2	2
Innovation, creativity and research	Digital Infrastructure	Connectivity and smart technologies	3	2	2	3	2
Health and care in the community	Healthcare Access	Primary Healthcare	2	1	2	3	1
	Public health	Disease Management	4	2	3	4	2
Culture and community identity	Cultural Heritage	Heritage Protection	1	1	3	3	1
	Cultural Activities	Cultural Engagement	2	2	2	3	2
Living together, interdependence and mutuality	Public Safety	Crime Rates	4	2	2	3	2
	Community Cohesion	Social Integration	2	2	1	3	1
Economy and sustainable production and consumption	Economic Development	Employment	4	4	3	4	3
Living and working environment	Health	Environmental Health	4	3	2	4	4
	Recreation	Public spaces	1	1	3	1	2
	Shelter	Affordable Housing	2	3	1	3	2
	Urban planning	Sustainable Planning	3	3	2	4	3
Smart community infrastructures	Energy	Renewable Energy	4	2	2	4	2
	Fire and emergency response	Emergency Preparedness	5	3	2	3	3
	Telecommunication and innovation	Digital Infrastructure	3	2	2	4	2
Mobility	Transportation	Public Transport	3	2	2	3	3
Smart community infrastructures	Wastewater	Water Management	4	3	3	2	2
Biodiversity and ecosystem services	Environment	Air Quality	3	4	3	3	2
	Solid waste	Waste Management	3	2	2	4	2
	Biodiversity	Biodiversity Conservation	4	3	2	4	3

Public spaces and cultural engagement indicate different materiality levels. While these may not severe impacts like other sub-topics, they are still connected with social well-being and community cohesion. Both air quality and environmental health have a direct impact on public well-being. High scores in these areas indicate the potential for significant negative consequences if not adequately managed. Biodiversity conservation, public spaces, and environmental health are directly related to one of the ESG indicator selection objectives: “enhancing green in the cities.' Green spaces contribute to better health, reduce stress, and provide recreational opportunities, which are key to high living standards. The heatmap might indicate that enhancing greenery has moderate to high negative materiality, especially in terms of any possible related adverse conditions that can lead to poor air quality, reduced biodiversity, and increased urban heat island effect, exacerbating environmental and social risks.

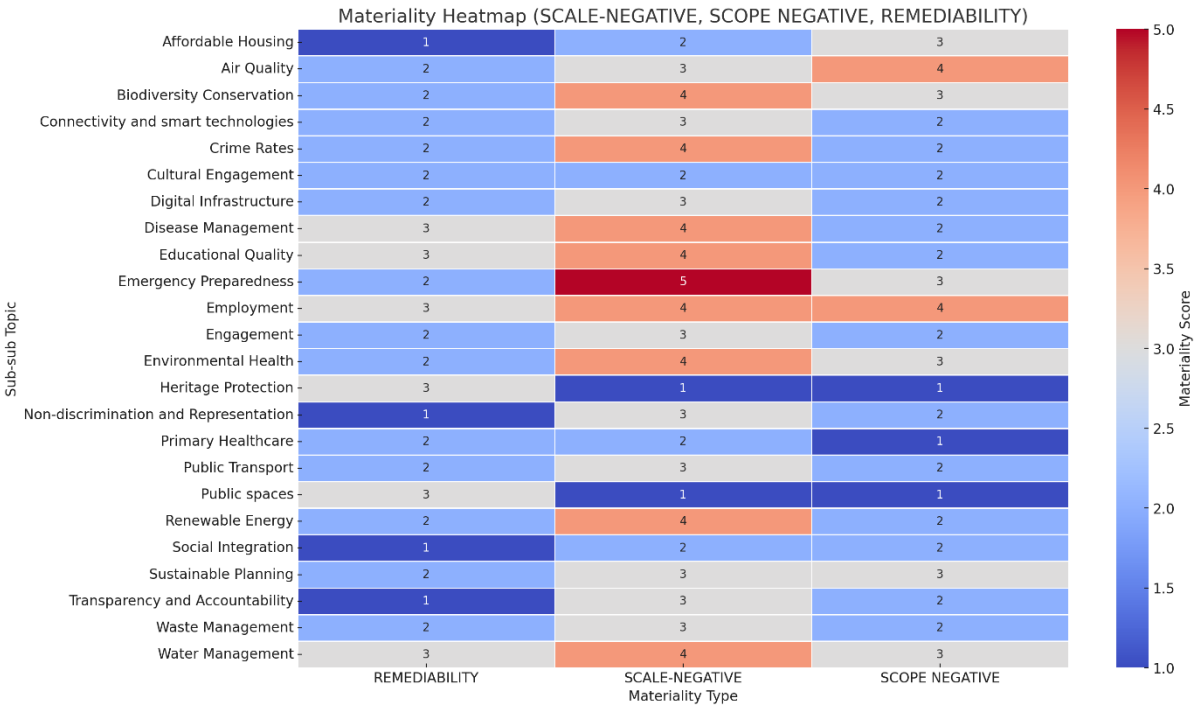

Figure 6 Negative materiality heatmap

From the positive materiality heatmap, the highest materiality score from the scale and scope belonged to environmental health (Figure 7). Any possible improvement in environmental health can result in better environmental conditions and improve the health status of the public and biodiversity. Effective management of the environment, including waste management and improving air quality, can create a positive impact broadly. On the other hand, renewable energy and sustainable urban planning are the key actions towards the climate-related targets of the cities, including net zero. In terms of ESG, a high materiality score shows that not only reducing carbon emissions and providing climate resilience and mitigation but also the importance of renewable energy project investments and sustainable urban planning attract green investments and create long-term economic opportunities.

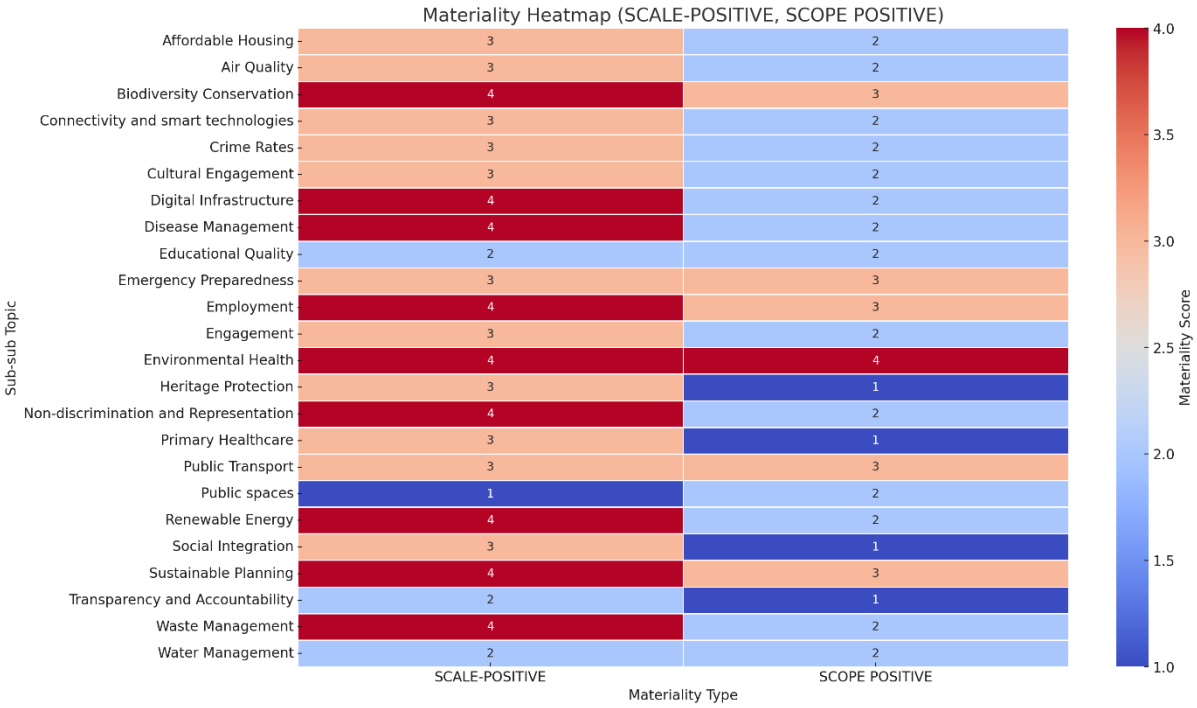

Figure 7 Positive materiality heatmap

High materiality scores in the employment and non-discrimination areas are the results of consideration of any possible positive economic and social outcomes of any improvement of increasing employment, ensuring representation and ending discrimination. On the other, high materiality scores for digital infrastructure and smart technologies result from their importance in supporting economic development by enabling better access to city services and improving governance practices by providing transparency and data-driven decision-making. From the ESG perspective, these topics are highly important in terms of economic and governance.

3.5. Scoring methodology

3.5.1. Weighting

The method used for normalizing and calculating weights involves vector normalization. The initial step includes normalizing each impact materiality score by considering financial score. Next, a weighted average of the normalized financial and impact scores is calculated to derive the final materiality score. Finally, the scores are normalized to ensure that the sum of each score within each indicator group equals one.

Step 1: Normalization of individual impact scores: Normalization is a method to standardize individual data points to a uniform scale without compromising the differences in value ranges. The objective is to normalize all values to a consistent range, between 0 and 1.

$$Normalized\ score = \frac{Raw\ score}{Max\ Possible\ Score} \quad (1)$$

This formula (1) scales the raw scores to a range between 0 and 1 by dividing each raw score by its respective maximum possible score.

$$Normalized\ Financial\ materiality\ score\ = \frac{Financial\ score}{4} \quad (2)$$

Given that the maximum financial score is 4, this formula normalizes the financial score to a range between 0 and 1.

$$Normalized\ Impact\ materiality\ score = \frac{Impact\ score}{22} \quad (3)$$

By considering the maximum impact score is 22, this formula normalizes the impact score to a range between 0 and 1.

Step 2: The average of the raw normalized financial score and impact score is calculated. This process allows the combination of the multiple normalized scores into a single materiality score.

$$Final\ materiality\ score = \frac{Raw\ Normalized\ FinancialScore + Normalized\ Impact\ Score}{2} \quad (4)$$

Step 3: Vector normalization : The process of vector normalization involves scaling a set of values such that their sum equals 1. This ensures that the collective weightings of all indicators within a group are proportional and sum to a specific value, typically 1.

$$Normalized\ final\ score(\mathrm{Wi}) = \frac{\mathrm{Si}}{\sum_{\mathrm{i}-1}^{n}(\mathrm{Si})} \quad (5)$$

For example, the hydrology score under the environmental category had two indicators: water stress level and water pollution level. If the financial and sum of the positive and negative impact materiality are 2 and 17, respectively, normalization of the scores was as follows:

$$NF = \frac{2}{4} = 0.5 \quad (6) \qquad NI = \frac{17}{22} = 0.773 \quad (7)$$

The combined scores were calculated as follows:

Water stress	Water pollution	Sum

$$S = \frac{0.5 + 0.773}{2} = 0.6365 \quad (8) \qquad S = \frac{0.5 + 0.773}{2} = 0.6365 \quad (9) \qquad 0.6365+0.6365=1.273$$

Finally, normalized final weightings were calculated as follows:

Water stress

$$W_{Water\ Stress\ Level} = \frac{0.6365}{1.273} = 0.5 \quad (10)$$

Water pollution

$$W_{Water\ Pollution\ Level} = \frac{0.6365}{1.273} = 0.5 \quad (11)$$

3.5.2. Environmental Score

Environmental score (E_{score}) was divided into 4 subcategories as $E_{Hydrology}$, $E_{Biodiversity}$, $E_{Pollution}$ and $E_{Climate}$ score and weights are decided by the outcomes of the double materiality assessment. For the calculation of the final environmental score, the following equation was used:

$$E_{Score} = E_{Hydrology} * W_H + E_{Biodiversity} * W_B + E_{Pollution} * W_P + E_{Climate} * W_C \quad (12)$$

The variation in methods employed to evaluate ESG issues presents significant challenges to analysing and comparing sustainability performance. Different rating agencies employ different criteria, measures, and weights, leading to inconsistent and sometimes conflicting ESG ratings (Dimson et al., 2020). The use of varied data sources significantly contributes to these differences. Some agencies primarily rely on publicly available organisation information, while others integrate third-party reports or private datasets. The two modifications result in notably different analyses of the ESG performance of the same organisation (Berg et al., 2021). On the other hand, geospatial data and analyses provide a number of significant benefits for ESG evaluations, such as consistency, the possibility of increased accuracy, and the capacity to recognise and evaluate environmental impacts at the level of specific physical assets in addition to analysing the larger spatial context. Rating methods can be enhanced, and discrepancies can be more effectively addressed by including geographical information (obtained by manually processing remotely sensed data or by leveraging existing products). For this reason, pollution and water-related data for calculating the environmental score was derived from the geospatial data, and the calculation methodology introduced in Rossi, Byrne and Christiaen, 2024. The environmental indicator parameters and dataset information was given in Table 9.

The existing environmental score methodology from Rossi et al, 2024 is enriched by the addition of the “E-Climate” score. The E-Climate score is mainly adopted to provide guidance to the city’s net-zero targets as well as climate adaptation and mitigation affords.

Table 9 Environmental indicator parameters and datasets

Pollution parameter	Dataset	Processing	Spatial Resolution & Revisit Time
Nitrogen dioxide (NO_2) emissions	Sentinel-5P	Google Earth Engine	1 km & 1 day
Sulphur dioxide (SO_2) emissions			
Carbon monoxide (CO) emissions			
Methane (CH_4) emissions			
Normalized Difference Chlorophyll Index (NDCI)	Sentinel-2		10 m & 5-10 days
Water stress level	WRI Aqueduct	Aqueduct Water Atlas(Kuzma et al., 2023)	-

3.5.3. Social Score

Social score (S_{score}) was divided into 9 subcategories as follows: $S_{nclusion}$, S_{Gender}, $S_{Development}$, $S_{Mobility}$, $S_{Engagement}$, S_{Health} , $S_{Quality}$, S_{Safety} , $S_{Culture}$ score and the weights of each indicator was decided according to the results of the double materiality assessment. For the calculation of the final environmental score, the following equation was used:

$$S_{Score} = S_{Inclusion} * W_I + S_{\text{Gender}} * W_G + S_{Development} * W_D + S_{Mobility} * W_D + S_{Engagement} * W_E + S_{Health} * W_{Ht} + S_{Quality} * W_Q + S_{Safety} * W_S + S_{Culture} * W_C \quad (13)$$

3.5.4. Governance Score

Governance score (G_{score}) was divided into 4 subcategories as $G_{Leadership}$, $G_{Integrity}$, $G_{Digital}$ and $G_{Engagement}$ score, and weights are decided by the outcomes of the double materiality assessment. For the calculation of the final governance score, the following equation was used:

$$G_{Score} = G_{Leadership} * W_L + G_{Integrity} * W_{In} + G_{Digital} * W_D + G_{Engagement} * W_E \quad (14)$$

3.5.5. Determination of the scoring ranges

Each of the indicators was scored on a scale from 0 to 1, where:

- 0 indicates the best performance and lowest risk
- 1 indicates the worst performance and highest risk

The distribution of the scoring ranges is given Table 10:

Table 10 Scoring ranges and risk level

Risk level	Scoring range
Very low risk	0–0.1
Low risk	0.1–0.3
Medium risk	0.3–0.5
High risk	0.5–0.8
Very high risk	0.8–1

Intermediate values were used to reflect varying levels of performance or risk. The scores were assigned based on the value ranges for each indicator. Defining these ranges includes steps as:

1. Establishing benchmarks: Benchmarks for each indicator were established using the average values from EU cities. These benchmarks provide a reference point for creating the scoring ranges. For each of the indicators, European Union (EU) cities average, best and worst performance data was used as medium risk, low and highest benchmarks. When the city-level data were unavailable, EU level-country statistics were used.
2. Defining the ranges: Scoring ranges were defined based on the data distribution around the established benchmarks. Based on the data characteristics, the ranges were divided into five, four, or three categories.

3.6. Data inventory

Data inventory was created using geospatial data analysis with the Google Earth Engine and secondary data research. For the environmental pollution score data, Sentinel-5P data was used to assess specific air pollutants, and the data was processed using the Google Earth Engine for accurate pollution analysis. Water pollution and water stress impacts were analysed by using the Sentinel-2P data and WRI Aqueduct Water Stress Tool[14]. Only open public online data sources, including the cities' own open public publications, reports, and statistical data from reliable sources, were used for the remaining data. Each of the data sources used for the evaluation of the case study cities ESG score for Lahti and Glasgow were disclosed in Appendix 2 and 3 respectively.

[14] https://www.wri.org/aqueduct

CHAPTER 4: RESULTS AND DISCUSSIONS

This chapter presents the findings from the synthesized ESG indicator selection study and the double materiality analysis of the chosen indicators. Additionally, it includes the results of the ESG scoring applied to the cities of Lahti and Glasgow. The chapter is divided into three main sections: selected ESG indicators identified through literature review, double materiality analysis, and the results of the ESG scoring system application, which incorporates GIS analysis findings as part of the environmental pollution score.

4.1. Results of the double materiality assessment

The results of the double materiality assessment given in Table 11 shows the scores for financial materiality, negative impact materiality, and positive impact materiality, with the colour gradient representing the magnitude of the scores.

Table 11 Double materiality assessment results

Indicators	Financial Materiality	Negative Impact Materiality	Positive Impact Materiality
Non-men (Women) mayors or other leaders and members as a % of total elected to city-level office Training for city officials on gender equality Programs to increase the availability of quality childcare Program to strengthen women in disaster management	1	6	7
Number of convictions for corruption and/or bribery by city officials per 100,000 population,	3	6	4
Efficient feedback mechanism Citizen involvement in decision-making	1	7	7
Tertiary education level	2	9	7
Percentage of households with Internet access	3	7	7
Number of physicians per 1000 population Waiting time for the access to the healthcare Average travel time to the nearest healthcare facility by walking	4	5	6
Mortality rates from preventable diseases among persons less than 75 years (per 100,000 inhabitants) Rates of chronic diseases (e.g., diabetes, hypertension)	2	9	9
Protection policies for cultural heritage sites	2	5	7
Number of cultural institutions and sporting facilities per 100,000 population Annual number of cultural events per 100,000 population (e.g., exhibitions, festivals, concerts)	1	6	7
Number of violent crimes against women per 100,000 population Crimes against property per 100,000 population	3	8	7
Number of homeless % population Persons having cost overburden rate (%)	2	5	5

Unemployment rate	4	11	10
Policy or target to enhance biodiversity and natural ecosystems	3	9	10
Living space (m^2/person)	2	5	6
Residential rental dwelling units as a percentage of total dwelling units	2	6	6
Policy or program to increase urban green cover, Green infrastructures or nature-based solutions for stormwater management Cooling and/or heating centers Food Policy Policy to enhance the health and well-being of citizens	2	8	9
Percentage of renewable energy use in the current energy mix Target to increase renewable energy production capacity	2	8	8
Emergency plan against climate hazards, i.e, extreme weather conditions, flooding, forest fires, droughts, etc	2	10	8
Electronic governance services	4	7	8
Water stress level, Water pollution levels	2	10	7
Share of CO2-free city buses in the fleet	1	7	8
The impact of nitrogen dioxide emissions The impact of sulphur dioxide emissions The impact of carbon monoxide emissions The impact of methane emissions	2	10	8
Waste landfilling rate of the city	3	7	8
Interaction with the protected areas	2	9	9

4.2. Case study results

This chapter presents the results derived from the assessment, in accordance with the methodology provided in Chapter 4, and the performance of the cities of Lahti's and Glasgow's against the selected ESG indicators.

4.2.1. ESG Assessment Results – Lahti

The ESG scores for the city of Lahti were assessed by using the selected indicators. The environmental score was grouped into four sub-topics: hydrology score, biodiversity score, pollution score, and climate score, as described in Chapter 3. The social score was grouped into nine sub-topics: inclusion, gender equality, development, mobility, engagement, health, quality, safety and culture. The governance score was grouped into representation, accountability, digital governance and engagement. These indicators were analysed to calculate assessment scores for each ESG dimension.

Appendix 1 of the study provides detailed assessment information, performance against the indicators, and information on data sources used to evaluate the city's performance. In

contrast, this chapter presents only the overall scores. Figure 8, Figure 9 and Figure 10 illustrate the environmental, social and governance scores calculated for Lahti.

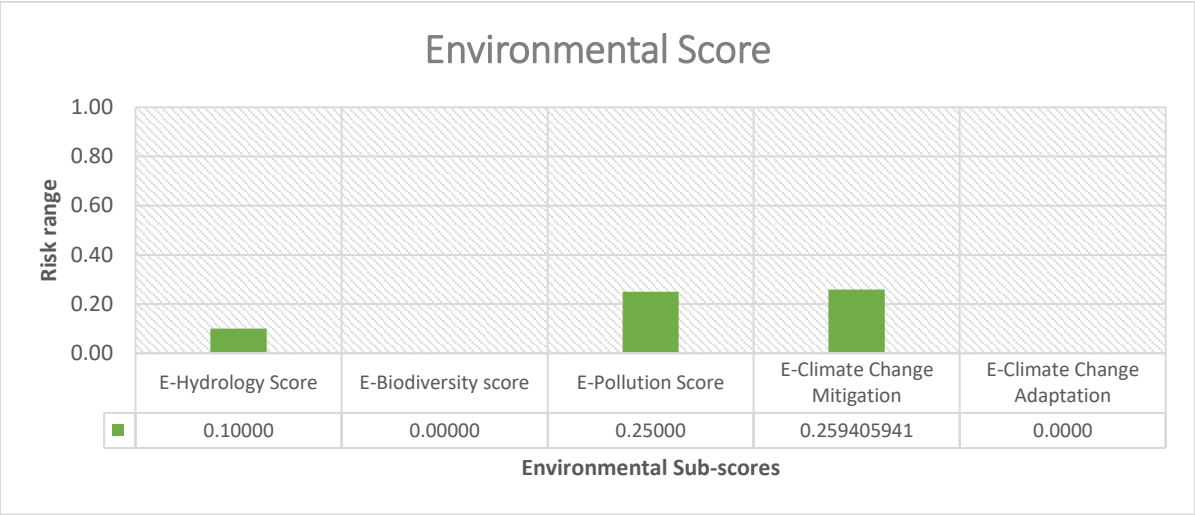

Figure 8 Environmental scoring of Lahti

Based on the results presented in Figure 8, the highest risk among the other sub-scores is calculated for climate change mitigation actions for Lahti with 0.26 out of 1. Climate change adaption and biodiversity scores are calculated as 0, representing the lowest risk. Each of the sub-score indicator scores was multiplied with the statistical weights, which were calculated according to the results of the double materiality assessment as described in Chapter 3, and the sum of the results for Lahti's environmental scoring was calculated as 0.14 out of 1; categorizing it as "*Low risk*".

The low-risk environmental score classification is not unexpected for Lahti. Lahti was awarded by a European Green Capital award in 2021, which acknowledges strong climate, nature and environmental policies in place. Notably, the city excels in biodiversity and climate adaptation performance, achieving the lowest possible score (0), which signifies robust strategies and effective management and disclosure performance. Although the environmental score is quite low, the most significant contributors to the calculation were the GHG footprints per resident, carbon monoxide (CO) and methane (CH_4) emissions. The City of Lahti residents have 7.2 tons of CO_2e carbon emissions per person, which is the lowest level in the national comparison for 2022 and was interpreted as a "*high emission level*" according to the scoring range (City of Lahti, 2024). This indicates a disparity between national benchmarks and local expectations, highlighting Lahti's ambitious environmental performance.

The other fossil fuel combustion-related emissions, CO and CH_4, calculated as 0.03 mol/m^2 and 1886 ppb, respectively, were the second highest risk contributors to the environmental score. These air pollutants are known for their adverse environmental and climatic impacts, reinforcing the importance of targeted mitigation strategies.

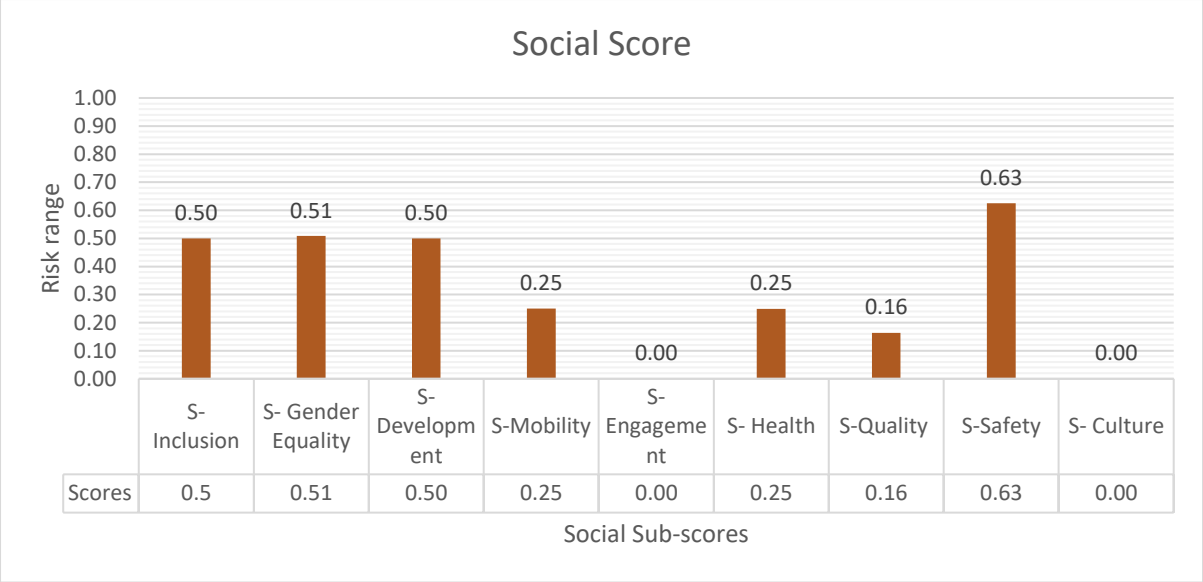

Figure 9 Social scoring of Lahti

The highest social sub-score for Lahti was Safety, with 0.63 out of 1, followed by Gender Equality, Inclusion and Development, with scores of 0.51, 0.5, and 0.5, respectively. Lahti's social score was calculated as 0.37 out of 1, categorizing it as a "medium risk" category.

The "Safety" sub-score caused the highest risk for the city of Lahti's social score. The high-risk rating in safety is primarily due to the rates of violence against women and crime rates against property. According to the statistics, 47% of women experienced physical and/or physiological violence in Finland (The European Institute for Gender Equality (EIGE), 2016). In Finland, a significant proportion of women, namely 53%, have encountered cases of violence conducted by an intimate partner at some point in their adult lives. In the EU, according to the data from 2017, 27.2% of women have experienced physical and/or sexual violence by any perpetrator since age 15 (18-74). In Finland, the rate of violence is almost double the EU average data and safety score was interpreted as "*medium-high*" according to the scoring ranges. This scoring range was developed to help understand the extent of the situation. Still, it needs to be remembered that any level or form of violence against women should be unacceptable.

Additionally, crime rate against property per 1000 population was 54.5, though classified in the "*medium*" range, was another contributor to the Safety sub score of 0.625. This classification suggests that property-related crime is a significant concern that could impact perceptions of safety and overall community well-being.

According to Lahti's Sustainability Report, 2023, the city's unemployment rate was 11%; however, when comparing the overall unemployment rates in the 12 largest cities in Finland, Lahti still ranks among the cities with the highest unemployment rates. The unemployment rate of 11% is evaluated in a "*medium*" range with a 0.5 sub-score. The 11% unemployment rate, while better than some other Finnish cities, still positions the city among those with high

joblessness, impacting social inclusion and economic stability, which are integral components of the social category of the ESG.

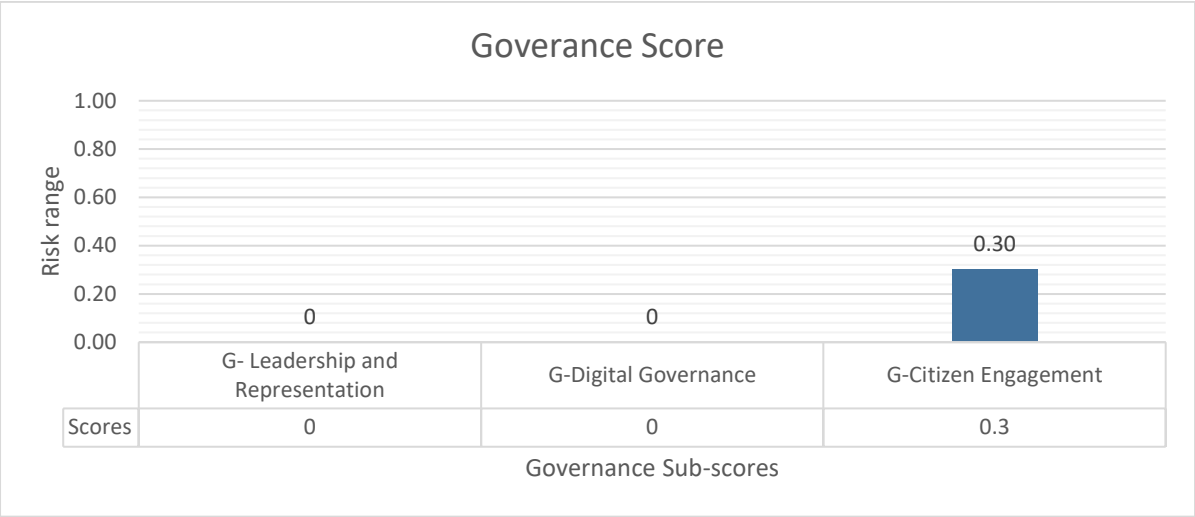

Figure 10 Governance scoring of Lahti

The highest governance sub-score for the city of Lahti was citizen engagement, 0.30 out of 1. Leadership, representation, and citizen engagement scores were calculated as 0 out of 1, which represents the minimum score. Overall, Lahti's social score was 0.12 out of 1, categorized as "*low risk*."

The Governance category indicators included the "*Number of convictions for corruption and/or bribery by city officials per 100 000 population*, " another indicator derived from the ISO 37120 standards as a supporting indicator. The assessment encountered challenges in measuring the accountability of city officials due to unavailable data on convictions for corruption and bribery, leading to the removal of this indicator from the Governance category. The absence of this data limits the ability to comprehensively evaluate the integrity and transparency of Lahti's governance, which are critical for assessing the city's overall governance health and effectiveness. Without this data, assessing the city's true governance quality becomes challenging, potentially obscuring risks related to corruption that could impact investor confidence and municipal integrity.

In addition, for the "*Non-men (Women) mayors or other leaders and members as a percentage of the total elected to city-level office*" indicator, no data for the non-men representation could be found, and only women representation was considered for the data. Women's major and member percentage of the total elected city-level office was 42% in the 2021 elections in Lahti (Yle.fi, 2021). The average of this data was 34.5% for the European Union's 27 member countries' municipalities. According to the scaling range, the representation related risk level for the Lahti city council was evaluated as "*low*". This result positions Lahti as a progressive city in terms of gender equality in local political representation and inclusive governance.

On the other hand, Lahti has a 51.1% voter turnout rate for the municipal elections in 2021, which is located in the "*lower than average*" range of the scaling framework (Yle.fi, 2021).

4.2.1.1. Pollution score

The pollution score was calculated by evaluating four air pollution parameters, including NO_2 emissions, SO_2 emissions, CO emissions, and CH_4 emissions. Emission data maps created by Google Earth Engine were obtained from Sentinel 5P data for two years of monitoring: from January 1, 2022, to January 1, 2023, with 52 weeks each year. The data was averaged over the area of interest as demarcated by the municipality boundaries. The scoring ranges were directly integrated from Rossi et al., 2023, categorizing the pollution levels as low, medium, or high. The results were used to calculate the E-Pollution and the final Environmental score.

Table 12 NDCI evaluation ranges

Classification	NDCI values
Clean water	Close to zero or slightly negative (around -0.1 to 0.1)
Moderately polluted water	Between 0.1 and 0.4
Highly polluted water	Above 0.4

As part of the hydrology score, the Normalized Difference Chlorophyll Index (NDCI) was used to indicate the water pollution levels. NDCI is computed with Sentinel-2, and water pollution events are tagged for NDCI values larger than 0.1. The measurements were conducted for the four randomly selected points alongside Lake Vesijärvi, as can be shown in the Figure 11. NDCI values were computed as "0" for the three measurement points, and no pollution was detected alongside the lake and classified as "clean water" in terms of NDCI for the monitoring period in 2023 according to the evaluation method derived from (Rossi, Byrne and Christiaen, 2024).

Figure 11 NDCI measurement points for Lahti

The Figure 12 illustrates the spatial distribution of the methane emissions levels across Lahti, mapped using a colour gradient to pollution levels. The data was sourced from 2022 Sentinel 5P map imagery; the average methane emissions were calculated as 1885 ppb, resulting in

"*Medium risk*" as part of the environmental pollution score for the monitoring period 2023-01-01 to 2023-12-31.

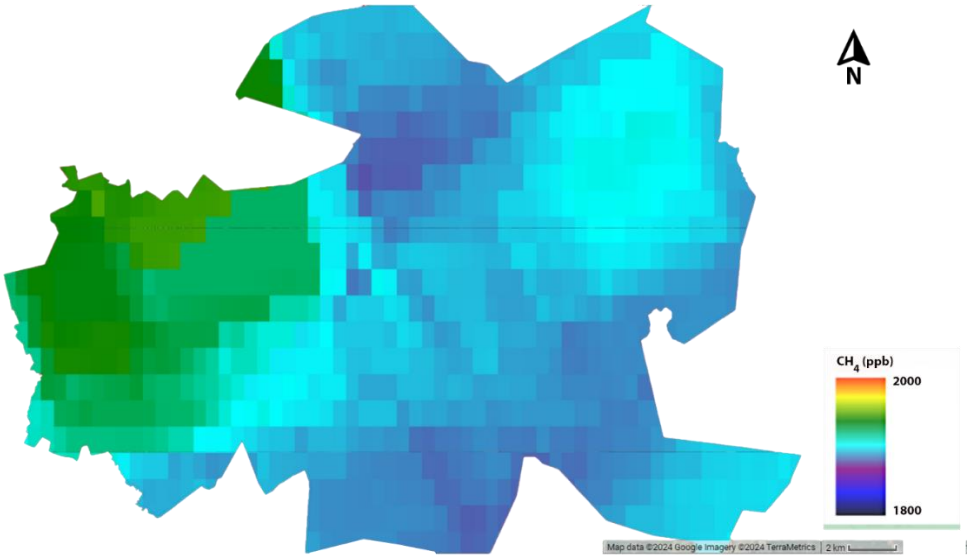

Figure 12 Methane (CH4) air pollution levels of Lahti

Figure 13 represents the carbon monoxide emission levels across Lahti, in which the average CO emissions were calculated as 0.028 mol/m^2. The data was sourced from 2022 Sentinel 5P map imagery for the monitoring period 2023-01-01 to 2023-12-31. Overall, carbon monoxide levels were evaluated as "*medium risk*" according to the pollution scoring range.

Figure 13 Carbon monoxide (CO) air pollution levels for Lahti

Figure 14 represents the nitrogen dioxide emission levels across Lahti, with the average NO_2 emissions calculated as 0.000029 mol/m^2. The data was sourced from 2022 Sentinel 5P map imagery for the monitoring period 2023-01-01 to 2023-12-31. Nitrogen dioxide levels were evaluated as "*low risk*" according to the pollution scoring range.

Figure 14 Nitrogen dioxide (NO2) air pollution levels of Lahti

Figure 15 represents the sulphur dioxide emission levels across Lahti, with the average SO_2 emissions calculated as 0.00013 mol/m^2. The data was sourced from 2022 Sentinel 5P map imagery for the monitoring period 2023-01-01 to 2023-12-31. Sulphur dioxide levels were evaluated as "*low risk*" according to the pollution scoring range.

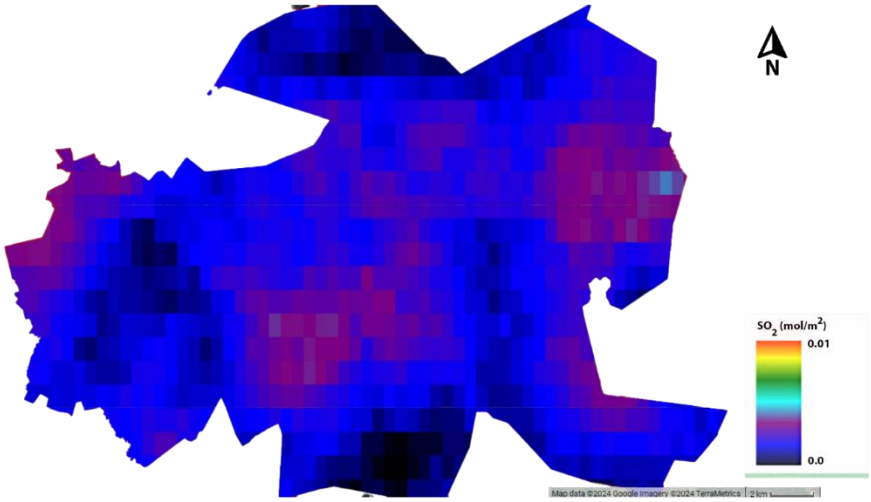

Figure 15 Sulphur dioxide (SO_2) air pollution levels of Lahti

4.2.2. ESG Assessment Results – Glasgow

Similar to Lahti, Glasgow's environmental, social, and governance scores were assessed using the same selected indicators. Appendix 3 of the study provides detailed assessment information, performance against the indicators, and data sources used to evaluate the city's performance. In contrast, this chapter presents only the overall scores. Figure 16, Figure 18, Figure 19 Illustrates the environmental, social and governance scores calculated for Glasgow.

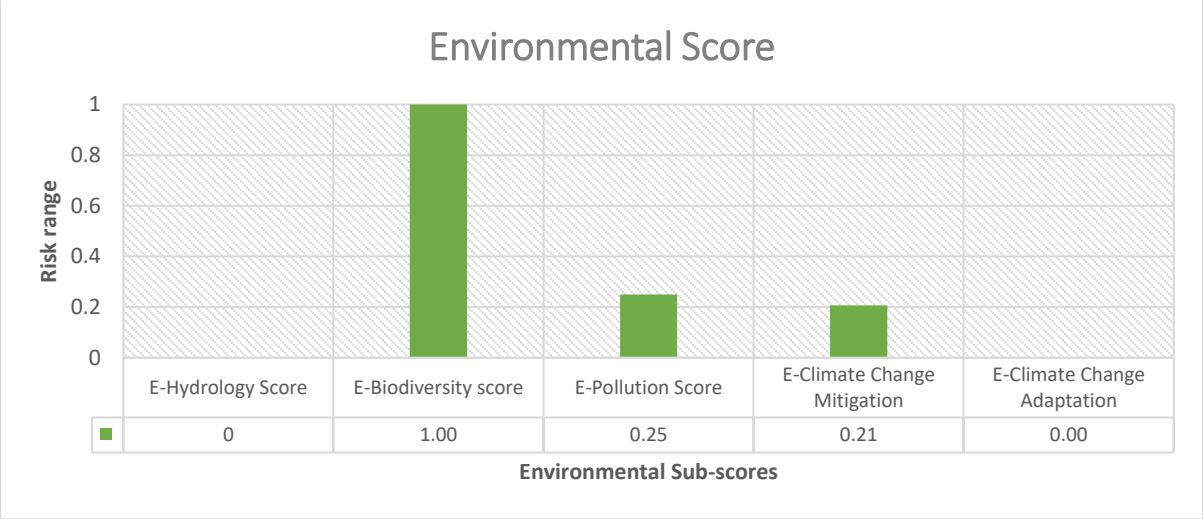

Figure 16 Environmental score of Glasgow

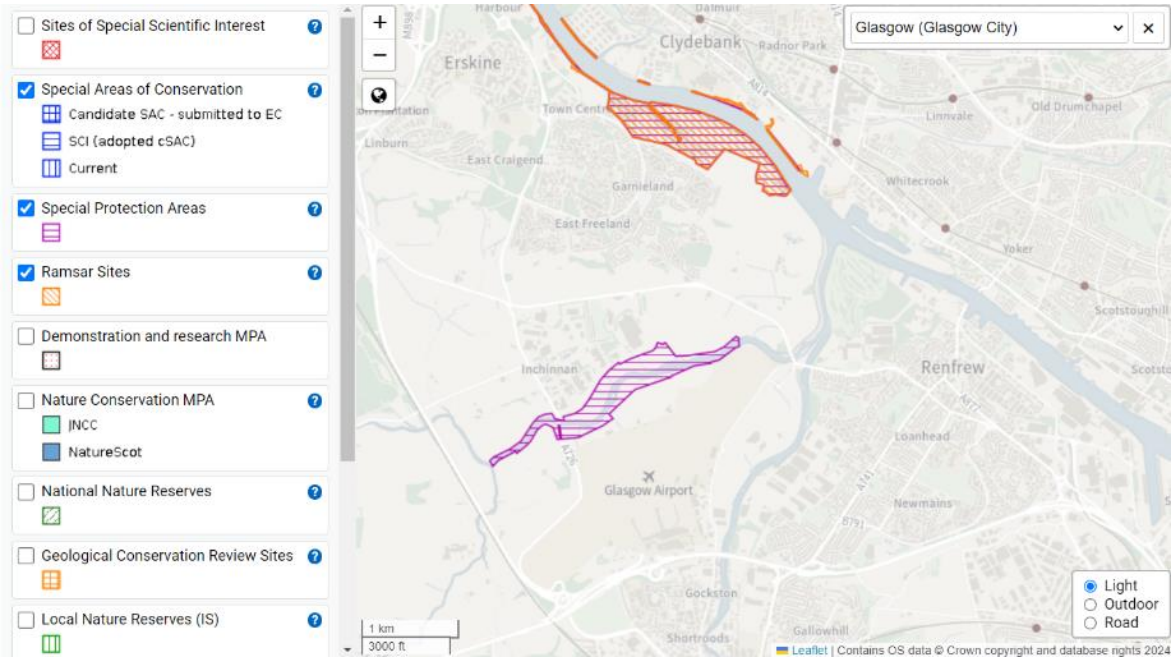

Figure 17 Protection areas and their proximity to the city (NatureScot, 2024)

Based on the results presented in Figure 16 Glasgow's biodiversity-related risks are the highest among the other sub-scores, with 1 out of 1. Climate change mitigation and pollution scores are 0.22 and 0, respectively. The sum of Glasgow's environmental scoring results was 0.15 out of 1, categorizing the environmental risk as "Low."

The biggest factor contributing to the high biodiversity risk is the proximity of the Black Cart Special Protection Area to the Glasgow Airport and the Ramsar protection sites alongside the River Clyde. The proximity of these protected lands to urban areas was evaluated as high risky due to the possible hazards and stresses posed by possible urban growth.

The city's carbon monoxide and methane emissions were factored into the Environmental Pollution score, as they were measured as 0.03 mol/m^2 and 1885 ppb, respectively, placing them in the "*medium risk*" category based on the evaluation scale derived from (Rossi, Byrne and Christiaen, 2024). These levels signify substantial emissions but are still within a manageable range under the current standards. At 4.3 tons of CO_2, GHG emissions per capita fall into the "*Low emissions*" range. The city's commitment to achieving a net zero target by 2030 and a Climate and Climate Adaptation Plan contribute positively to the climate adaptation and mitigation scores. On the other hand, the indicator data for "*Access to public green space (at least 0.5-1ha of public green space within 300m of each residential)*" could not be found; instead, the data for "*children live within 400 m of publicly accessible green space (e.g. public parks/gardens or residential amenity green space)*" was used for the evaluation of the indicator.

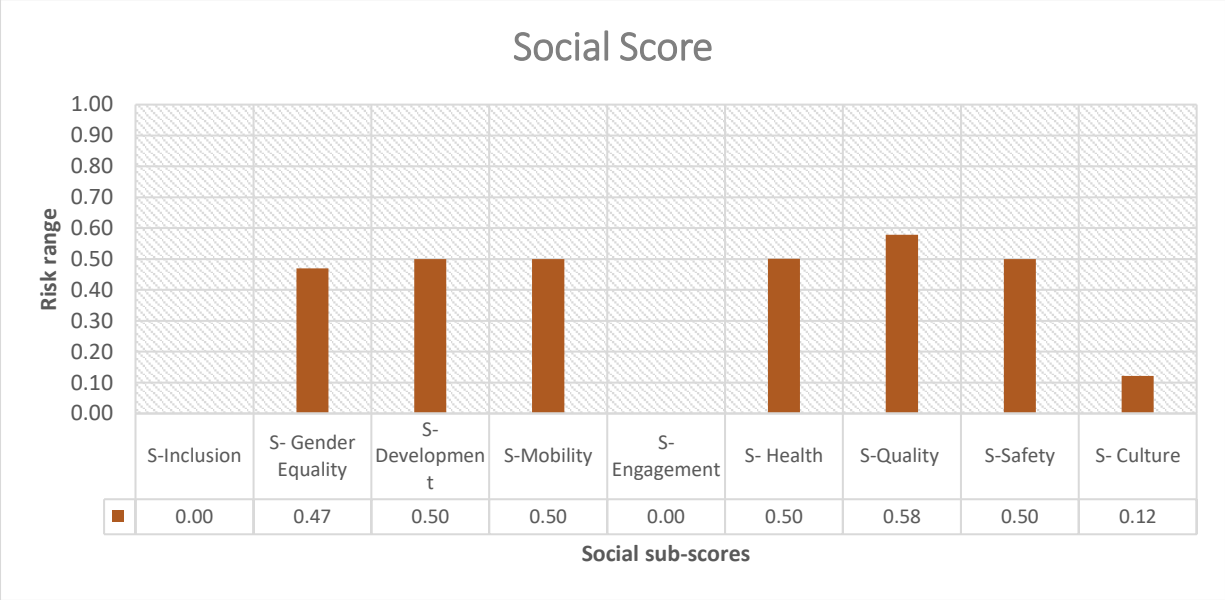

Figure 18 Social scoring of Glasgow

Glasgow's development, mobility, and safety scores are each calculated as 0.5 out of 1. Overall, Glasgow's social score was 0.36 out of 1, resulting in a "*Medium risk*" level classification. The highest sub-category score comes from the "*quality*" category as 0.58 (*high risk*), with the 19.3% rate of the population experiencing income deprivation, and with high homelessness levels and size of the rental housing (Glasgow Centre for Population Health, 2022). These are critical issues that indicate high social risk.

The crime rate was 76.8 crimes per 1000 people, which was higher than the EU average data, which is 15 crimes per 1000 people. The rate of violence against women is 11%, slightly higher than the lowest scoring range, indicating a concerning level. Safety concerns, particularly those impacting property, are the areas where Glasgow scores higher, indicative of substantial challenges. Such issues can deter residents and investors alike, affecting Glasgow's desirability and stability.

On the other hand, sustainable transport rate data could not be found from the open public data sources, so due to the lack of data, it was assumed that the mobility score calculations were at "1" *high risk*.

The average life expectancy levels for the males were also evaluated as lower than the EU average of 76.5 years. This data interpretation can be challenging from the ESG risk perspective; higher life expectancies might lead to higher health expenditures and pension fund burdens and can be interpreted negatively.

The gender equality score of 0.5 was derived from the lack of public information related to family-related leave and flexible working arrangements for city public authority employees. Although there might be some policies in place to arrange this issue, the publicly available information was not in place. In addition, any content regarding any possible programmes to strengthen women in disaster management could not be found, and the evaluation value is assumed as "No" and evaluated as "1" *high-risk* score.

"*Waiting time for an elective outpatient medical visit (physician) in primary health care exceeds 3 months from assessment of the need for treatment, % appointments kept*"; the data found as 42%, and the scoring range was evaluated as "*high risk*" (Public Health Scotland, 2024). The indicator demonstrates long waiting times for treatment access, impacting 42% of the population. Consequently, this reflects poor health services.

Glasgow's tertiary education level stands at 35%, which is under the average for the European Union. This level of higher education can serve as an indicator of the possible difficulties in the job market when it comes to hiring individuals with advanced skills. This statistic is crucial from the ESG perspective since it has a direct influence on the city's economic resilience and ability for innovation. An educated workforce has become essential for achieving sustainable economic growth and attracting high-value industries. Glasgow may face challenges due to its existing education levels. The unemployment rate is exceptionally low, currently at 4.4%. This indicates a high level of economic engagement and has a positive impact on the ESG risk perspective. In contrast, the high-income deprivation levels of Glasgow can be negatively viewed as ESG risk performance. It needs to be underlined that underemployment and job quality remain unaddressed and could represent hidden risks that are not fully captured by the unemployment rate alone. Underemployment and poor job quality can lead to an employed but not optimally utilized or compensated workforce, contributing to economic inefficiencies and social disconnect.

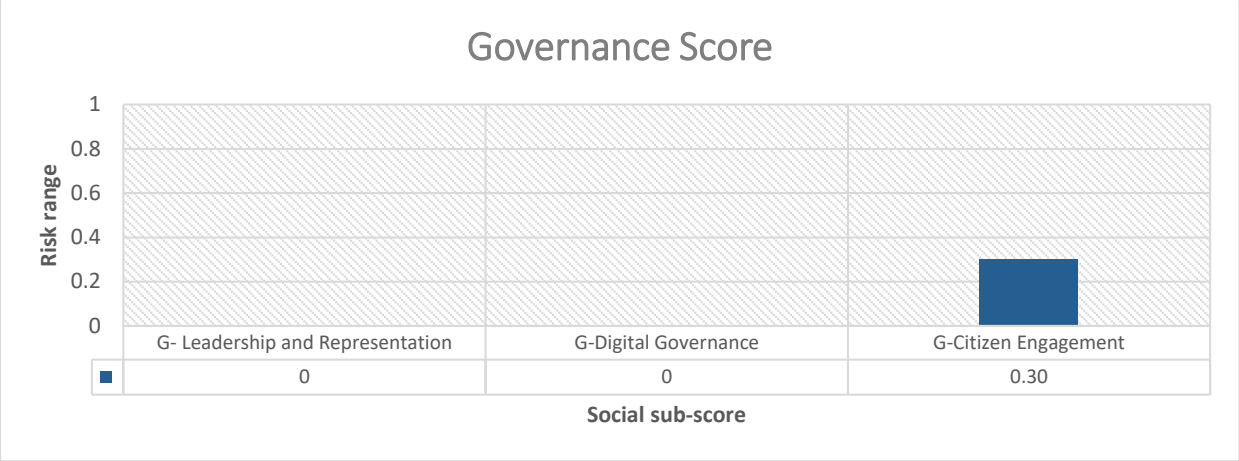

Figure 19 Governance scoring of Glasgow

The citizen engagement sub-score is the major contributor to the Governance score, which was calculated as 0.30 out of 1. This results in a "*Low impact*" level classification. The Leadership and Representation and Digital Governance scores were calculated as 0 out of 1, representing the minimum score.

Glasgow's high percentage of women leaders in city-level offices, at 73%, is particularly notable from an ESG perspective. This statistic significantly enhances the city's social and governance credentials under the ESG framework, demonstrating a commitment to diversity and inclusion.

The lack of available data on convictions for corruption and/or bribery per 1000 population presents a notable gap in the Governance aspects of ESG. Accountability and transparency are crucial for good governance, and the absence of this data can impede stakeholders' ability to assess the integrity of Glasgow's governance fully. For ESG-focused investors, such gaps could signal potential risks, as corruption and lack of accountability can lead to significant reputational and operational risks. Enhancing data availability and transparency in this area is critical for improving the city's ESG rating.

4.2.2.1. Pollution Score

Similar to Lahti, the pollution score was calculated for Glasgow by evaluating four air pollution parameters, including NO_2, SO_2, CO, and CH_4 emissions. Emission data maps created by Google Earth Engine were obtained from Sentinel 5P data for two years of monitoring: from January 1, 2022, to January 1, 2023, with 52 weeks each year. The data was averaged over the area of interest as demarcated by the municipality boundaries. The scoring ranges were directly integrated from Rossi et al., 2023, categorizing the pollution levels as low, medium, or high. The results were used to calculate the E-Pollution and the final Environmental score.

As part of the hydrology score implies water pollution levels, the Normalized Difference Chlorophyll Index (NDCI) was used as an indicator for the water pollution levels. NDCI is

computed with Sentinel-2 and water pollution events are tagged for NDCI values larger than 0.1. The measurements were conducted for the four randomly selected points alongside the river Clyde as can be shown from the Figure 20. No pollution was detected alongside of the river in terms of NDCI for the monitoring period.

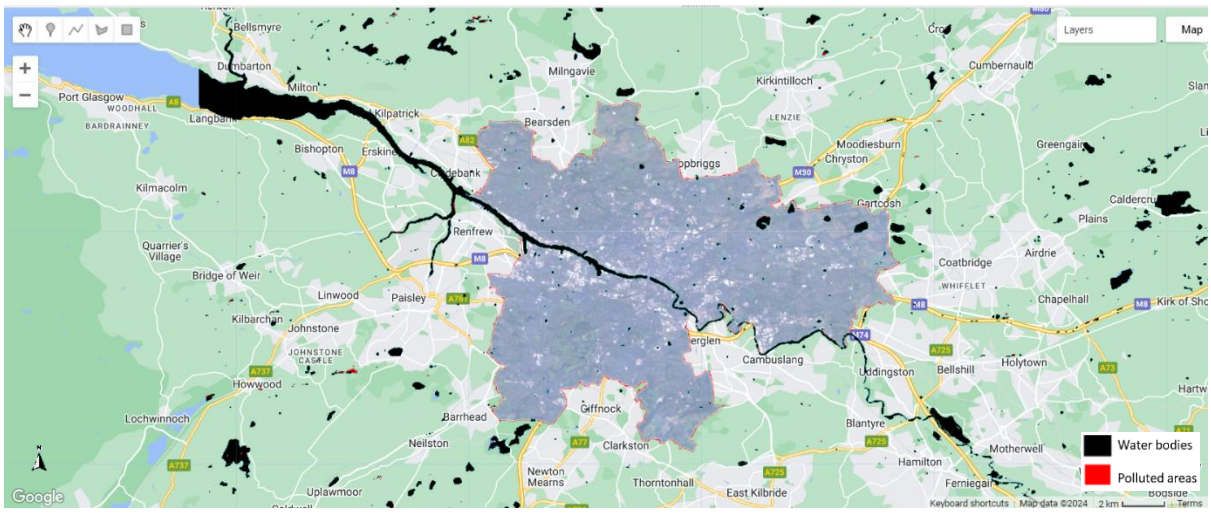

Figure 20 Water pollution level measurement points

The Figure 21 illustrates the spatial distribution of the methane emissions levels across Glasgow, mapped using a colour gradient to pollution levels. The data was sourced from 2022 Sentinel 5P map imagery; the average methane emissions were calculated as 1885 ppb, which resulted in "*Medium risk*" as part of the environmental pollution score for the monitoring period 2023-01-01 to 2023-12-31.

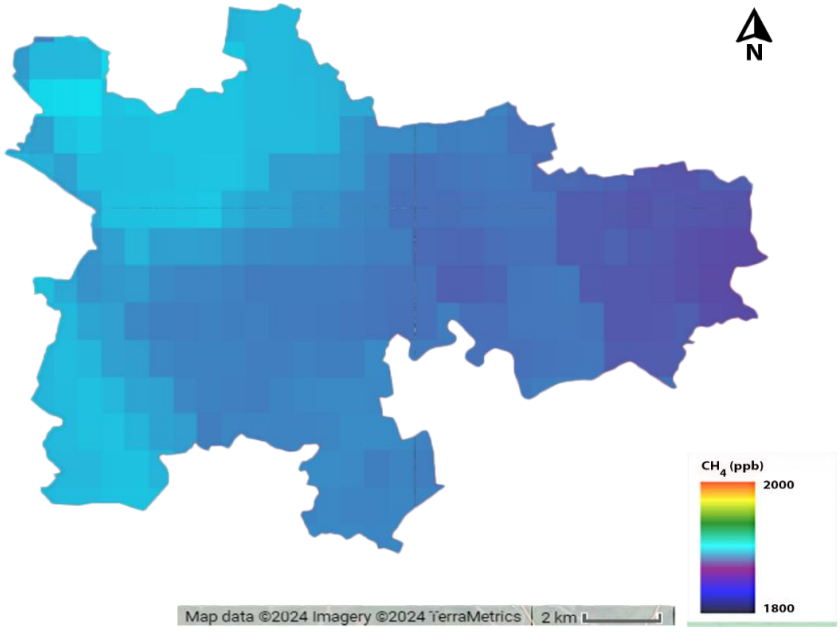

Figure 21 Methane (CH4) air pollution levels of Glasgow

Figure 22 represents the carbon monoxide (CO) emission levels across Glasgow, in which the average CO emissions were calculated as 0.0304 mol/m^2. The data was sourced from 2022

Sentinel 5P map imagery for the monitoring period 2023-01-01 to 2023-12-31. Overall carbon monoxide levels were evaluated as "*medium risk*" according to the pollution scoring range.

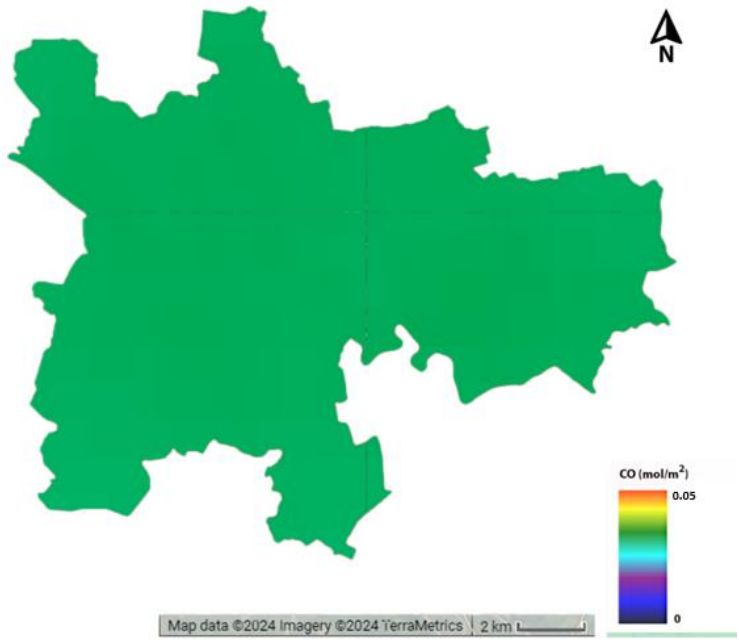

Figure 22 CO air pollution levels of Glasgow

Figure 23 represents the nitrogen dioxide emission levels across Glasgow, with the average NO_2 emissions calculated as 0.0000441mol/m^2. The data was sourced from 2022 Sentinel 5P map imagery for the monitoring period 2023-01-01 to 2023-12-31. Nitrogen dioxide levels were evaluated as "*low risk*" according to the pollution scoring range.

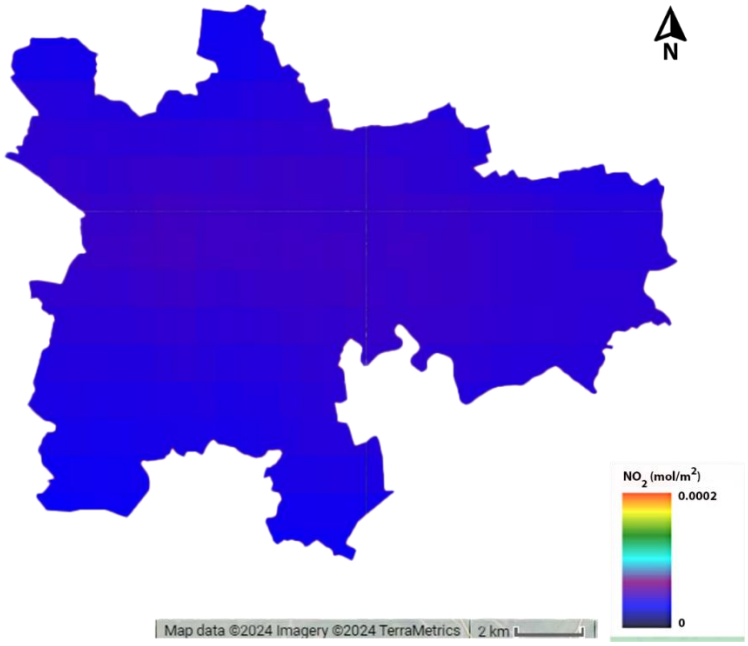

Figure 23 Nitrogen dioxide (NO_2) air pollution levels of Glasgow

Figure 24 represents the sulphur dioxide emission levels across Glasgow, with the average SO_2 emissions calculated as 0.00031 mol/m^2. The data was sourced from 2022 Sentinel 5P map imagery for the monitoring period 2023-01-01 to 2023-12-31. Overall, sulphur dioxide levels were evaluated as "*low risk*" according to the pollution scoring range.

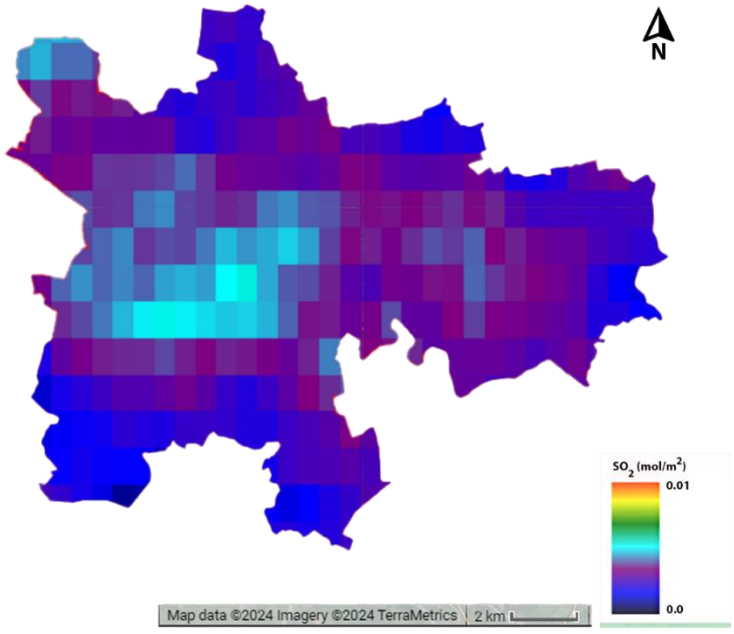

Figure 24 Sulphur dioxide (SO_2) air pollution levels in Glasgow

4.3. Benchmarking of the ESG scores of Lahti and Glasgow

This chapter presents the results from benchmarking the two case studies, Lahti and Glasgow. Table 13 summarizes the overall scores calculated for each case study to understand each city's existing performance in managing ESG risk capacity and the effectiveness of the ESG scoring framework developed within this study. This benchmarking highlights each city's strengths and weaknesses, providing a nuanced understanding of its perspective on ESG efforts.

Table 13 Benchmarking of ESG scores for Lahti and Glasgow

Category	Sub category	Case study – Lahti	Case study- Glasgow	Difference
Environment	Hydrology	0.10	0	0.1
	Biodiversity	0	1.00	1
	Pollution	0.25	0.25	0
	Climate change	0.26	0.23	0.03
	Climate Change	0	0	0
Social	Inclusion	0.50	0.00	0.5
	Gender Equality	0.51	0.47	0.04
	Development	0.50	0.50	0
	Mobility	0.25	0.50	0.25
	Engagement	0.00	0.00	0
	Health	0.25	0.50	0.25
	Quality	0.16	0.58	0.48
	Safety	0.63	0.50	0.13
	Culture	0.00	0.12	0.12
	Gender Equality	0.50	0.00	0.5
Governance	G- Representation	0	0	0
	G-Integrity and Accountability	-	-	-
	G-Digital Governance	0	0	0
	G-Citizen Engagement	0.30	0.30	0

Surprisingly, for the hydrology category, Lahti scored 0.1, indicating minor concerns, while Glasgow scored 0, which suggests no significant issues. This difference is caused by Lahti's slightly higher water risk score and might reflect the minor challenges related to water management compared to Glasgow. Lahti is rich in terms of water bodies; this context can provide further insight into the low hydrology score in the benchmarking table. This score likely does not reflect any deficiency in water resources but rather the city's effective management and abundance of water. Such an attribute can be advantageous from the ESG perspective, as it suggests that Lahti has robust resources to manage water sustainability, which is crucial for environmental sustainability, urban planning, and resilience to climate change.

A significant disparity is observed, with Glasgow scoring 1.00, indicating severe biodiversity concerns, possibly due to urban development pressures near sensitive ecological areas. Lahti scores 0, suggesting effective biodiversity conservation strategies. In terms of Pollution score, both cities score 0.25, indicating moderate concerns with pollution levels. This suggests that both cities face environmental challenges related to air and water quality that need addressing.

Lahti scores slightly higher at 0.26 compared to Glasgow's 0.23, indicating that Glasgow might be very slightly more effective in implementing climate adaptation strategies, though both cities show room for improvement.

For the inclusion subcategory under the Social category, Lahti scores 0.50, suggesting moderate inclusivity issues, whereas Glasgow scores 0, indicating effective social inclusion policies. For the Gender equality category, both cities score above 0.45, with Lahti slightly higher, showing room for improvement in addressing gender disparities.

Glasgow has a higher Mobility score (0.50) compared to Lahti (0.25), which can be interpreted as Lahti reflecting better public transport systems and infrastructure. Glasgow also scores higher in health (0.50) than Lahti (0.25), which might reflect that Lahti has more comprehensive healthcare services or better access to such services. In terms of quality of life, Glasgow's higher score (0.58) indicates significant challenges related to socio-economic disparities compared to Lahti's 0.16.

Glasgow shows a lesser score in safety but a slightly higher involvement in cultural activities compared to Lahti, suggesting different urban dynamics and social environments. For the Governance category, both cities score 0 in these categories, indicating no significant issues and a lack of data to establish a conclusive analysis for these governance aspects.

This analysis shows that while Glasgow excels in social infrastructure aspects like health and mobility, it faces environmental challenges, particularly in biodiversity. Lahti, with its effective management of natural resources and conservation strategies, demonstrates strong environmental stewardship but needs to improve social inclusivity and mobility.

From an ESG perspective, enhancing governance transparency, especially in areas like corruption and accountability, would benefit both cities. Strengthening these areas can improve their overall sustainability performance, making them more attractive to socially responsible investors and enhancing their resilience against ESG risks.

CHAPTER 5: CONCLUSION

The primary aim of this study was to define city-level ESG indicators, and a scoring system tailored to cities with a focus on their ability to facilitate climate change adaptation, mitigation efforts, and potential net-zero strategies. By developing city-specific ESG indicators and scoring systems, this present study seeks to enhance the city's ESG performance and transparency, aiming to close the climate investment gap needed to reach net-zero targets by making cities more attractive for ESG-impact focused investment instruments.

The literature review covers the evolution of ESG frameworks, urban sustainability indices, existing sustainability frameworks, ISO 37120 Sustainable City Standards, the importance, gaps, and challenges of existing urban sustainability frameworks, and objectives and factors for selecting city ESG indicators.

This study employed a mixed-method approach integrating qualitative and quantitative analysis with a pragmatic research philosophy. Two case studies were included to apply the developed ESG scoring system to Lahti and Glasgow to validate its effectiveness and assess its real-world applicability.

As a result, Lahti's and Glasgow's environmental scores were not showcased very differently, as both cities' scores were in the low-risk range. Similar to the environmental score, the social score of both cities was determined as medium risk. A main difference in the ESG scores was observed in the governance category, as Lahti's governance score was determined to be 0.12 and Glasgow's was 0.3. The highly similar results of two different cities can indicate the need to develop city-specific ESG (Environmental, Social, and Governance) risk assessment studies. Each city has unique structures, scales, climatic conditions, and ESG-related challenges, making it necessary to create different ESG frameworks. For instance, homelessness might be a significant issue in one city but not another, while the latter may face different problems. Therefore, conducting a city-specific ESG risk assessment study and developing specific indicators for a more comprehensive assessment of cities' ESG risks is important.

5.1. Research Limitations

There are several limitations to the data and methodologies used in this study due to the various methods that were employed:

- One major challenge was data availability. While several more indicators could be used to measure the cities' ESG performance, many had to be excluded because of the lack of data. Only country-level data can be obtained for some indicators, particularly governance and social indicators. For instance, data on corruption and bribery were unavailable for both Lahti and Glasgow, limiting the assessment of governance transparency.

- External factors such as economic fluctuations, political changes, and technologies advancements can significantly impact a city's ESG performance. The static nature of the assessment does not account for possible dynamic influences.
- The double materiality assessment could be conducted based on the expert judgement. While this approach provides a structured method for determining the weights of the indicators in the scoring system, it inherently includes subjective elements that will introduce biases.
- The use of Google Earth Engine for geospatial analysis provided valuable environmental data; however, technical limitations and the resolution of satellite data can affect the accuracy of pollution and water quality measurements.
- Average data for 2021 and 2022 were used for the pollution data; however, specific timeframes for geospatial data may not fully capture seasonal variations or long-term trends in environmental conditions.
- Many indicators focus on the availability of the municipality's policy or service, such as climate adaptation, food, and policy or targets to enhance green infrastructures. These indicators could provide more insights into these policies' effectiveness and application performance to measure ESG risks.
- To measure a city's current ESG performance, using the most recent data relevant to the city is more appropriate. However, older data were used due to the lack of availability of updated data for some social indicators. However, the oldest data included in the assessment are data from 2021.
- The study relied heavily on publicly available data and city reports. Although updated data can be obtained directly from the municipality, only publicly available data was used due to the transparency objective.
- Although using publicly available data provides transparency, the accuracy of the data could not be assessed. However, city reports and respectful sources was tried to be used for the assessment.
- The framework and indicators were primarily derived from European benchmarks, which may not be directly applicable to cities in other regions with different ESG challenges.

5.2. Recommendation for Future Studies

Each city possesses unique structures, scales, climatic conditions, and ESG-related challenges, necessitating the creation of distinct ESG frameworks. For instance, while homelessness may be a significant concern in one city, it may not be so in another, with each facing its own set of challenges. Factors such as population density, economic activities, and infrastructure development also contribute to the varying ESG risks across cities. Therefore, it is crucial to conduct city-specific ESG risk assessment studies and formulate specific indicators for a more comprehensive evaluation of the ESG risks in cities. This approach can enable tailored strategies and interventions to address the specific sustainability and social responsibility

issues faced by each city. For future studies, developing an ESG risk assessment standard for cities can be a pivotal step. Such a standard would allow for more consistent ESG risk assessment and scoring system development across different urban environments, facilitating better comparisons and more effective policymaking.

Environmental data could be obtained from geospatial tools for city ESG assessments; however, social data were not available. More geospatially available social data can improve ESG studies and increase their accuracy and objectivity.

It is beneficial for cities to conduct a double materiality analysis, not only for ESG weighting analysis but also to improve transparency in response to the main concerns of the city's stakeholders. It is important to follow a participatory approach and include city residents from different social, economic, educational, and age groups.

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APPENDIX -1 Indicators, scoring ranges and weightings

Indicators	Sub Category	Final Weighing	Value ranges	Scoring ranges
E Hydrology Score				
Water stress level	50%	3.94%	Low (10%)	0
			Low-medium (10-	0.2
			Medium-high (20-	0.4
			High (40-80%)	0.6
			Extremely high (80%)	0.8
			Arid and low water	1
Water pollution levels	50%	3.94%	Pollution levels	1
			Pollution levels are	0
E Biodiversity score				
Interaction with the protected areas	100%	4.08%	Not near protected	0
			Within 1 km of the	0.5
			There is a protected	1
E Pollution Score				
The impact of nitrogen dioxide emissions	24%	3.79%	0–0.0002 mol/m^2 -	0
			0.0002–0.0005	0.5
			>0.0005 mol/m^2 -	1
The impact of sulfur dioxide emissions	25%	4.08%	<0.001 mol/m^2 -	0
			0.001–0.01 mol/m^2	0.5
			>0.01 mol/m^2 -	1
The impact of carbon monoxide emissions	25%	4.08%	0–0.01 mol/m^2 -	0
			0.01–0.05 mol/m^2 -	0.5
			>0.05 mol/m^2 - High:	1
The impact of methane emissions	25%	4.08%	<1800 ppb - Low: 0	0
			1800–2000 ppb -	0.5
			>2000 ppb - High: 1	1
E Climate Score				
Climate Change Mitigation				
GHG Emissions / capita	9%	3.02%	Very Low Emissions	0
			Low Emissions (3.5-	0.25
			Medium Emissions	0.5
			High Emissions (7.0-	0.75
			Very High Emissions	1
City Net Zero Strategy	11%	4.00%	Yes	0
			No	1
			Planning	0.25
Climate Change Mitigation Policy	12%	4.00%	Yes	0
			No	1
			Planning	0.25
Science-based emission reduction target	8%	3.00%	Yes	0
			No	1

Net zero target for the city	9%	3.00%	Yes	0
			No	1
Baseline year for the interim emission reduction target	9%	3.00%	Between 1990-2010	0
			>2010	1
Percentage of RE use in the current energy mix	9%	3.00%	High (100%-90%)	0
			Medium (90%-45%)	0.5
			Low (<45%)	1
Target to increase RE production capacity	11%	4.00%	Yes	0
			No	1
Waste landfilling rate of the city	12%	4.00%	0-5% (Low)	0
			5%-16% (Medium)	0.5
			>16% (High)	1
Share of CO2-free city buses in the fleet	8%	3.00%	>80% (Very Low Risk):	0
			60%-80% (Low Risk):	0.25
			40%-60% (Moderate	0.5
			20%-40% (High Risk):	0.75
			<20% (Very High Risk)	1
Climate Change Adaptation				
Climate Risk Assessments	11%	4.08%	Yes	0
			No	1
			Planning	0.25
Climate Adaptation Policy	11%	4.08%	Yes	0
			No	1
			Planning	0.25
Policy or target to enhance green infrastructures	8%	3.02%	Yes	0
			No	1
			Planning	0.25
Access to public green space (at least 0.5-1ha of public green space within 300m of each residential)	6%	2.25%	80-100% (Low)	0
			60-79% (Medium-	0.25
			40-59% (Medium)	0.5
			20-39% (Medium-	0.75
			<20% (High)	1
Policy or program to increase urban green cover	7%	2.53%	Yes	0
			No	1
			Planning	0.25
Green infrastructures or nature-based solutions for stormwater management	7%	2.60%	Yes	0
			No	1
			Planning	0.25
Cooling and/or heating centers	7%	2.60%	Yes	0
			No	1
			Planning	0.25
Food Policy	8%	3.09%	Yes	0
			No	1
			Planning	0.25
Policy or target to enhance biodiversity and natural ecosystems	8%	2.74%	Yes	0
			No	1
			Planning	0.25

Policy to enhance health and wellbeing of citizens	8%	2.88%	Yes	0
			No	1
			Planning	0.25
Emergency plan against to climate hazard, i.e, extreme weather conditions, [illegible]	11%	4.08%	Yes	0
			No	1
			Planning	0.25
Membership in climate adaptation initiatives;	7%	2.60%	Yes	0
			No	1
			Planning	0.25

Social Score				
	SUB Weighing	**Final Weighing**	**Value ranges**	**Scoring ranges**
S-Inclusion				
Social Equity				
Unemployment rate	100%	8.63%	%0-5 (Low)	0
			%5-10 (Medium-Low)	0.2
			%10-20 (Medium)	0.5
			>20 (High)	1
S- Gender Equality				
	SUB Weighing	**Final Weighing**	**Value ranges**	**Scoring ranges**
City policies to promote gender equality initiatives and programs	17%	4.11%	Yes	0
			No	1
			Planning	0.25
Training for city officials on gender equality	16%	3.71%	Yes	0
			No	1
			Planning	0.25

City public authority gender pay gap	16%	3.71%	0%-1% (Low)	0
			1% - %5 Medium low)	0.25
			5%-10% (Medium)	0.5
			10%-15% (Medium High)	0.75
			>15% (High)	1
Family-related leave and flexible working arrangements for city public authority employees	16%	3.71%	Yes	0
			No	1
			Planning	0.25
Programs to increase the availability of quality childcare	16%	3.91%	Yes	0
			No	1
			Planning	0.25
Program to strengthen women in disaster management	20%	4.71%	Yes	0
			No	1
			Planning	0.25
S-Development				
	SUB Weighing	**Final Weighing**	**Value ranges**	**Scoring ranges**
Education				
Tertiary education level	100%	5.42%	%10-20 (Low)	1
			%20-30 (Medium)	0.5
			>45% (High)	0
S-Mobility				
Sustainable Transport Rate	50%	4.41%	%5-10 (Low)	1
			%10-20 (Medium-Low)	0.75

			%20-30 (Medium)	0.5
			%30-40 (Medium-high)	0.25
			>40% (High)	0
Percentage of households with Internet access	50%	4.41%	95-100% (Low)	0
			90-94% (Medium-Low)	0.25
			75-89% (Medium)	0.5
			50-74% (Medium-high)	0.75
			<50% (High)	1
S- Engagement				
Efficient feedback mechanism	50%	3.91%	Yes	0
			No	1
			Planning	0.25
Citizen involvement in decision-making	50%	3.91%	Yes	0
			No	1
			Planning	0.25
S- Health				
	SUB Weighing	**Final Weighing**	**Value ranges**	**Scoring ranges**
Waiting time for elective outpatient medical visit (physician) in primary health care exceeds 3 months from assessment of the need for treatment, % appointments kept	17%	2.21%	0% (Low)	0
			25% (Medium-low)	0.25
			50% (Medium)	0.5
			75% (Medium-high)	0.75
			100% (High)	1
			0-15 min (Low)	0

Average travel time to the nearest healthcare facility by walking			15-30 min (Medium)	0.25
			>30 min (High)	1
Mortality rates from preventable diseases , all persons (per 100,000 inhabitants)			Low risk: Below 294.1	0
			Low-medium risk: 294.1 to 367.6 (1.25x of 294.1)	0.15
			Medium risk: 367.6 to 441.2 (1.5x of 294.1)	0.3
			Medium-high risk: 441.2 to 514.7 (1.75x of 294.1)	0.5
			High risk: 514.7 to 588.2 (2x of 294.1)	0.75
			Very high risk: Above 588.2	1
Average life expectancy at birth for females (core indicator)	42%	5.42%	>85 (Low risk)	0
			83.5 - <85 (Low-mediium)	0.15
			80.5 – < 83.5 (Medium risk)	0.3
			78 – < 80.5 (Medium high)	0.5
			75 – < 78 (High)	0.75
			< 75 (Very high risk)	1
Average life expectancy at birth for males (core indicator)	42%	5.42%	>85 (Low risk)	0
			83.5 - <85 (Low-mediium)	0.2
			80.5 – < 83.5 (Medium risk)	0.4
			78 – < 80.5 (Medium high)	0.6
			73 – < 78 (High)	0.8
			< 73 (Very high risk)	1
S-Quality				
Persons having cost overburden rate (%)	33%	4.21%	>= 13.5 (High)	1
			10.0 - < 13.5	0.8
			8.0 - < 10.0	0.6

			6.0 - < 8.0	0.4
			4.0 - < 6.0	0.2
			< 4.0 (low)	0
Number of homeless % population (supporting indicator)	33%	4.21%	Low risk (<= 0.0626%)	0
			Medium risk (<= 0.1252%)	0.5
			High risk (<= 0.1878%)	0.75
			Very high risk (>0.1878%)	1
Residential rental dwelling units as a percentage of total dwelling units (profile indicator)	34%	4.41%	30%-40%	0
			20-30% or 50-60%	0.25
			10-20% or 60-70%	0.5
			10% or 70-80%	0.75
			<10% - >80%	1
S-Safety				
	SUB Weighing	**Final Weighing**	**Value ranges**	**Scoring ranges**
% of women who have experienced violance	50%	5.22%	0-10% (Low)	0
			11-20% (Medium-low)	0.25
			21-30% (Medium)	0.5
			31-40% (Medium-high)	0.75
			>40% (High)	1
Crimes against property per 1000 population (supporting indicator)	50%	5.22%	0-20 (Low)	0
			21-40 (Medium-low)	0.25
			41-60 (Medium)	0.5
			61-80 (Medium-high)	0.75
			>80 (High)	1

S- Culture				
Percentage of municipal budget allocated to cultural and sporting facilities (supporting indicator)	41%	3.71%	≥ 6% (Low)	0
			≥ 4%-6% (Medium-low)	0.3
			≥ 2%-4% (Medium)	0.6
			≥ 0-2% (High)	1
Protection policies for cultural heritage sites	59%	5.42%	Yes	0
			No	1
			Planning	0.25

Governance Score				
	SUB Weighing	**Final Weighing**	**Value ranges**	**Scoring ranges**
Representation				
Non-men (Women) mayors or other leaders and members as a percentage of total elected to city-level office (core indicator)	100%	19.89%	High ≥40	0
			Higher than average ≥20-30	0.25
			Average ≥10-20	0.5
			Lower than average ≥5-10	0.75
			Low 0-5%	1
Digital Governance				
Electronic governance services	100%	39.78%	Yes	0
			No	1
			Planning	0.25
Engagement				
Grievance mechanism	40%	16.13%	Yes	0

			No	1
Voter turnout rate (Voter participation in last municipal election (as a percentage of registered voters) (supporting indicator)	60%	24.19%	High >80	0
			Average 70-80%	0.2
			Lower than average 60-70%	0.5
			Low <60	1

APPENDIX-2 Lahti ESG Scoring

Indicators	Data	Score	Source
Water stress level	Low - Medium (10-20%)	0.2	WRI Aqueduct Water Stress Tool
Water pollution levels	Pollution levels are stabilized (t1-t2)	0	Geospatial analysis of NDCI - Sentinel 2
Interaction with the protected areas	No negative interaction	0	World Database on Protected Areas
The impact of nitrogen dioxide emissions	0.000029 mol/m2	0	Geospatial analysis - Sentinel 5 Own data
The impact of sulphur dioxide emissions	0.00013 mol/m2	0	Geospatial analysis - Sentinel 5 Own data
The impact of carbon monoxide emissions	0.028 mol/m2	0.5	Geospatial analysis - Sentinel 5 Own data
The impact of methane emissions	1885 ppb	0.5	Geospatial analysis - Sentinel 5 Own data
GHG Emissions / capita	7.2 ton CO_2e	0.75	https://www.lahti.fi/tiedostot/sustainability-report-2023/
City Net Zero Strategy	Yes	0	https://www.lahti.fi/en/
Climate Change Mitigation Policy	Yes	0	https://www.lahti.fi/en/
Science-based emission reduction target	Yes	0	https://www.lahti.fi/en/
Net zero target for the city	Yes	0	https://www.lahti.fi/en/
Baseline year for the interim emission reduction target	Between 1990-2010	0	https://www.lahti.fi/en/
Percentage of renewable energy use in the current energy mix	90%	0	https://www.lahti.fi/en/
Target to increase renewable energy production capacity	Yes	0	https://www.lahti.fi/en/
Waste landfilling rate of the city	4%	0.5	https://www.lahti.fi/en/
Climate Change Adaptation	Yes	0	https://www.lahti.fi/en/
Climate Risk Assessments	Yes	0	https://www.lahti.fi/en/
Climate Adaptation Policy	Yes	0	https://www.lahti.fi/en/
Policy or target to enhance green infrastructures	Yes	0	https://www.lahti.fi/en/
Access to public green space (at least 0.5-1ha of public green space within 300m of each residential)	96%	0	https://greenlahti.fi/en/
Policy or program to increase urban green cover	Yes	0	https://www.lahti.fi/en/

Green infrastructures or nature-based solutions for stormwater management	Yes	0	https://www.lahti.fi/en/
Food Policy	Yes	0	https://greenlahti.fi
Policy or target to enhance biodiversity and natural ecosystems	Yes	0	https://www.lahti.fi/en/
Policy to enhance health and wellbeing of citizens	Yes	0	https://www.lahti.fi/en/
Emergency plan against to climate hazard, i.e, extreme weather conditions, flooding, forest fires,droughts etc	Yes	0	https://www.lahti.fi/en/
Membership in climate adaptation initiatives	Yes	0	https://eurocities.eu/cities/lahti/
Unemployment rate	11%	0.5	https://www.lahti.fi/en/
City policies to promote gender equality initiatives and programs	Yes	0	https://www.lahti.fi/en/
Training for city officials on gender equality	N/A	1	No data was available
City public authority gender pay gap	N/A	1	No data was available
Family-related leave and flexible working arrangements for city public authority employees	Yes	0	https://www.lahti.fi/en/
Programs to increase the availability of quality childcare	Yes	0	https://www.lahti.fi/en/
Program to strengthen women in disaster management	N/A	1	No data was available
Tertiary education level	30.1%	0.5	https://www.lahti.fi/en/
Sustainable Transport Rate	37%	0.25	https://www.lahti.fi/en/
Percentage of households with Internet access	96.78%	0	https://www.statista.com/ - Country level data
Efficient feedback mechanism	Yes	0	https://www.lahti.fi/en/
Citizen involvement in decision-making	Yes	0	https://www.lahti.fi/en/

Waiting time for elective outpatient medical visit (physician) in primary health care exceeds 3 months from assessment of the need for treatment, % appointments kept		0	https://thl.fi/en
Average life expectancy at birth for females	>85	0	Statistics Finland's free statistical databases (https://pxdata.stat.fi/PxWeb/pxweb/fi/)
Average life expectancy at birth for males	78 – < 80.5	0.6	Statistics Finland's free statistical databases (https://pxdata.stat.fi/PxWeb/pxweb/fi/)
Persons having cost overburden rate (%)	>13.5	1	https://www.lahti.fi/en/
Number of homeless % population	<= 0.1252%	0.5	https://www.ara.fi/en
Residential rental dwelling units as a percentage of total dwelling units (profile indicator)	40%	0	https://www.lahti.fi/en/
% of women who have experienced violence	47%	0	https://eige.europa.eu
Crimes against property per 1000 population	54.5	0.5	https://poliisi.fi/en/
Percentage of municipal budget allocated to cultural and sporting facilities	6%	0	https://www.lahti.fi/en/
Protection policies for cultural heritage sites	Yes	0	https://www.lahti.fi/en/
Non-men (Women) mayors or other leaders and members as a percentage of total elected to city-level office	42%	0	https://eige.europa.eu
Electronic governance services	Yes	0	https://www.lahti.fi/en/
Grievance mechanism	Yes	0	https://www.lahti.fi/en/
Voter turnout rate (Voter participation in last municipal	51.1%	0.5	Yle.fi

election (as a percentage of registered voters)			

APPENDIX-3 Glasgow ESG Scoring

Indicators	Data	Score	Source
Water stress level	Low (10%)	0	WRI Aqueduct Water Stress Tool
Water pollution levels	Clean water	0	Geospatial analysis of NDCI - Sentinel 2
Interaction with the protected areas	High interaction	1	NatureScot
The impact of nitrogen dioxide emissions	0.0000441mol/ m2	0	Geospatial analysis - Sentinel 5 Own data
The impact of sulfur dioxide emissions	0.00031 mol/m2	0	Geospatial analysis - Sentinel 5 Own data
The impact of carbon monoxide emissions	0.0304 mol/m2	0	Geospatial analysis - Sentinel 5 Own data
The impact of methane emissions	1885 ppb	0	Geospatial analysis - Sentinel 5 Own data
GHG Emissions / capita	4.3 ton CO2e	0.25	https://www.understandingglasgow.com
City Net Zero Strategy	Yes	0	https://glasgow.gov.uk/carbon
Climate Change Mitigation Policy	Yes	0	https://glasgow.gov.uk/carbon
Science-based emission reduction target	Yes	0	https://glasgow.gov.uk/carbon
Net zero target for the city	Yes	0	https://glasgow.gov.uk/carbon
Baseline year for the interim emission reduction target	Between 1990-2010	0	https://glasgow.gov.uk/carbon
Percentage of renewable energy use in the current energy mix	97%	0	https://www.scottishrenewables.com/our-industry/statistics
Target to increase renewable energy production capacity	Yes	0	https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2017/12/scottish-energy-strategy-future-energy-scotland-9781788515276/documents/00529523-pdf/00529523-pdf/govscot:document/00529523.pdf
Waste landfilling rate of the city	37.60%	1	https://www.understandingglasgow.com
Share of CO2-free city buses in the fleet	<40%	0.75	https://www.firstbus.co.uk/
Climate Risk Assessments	Yes	0	https://glasgow.gov.uk
Climate Adaptation Policy	Yes	0	https://glasgow.gov.uk

Policy or target to enhance green infrastructures	Yes	0	https://glasgow.gov.uk
Access to public green space (at least 0.5-1ha of public green space within 300m of each residential)	80% (only for children)	0	https://www.understandingglasgow.com
Policy or program to increase urban green cover	Yes	0	https://glasgow.gov.uk
Green infrastructures or nature-based solutions for stormwater management	Yes	0	https://glasgow.gov.uk
Cooling and/or heating centers	Yes	0	https://glasgow.gov.uk
Food Policy	Yes	0	https://glasgowfood.net
Policy or target to enhance biodiversity and natural ecosystems	Yes	0	https://glasgow.gov.uk
Policy to enhance health and wellbeing of citizens	Yes	0	https://glasgow.gov.uk
Emergency plan against to climate hazard, i.e, extreme weather conditions, flooding, forest fires,droughts etc?	Yes	0	https://glasgow.gov.uk
Membership in climate adaptation initiatives; (i.e ; Signatories to Covenant of Mayors:	Yes	0	C40 Cities
Unemployment rate	4.40%	0	https://www.understandingglasgow.com
City policies to promote gender equality initiatives and programs	Yes	0	https://glasgow.gov.uk
Training for city officials on gender equality	Planning	0.25	https://glasgow.gov.uk
City public authority gender pay gap	5.43% (in favour of men)	0.5	https://glasgow.gov.uk
Family-related leave and flexible working arrangements for city public authority employees	N/A	1	-
Programs to increase the availability of quality childcare	Yes	0	https://glasgow.gov.uk
Program to strengthen women in disaster management	No	1	No data was available

Tertiary education level	35%	0.5	https://www.understandingglasgow.com
Sustainable Transport Rate	-	1	No data was available
Percentage of households with Internet access	100%		Thriving Glasgow portrait report
Efficient feedback mechanism	Yes	0	https://glasgow.gov.uk
Citizen involvement in decision-making	Yes	0	https://glasgow.gov.uk
Waiting time for elective outpatient medical visit (physician) in primary health care exceeds 3 months from assessment of the need for treatment, % appointments kept	41.70%	0.75	https://publichealthscotland.scot
Average life expectancy at birth for females (core indicator)	80	0.3	https://www.understandingglasgow.com
Average life expectancy at birth for males (core indicator)	76.5	0.6	https://www.understandingglasgow.com
Persons having cost overburden rate (%)	19.30%	1	https://www.understandingglasgow.com
Number of homeless % population (supporting indicator)	1.1 % (Total number of homeless 6995)	0.5	https://www.understandingglasgow.com
Residential rental dwelling units as a percentage of total dwelling units (profile indicator)	47%	0.25	https://www.understandingglasgow.com
% of women who have experienced violence	11%	0.25	https://www.glasgow.gov.uk/article/6496/Crime
Crimes against property per 1000 population (supporting indicator)	76.8	0.75	https://www.statista.com Regional data
Percentage of municipal budget allocated to cultural and sporting facilities (supporting indicator)	5%	0.3	https://glasgow.gov.uk
Protection policies for cultural heritage sites	Yes	0	https://glasgow.gov.uk

Non-men (Women) mayors or other leaders and members as a percentage of total elected to city-level office (core indicator)	73.10%	0	https://glasgow.gov.uk
Electronic governance services	Yes	0	https://glasgow.gov.uk
Grievance mechanism	Yes	0	https://glasgow.gov.uk
Voter turnout rate (Voter participation in last municipal election (as a percentage of registered voters) (supporting indicator)	56%	0.3	https://www.understandingglasgow.com