Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Architecture and Planning

Kritika Singh

Towards a Positive Energy District

Analyzing Key Performance Indicators in Urban Planning for a Sustainable District: A Case Study

Master's thesis in Urban Ecological Planning
Supervisor: Rolee Aranya
Co-supervisor: Devika Prakash
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Supervisors:
Rolee Aranya, Professor, Program Leader Urban Ecological Planning
Norwegian University of Science and Technology
Devika Prakash, Ph.D. Candidate, Urban and Regional Studies
KTH Royal Institute of Technology

Norwegian University of Science and Technology;
KTH Royal Institute of Technology
June 2022

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Trondheim - June 14, 2022

Kritika Singh

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Kritika

Abstract

Urban neighborhoods that work toward carbon-free, climate-neutral goals, attain a positive energy balance, and aspire for excess renewable energy production are defined as Positive Energy Districts (PEDs). PEDs are designed to contribute to sustainable urban growth, and it is also true that sustainable urban growth can lead to the creation of PEDs. Essentially, PEDs can be achieved by developing and following sustainable infrastructure and urban planning practices including spatial, transportation, and social planning. As per JPI Urban Europe, the key aspects of PEDs along with the funding include implementation strategies, stakeholders, climate transition, governance, legal frameworks, as well as technological and system innovation [1].

As the name suggests, PED mainly comprises positive energy (energy management) and district (neighborhood) elements. The district aspect encompasses urban planning that constitutes strategic planning for sustainability implications consisting of environmental, social, economical, mobility, and transportation-related factors, all of which involve the users and its people. The positive energy aspect of a PED enables local energy production resulting in energy efficiency and potential cost savings for its residents.

The thesis examines the performance of urban planning factors with the potential to develop an existing neighborhood toward a PED. This research study explores the overall sustainability of a neighborhood in terms of mobility, social, economic, and environmental factors. The performance of these factors is measured through Key Performance Indicators (KPIs), which measure the attributes of sustainability. These contributing KPIs have been studied on a scale through a case study of Hammarby

Sjöstad (HS) in Stockholm. The perception of stakeholders is collected for evaluating KPIs. These KPIs have been thoroughly analyzed as designed during the planning stage and post-implementation to evaluate their success. The findings of this thesis can be employed as guidelines for setting benchmarks and goals for the development of PEDs in cities throughout the world.

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List of Abbreviations

PED - Positive Energy District

KPIs - Key Performance Indicators

JPI - The Joint Programming Initiative

CO_2 - Carbon dioxide

GHG - GreenHouse Gas

GDP - Gross Domestic Product

HS- Hammarby Sjöstad

EU - European Union

LCA - Life cycle assessment

1. Chapter One: Introduction

1.1 Background

The world is becoming increasingly urbanized. Since 2007, more than half the world's population has been living in cities, and that share is projected to rise to 60% by 2030 [2]. The world's cities occupy 3% of the earth's land surface but account for 65%-70% of global energy consumption and 70%-75% of carbon emissions [3]. Rapid urbanization is further exerting pressure on fresh water supplies, sewage, the living environment, and public health [2]. The urban settlements in developed countries are facing serious challenges such as looming threats of climate change, green and digital transitions, and limited job creation and social progress leading to economic stagnation. Cities and metropolitan areas are powerhouses of economic growth, contributing about 60% of global gross domestic product (GDP) [4]. Consequently, they are focal areas of concerted efforts for achieving sustainable development goals. Therefore, urban settlements are seen both as a source and a solution to today's economic, environmental and social challenges[5].

The important challenge of how to plan cities to enable their role as '*drivers of sustainable development'* and their contribution to the implementation of the Paris Agreement and Sustainable Development Goals on climate change was discussed in the United Nations Conference on Housing and Sustainable Urban Development, 2016. This was the first UN global summit on urbanization after adopting the Sustainable Development Agenda 2030 [6]. At the UN conference, world leaders adopted the New Urban Agenda to set global standards for achieving sustainable urban development. For this, relevant stakeholders, partners, and urban actors at all levels of administration, society, and the private sector can cooperate to rethink the way we build, manage and live in cities [7].

Europe aims to be a global role model in sustainable urban development. Over two-thirds of the EU's population lives in urban areas [8] and accounts for about 80% of energy use while generating up to 85% of Europe's GDP [9]. European Union (EU) policy on sustainable urban development states that these cities are the backbones of the European economy serving as drivers for creativity and innovation across the union. However, these are also regions where long-standing issues such as unemployment, segregation, and poverty are at their severe. As a result, urban policies have a wider cross-border impact which is why urban development is important to the EU's regional policy [5].

Cities in Europe are actively integrating sustainable urbanization strategies. The Program on Positive Energy Districts and Neighborhoods provides cities collaboration and assistance in becoming frontrunners in the field of energy transition and sustainable urban development [1]. A Positive Energy District (PED) is defined as "*an urban neighborhood with annual net-zero energy import and net-zero carbon dioxide (CO_2) emissions (carbon neutral), and furthermore is working towards renewable energy generation (a net energy surplus), as a part of a larger urban and regional energy system"* [1]. These neighborhoods necessitate interaction and integration among the built environment, people, regional energy, mobility, and information technology systems.

JPI Urban Europe states that PED combines the built environment, sustainable production and consumption, and mobility to minimize energy consumption and greenhouse gas emissions while also providing its residents with added value and incentives [1]. Furthermore, the implementation must be accompanied by a good, yet affordable quality of life for the community and its residents. PEDs and neighborhoods are critical components of urbanization towards sustainability that include technological, spatial, financial, regulatory, legal, economic, and social perspectives. Interaction and integration between buildings, users, energy, mobility, and new digital technology systems are required in these neighborhoods.

The Program “Positive Energy Districts and Neighborhoods for Sustainable Urban Development” helps to plan, deploy and replicate 100 Positive Energy Neighborhoods in Europe by 2025 [10]. PEDs are expected to facilitate the achievement of the Paris Agreement goals. PEDs will potentially boost Europe’s capacity and knowledge allowing it to become a global role model meanwhile improving the quality of life in the European cities [10].

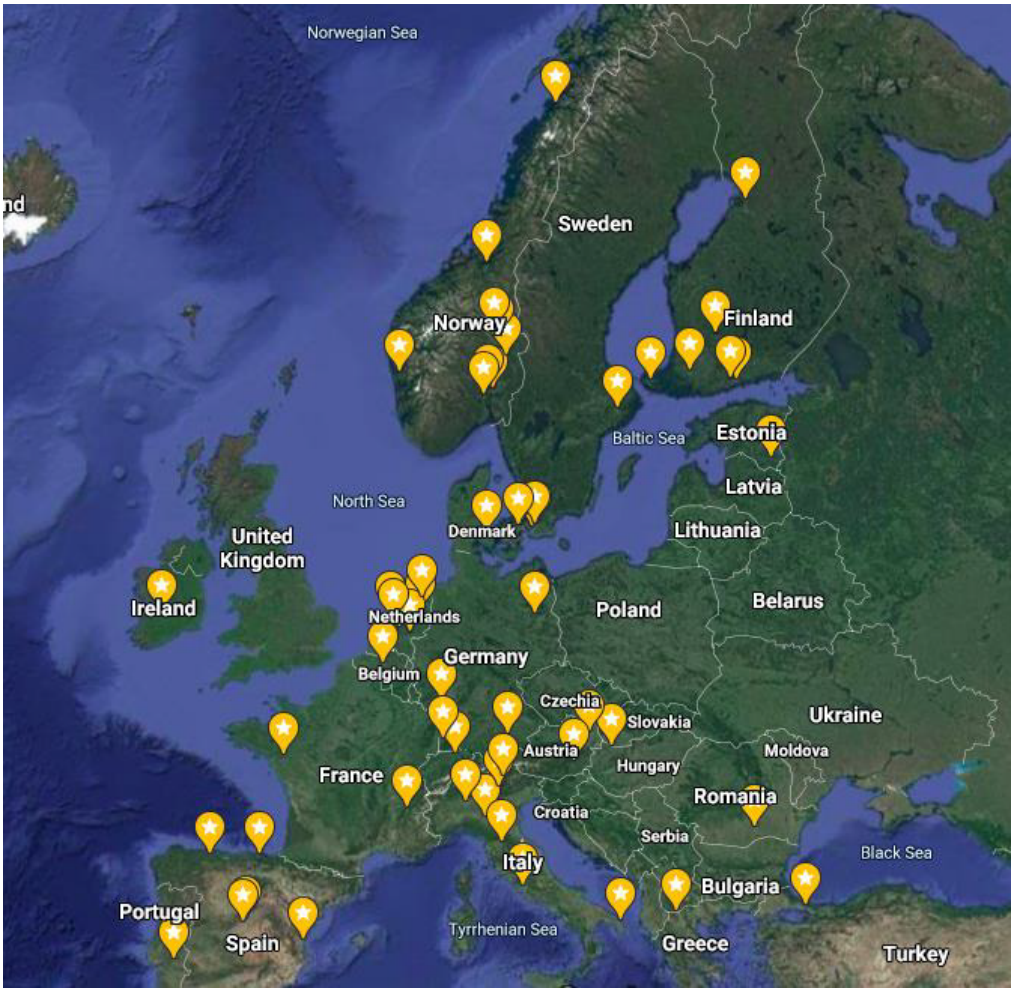

Figure 1.1 Graphical Distribution of proposed PEDs in Europe taken from JPI Urban Europe [10].

The thesis aims to understand and assess the level of success in the transition of an urban neighborhood toward a climate-neutral district and then a PED in terms of sensitization and mobilization of stakeholders. For this work, a case study focusing on sustainable development and goals was conducted in the Hammarby Sjöstad (HS) district in Stockholm, the capital city of Sweden. This district represents an emerging urban development that aims to address not only the reducing the carbon footprint with innovations in energy efficiency but also focuses on the social equity and accessibility aspects with citizens' active engagement in their community.

For accessing the performance of the HS district, the district's goals, indicators, and related benchmarks are analyzed. The goals are driven by sustainability factors that aid the district toward carbon neutrality. Sustainability factors are measured by Key Performance Indicators (KPIs). KPIs determine to what extent the goals are met, the progress of the goals, the performance of sustainability factors, and their relevance in the current scenario.

1.2 Aims and objectives of thesis

The thesis aim to explore the following research questions concerning the district, sustainability factors that include aspects of the environment, social, economic, and transportation. The objective of the research is to understand and analyze the perspectives of different stakeholders working towards common interests. The research question also tries to examine the stakeholder relationships and their significance in the project. Similarly, the KPIs differ from the project development's timeline. The research objectives of this thesis include-

Q.1 How do residents (compared to other stakeholders) perceive KPIs for Hammarby Sjöstad across different categories such as environmental, social, and economic dimensions?

Q.2 How do other stakeholders (non-residents) perceive KPIs and how do they use them?

Q.3 How can KPIs be more comprehensively used to enable sustainable urban planning post-implementation in Hammarby Sjöstad?

1.3 Scope and structure of thesis

This thesis consider the case of Hammarby Sjostad district with its goal of becoming a PED. The study examines the relevant factors, stakeholders' roles, and citizens' involvement in acting toward achieving these goals. Additionally, it explores if there are any challenges and gaps in transitioning Hammarby Sjöstad to becoming a sustainable neighborhood. The broader context and the motivation of this work are described in the present chapter.

Chapter 2 explores the relevance of PEDs, the role of urban planning in establishing PEDs, the assessment frameworks in other similar projects that have been considered, and how some measurement criteria for sustainability goals can be tracked by KPIs. The literature review introduces some definitions and concepts undertaken in the field with similar backgrounds.

Chapter 3 focuses on the relevant history and background of the Hammarby Sjostad district and elaborates on the sustainability goals when the city administration first conceptualized the planning and operation of phase 1.0 (1996-2014) and then more

ambitious goals towards carbon-free, climate neutrality, and affordability during the second phase 2.0 (2014-ongoing). The specific KPIs associated with each phase of planning, development, and operation are listed in this chapter.

Chapter 4 describes the methodology of research and data collection. The data collection is based on a case study module through the combination of collection techniques such as semi-structured interviews, fieldwork, desk-based research, and the conversion of qualitative and narrative data into overall performance scores.

Chapter 5 discusses the results and findings and covers different aspects that are discovered through this case study. The descriptive analysis revolves around the narrative inquiry about the KPIs and how these qualitative metrics can be interpreted as quantitative outcomes. This is done to analyze and visualize the performances of KPIs in relation to all the groups of stakeholders.

Chapter 6 states the discussion and recommendations. The chapter discusses the implications of the findings related to the effectiveness of KPIs and identifies the gap in the understanding of KPIs between stakeholders along with some recommendations on moving toward the sustainable goals of the district. This chapter also discusses the scope for future work which would be relevant for urban planners.

2. Chapter Two: Literature Review

2.1 Urban Planning for Positive Energy Districts (PEDs)

To meet the European energy and climate targets, urban development ought to move away from past building solutions toward PEDs and neighborhoods as well as incorporate other innovative concepts [11], [12]. Establishing sustainable PEDs as an integral part of comprehensive urbanization emphasizes positive energy blocks rather than individual positive energy buildings, which allows for utilizing synergies [13].

According to Wiik and coauthors [14], the positive energy blocks should focus on planning, designing, and operating buildings and their associated infrastructure components to reduce greenhouse gas emissions during their entire life cycle. The purpose is to become highly efficient and increasingly reliant on renewable energy.
In terms of energy consumption patterns, this would allow for the flow of energy inside and between buildings and additional exchanges of energy with the rest of the energy system in a smooth manner.

PEDs are intended to be a driving concept for the city's transition to a more sustainable future. However, sustainability encompasses more than environmental sustainability, for which the term is commonly used. For example, Tanguay et al. [15] define balanced sustainable urban living to comprise the following elements as shown in this Venn diagram (Figure 2.1).

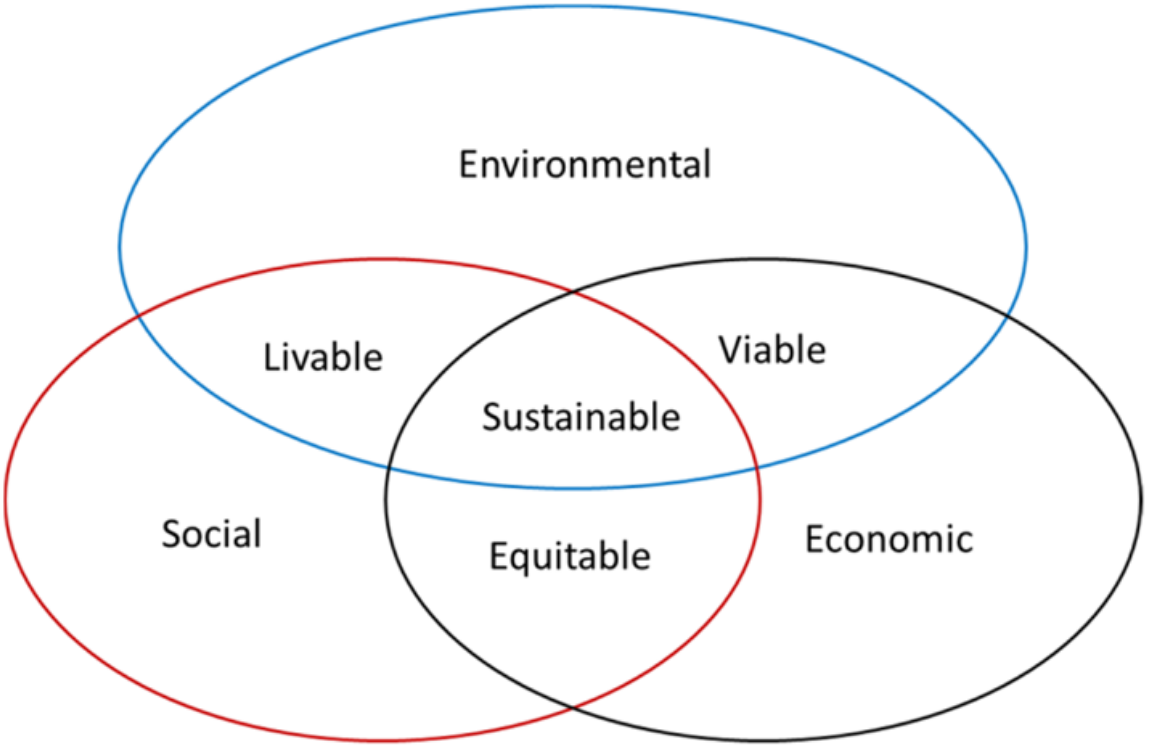

Figure 2.1: "Pillars of sustainability" and their intersection. Taken from [15], [16].

According to the diagram (Fig. 2.1 [15]), environmental sustainability combined with social sustainability contributes to creating a livable area. Environmental sustainability combined with economic sustainability achieves viability. Economic sustainability in combination with social sustainability contributes toward equitability.

Several cities around the world are moving towards sustainable goals, and notably, many of them are in Sweden [17]. Royal Seaport is heralded as one of the leaders and a model in this space. Figure 2.2 shows the vision and the overall goals for the neighborhood and how the city officials identified specific focus areas and sectors to achieve those goals.

The environmental and sustainability program of the Stockholm Royal Seaport arose from the realization that having a guiding document was one of the aspects that contributed to the success of Stockholm's first sustainable urban neighborhood that is HS [18], [19]. Figure 2.2 shows the connection of goals with the focus areas. The HS development goals also followed all the focus areas and sectors as shown in the planning process of the Royal Seaport [20].

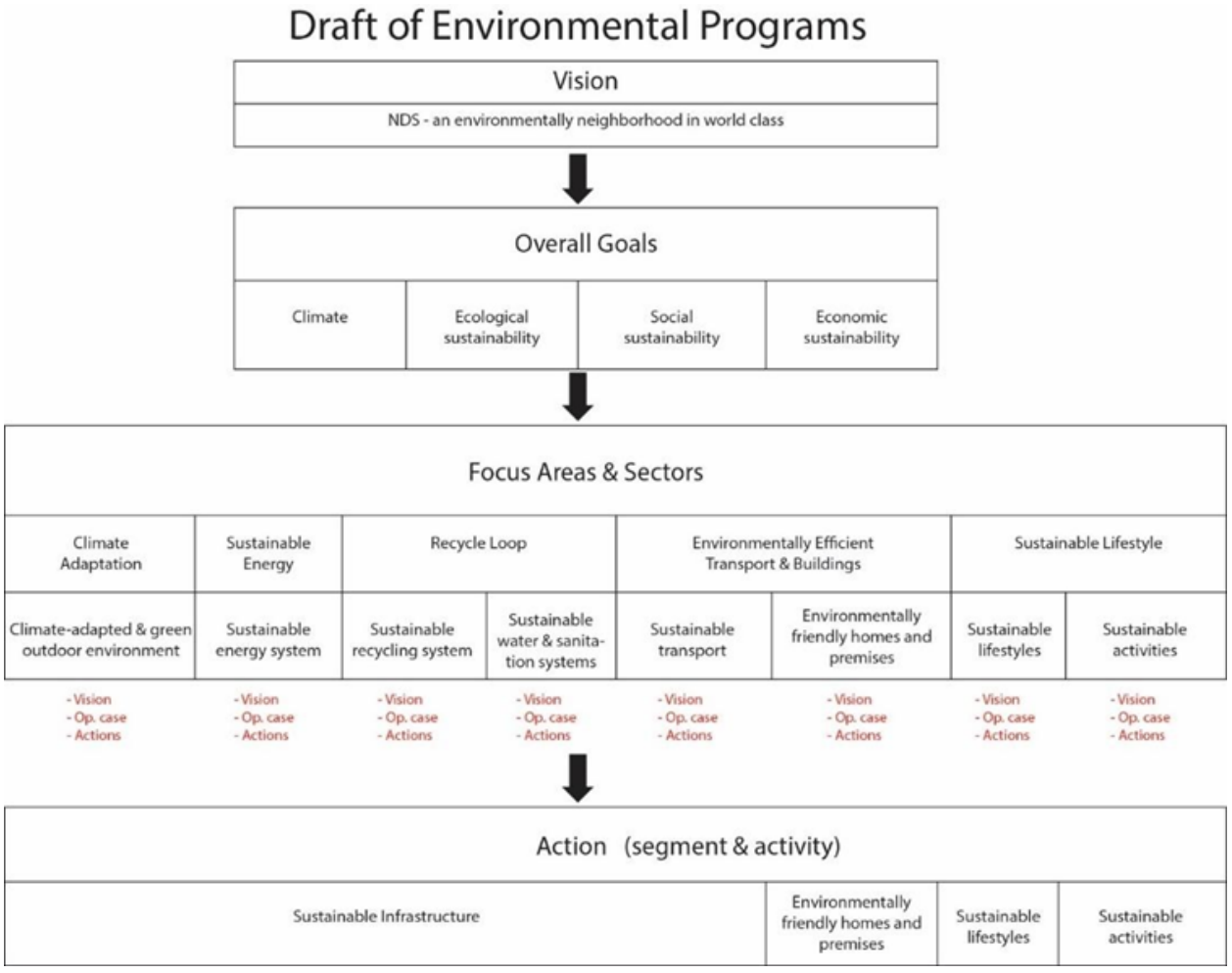

Figure 2.2. The draft of the Environmental Program for the Stockholm Royal Seaport.

Source: City Of Stockholm, 2009, taken from [20].

2.2 Different PED projects and their implementation

Several ongoing projects in the European Union have a common objective of developing a PED[21]. Table 2.1 below lists relevant examples of such projects and their related assessment frameworks.

The steps for the development of a PED framework constitute (1) building on broad stakeholder consultations and dialogues; (2) connecting to ongoing policy and strategy debates, such as the implementation of agenda 2030 sustainable development goals, the EU urban agenda, or the national energy and climate plans; (3) taking into account results and lessons learned from earlier PED-related projects and other sustainable urbanization projects [22]. However, as evident from the examples below in Table 2.1, there's no clear or consistent definition of a PED and the assessment framework/criteria for tracking the progress towards achieving PED (see Table 2.1). That's because they differ in their geographic locations, different priorities of the local city government and hence policies, different project developers, and utility providers for renewable energy [23].

Assessment frameworks define, determine, and develop a set of KPIs that can be used for monitoring and recommendations. The assessment frameworks are used to examine and assess existing KPIs to extract what is working, new ideas, and learnings. For example, POCITYF is a project that has two lighthouse cities Evora in Portugal and Alkmaar in the Netherlands, and six other cities that would replicate their models. Therefore to monitor these projects, a common framework is needed on different parameters of solar energy, energy management, e mobility, ICT, and citizen engagement in the form of KPIs [24].

Table 2.1: Types of assessment framework/criteria for setting KPIs as adopted in different PED projects. Taken from the literature Angelakoglou et al., 2020 [24].

Project Name	Assessment Framework
IRIS Integrated and Replicable Solutions for Co-Creation In Sustainable Cities	The assessment framework takes a flexible holistic approach defining 75 KPIs categorized in six dimensions—technical, environmental, economic, social, ICT and legal—along with a targeted clustering of solutions in five Transition Tracks including Smart renewables and closed-loop energy-positive districts, Smart Energy Management and Storage for Grid Flexibility, Smart e-Mobility Sector, City Innovation Platforms (CIP) and Citizen Engagement and Co-Creation.
REPLICATE Renaissance of Places with Innovative Citizenship and Technologies	The assessment framework contains 56 KPIs classified under seven dimensions covering a whole city's performance - City description (5 indicators), Energy and Environment (14 indicators), Mobility and Transport (14 indicators), Infrastructure (6 indicators), Governance (5 indicators), Social (5 indicators), and Economy and Finance (7 indicators). The indicators are broken down into three applicability levels - National, Local/City, and District.

MATCHUP Maximizing the Upscaling and Replication potential of high-level urban transformation strategies.	MatchUp's assessment framework is based on the concept of sustainable development, with two evaluation levels (city level and project level) and a total of 188 KPIs. The indicators have been classified into three dimensions - environment, economy, and social, and grouped into four fields of implementation activities.
SMARTEnCITY Towards Smart Zero CO_2 Cities across Europe	The evaluation framework was developed considering the type of implemented solutions within the project - district renovation, urban mobility, and citizen engagement. The adopting indicators were grouped into four categories — technical, environmental, social, and economic. These KPIs are further divided into five evaluation protocols - Energy Assessment, ICT, LCA, Mobility, and Cross-Cutting.
MySMARTLIFE Smart Transition of EU cities towards a new concept of Smart Life and Economy	The assessment framework defines 151 KPIs classified across six fields, namely, Energy and Environment, Mobility and Transport, Urban Infrastructure, Citizens, Economy, and Governance. The framework relies on the five major themes of CITYkeys - People, Planet, Prosperity, Governance, and Propagation. A two-fold evaluation approach is followed in order to measure the demonstration activities - project level and city level.

SHARING CITIES Building Smart Cities Together	The proposed framework is structured around 127 KPIs. The solution attempts to deliver the effects of the People/Place/Platform (PPP) measures by setting evaluation targets categorized into six domains - technical performance, attitudes and behaviors, wider systemic and environmental impacts, security, safety and sustainability, institutional and business consequences and economic and social implications.
TRIANGULUM The Three Point Project - Demonstrate. Disseminate. Replicate	The project introduces an assessment framework based on a seven-stage methodology for defining the expected impacts, resulting in 79 KPIs. These KPIs are organized in five (5) impact domains - Energy, Transport, Citizen Engagement, Socio-economic/financial and ICT deployment.
GROWSMARTER Transforming Cities for a Smart, Sustainable Europe	The evaluation framework of this project is based on 104 KPIs to measure and evaluate the project/city's performance. These are distributed across three main dimensions - better quality of life, environmental factors, and economic well-being.
+City x Change Positive City ExChange	The evaluation framework process relies on 33 KPIs and follows a holistic approach focusing on technical and economic aspects of energy-related measures. The KPI framework is divided into the three core themes -

	Integrated Planning and Design (IPD), Common Energy Market (CEM), and CommunityxChange (CxC).
STARDUST Enlightening European Cities	The assessment framework structure proposes 17 KPIs to monitor and assess the performance of the project solutions across five diverse clusters - Building and Energy, e-Mobility, ICT, Common City Level, and Long-Term Effects. The monitoring of the project is based on the immediate as well as long-term impact.

2.3 Key performance indicators (KPIs) in urban planning of PEDs

Key Performance Indicators (KPIs) are a set of quantifiable performance measurements that generate a set of values based on project data and make it easier to monitor and evaluate the performance of the neighborhood goals over time and in comparison to other similar initiatives [25]. KPIs are used to assess the progress of strategies aimed at achieving positive energy transformation, as well as to track the progress of related solutions and initiatives. A key element to achieving sustainable development goals is having KPIs [26]. KPIs can track performances over time, show development trends, and benchmark performance to goals.

In the context of this thesis, KPIs establish a connection between urban planning in achieving carbon-neutral districts or PEDs [27] [21]. As stated by Wiik et al. [14], KPIs are adopted in urban planning to determine whether and to what extent goals are met. KPIs can be divided into environmental, economic, and social categories, with specific focus areas, such as mobility, governance, and citizen

participation/involvement [24]. Therefore, monitoring projects enable informed reflection on how to optimize the solutions and increase their efficiency. KPIs can also be useful for scalability because the city's energy transition project can then attempt to scale the positive energy district to the city level [24].

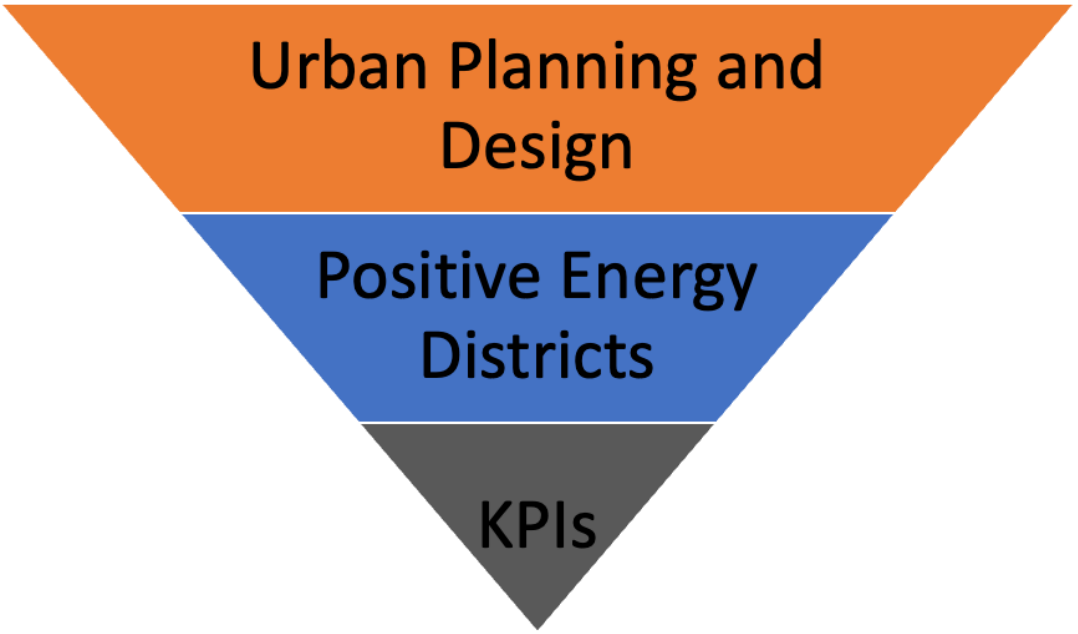

Figure 2.3: Urban planning, PED, and KPIs are interrelated as illustrated. Urban planning is a broader field of work where PEDs are increasingly becoming more prominent. KPIs present a method to track progress towards PED sustainability goals.

CITYkeys develops and validates key performance indicators and data collection methods with the help of the involved cities. The aim is to make monitoring common and transparent. The CITYkeys compare smart city solutions across European cities [28].

CITYKeys address the most pressing social concerns relating to the expansion and densification of cities with respect to the EU's energy and climate targets. The challenge with the KPIs is that they are difficult to maintain and monitor after the project is funded or completed. One of the takeaways from the CITYKeys 2016 project was that while KPIs can make planning, implementation, and monitoring of

sustainable communities easier, determining the most appropriate KPIs for individual projects can often be difficult [28].

2.4 Examples of KPIs in PEDs

The list of KPIs can be used as a basis for project monitoring and assessment, in terms of not only technological performance, but also in terms of social engagement, acceptance of positive energy change, and propagation of scalable and replicable innovations [24].

The criteria of KPIs are based on existing regional and city regulations, and the best practices, guidelines, and standards for the construction and operation of a project. Such criteria of KPIs can be used to track, understand, and validate the progress and performance of the zero-emission neighborhood pilot projects. As claimed by JPI Urban Europe, the factors that have been included in implementation strategies are local renewable resources, regional energy systems, mobility, buildings, and local governance [22], [21]. Greenhouse gas emissions, energy power, and load, mobility, economy, and social and environmental innovations can be categories of criteria of KPIs [14].
Some examples of KPIs across different dimensions are listed in Table 2.2.

Table 2.2: List of KPI types and examples. Taken from Angelakoglou et al., 2020 [24].

KPI Dimension	KPI Description	KPI Examples
Energy	Energy performance is focusing mainly on the interventions facilitating energy transition.	Energy demand and consumption, Renewable Energy Sources generation ratio, Peak-load reduction
Environmental	Environmental performance is increasingly important for smart cities striving to identify environmental risks and factors that are essential for humans and natural resources and special for smart city planning and operation.	CO_2 emissions reduction, Air quality, Noise pollution, Blue-Green solutions, Circular economy
Economic	Economic performance refers to the business efficiency and cost of each application and usage scenario from a market perspective.	Average cost of energy consumption, Energy cost savings to residents, Return on capital investment

Information and Communications Technology (ICT)	ICT performance is regarded as a key pillar for technology advancements in the smart city concept, enabling data management, privacy and security and data monitoring for the development of new innovative services.	Cybersecurity, Data privacy, Improved interoperability
Mobility	Mobility performance is appropriate for smart city projects concerning the convergence of energy and transport sectors, the global EV market uptake and the increasing citizens' needs for sustainable mobility and e-mobility services.	Public Transportation System, EVs charging points, Clean mobility utilization, E-vehicle sharing solutions
Social	Social performance is crucial to estimate the extent to which the project and its designed collaborative action model facilitate the involvement of citizens and social actors in the planning, decision-making and	Citizen participation in co-creation processes and online decision making, Degree of users' satisfaction

	implementation activities through social citizen-driven innovation mechanisms.	
Governance	Governance performance refers to the city governance from the side of the municipality administration, planning and evaluation mainly, and also includes aspects of the legal domain regarding the regulatory framework and its compatibility with the proposed solutions and implemented policies at the project or city level.	Involvement of the city administration, New rules, and regulations due to the project, Legal framework compatibility
Propagation	Propagation performance assesses the potential for wider scalability and replicability of the solutions and actions demonstrated.	Social compatibility of solutions, market demand, diffusion potential

Some descriptors of the KPIs dimension are discussed below.

Environmental Dimension:

Environmental sustainability includes several aspects such as reduction of GHG (Green House Gas) emissions, waste management, energy-efficient buildings, access to green spaces, etc. The spatial attributes encompass various aspects of the built environment such as the ratio of buildings to green/open public areas that might influence a neighborhood's appeal. Many of these factors can be considered during the design phase (pre-construction), for instance, street networks, parks, waterfronts, and squares, as well as their interconnections. It is crucial to pay attention to the many features of urban space because they influence whether people who live and work in the area feel inspired to stay and use the area to enable sustainable low carbon behavior. In the worst-case scenario, users will have to satisfy their needs outside of their immediate area for all the services. This would necessitate more travel, which would result in higher GHG emissions. On a district and neighborhood level, green and blue infrastructures are critical building blocks for climate adaptation measures [14].

Another prevailing concept is the circular economy. Collaborative consumption is gaining popularity for environmental sustainability. Business-to-consumer (B2C) Peer-to-peer (P2P) sharing platforms for sharing services, and products are a more sustainable form of consumption [29]. Therefore the circular economy model offers a new path to sustainability because it is considered a more sustainable form of consumption [30].

Economic Dimension:

Quality of life and prosperity are cornerstones of smart and sustainable PEDs [31]. Several initiatives to transform an urban neighborhood into a PED can be truly successful only if they improve residents' economic and financial well-being. In this context, this particular dimension covers the major aspects of economic development including factors such as if there are opportunities, visible benefits,

and profits to the citizens on implementing the solutions and actions. The most indicative aspects that can be covered by this set of indicators are reduced energy poverty as measured by the average cost of energy peer-to-peer and energy cost savings, jobs creation and business opportunities, innovation uptake, and return on investment (ROI) on the capital investment [24].

Social Dimension (citizen participation and resident's behavior):

The social performance of a project and its proposed collaborative action model are critical in determining how well the citizens and social actors are involved in planning, decision-making, and implementation activities through citizen-driven innovation mechanisms [24]. Participation of citizens along with effective communication mechanisms are critical success factors in the implementation of PEDs. This will help people adopt new technological solutions and encourage them to make the necessary lifestyle changes.

The PED concept cannot be realized without changes in user behavior and personal lifestyle. Behavioral changes and mobility patterns can be tracked to address users with awareness-raising as a key concept [32]. Energy consciousness is the behavioral factor that influences how much energy is used and can be changed by removing occupant (resident)-centric obstacles and educating about energy consumption impacts [33]. Based on standard behavioral models, the household survey extracts human motives behind environmental, energy, and technology-related decisions [34]. These aid in classifying the main drivers by social group, as well as providing advice on how to respond to certain driver groups.

Information and Communications Technology (ICT) Dimension:

Modern cities have undergone a dramatic shift primarily because of advancements in digital technology that they are now smart data exchange networks. People, vehicles, goods, data, and information flow across such networked cities [35], [36].

Dashboards will be used to provide an integrated and balanced evaluation system for urban sustainability performance in Stockholm, Sweden, one such endeavor is the I-city dashboard. To support policies, strategies, and qualitative considerations, the dashboard provides a straightforward and systematic classification system that is stated in plain terms. In addition, the system of dashboards is seen from a Triple-Layer or multi-layer perspective, to encourage data and information exchange. Such data exchanges support transparent communication and coordination among a variety of interested actors and stakeholders associated with everyday lives and actions in the overall urban system [37].

Mobility Dimension:

The overall architecture of the neighborhood and integrated traffic planning initiatives backed by smart mobility technology result in sustainable transport patterns. These are intended to lessen transportation's environmental footprint in the neighborhood while also improving the quality of life for its users [14].

Furthermore, sustainable transportation and smart mobility systems aid in the reduction of travel times, pollution, and congestion with the promotion and encouragement of healthier travel behavior and sustainable travel options by expanding the traffic network capacity. As a result, the mobility category's KPIs evaluate the mode of transportation and availability of public transportation [14].

Combined KPI Dimensions: Example of livability and affordability

Livability (combination of environmental and social factors, see Figure 2.1): The primary qualitative and quantitative data input should be livability indices, according to [38]. The authors recognize that although livability is a challenging concept to define and measure, groups involved in the planning, programming, and management of urban districts must be aware of its objective and rigorous quantification and qualification through a set of recognized KPIs. They affirm that long-term planning can be guided and directed by indicators, which can identify where improvements are needed and then show whether progress is being achieved over time [39].

Affordability (combination of economic and social factors, see Figure 1): Another example to consider in social KPI is the affordability of the neighborhood [40]. Affordability refers to determining the percentage of people who have a housing cost burden in a household survey by mapping the income required to afford housing in the PED. This is partially in line with the European standard of matching housing costs to income but it considers other cost components particularly mortgage principles to completely reflect the real cost of housing. In addition, another KPI statistic specifies whether the PED is gated or accessible to the larger population [16]. Affordable housing promotes social inclusion, engagement, and empowerment.

2.5. Primary Stakeholders make PEDs a success

The United Nations has defined 17 sustainable development goals, that are the blueprint to achieve a better and more sustainable future for all [41]. In most cases, energy goals are not sufficiently integrated and linked with the urban planning processes.

The conversion of districts into climate-neutral zones offers a lot of potential for PED development. Nonetheless, it requires extensive collaboration between local administration, industries, and research institutes, which are all termed stakeholders. A project can only be conceived, conceptualized, financed, built, and operated only because of the coming of all stakeholders.

In 1984, the stakeholder idea was first introduced to the management discipline [42]. Persons or groups who are directly or indirectly affected by a project and/or have the power to influence its outcome are considered stakeholders.

Identifying the relevant stakeholders and getting them to take part in participatory procedures can be difficult. Therefore, to follow up on the participatory goals, additional investment and coordination measures are needed. As a result, developing a system that identifies key stakeholders and pulls key information that supports their performance goals can pose a major challenge.

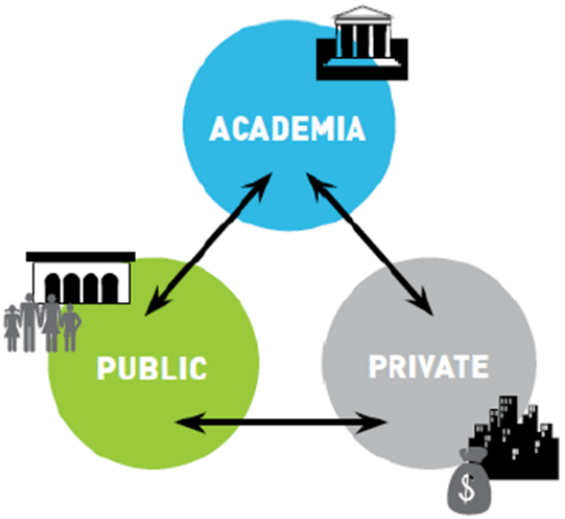

Figure 2.4: Model depicting actors as primary stakeholders identified in three sectors - public, private and institutional. Taken from [20], The SymbioCity Approach.

Collaborative planning processes between all stakeholders are essential for achieving PEDs. Discussions led by city governments with stakeholders from research and innovation, industry, investors, and residents aim to raise awareness, discover common ground on the topic, and outline potential approaches to putting PEDs in place (Figure 2.4) [43].

2.6. Theoretical Framework

Arnstein's Ladder:

Arnstein utilizes the image of a ladder to express gradations of citizens' participation in urban programs that impact their lives [44]. The ladder signifies that citizen control is vital to any project. Manipulation and therapy are two types of non-participation that are placed at the bottom of the ladder. Manipulation is where it seems that the citizens are involved in the decision-making while they are not. It is a misleading form of participation. Therapy concerns curing citizens of their attitudes and behavior in the manner that decision-makers prefer.

At the middle of the ladder are Informing, Consultation and Placation. Informing is where citizens are informed about the programs and their rights through information and communication. Consultation involves consulting citizens on the decisions. However, in these systems, there are no guarantees of follow-ups. Placation enables citizens to offer advice in the decision-making process [44].

At the top of the ladder are Partnership, Delegation, and Citizen Control. This is where the role of citizens in decision-making is significant The partnership allows for negotiation and trade-offs with citizens through collaboration between local government, private companies, and nonprofit organizations of communities. Delegation and Citizen Control as the name suggests is where citizens have power and say in the decision-making process [44].

Since PEDs are a relatively new concept, the decision-making largely is done by the authorities, guided by innovation and research. Although almost all PEDs have KPIs revolving around citizens, it is yet to be seen the actual significance and role of the citizens in the process. It would be interesting to see how and to what extent the citizens will be involved. In addition, PEDs have energy-related KPIs which are heavy on technological aspects. Therefore it has become more important than ever to train or share knowledge among residents.

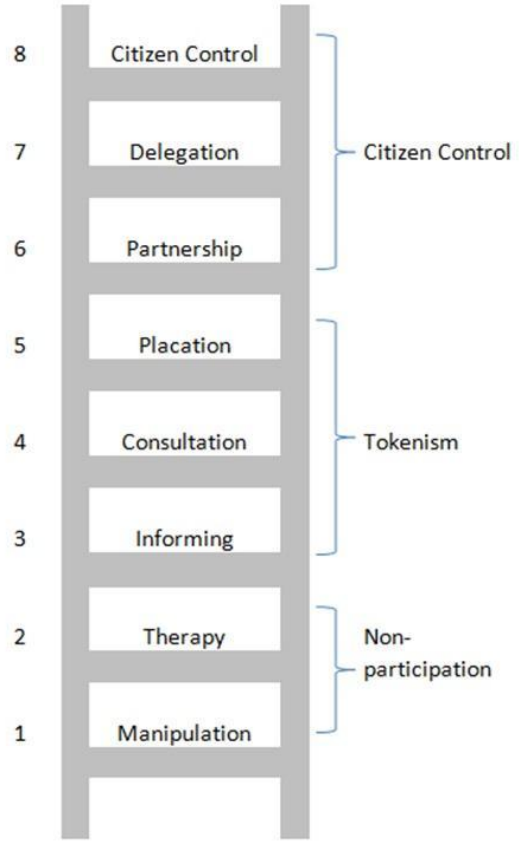

Figure 2.5: Arnstein's ladder of participation. Taken from [45].

A criticism of the citizen control system is that sometimes citizens stall required projects according to Frieden. Citizens claim it under the concern for the environment while they want to protect their own interests, often their private properties. The phrase 'Not In My Back Yard' conveys a common reason for project delays [46].

Collins and Ison claim that it is time to shift from Arnstein's ladder to focus on social learning. They believe when it comes to environmental resources, participation is becoming a fundamental issue in policy discussions across the EU at national and local levels. This kind of social learning represents a transformation in policy-making thinking and practices. This shift is due to the fact that no single group can solve the whole project with certainty. Therefore the concept of social learning rather than participation is more relevant since it encapsulates the

different roles, relationships, and sense of purpose that is necessary to undertake complex projects. From this, social learning can be viewed as emergent governance that encourages collective actions [47].

Democracy and Participation in planning of PEDs:

Public participation, stakeholder involvement, co-creation, civic engagement, participatory democracy, and activism are all examples of citizen engagement [48]. Individual or communal behavior aimed at resolving social problems in a community is another concept. Interaction between administration and citizens ensures democracy and participation in planning.

Campbell's planner's triangle brings out the conflicts between green cities (environment), growing cities (economic), and just cities (social) that are the fundamentals of planning [49]. These are highly relevant to PEDs as well, being a subset of cities.

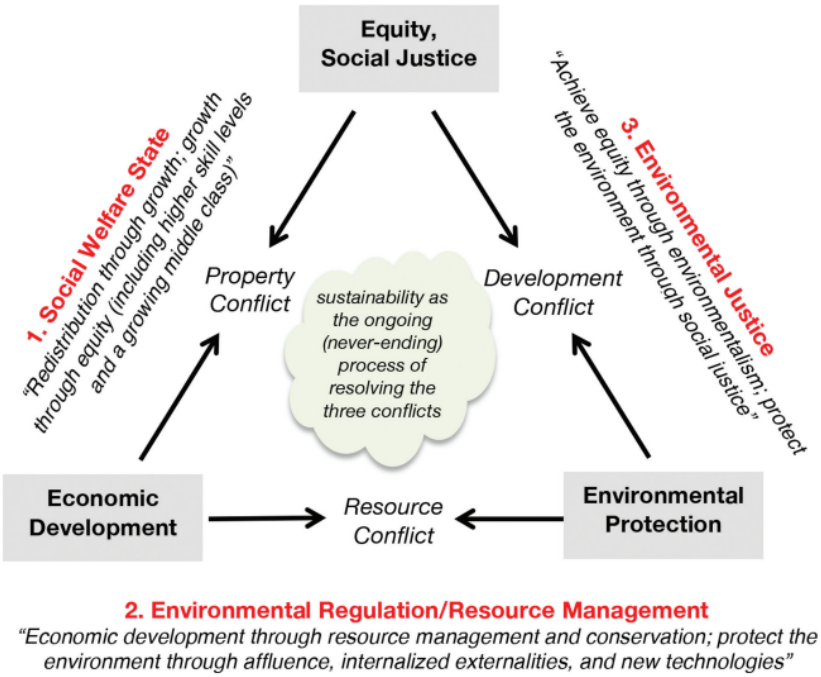

Figure 2.6: Campbell's planner's triangle. Taken from [49].

As per Campbell, a development conflict exists between environmental protection and equity, social justice; a resource conflict exists between the environment and economic development; and a property conflict exists between economic and equity, and social justice. Socio-political institutions such as environmental justice are achieved by combining environmental protection with equity and social justice. Similarly, the social welfare state is created by combining economic development with equity and social justice, and environmental regulation or resource management is responsible for resolving resource conflicts. Sustainability, according to this, is a continuous, cumulative process of resolving conflicts with no end state of equilibrium (see figure 2.6) [49].

In PEDs with increasing building technologies and large-scale urban development citizen engagement has become necessary. Citizens should be kept informed, involved, and satisfied with new developments. If the city has active public involvement before PED, then it paves the path for further enhancements and

changes. When it comes to PEDs, it's difficult to start from scratch if the cities or neighborhoods did not have citizen's involvement before. Citizens play an active role in defining concerns, determining solutions, and making decisions about the future course of action [43].

It is critical to include the younger generation, children, teenagers, and vulnerable young people. It causes energy transition awareness to emerge at an early level. It contributes to the development and strengthening of community ties, as well as a sense of ownership. Children and teens can inspire their families to adopt sustainable practices by being early adopters. This could be a target group for PED enablers [43].

Power Interest Matrix:

The Power Interest Matrix is the process of identifying, mapping, and categorizing stakeholders. Well-managed and effective stakeholder relationships are key to successful projects. Active involvement of stakeholders along with their satisfaction is vital for any sustainable development project [50].

Stakeholder identification is a continual activity that takes place throughout the project's lifecycle [51]. Stakeholders must be identified and understood in order for their demands, expectations, and requirements to be appropriately handled [52]. For the success of a project, stakeholder identification is critical. [51].

Based on the power or interest in the project, the power interest grid is a technique to categorize stakeholders. This matrix is useful to manage all the stakeholders effectively [53].

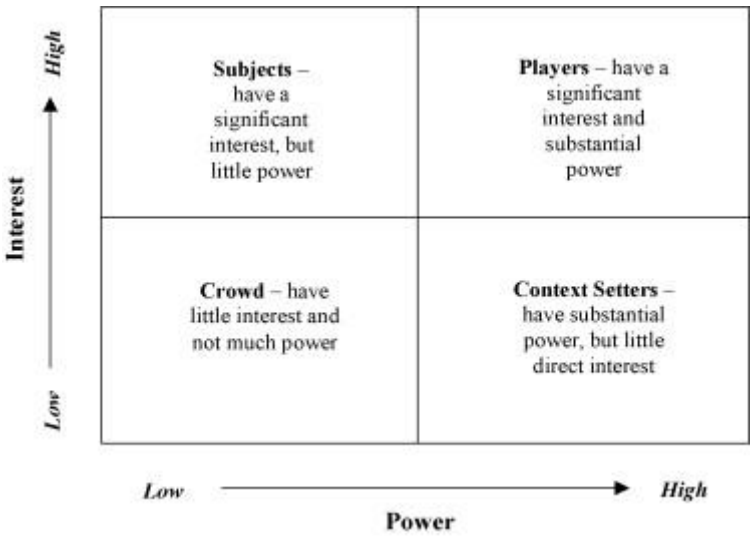

Figure 2.7: Power Versus Interest grid. Taken from [54].

Power versus interest is described by Eden and Ackermann. On a two-by-two matrix, the identified stakeholders are placed along two dimensions. There are two dimensions namely interest and power. The interests of stakeholders or issues at hand are the dimensions of Interest. The power to affect the organization or the power to influence the issue's future is another dimension of the matrix [55].

The concept of power vs interest aids in determining which players' interests and power bases should be considered while dealing with the current scenario. Key Stakeholders or key players have both interest and power. Key players are influential in decision-making or can influence the impact. This matrix results in coalitions among stakeholders. As a result of this matrix, stakeholders can form coalitions, and communicate better [55].

For power vs interest setup, there are a few necessary steps to do that include identifying stakeholders, prioritizing stakeholders, engaging stakeholders, and monitoring the effectiveness of communication among stakeholders [56]. This is done in order to assign duties to each stakeholder group [57].

Analytical Framework:

Positive Energy Districts have more of a technocratic approach as their fundamental approach. There is a need to bring a human-centric perspective and approaches to PEDs [58]. The parameter to make a sustainable district more livable for its people is the current need for PEDs.

The theoretical framework of the thesis is as depicted in the figure where the focus areas are represented by the research questions.

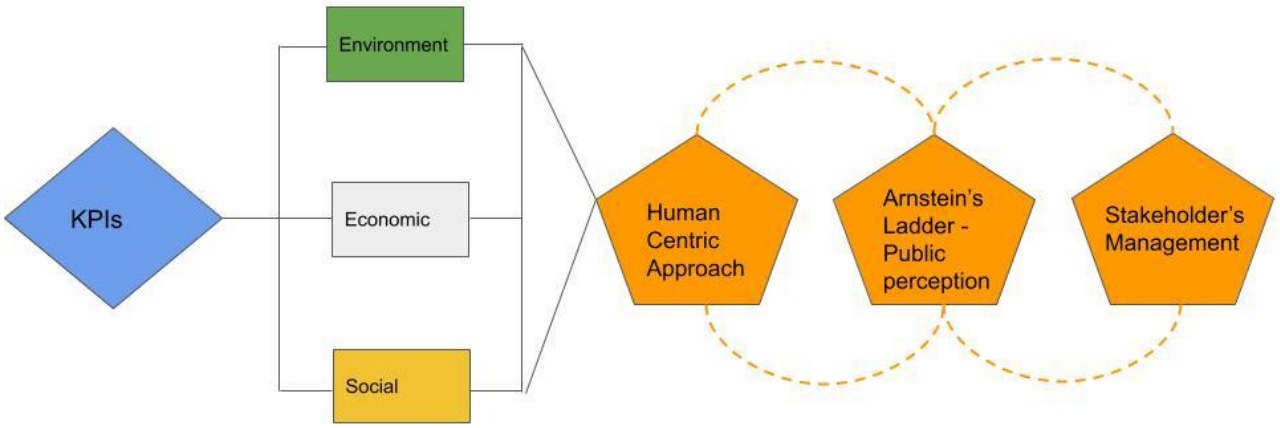

Figure 2.8: Theoretical Model connecting the sustainability factors with the main themes of a human-centric approach to KPIs, citizen-driven initiatives in PED, and changing stakeholder dynamics in PED.

The KPIs in PEDs focus on different parameters across dimensions. As evident from the literature study, there is a clear gap in taking the user's perspective into

consideration about the KPIs. There are few KPIs to involve citizen engagement, however the aspect of what users think of KPIs or how they perceive KPIs is missing. Users and residents are the primary beneficiaries of PEDs.

The literature suggests citizen involvement in the planning stages. After the project's completion, the provision for follow-ups from the citizens is lacking in the literature study. The thesis aims to discuss the need for follow-ups when the district is transitioning into becoming a PED.

As seen from the literature review the power versus interest diagram is effective in managing stakeholders. However, stakeholder management is affected by the timeline of the project. The actors and groups of stakeholders, their interests, and their powers change according to the timeline of the project. This aspect is highlighted in the thesis and aims to study the changes in stakeholders mapping and its impact on the project and tracking of the KPIs.

3. Chapter Three: The case for Hammarby Sjöstad

3.1 Hammarby Sjöstad (Phase 1.0) - History and Background

Hammarby Sjöstad, is a district in Stockholm city, the capital of Sweden, and a former industrial and harbor brownfield area, that was originally intended as an Olympic village (See Figure 3.1). To participate in the hosting competition for the Olympic games (1996), the city launched an environmental sustainability program for Hammarby Sjöstad and highlighted it as a key attribute in their bidding pitch. This program came to be known as the Hammarby model. Unfortunately, Hammarby Sjöstad lost the competition, however, the city's sustainable model of development continued as initially planned and was designed as a comprehensive infrastructure project covering 200 hectares. In 1999 construction began in different phases based on the model. From 2000 to 2018 the district expanded in different phases. Currently, there are 12,700 residential homes in the district where 21,000 residents live and about 3,680 apartments are left to build which is 29% of the district (See Figures 3.1 and 3.2) [59].

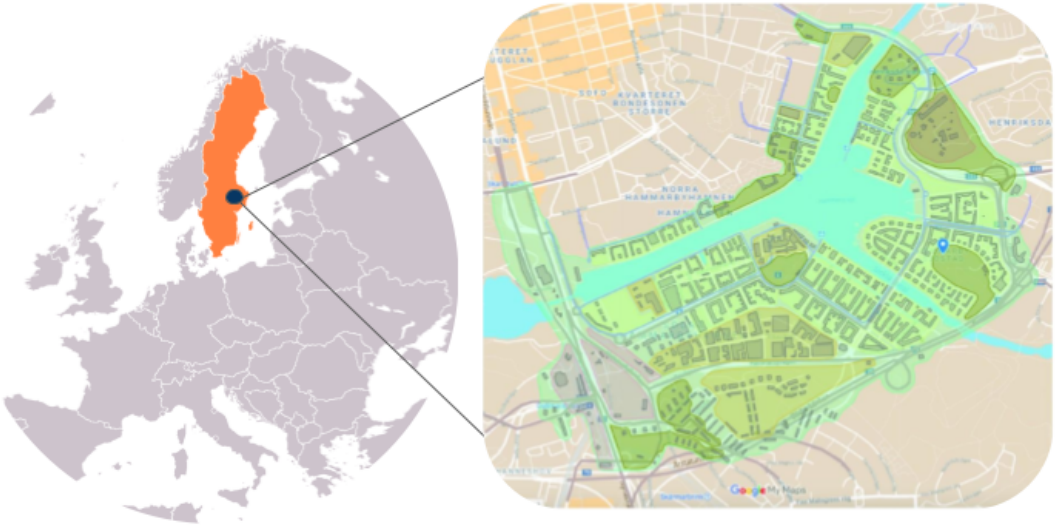

Figure 3.1: Location of HS district in Stockholm, Sweden. The (ii) map is taken from [60].

Hammarby Sjöstad was originally an urban planning project and is considered one of the first urban projects that adopted the "concept of sustainable development to the next level" [20].

When the building's and district construction began in the late 90s, their environmental goals were very high (see Table 3.1). The goals were that it would be a modern district that was built on the latest environmental technology with an aim of low energy consumption among buildings and more people choosing public transport, waste to be converted into district heating and food waste to be utilized as biogas that could be used locally by the citizens. It came to be known as the Hammarby Model [61].

According to the urban development case study report [20], Hammarby Sjöstad was developed on twelve "green" guidelines. The guidelines are stated in table 3.1 below.

Table 3.1: Urban planning goals and KPIs set for Hammarby Sjöstad PED during phase 1.0 taken from Jernberg et al., [20].

Guideline	Quantitative benchmarks	Target level of benchmark	Hammarby quantitative level of benchmark
1. Urban Growth Boundary	NA (Not applicable)	NA	Yes
2. Transit-Oriented Development (TOD)	% residents within TOD area	70% for big cities	100%
	Ratio of TOD FAR to overall district level FAR	2x	NA
3. Mixed-use	% of residential units within 500 m of these amenities	100%	100%
	The job to resident ratio (the number of people employed divided by the number of residents)	Should be between 0.5 and 0.7	0.40 (expected in 2025)
4. Small Blocks	Blocks size as measured by area equal to 2 ha and 70% of blocks should comply with this standard.	70% of blocks ⩽ 2 ha. (excluding industrial areas)	100%
5. Public Green Space	% of residents within 500 m of publicly accessible green space	100%	100%
	% of land area devoted to publicly accessible green space/blue space.	20-40% in commercial areas and higher levels in residential areas	40%
6. Non-motorized Transit (NMT)	Density of pedestrian paths (km in length/ sq.km. of district land area)	⩾ 10	Yes
	Density of bike paths (km in length/ sq.km. of district land area)	⩾ 10	Yes
7. Public Transit	% of new development within 500 m of transit	100%	100%
8. Car Control	NA	NA	Yes

9. Green Buildings	MOHURD green building standard	⩾ 70% 1-star; 20% to 40% 2-star; 5% to 15% 3-star	NA in Sweden
10. Renewable and District Energy	NA	NA	Yes
	% of electricity locally-generated, renewable	5% to 15% for residential areas	Approximately 50.5%
		2% to 5% for commercial areas	50% of energy recovered from waste 0.5% rooftop solar for heating supply
11. Waste Management	All buildings should have waste sorting facilities	100%	100%
	% of waste composted	30-50%	Food waste: 35% of total household 50% of waste separated 90% separated food waste into biogas
	% of waste recycled or reused	35-50%	33% material recycling 50% used for energy
12. Water Efficiency	% of water use subject to metering	100%	100%
	% of water used should be from rainwater or recycled wastewater	20-30%	

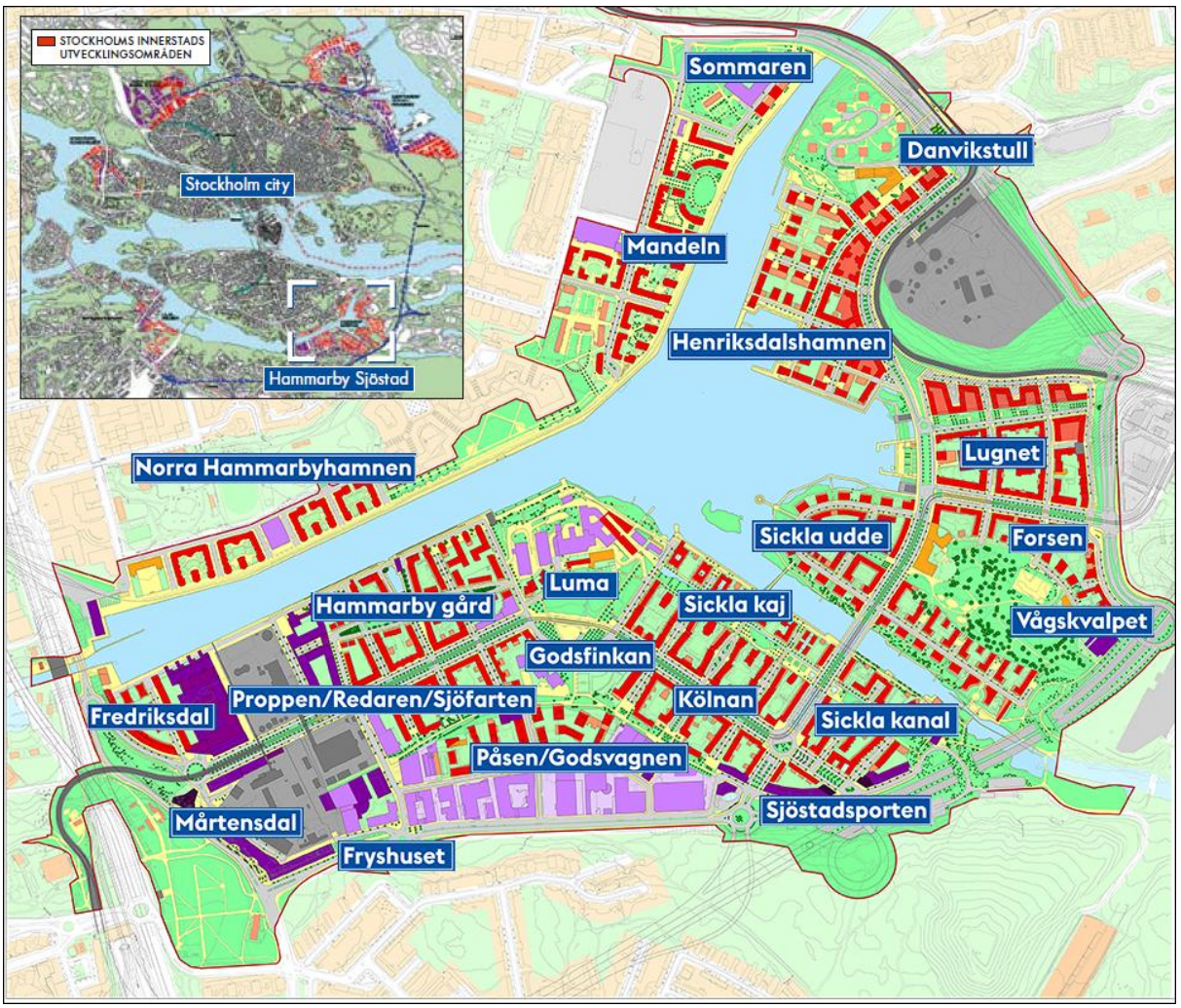

Figure 3.2: Map of Hammarby Sjostad, source by Stockholm Stad [62].

Jernberg et al., report the district was overall a “success”[20]. The property values increased and the district attracted private investment. It is considered one of the role models with an impressive urban form, planned architecture, abundant public greens, and efficient waste management system. There were a few takeaways from this project according to the report which stated that a holistic approach is necessary for sustainable urban development. The report emphasized that the public sector, private sector, and academic institutions must all be extensively involved in the planning process. Another critical lesson was the mindset and behavioral changes among residents that were necessary with assistance from design and financial channels.

The report by Urban Europe [10] claimed that the district did not meet all the goals in terms of performance. Most of the buildings in the area use more energy than was initially planned. The project Hammarby Sjöstad 2.0 began to meet the targets of previously missing energy goals. The revised goals align with the Paris Climate Agreement 2050 with an intention to achieve them ahead of the timeline, by 2030. Such ambitions target the district to become carbon-free and climate neutral. The social aspects and affordability are the new ambition of the project. Environmental, societal, social, and economic aspects and considerations will be the key indicators that are expected to create an impact. The overall strategies of the city and municipality connected with the project are to further commercial development in the district and let the district be driven by citizens [10].

Figure 3.3: Picture of district buildings and waterway near the urban district of Hammarby Sjostad (taken during one of the transects walks).

It was later realized that not all the climatic goals have been achieved, since most of the properties in Hammarby Sjöstad have very high energy usage - much higher than was stated in the goal, and many suffer from the lack of technical maintenance. Note that this is not unique for Hammarby Sjöstad; it's a very common problem overall [61].

With all this, in 2012 the Citizen initiative Hammarby Sjöstad 2.0 was formed and it's operating in the Economic Association called ElectriCITY innovation. Hammarby Sjöstad 2.0 is formed to address the situation that “the district has failed to live up to these ambitious goals” and ask questions like “how can we renew a new city” and “what can be done to ensure that Hammarby Sjöstad becomes more climate-smart and sustainable?” “How can the energy efficiency in the buildings be increased and promote a transition toward electric vehicles and at the same time be role models for other city districts as well”? “How to opt for a green economy approach and how to influence urban developments in other areas as well” [61]?

Thirty innovative companies and research organizations teamed up with the project after the creation of ElectriCITY and Hammarby Sjostad 2.0 to formulate a way forward together. And the overall vision was to achieve the climate goals by using innovative ideas and practical actions to create a climate-neutral district by 2030 [61].

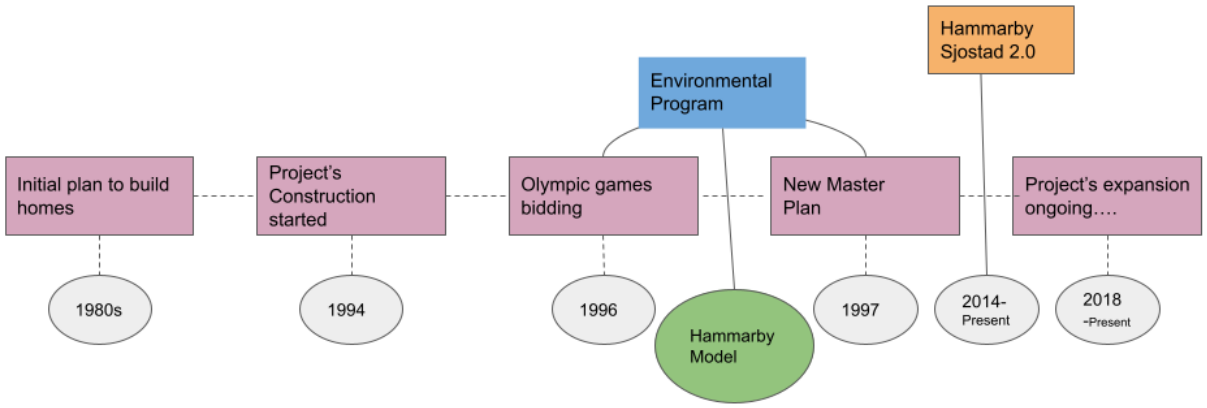

Figure 3.4: Timeline of HS project from its inception to till its ongoing expansion. To this day, some parts of the district remain to be built. HS 2.0 is formed along the journey to realize unmet and new district goals towards sustainability.

3.2 Plan 2.0 - Towards Positive Energy District - Carbon-Free and Climate Neutral Hammarby Sjöstad 2.0

Hammarby Sjöstad 2.0 is primarily working toward UN Sustainable development goals. The goals that are focused on in this project are Goal 6, clean water and sanitation; Goal 7, which is regarding affordable and clean energy; Goal 8, decent work and economic growth; Goal 9, industry innovation and infrastructure; Goal 11, which is for sustainable cities and communities; Goal 12, concerning responsible consumption and production; Goal 13, which is climate action; Goal 15, life on land and finally, Goal 17 about partnerships for the goals [61].

Hammarby Sjöstad 2.0 (reconceptualized in 2014) specifies the goals and ambitions for HS that move specifically toward carbon-free, climate neutrality that also fares well on social aspects and affordability. Such a change is expected to have environmental, societal, social, and economic sustainability impacts on all its citizens.

Indicators	Models	Actors
Environmental	Circular Economy	Citizens
Economic	Energy	Companies
Societal	Digitalization	Cities/Municipalities
Social	Transport	Academia

Figure 3.5: HS 2.0 goal is to be climate neutral by 2030. The figure shows the indicators, models undertaken and actors involved in HS 2.0

ElectriCITY is an intermediary organization between private companies, the city of Stockholm, HS residents, research institutes, and universities is a new stakeholder. This consortium faced the challenge of how to engage residents in an effective way, both on energy and all kinds of different sustainability aspects.

ElectriCITY's foremost approach is working with Sjöstadsföreningen's housing associations and residents in Hammarby Sjöstad. Another one of their goals is to install more locally produced energy sources, such that the community produces more energy than they consume (supported by a grant from the Swedish Energy Agency). They are targeting 60% of the housing associations to be climate neutral by 2025. Additionally, there are plans to trade energy locally - a model that should be tested before 2023. The goal is to share excess energy among neighbors, locally located stores, and restaurants. The 2030 goal is to keep track of data regarding investments, improvements, and how the initiative has turned out.

Hammarby Sjöstad was planned to follow a natural cycle approach to urban living and its planning. The initial goals of the development project were that residential and commercial energy consumption must be low and people should take public transportation instead of driving. These goals were only partially met and hence they were reconsidered.

The Hammarby Sjöstad 2.0 was initiated to meet the missing goals. The entity in charge of running the second phase of the project is an organization called ElectriCITY innovation. They have a strategy to meet the Paris Climate Agreement's 2050 deadline in 2030. According to ElectriCITY, Hammarby Sjöstad aspires to be a climate change pioneer, with a goal of being carbon neutral by 2030. ElectriCITY will accomplish this by focusing on energy, buildings, mobility, digitalization, communication, and circular and sharing economies [61].

Hammarby Sjöstad's development is an example of the triple helix concept [20].In this model, the public/municipality, private sector, and academia interact to contribute to the development. At the start of the project, it is critical that an interdisciplinary project group composed of city officials, real estate developers, energy and planning researchers, private companies, and consultancies is developed. The following chapters present the methods section and an evaluation of the KPIs.

4. Chapter Four: Methods

The chapter on methods describes the data collection methods and procedures. The primary source of data collection is fieldwork and interviews, which are further supplemented by secondary data collection methods such as desktop research, and review of previously published reports and documents on the subject [63].

4.1 Case Study Approach - Hammarby Sjöstad Case

This thesis adopts the methodology of a case study [64] and is based on a case study in Hammarby Sjöstad, Stockholm (see Chapter 3). Such methodology has been applied before and Flyvbjerg [65] claims the case study approach is an excellent method for researching and learning [66]. Yin states that *"a case study is an empirical inquiry that investigates a contemporary phenomenon in a real-life context when the boundaries between the phenomenon and context are unclear"* [66]. An exhaustive and elaborate case study can span multiple variables of interest, and relies on multiple sources of information, including the prior development of theoretical investigations [67].

The chapter describes the data collection methods and analysis. This work takes a qualitative approach to data collection with a narrative inquiry as to the primary methodological tool [66] [68]. Responses were gathered through a sampling method called snowball sampling. In the snowball sampling technique, the respondents further provide referrals that can be potential subjects for the research study, in this case, data collection from interviews [69]. Additionally, fieldwork and desk-based research are used to supplement the primary data collected via interviews with diverse stakeholders. The Norwegian center for research data (NSD) has approved

the research project and the thesis follows all ethical rules and protocols of data collection.

4.2 Research Questions

Building upon the sustainable development goals set during HS Phase 2.0, this work further analyzes the following research questions in the context of the HS case study. The key questions identified are:

Q.1 How do residents (compared to other stakeholders) perceive KPIs for Hammarby Sjöstad across different categories such as environmental, social, and economic dimensions?

Q.2 How do other stakeholders (non-residents) perceive KPIs and how do they use them?

Q.3 How can KPIs be more comprehensively used to enable sustainable urban planning post-implementation in Hammarby Sjöstad?

4.3 Identified KPIs in Case Study (Qualitative Metrics)

The KPIs are a combination of Hammarby Sjöstad planning documents from phase 1.0 and phase 2.0 while a couple of KPIs are identified as significant variables in this study. These KPIs are only qualitative in nature (as opposed to comparing against set benchmarks) and are primarily assessed through ratings of “user satisfaction”. These narrative inquiries are human-centric in their approach. See Table 4.1 for the list of KPIs investigated in this case study. Such qualitative research methods allow

the researcher to embrace complex social phenomena and respond to them in a flexible way, resulting in a detailed description of the researched phenomena [70].

Table 4.1: All the KPIs from Hammarby Sjostad Phase 2.0 tracked in this project (qualitative metrics).

Category	KPIs Tracked	KPI conceived during Plan 1.0 or 2.0
Information and Communication technology (ICT)	Digital Dashboards	2.0
Mobility	Public Transportation System	1.0
Social	Citizen's involvement and participation	2.0
	Social equity and accessibility	Identified in this study
	Residents training	2.0
	Change in behavior of residents since moving in	Identified in this study
	Housing affordability	2.0
Environmental	Sustainability Rating	1.0
	Livability	2.0
	Urban build and Infrastructure	1.0
	Waste and water management	1.0
	Spatial Attributes	1.0
	Circular Economy	2.0
Economic	Average cost of energy consumption	2.0

4.4 Data collection methods

4.4 (a) Desk Based Research

Reports, documents, official websites were studied for understanding the case, current practices, initial planning, and background. As Flick, 2015 [71] points out, research should begin with reading as it provides valuable context to the study.

4.4 (b) Site Visits/ Observations and Photographs

During walks, I kept taking notes primarily from observations. These notes were translated to formulate questions for interviews. According to Bryman, [72] observations add considerably to the richness of the research data and involve the systematic observation, recording, description, analysis, and interpretation of people's behavior.

4.4 (c) Semi-Structured Interviews

Semi-structured interviews are defined as a purposeful discussion between two or more people [73] that allow for data collection, particularly from the perspective of the participants [74]. Interviews were guided by an interview guide that focused on specific themes for framing questions.

The participants were categorized into four divisions of stakeholders and belonged to public, private, institutional, and residential stakeholders. Semi-structured interviews were done to collect the data and analyze the know-how from all the different actors directly involved in the project or impacted by the project. The purpose was to know how each kind of actor perceives the district and its use for them. All the major stakeholders were covered for obtaining reliable information.

Table 4.2: A total of 15 interviews are done so far for collecting the data. The respondents are divided into different stakeholder categories.

Type	Abbreviation	Number of interviews
Researchers	E	3
Private Companies' Employees	P	2
Residents	R	8
Administration Officials	A	2

It is interesting to see that the ongoing COVID-19 has changed our ways of working and thus has also influenced the data collection methods. It is now more accessible to communicate remotely through online zoom calls. This has enabled accessibility and remote data collection options. Out of these some of the interviews were held online with the stakeholders.

The participants for semi-structured interviews were identified through desk-based research. The resident's group was contacted through snowball sampling. The interviews would begin with brief introductions, the context of the work, research questions, expectations, and typical questions in this interview. The consent was taken via verbal and email in advance as well as during interviews. Permission to record interviews via audio was obtained. This data collection was supplemented with hand notes with emphasis on keywords and takeaways in between to confirm certain points. The length of the interviews varied from 30-90 minutes.

Interviews with Researchers (E):

These researchers (more commonly working as planners) were directly involved in the project which means they had a deep understanding of the whole project. Also, they had broader perspectives from all the stakeholders, such as how stakeholders

think and view the project. These interviews were informative on the roles and responsibilities of the major stakeholders, allowing for a better understanding of the power interest dynamics of different stakeholders.

Interviews with Private Entities (P):

The interviews directly from ElectriCITY were informative to learn about their work, their vision, and how they establish KPIs. The interview focused on KPIs adopted by ElectriCITY, particularly the role of citizen involvement and economical aspects of energy saving for residents. The sustainability aspects were also discussed with a focus on climate-neutral goals.

Interviews with Residents(R):

Residents expressed their views and concerns freely, which provided substantial data, such as how residents live in and use the area. Their first-hand experience, their stories, their expectations, and above all understanding of KPIs from the user's perspective provided rich data. Most residents followed storytelling techniques in response to different themes and at the same time they were specific and to the point in storytelling [75].

Interviews with Administrative Officials (A)/ Transect walk in Hammarby Sjöstad

World Bank describes a transect walk as a tool for describing and showing the location and distribution of resources, features, landscape, and land uses along with the site [76]. During one such walk in the Hammarby Sjostad district with a representative from the city government, information on the governance, history, background, stakeholder interests, environmental spatial factors, economic and social attributes was obtained. The interviews with municipality officials led to an overall understanding of the place, how it functions, the roles of responsibilities of stakeholders, and how the district was formed, with the planning principles that

were adopted. KPIs and how they can assist in urban planning for sustainable districts were key points of discussion. Additionally, the challenge of how to collect effective feedback and conduct surveys to keep up with KPIs post-implementation of the project was discussed.

4.5 Data Analysis and checking its Reliability/Validity

Open coding process was used to conceptualize and categorize the data [74]. All interviews were transcribed. After each interview, the key highlights, important factors, and design aspects that were brought up during the interview were summarized. This assisted in making connections with the conceptual framework, theory, and literature review. Transcripts and notes were read multiple times to analyze themes, patterns, and categorization [77].

To construct validity multiple sources of evidence were adopted. The triangulation method assisted in validating and exposing any inconsistencies. To triangulate the data, the primary results and findings were discussed in the subsequent interviews. For internal validity, the pattern matching technique is undertaken with the use of logical models. The theory and documents supported the evidence in the case study.

Research Limitations

For master thesis work, there was a time limitation in interviewing more people. In the obtained sample size of 15, two are public, two are private, three are researchers, and eight are from citizen/resident stakeholder groups.

Being an international student, I faced difficulties in reading some of the official documents in Swedish. In some cases, I had to use the translation feature to understand the official reports and documents. The process of finding the first interviews in every stakeholder category was challenging to begin with. Eventually, I searched for the leads and reached out to the participants, and later the process became smooth and rewarding.

Research Ethics

Because ethical guidelines for academic research demand that respondents explicitly agree to be interviewed and the ways in which information obtained during the interview will be used, prior to conducting interviews, oral consent and written consent through email were obtained. Personal data obtained throughout the study, as well as real copies of collected data in the form of recordings, transcripts, and prints, were never shared with unauthorized individuals or institutions. The following chapter presents a case analysis and the results from it.

5. Chapter Five: Case Analysis and Results

This chapter presents the results from narrative inquiries for the sustainability goals. The interviews helped navigate the project ownership and changing dynamics of stakeholders. The performance of KPIs from the responses of respondents, including environmental, economic, social, transportation and mobility, as well as ICT, are evaluated.

The chapter presents the data interpreted from the case study. The data was primarily collected through semi-structured interviews supplemented by documents, literature, and observations. The narrative data collected from interviewing the stakeholders were analyzed and converted to a semi-quantitative format which was then used to identify the barriers and gaps in achieving the PED goals.

Mixed methods in research have evolved as the third paradigm for social research [78]. Mixed methods research appears to be gaining popularity in research design [79]. Understanding human behavior in difficult situations can be aided by converting qualitative data into quantitative analyses [80]. In this process, the researcher begins with qualitative data and converts it to numerical data, which is then used for further quantitative analysis with the goal of obtaining generalizable results [81]. This methodology begins with open-format data and uses a systematic qualitative procedure to convert it into nominal data that can be used in additional quantitative analysis. It is done because in general, the respondents find it far easier to provide qualitative answers over quantitative information [82].

5.1 Converting Qualitative KPIs to Quantitative Metrics

To quantify the narrative responses of the stakeholders in a numeric format for each of the identified KPIs and goals, a scoring approach was adopted (see Table 5.1). Here, a positive/favorable response was assigned a score of 5 (and color-coded green), a neutral/indifferent response was assigned a score of 3 (color-coded mustard), and unfavorable response was assigned a score of 1 (color-coded red). Ratings from respondents were estimated based on the majority of responses (positive/negative). Table 5.1 shows the color map used in the summary of the key findings in KPIs according to stakeholders involved in Hammarby Sjöstad.

Table 5.1: Qualitative/narrative data collected from different stakeholder interviews was converted to a semi-quantitative format using the selected scoring system.

Color Coding	Favorable	Neutral	Unfavorable	No information
Score	5	3	1	0

E= Researchers, P= Private groups, A= Administrative officials, and R= Residents

KPI Dimension	KPI Selected	E1	E2	E3	P1	P2	A1	A2	R1	R2	R3	R4	R5	R6	R7	R8
Information and Communication technology	Digital Dashboards	5	5	5	5	0	5	5	5	1	1	1	1	1	3	3
Mobility	Public Transportation	3	1	3	3	1	5	3	5	3	1	3	5	3	1	5
Social	Citizen's engagement	1	3	3	5	3	3	3	1	1	3	1	3	3	1	1
	Equity and accessibility	1	1	1	0	0	5	5	1	1	3	1	1	1	3	3
	Residents training	3	3	3	5	5	0	0	3	3	1	1	3	1	1	1
	Behavior change of residents since moving in	0	0	0	0	0	0	0	1	3	1	1	1	1	1	3
	Housing affordability	1	3	1	0	0	5	5	1	1	5	3	1	1	3	1
Environmental	Sustainability Rating	3	3	5	5	3	5	5	3	3	3	5	5	3	3	5

	Livability	5	3	5	0	0	0	0	3	3	5	5	3	5	5	3
	Urban build & Infrastructure	5	3	5	5	0	5	5	5	3	3	5	5	5	3	5
	Waste/water management	5	0	0	0	0	5	5	5	5	3	5	3	5	5	3
	Spatial Attributes	5	5	5	0	0	5	5	5	3	5	5	3	5	5	3
	Circular Economy	3	5	5	5	0	0	0	5	3	3	5	5	5	3	5
Econo mic	Average cost of energy consumption	3	3	3	5	5	0	0	3	3	1	3	1	5	3	3

Based on individual responses, an average score of each KPI across the four stakeholder categories was generated as shown in Figure 5.1 (which contains the relevant ICT, mobility, and social KPI dimensions) and Figure 5.2 (which contains the environmental and economic KPI dimensions). This figure shows the perception of KPIs among stakeholders during the post-construction/operational phase.

The overall average score from all stakeholders might be biased on the side of residents who outnumber other stakeholder categories. Two different kinds across stakeholder categories were compiled, of which the first reflects the average response within the stakeholder category, and the second represents the average of all stakeholder responses for a specific KPI (see Figure 5)

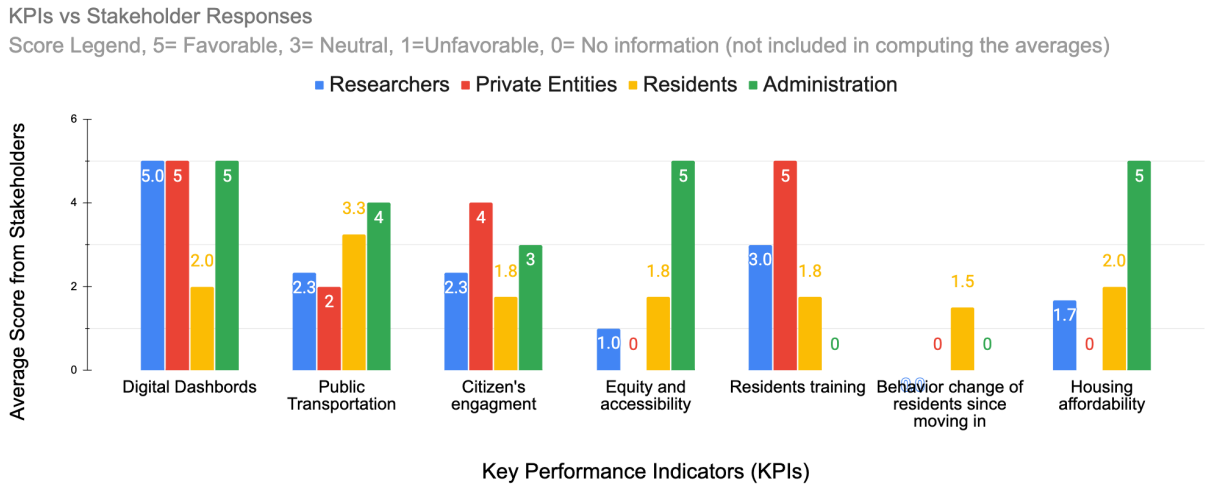

Figure 5.1: Average score/ response from each category of stakeholder was compiled for all the KPIs of interest. This figure shows the relevant ICT, mobility, and social dimensions of the PED during the post-construction/operational phase.

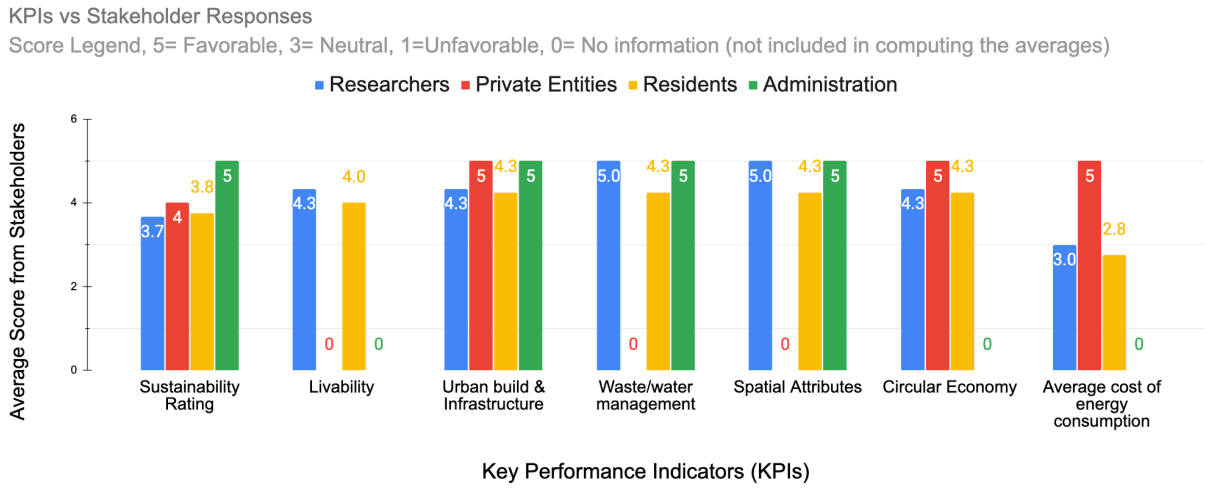

Figure 5.2: Average score/ response from each category of stakeholder was compiled for all the KPIs of interest. This figure shows the relevant environmental and economic dimensions of the PED during the post-construction/operational phase.

Detailed responses for each of the KPIs, as discussed during the semi-structured interviews, are presented in the following section.

5.2 Environmental: Spatial Attributes

Residents admit the district has good spatial qualities as a result of good urban planning and development. This aspect is confirmed in the literature study of HS [83], [84]. Proximity to convenience stores, shops, cafes, restaurants, and grocery stores is beneficial to residents. This enables the district to become self-sufficient, reducing the need to travel far for basic needs. The residents assert that the district is a mix of nature and infrastructure. Proximity to nature and water makes the environmental aspect livable.

The researcher group also confirmed that there is a good balance of density and space, as indicated by the density of buildings and public parks. They further suggested that the car parking spots that remain free in the basement can be allotted for different appropriate uses. The storefronts that have always been vacant can be turned into a community hub.

5.3 Environmental: Urban Build and Infrastructure

For several residents, the motivation to move to Hammarby Sjostad was the relatively new construction and not so much the success of its environmentally sustainable programs. For them, such high standards for environmental friendliness could have been accessed in other parts of Stockholm as well. Hammarby Sjostad is a *"fresh newly built urban place",* Quote by R1, R2. The buildings in Hammarby Sjostad are green rated. Researchers say it is well planned and better than most modern places but there is always a scope for improvement. Researchers suggested that the

urban infrastructure can be improved by turning rooftops into green roofs. Photovoltaic cells can be placed in the vacant spaces available on the roofs.

5.4 Environmental: Sustainability Rating

Sustainability is an important aspect of living in Hammarby Sjostad and has been embedded from the origins of the district. The high environmental goals at the start of the project supported by the Hammarby Model lead to a positive response among stakeholders. The overall responses were in favor of the environmental sustainability metrics.

While researchers think that the residents should take responsibility for extending and maintaining sustainability measures, residents, generally, were not aware of the proposed plans for the next twenty years. A few residents pointed out that not all aspects of climate and sustainability are considered by authorities but recognized that they may lack information on the future plans for some of these aspects.

5.5 Environmental: Water and Waste Management

Waste and water management systems are efficiently running in the district. Residents added that there is an adequate and efficient waste management system. Stormwater management and vicinity to the lake are assets of the district. Authorities pointed out that the waste from the kitchen is converted into biogas that is used in cooking. The waste collection points are not more than 30 meters away from the entrance of any building in Hammarby Sjostad.

5.6 Environmental: Circular Economy

Respondents say that there are some highly active social media groups that have listings of borrowing, buying, or selling stuff. Residents call it indirect or informal circularity. Some residents also believe that this concept is not unique to Hammarby Sjostad and is in place in different districts of Stockholm.

Martin et al. calculated the environmental impact of collaborative consumption in HS based on the potential for peer-to-peer product sharing. The sharing becomes more accessible which leads to changes in consumption patterns and thus behavioral shifts [85].

5.7 Economic: Average cost of energy

Researchers have differing claims on energy savings and management. A researcher argues that Hammarby Sjostad is perhaps not a suitable place to look for energy innovation. They are skeptical of the fact that residents might not care about saving money on energy bills as Hammarby Sjostad is a district where rich residents live. According to them, the energy-saving program would not have much effect on the residents in this scenario.

On the contrary, a researcher believes that the rich enclaves can be testbeds for energy investments and tech innovations. Hammarby Sjostad can have more freedom to experiment because of their large financial capacity. They have the potential to be hotspots for innovation and laboratories for experiments. If some things work here, they can be scaled up to other neighborhoods, districts, regions, and the whole of Stockholm. The successful factors can further act as recommendations to other cities and the European Union at large.

Private groups, such as ElectriCITY are working in the direction of energy efficiency and have initiated an activity called eco drives. It involves energy mapping of the properties and buildings and appointing energy managers for all houses or apartments. The energy managers, who receive specific training, have been reported to share knowledge among themselves through the energy meetings that are arranged periodically four or five times a year.

Another project of ElectriCITY helps with strategic partnering where board members from twelve housing associations work together to negotiate better deals. The idea of this program is that the residents together can co-invest in renewable energy, for example, geothermal heat or solar power. This enables them to buy at better terms and at lower prices, and at the same time, private utility companies that want to sell their products get a higher volume of orders. *"They (residents) also feel secure in making investments together"* - Quote P1.

General residents of the interview, on the other hand, declared that they do not know about such programs or measures. Rather some residents in their interviews expressed displeasure about not being able to choose their electricity provider. A resident quoted that he is even willing to pay more for sustainable energy. "*I agree to pay a little more if it is for climate neutrality. At least, I can actively make that choice, but I don't have that opportunity"* - Quote R3.

Two residents pointed out that they have a third organization in between them and the energy provider, who negotiates the cost of energy from the different energy companies. The electricity provider is selected by what that organization decides, which is agreed upon by the residents in that community. However, residents are not aware of energy managers or meetings in their communities.

There is clearly a communication gap between residents and private stakeholders regarding expectations in terms of cost savings and sustainable choices. It would be interesting to see what happens after the training programs are given to building managers to identify the gaps. Does the training translate from building managers to its residents?

5.8 Social: Housing Affordability

Respondents shared their views on housing affordability. Researchers claimed that sustainable districts, eco-districts, or low carbon districts tend to be more desirable places to live among people. This results in high demand for housing. Consequently, property prices go up which creates a question of affordability. "*Sustainable eco-districts promote and lead to gentrification"* - Quote E1.

Authorities deny any claims of gentrification. Their focus is to build housing for the middle class since the majority of people in Sweden belong to that economic group, and therefore, would serve the maximum number of people. Authorities take pride in the increased value of the district because it generates good income for all stakeholders. Initially, when the Hammarby Sjostad district was first built nobody wanted to live there since it was a relatively new district that was a part of old brownfield development. For authorities, it is an incredible success story of urban development.

The concept of the city as a business must give way to the city as a democratic space. That involves reinforcing the right to housing as a fundamental human right that should drive the use of financial resources, particularly public resources [86].

Researchers brought up the topic of low-income housing in the district. For instance, if the administration reserves 20% (or a given percentage) of the neighborhood apartments for low-income families, it was not clear who will bear the cost of that. They believe that the private developers will never decrease or reduce their profits, so the responsibility for low-income housing will fall on the local government.

Authorities deny the possibility of allocating low-income housing. They justify it by saying social housing will become identifiable in the districts that can lead to segregation among people of different groups.

Residents agree that the district is gentrified. Some residents claim it is almost impossible to live on a single salary. Few residents also state the reason for its gentrification and higher property prices is due to its proximity to the Stockholm city center. Residents do not want the district to be expensive and at the same time, they want the district to have environmentally friendly buildings. They want a balance between sustainability, affordability, and cost of living.

5.9 Social: Equity and Accessibility

Residents living in the district share that they had to wait in long queues to rent an apartment in Hammarby Sjostad. As per the citizens, the higher property prices and long waiting queues have resulted in high inaccessibility. *"Unfortunately, these sought-after factors have become a measurement of an attractive place"* - Quote R4

The administration has included the student housing in the district to accommodate diversity among age groups living in the area. Provisions were made to make it affordable for the students.

5.10 Social: Citizens Involvement

Authorities hold citizens accountable for not showing active involvement and participation in the major decisions of the district. They feel citizens should be responsible to keep up with what is happening. According to the local administration, citizens should be proactive in exercising their voice on different aspects of development or sustainability.

Researchers have been looking for ways to effectively involve citizens and build that proactive community. Residents declared that they are not currently involved in initiatives that directly involve them. They expressed their desire to be involved more in the decision-making process. This indicated that all stakeholders have common interests in citizen involvement. However, there is a lack of solid measures where citizens can be involved directly.

5.11 Social: Resident's Behavior

The behavior of residents did not seem to be affected by living in a sustainable district. According to the residents, they do the same things that they did before moving into the district. They sort their waste, some ride bikes and beyond that, they don't seem to know what else they can do or are expected to do.

From the excerpts of the literature study, the authors argue that residents do not want to give up their comfort in achieving goals that were set as the initial goals [87], [88]. Local administration and researchers believe that it is easier to inculcate sustainable behavior in kids than in adult residents, according to social science. They maintain that the kids or students can be taught the benefits of a greener life and trained for sustainability practices. Kids can further motivate their parents to adopt more sustainable habits.

5.12 Social: Resident's Training

'Energy at home' is a concept proposed by the ElectriCITY group. It is focused on increasing knowledge of energy systems to encourage money-saving investments that reduce energy costs. Through these activities, residents are intended to be the center of attention and this program serves to create knowledge and awareness among them for potential opportunities in making a positive sustainable impact. As per ElectriCITY, it can be a way for community building and increasing the sense of belonging among residents.

Other interviewed candidates denied receiving any such form of training. Some residents mentioned that this discrepancy could be due to a rapid turnover of district inhabitants due to people moving in and out of the district. Residents wanted a continuous process and dialogue on training.

5.13 Environmental: Livability

Livability has gained more importance recently and it has become one of the crucial aspects in most projects aiming at creating sustainable communities. The human need for social amenity, health, and well-being, both individual and community well-being, is referred to as livability [89]. Livability also relates to user satisfaction.

All stakeholders have similar opinions on the concept of liveability. Authorities believe it is an iconic globally renowned district. Researchers state that it is a well-planned modern district with scope for further improvements. But most importantly, the views of residents were important in determining the livability parameter. Most of them are satisfied with living in the district. The good environmental quality, public spaces including parks, efficient waste, and water management system, proximity to a lake, and provision of utilities and shops

increase the overall user satisfaction. However, the cost of living is significantly high plus the long queue to buy or rent an apartment makes the district fairly inaccessible.

5.14 Mobility: Public Transportation System

Interestingly, the topic of public transportation was often brought up by the residents who were curious about the upcoming metro and subway. They believe it will improve connectivity with the city. Residents are under the impression that more people will use public transport as a result of the metro project.

One of the residents wanted to know if there would be a free connection in the subway tunnel from crossing at one point of HS to the other end, if they wanted to walk, it would make a big difference to accessibility. If the metro project and public transportation are in place before the new construction is built, it will be easy to measure the success of the use of public transport with the new incoming residents.

There was a mixed response to the use of trams in the district. Some residents found it is hectic to change from tram to metro to go to the city, while other residents were content with changing from tram to metro and vice versa. To reach the other end of Hammarby Sjostad, some residents use boats as public transportation which they believe is a lackluster solution. They point out that constructing a bridge would reduce their dependence on using boats that operate in a triangular pattern and take more time.

There are currently an overwhelming number of cars in the district [90]. According to the residents, car parking is not expensive at all in the district. In some sub-districts of Hammarby Sjostad, the parking is free during weekends. The initial car parking standards were 0.25 parking spaces per apartment and 0.4 if the guest and workplace parking were included. The number of parking spaces was soon raised

to 0.7 per apartment. Such measures are in conflict with the environmental goals to reduce emissions and probably were an obstacle in raising the mode share for the public transport system [90].

5.15 Information and Communication Technology: Digital Dashboards

Digital dashboards in Hammarby Sjostad display numerals of energy in kilowatt-hours on some buildings. For residents, these metrics are nothing but abstract numbers with no context for them to understand what is the significance of the digital dashboards. Residents also found it hard to relate and therefore not motivated for any change.

"The readings are abstract to me, I can't put them in context as I have no clue what they mean. I don't care about them because they are irrelevant. Giving a context or comparison would be helpful, for example, the building today saved electricity equivalent to taking a train from Stockholm to Gothenburg. Then I will understand but….. "- Quote, R3.

This demonstrates that, while the campaign was well-intentioned, it did not communicate to the average person who requires more information to comprehend. Residents do not relate to smart digital tools unless they are involved and communicated with. This is a challenge of expert-driven KPIs.

6. Chapter Six: Discussion & Recommendations

Based on the previous analysis of KPIs performance for the transition of a Hammarby Sjostad district to a climate-neutral district, a summary of implications and recommendations follow from the analysis of results, case study, and literature review. The discussion and recommendations are presented in this section.

6.1 Shift in Stakeholder Dynamics and evolution of KPIs

At the time of planning, the vision of Hammarby Sjöstad authorities was to make the district "twice as good as any other urban development of this decade" [20]. To manage the high standards of sustainability and materialize the vision, some guidelines were set before the start of the project. The municipality drafted and issued green guidelines and organized workshops on building and development guidelines with private developers, architects, and landscape planners. At the start of the project, the municipality is the major stakeholder and owns the land. It leases it to builders and developers. The area was built according to the European district standards with residences, shops and utilities, and few offices [91].

Then it was realized that some goals were not achieved and new goals of the Paris Agreement were added to the project to make the district carbon neutral. The important thing was "to realize that the district didn't perform enough" by accepting the shortcomings and setting a new roadmap, which launched a second version of the project. This time the project was to be citizen-driven, using centric principles with concepts focusing on environmental, societal, social, and economic impacts. In the built district, different stakeholders are playing a major role. ElectriCITY is working to realize the incomplete initial goals and additional goals that will lead the project towards a carbon-neutral and positive district. Moreover, ElectriCITY has

collaborated with private companies including energy companies to realize the goals.

The stakeholder mapping changes with the project's timeline (See Figures 6.1 and 6.2). When HS was in the planning and construction stage, the City of Stockholm, the government was in charge of the project. Stockholm Stad which is the municipality of Stockholm owned the land and leased it further for the development of HS. The Stockholm Stad was the key player that issued directions to the developers for the construction of the district. At this stage, potential residents were nowhere to be seen in the picture. Stockholm Vatten och Avfall (water and waste) followed the environmental program for the development of HS.

At the planning and construction stage of the district, HS's sustainability is primarily concerned with the environmental components of sustainability, not the social and economic [19]. This is related to the environmental program's stated aims and goals that considered ecological aspects only [92].

A literature review also revealed that the environmental program was implemented late in the planning process. The extensive planning of HS began around 1990 when possible developers were identified [93], and the environmental program was established in 1996 in preparation for the Olympic Games bidding process [92].

Only essential stakeholder representatives are included, resulting in great autonomy and influence over decision-making. Many developers, for example, thought the development design codes were too stringent. Another important component is public participation, which is missing because the studies only show them at the project's post-occupancy phases [83]. The irony is that the environmental program explicitly stated that changes in residents' lifestyles were required to attain the HS goals [92].

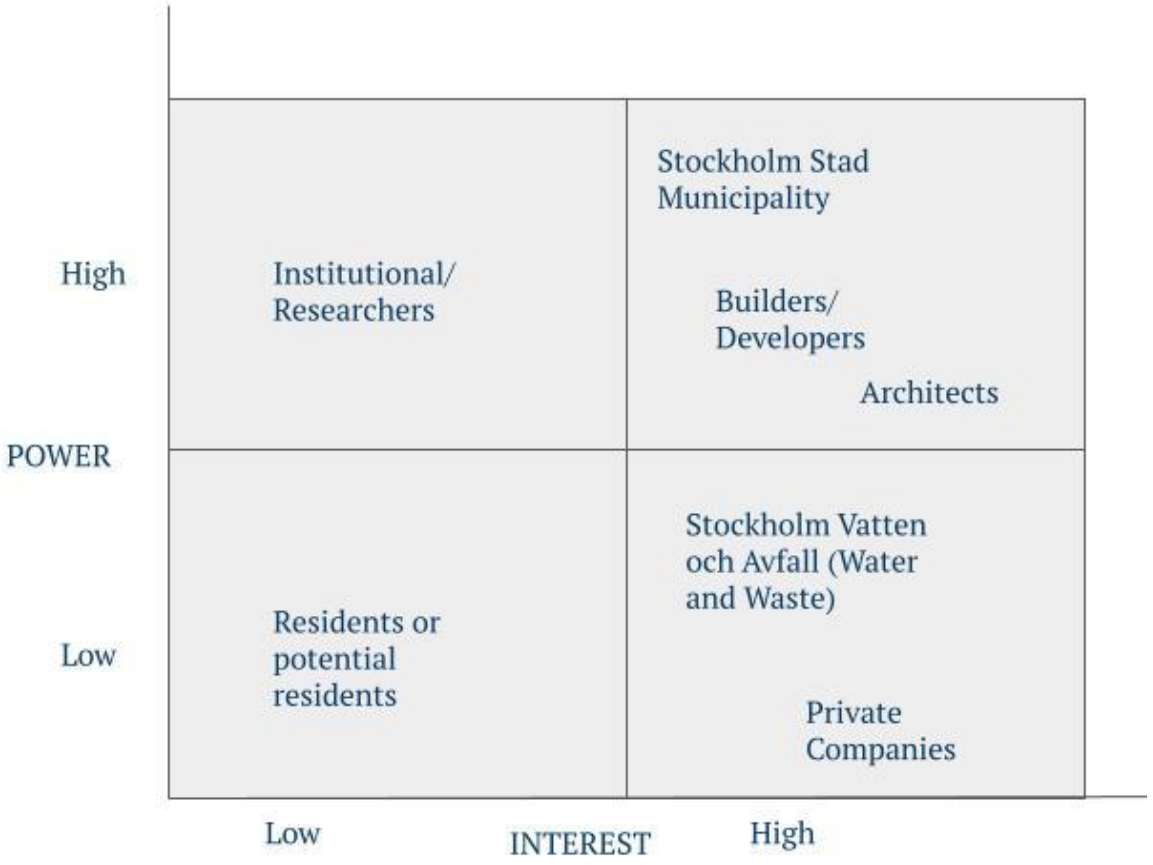

Figure 6.1: (a) Identification of primary stakeholders before the project was built, at the planning stage.

In the later stage which is also known as the post-implementation or operational stage, the stakeholder dynamics have completely changed and shifted (see figure 6.2). The municipality is only focussing on those areas that need to be constructed in the district. The responsibility of management is among the housing associations. The role of residents has become central during the post-implementation stage. ElectriCITY Innovation has the responsibility of fulfilling set goals, and benchmarks. The new private companies, especially in the energy sector have entered with the possibility of getting investment and doing innovations. The researchers and institutions collaborate with stakeholders to formulate testing and exploration.

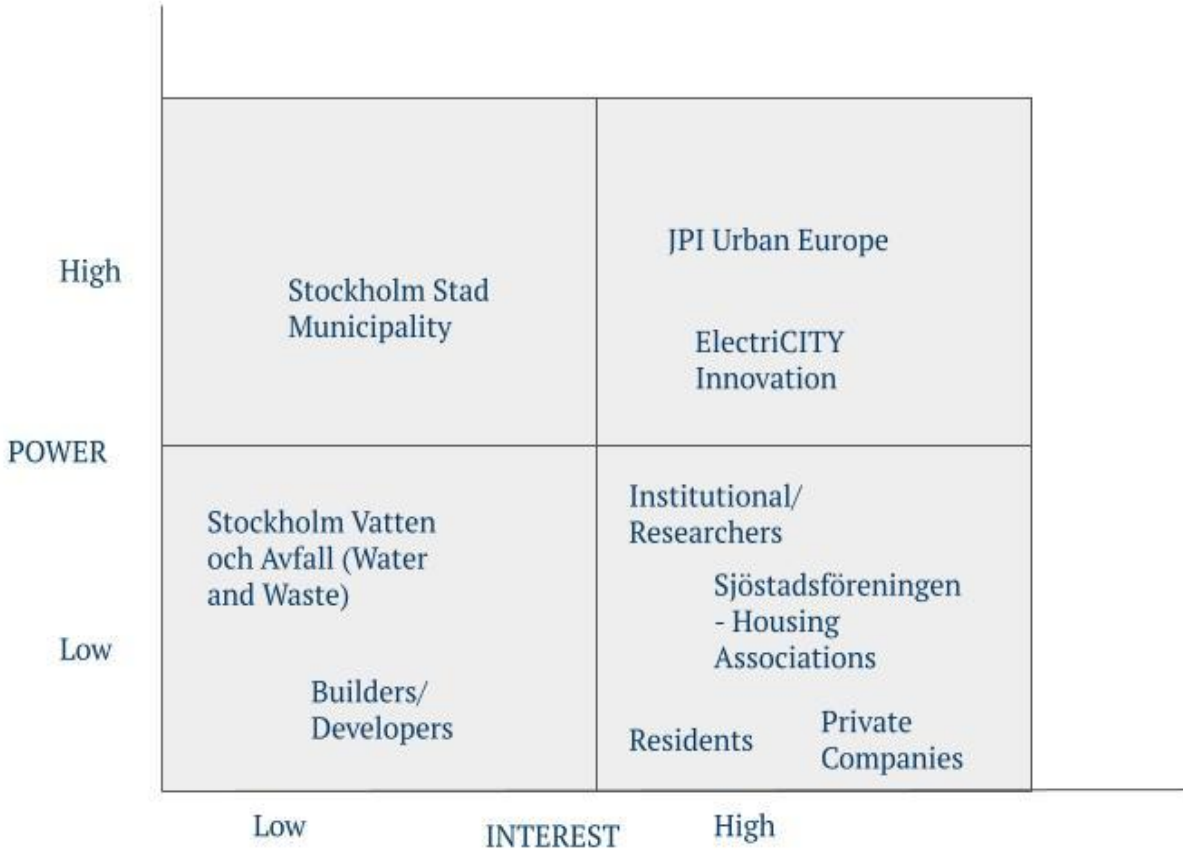

Figure 6.2 (b) identification of primary stakeholders post-implementation from analysis

The stakeholder dynamics change with the project stage, in this case, the district (See Figure 6). As a consequence, power interest shifts among the stakeholders. Different stakeholders come on board and exit depending on the stages of the district planning, construction, and operation. KPIs (environmental, social, economic, etc.) can be comprehensively used to ensure that the district is headed in the right direction in achieving the set goals - both during the pre-construction/planning stage and post-construction/operational phase.

The method of setting KPIs is an effective way to track vision, goals, and benchmarks, at the same time identify the gaps, communicate between stakeholders, and manage expectations from all stakeholders. Some recommendations for the program managers of PED are:

- Discuss specific handoffs of responsibility and data metrics (KPIs) and programs intended to benefit the primary beneficiaries.
- Discussing expectations with all stakeholders at the beginning or start.
- Designing programs that ramp up and down based on stages or urban development.
- Better allocation of time, effort and resources can be managed from different stakeholders at different stages of planning, construction, and operation.

6.2 Gaps and Recommendations

There is still more work to be done on the citizen-centric approach. There is apparently a disconnect between the residents' perception and the overall vision. Through narrative inquiry in this thesis, it was discovered that these goals need to reach more residents in a prominent way. The goals should be conveyed and discussed with the residents and also it is important to make sure they align with the needs of residents. Because if the goals are not aligned with citizens' interests, they will be difficult to implement. The case study has helped in identifying those gaps. The following are the gaps identified with the possible scope of implementing recommendations.

(1) Average cost of energy

Gap: Some residents were not aware of the cost savings options available to them because of sustainable buildings. Or if they adopted any changed practices, how was it going to affect their electricity bills? There is a need for establishing a direct connection between sustainability and energy savings.

Recommendation: New business models must be developed based on current building ownership practices, cost-sharing for building restoration and refurbishment, and current energy service costs to ensure that the costs of realizing PEDs are accessible to the majority of citizens. Also, consumers' interest in energy savings can be pandered by creating visible incentives, which are concretely related to significant savings. Alternatively, it can be acceptable if there are initial additional costs for those who are motivated to contribute to addressing global causes, with eventually a payback due to guaranteed recovery costs with time.

(2) Energy efficiency training

Gap: It was unclear as to what happens after the training on energy efficiency is given to the building managers. What did the residents take away from these training sessions, or to what extent were these training helpful for them? Through the narrative inquiry, it is realized that the residents in the area are active, aware, and engaged in the betterment of their district. They are looking for ways of involvement and need motivation. Is it important to see to what extent involvement programs cater to this aspect?

Recommendation: More communication with not just the building managers but also the building's inhabitants/residents will be a key factor for success. There should be a system in place to track how the training is transferred and translated to the residents, and consequently, the actual cost savings in terms of energy consumption. It is important to find answers to how the residents perceive the

effectiveness of the training and to ensure that the training is continuous because the residents frequently might move in/out of the district.

(3) Mobility

Gap: While cars are convenient to use, people expressed their desire for access to the metro because taking the tram is time-consuming. Also, the authorities encouraged the use of public transport but at the same time, there are easily available parking spots, often free of charge. The residents noted how the change of mode of transport from the tram to the metro to go to other parts of the city was tiresome for them.

Recommendation: People want to minimize their travel time, so the total time taken to travel is also an important factor for consideration. They want one public mode directly connecting to the city center that takes less time. Policies support public transport by providing easy parking for cars, thus promoting the use of private cars indirectly. Therefore it is important to align policies with KPIs. Residents wanted one public mode directly connecting to the city that takes less time.

(4) Affordability and accessibility

Gap: When it comes to societal sustainability, there are a lot of gaps, especially with affordability being the major one. There is a particular concern about affordability among single people. Also when it comes to accessibility there is a long queue or wait to get the apartments.

Recommendation: Some policies and programs can be launched in this direction to support housing needs. However, the district takes pride in increasing property prices citing that the value of the district has increased. This is contrary to the wants of residents.

(5) Citizen Participation and Behavior Change

Gap: Citizens expressed their desire to be involved more in the process. Surprisingly, living in a certain area did not seem to affect their behavior patterns or consumption patterns. Residents sort their waste which they do so living in any other districts.

Recommendation: Citizen communication has to be a continuous ongoing process. A lot more work needs to be done to reach a larger number of residents. In general, residents are aware and hold a lot of potential which needs to be tapped into. With the help of proper programs, they can be an asset. Right direction and continuous monitoring can be a way of achieving it.

(6) Aligning KPIs with policies

Gap: KPIs are a tool through which a citizen-centric approach can be strengthened and involve all stakeholders - from city officials to urban planners, area developers, and citizens. KPIs in urban planning is a medium to achieve the goals involving citizens. KPIs in the form of an assessment or feedback system and follow-ups can be used in urban planning.

Recommendation: KPIs can be a way to evaluate the performance of set policies. The progress towards sustainability goals can be lacking because of less effective policies and their shoddy management. If needed, the policy can be changed or altered to achieve the performance of intended goals.

For example, in some cases, if a building produces more energy, then the developer has to have its own energy company to transfer it to the national grid. The developer has to pay taxes on that. Therefore developers don't know what to do if the building produces more energy than it consumes. Henceforth, there is a need to look at policies and amend them for achieving better performance and think about the future implications. All the discussion is on making building positive but actually looking at the whole scenario, maybe building positive is not a profit-driven approach for developers.

(7) Follow-Ups on KPIs

Gap: From the semi-structured interviews, it was discovered that there is a lack of follow-ups on the goals. Other researchers [94] also mention that there was nothing specified in the environmental program of Hammarby Sjöstad (from the year 1996) on the outline of follow-ups for evaluating the goals and who should take the responsibility for the evaluation. There is clearly a communication gap in terms of meeting the expectations of the residents. There are no surveys or feedback collected on any topic or indicator from the residents by the authorities.

Recommendation: KPIs are required at both the planning/pre-construction phase and the post-construction/operational phase of the district. Often, before the project begins, the goals are set, mostly quantitative at the planning stage. Later, after the construction when residents have moved in, there is no tracking of goals or performance indicators. Therefore feedback is important to keep progress towards the goals. In addition, the KPIs play an important role post-construction to see the overall growth. The analysis of the performance of KPIs helps identify the gaps in knowledge, expectations, and course of actions. It is important to align and communicate goals between stakeholders including residents to lessen the gap.

(8) Role of urban planning in Positive Energy District

Urban planning combines technical with societal impact creating a socio-technical approach. Energy has social and spatial issues attached to it, and the people are the ultimate beneficiaries who use energy. Residents don't use the energy the way engineers want them to, expecting a certain amount of consumption and utilization from them.

Gap: It is thus challenging to govern and organize the people to use the energy systems effectively. *Most of the time the energy experts are thinking about energy, but they're not thinking about people. "Energy is a service for human beings, right?"*
About the urban district is those who are drawing these boundaries. Who's policing these boundaries? Do the residents even recognize where they live? - Quote E1
Recommendation: Urban planners can undertake the challenge of figuring out how people use energy, services, utilities, and transportation patterns and encourage them to use it differently. Urban planning takes into account urban development in the built environment and the people that inhabit it. While most residents perceive good environmental sustainability measured in place and were content with green spaces, some reported that there can be more provision for green spaces. Thus urban planning can work toward bringing a human-centric approach to the development of PEDs.

Table 6.1 The key takeaways of all the goals and recommendations are summarised below:

Concept	Gaps	Recommendations
Average cost of energy	Unaware of cost saving options	- New business models - Creating visible incentives
Energy efficiency training	Unclear follow ups on energy related trainings transferred to residents	More communication with building managers as well as residents
Mobility	Cars are convenient to use but people expressed their desire of better connections in public transportation	- Minimize travel time - Direct city connection - Easy parking promotes private cars - Align policies with KPIs
Affordability and accessibility	- Particular concern among single residents - Long queue or wait to get the apartments	- Need for policies, and programs to be launched to support the housing needs
Aligning policies with KPIs	KPIs are a tool through which citizen centric approaches can be strengthened - Involvement of all stakeholders necessary	KPIs can be a way to evaluate the performance of set goals and policies. - The progress of KPIs can be lacking due to less effective policies and management
Citizen participation and behavior change	- Citizens expressed their desire to be involved more in the process - Living in the area does not affect their consumption and behavior patterns	- Citizen communication has to be a continuous ongoing process - Need to reach more number of residents - Residents of HS are lot more aware about sustainability, they have potential that can be tapped by the stakeholders - Proper programs, right direction and continuous monitoring
Follow ups on KPIs	- Some previous goals lacked reference or baseline A lack of follow ups on the goals	KPIs are required at both planning/preconstruction phase and post-construction/operational phase of the district
Role of urban planning in PEDs	-Challenging to govern and organize people to use energy systems - To see if citizens needs are addressed	- Combine socio technical approaches - By planning PEDs with a human centric approach

6.3 Revisiting the Research Questions (with recommendations)

Here we revisit the original research questions proposed and attempt to answer based on the information collected and analyzed in this work.

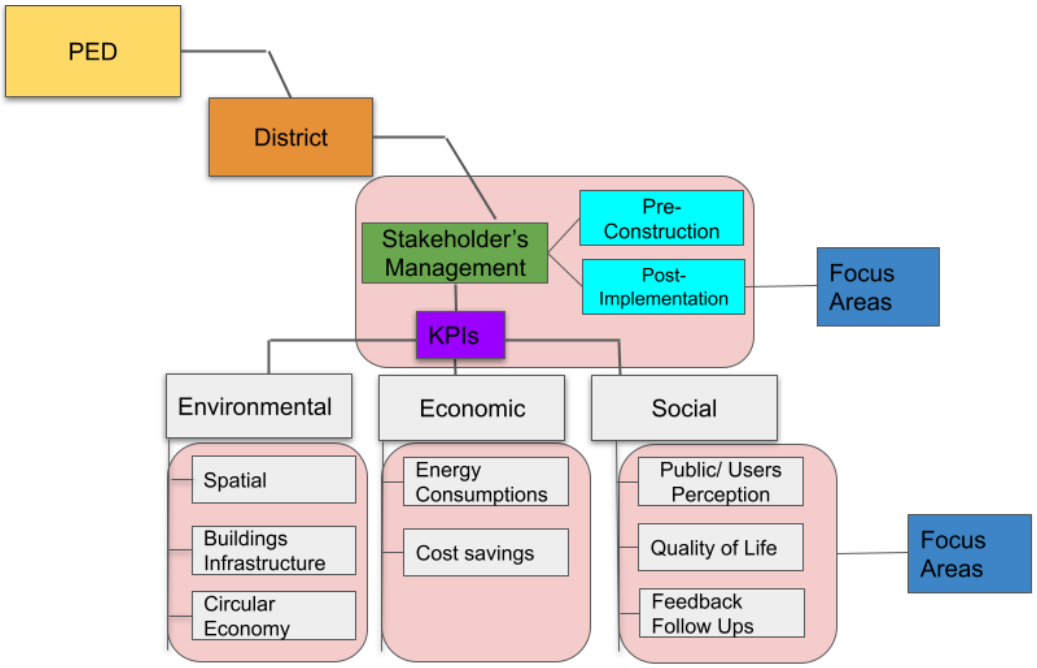

Figure 6.3 Summary of the focus areas in KPIs and stakeholder management.

Q.1 How do residents (compared to other stakeholders) perceive KPIs for Hammarby Sjöstad across different categories such as environmental, social, and economic dimensions?

The residents are the primary beneficiaries in the district. Their perception holds utmost importance because they can act as a reality check on the goals of the program and determine the performance of KPIs. The views of residents can be utilized for receiving effective feedback collection. For instance, the digital dashboards are a good scheme where data related to buildings is displayed. The PED program is well-intentioned and forward-thinking. However, residents cannot relate

to the data displayed in the form of figures because they don't have the context to understand the numbers. The gap between program goals/intentions and relatability with residents is highlighted here. Therefore it is important to verify that the programs launched by experts effectively reach the residents.

In addition to seeing the overall score of KPIs, it is important to verify the individual scores among all stakeholder groups. It might be that one group of stakeholders gives a low rating of a KPI, while another group for the same KPI gives a higher rating (potentially due to conflict of interest). By checking scores for each group of stakeholders, it is critical to measure if there are any gaps in the program's expected outcomes for different stakeholders. This will give a better picture of closing the gaps between those groups of stakeholders.

Living in the Hammarby Sjostad district doesn't affect residents' behavior or consumption patterns. It is a surprising discovery as residents claim their lifestyle is largely the same after moving in as were before moving in. Although residents in Hammarby Sjöstad are a lot more aware of sustainability with respect to environmental sustainability, most of the residents showed a willingness to do their part, even if the rest didn't care. They lack knowledge of what to do beyond since they only do whatever they know. When it comes to technical know-how, they lack training. In Hammarby Sjostad residents have a lot of potentials and come across as curious and cooperative. It's up to the authorities how they tap into residents' potential to achieve desired goals and results.

Q.2 How do other stakeholders (non-residents) perceive KPIs and how do they use them?

Public administration and private companies with the assistance of researchers are the main groups of stakeholders primarily that use KPIs. Researchers play a prominent role in defining KPIs. Public administration uses KPIs at the start of the project. Builders and developers follow these KPIs as guidelines along with private construction, architecture, and landscape consultancies. Developing infrastructure, spatial planning, public spaces, transportation planning, and water and waste management have benchmarks. Usually after the construction of districts, at this stage, the KPIs are forgotten. There is a lack of a system to track and update KPIs post-implementation or post-construction of the district. Livability, sustainability, mobility, and societal KPIs including resident involvement, and resident consumption patterns are some of the major KPIs in the operational stage. This research assists in analyzing these sets of KPIs that are important in reaching sustainable goals.

Collected data indicates that there is seemingly a communication and expectations gap between the actors/stakeholders. As highlighted above, hopefully, this research will help in identifying these gaps and filling them for better outcomes. Communication of residents with the rest of the stakeholders can be increased. For this, the communication of building managers to residents is critical to understand how it translates. Continuous training and follow-ups are necessary because residents can move in and move out from Hammarby Sjostad. New residents must be involved in the sustainability drive. Most of the residents have little clue about the programs and incentives that they can get with energy savings. Hence, continuous monitoring of the above factors can help achieve targets with an increase in citizen involvement.

Q. 3 How can KPIs be more comprehensively used to enable sustainable urban planning post-implementation in Hammarby Sjöstad?

One of the key findings of this work was understanding how KPIs differ with the project timeline (planning vs operational phase) and therefore, KPIs should evolve to reflect this change. It's critical to start with a set of fundamental indicators that all stakeholders agree on and can be developed year after year. KPIs can be mainly categorized into two stages namely the pre-construction/planning stage, and the post-construction/operational stage for effective tracking of goals. The goals should be traceable and measurable with a benchmark for all indicators. Even for qualitative KPI ratings, such as “as good as”, and “better than before”, the data can be converted to numeric format obtained from benchmarking, measurements, and follow-ups.

Post-implementation/operational phase is marked by a change of interests and stakeholders (see Figure 6). Different stakeholders exit and enter according to the power interest matrix. A major category of stakeholders is added at this stage - the residents of the neighborhood. This is the stakeholder group that’s most influential and impactful for the success of a PED and ultimately can help achieve the desired goals through their consumption and behavior patterns. Narrative inquiry, surveys, follow-ups, training, and citizen involvement become critical sets in KPIs post-implementation. Community building and establishing a regional circular economy are some ways to modify behaviors among residents.

6.4 Next steps

The city government of Stockholm initially pushed forward Hammarby Sjöstad as a sustainability project. The two-decade-long project is nearing its completion. The city of Stockholm now wants to share the responsibility of moving toward the PED status of Hammarby Sjostad with its residents and private stakeholders. However, there are major challenges in moving toward carbon neutrality goals, for example, the existing buildings are falling short of their energy efficiency goals.

The three main takeaways from this narrative study can be summarized below.

1. Lack of program awareness: One of the major findings of the study is that different stakeholder groups were not at the same level of awareness in regard to the objectives and benefits of the PED program. Follow-ups are a great way of measuring KPIs in urban planning projects.
2. Untapped creativity: There were interesting and creative suggestions that emerged from the discussion with respondent groups that can contribute to the success level of the PED program. For example, the suggestions from residents on improving mobility and energy dashboards can be implemented for an effective and sustained engagement of it
3. Need for an integrated approach: An integrated approach that can facilitate a common platform for all stakeholders of PEDs for effective awareness generation and participatory planning and program execution would help in taking due care of the concerns of residents, tapping the creativity and wisdom of beneficiary groups, develop a sense of belongingness and ownership, and would help in improving quality and sustainability of PED program. KPIs focused on a human-centric approach will be more effective in the success of a PED.

As discussed in the ZEN report [14] a project can include multiple stages of planning, briefing, and preparation, early design, detailed design, as-built, and operational phases, and not all the KPIs can be measured at all the stages. Hammarby Sjöstad, at the start of the project, had high sustainability goals. Some KPIs were identified as a means of achieving those goals. Hammarby Sjöstad 2.0 displayed a good example of accepting and releasing unmet goals. The goals were modified and revisited. Therefore setting KPI parameters can help in urban planning projects.

A combination of qualitative and quantitative KPIs is necessary for a successful project. Quantitative is about measurement because “what gets measured has a scope of getting improved”. Additionally, qualitative performance indicators have an equally important role to play because “it is about the perception, satisfaction, experience, and livability”. After all, the development is for the residents who are the primary beneficiaries in the district.

Balancing socio-economic and environmental goals also appears to reflect varied viewpoints on what role citizen engagement should play, according to Neilsen and coauthors [95]. While on one hand, municipal planners see participation as a democratic exercise, on the other hand, climate and emission stakeholders, as well as commercial developers, see it as a way to change people's behavior. They symbolize two sides of Arnstein's ladder: one that seeks to empower individuals by allowing them to develop their own visions, and the other that seeks to persuade or enlighten citizens in order to influence their behavior. As a result, Neilsen and coauthors recommended that city planners must be aware of these distinctions and understand the importance of socioeconomic goals and inclusivity in the building of sustainable neighborhoods.

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Appendix

Table 3.1: Urban planning goals and KPIs set for Hammarby Sjöstad PED during phase 1.0, taken from Jernberg et al., [20].

Guideline	Description	Quantitative benchmarks (if applicable)	Target level of benchmark	Hammarby quantitative level of benchmark	Notes
1. Urban Growth Boundary	Every city should establish one.	NA (Not applicable)	NA	Yes - Hammarby is built within the urban growth boundary of Stockholm.	Hammarby is an infill development that seeks to promote compact growth within existing city limits.
2. Transit-Oriented Development (TOD)	Emphasize development in TOD areas, which are defined as those within 500 m of a transit stop (or within 800 m of major transit stations, such as	% residents within TOD area	70% for big cities	100%	

	metro or Bus Rapid Transit).				
	Floor Area Ratio (FAR) of buildings in TOD area should be higher than overall district average.	Ratio of TOD FAR to overall district level FAR	2x	NA	The FAR ranges from 1.2-2.3 for the entire district of Hammarby, which is a TOD district.
3. Mixed-use	All residential units should be close to at least six kinds of amenities within a 500 m radius of building entrance.	% of residential units within 500 m of these amenities	100%	100%	
	Achieve a balance of employment and local residential population.	The job to resident ratio (the number of people employed divided by the number of residents)	Should be between 0.5 and 0.7	0.40 (expected in 2025)	20,400 residents currently and 11,000 jobs (27,500 residents at completion in year 2025)
4. Small Blocks	Blocks should be small to promote	Blocks size as measured by area equal to 2 ha and 70% of	70% of blocks ≤ 2 ha. (excluding	100%	Typical block sizes are 50x70 m and 70x100 m

	non-motorized transit.	blocks should comply with this standard.	industrial areas)		
5. Public Green Space	Well distributed access to green space.	% of residents within 500 m of publicly accessible green space	100%	100%	
	Sufficient quantity of green space/blue space.	% of land area devoted to publicly accessible green space/blue space.	20-40% in commercial areas and higher levels in residential areas	40%	19% of total area consists of public green space with varied parks, green spaces, quays, plazas and walkways. 40% of the area is green/blue areas such as courtyards, lakes, and recreation grounds. The Hammarby Lake occupies 25%

					of the blue space area. 25 sq.m. per person of free space. For all residents in Hammarby this implies an area of 650,000 sq.m. of public space.
6. Non-motorized Transit (NMT)	Promote NMT through well-developed pedestrian path networks.	Density of pedestrian paths (km in length/ sq.km. of district land area)	≥ 10	Yes	25.8 km/sq.km. Length of pedestrian path: 45.7 km
	Promote NMT through well-developed bike path networks.	Density of bike paths (km in length/ sq.km. of district land area)	≥ 10	Yes	10.5 km/sq.km. Length of pedestrian path: 18.6 km
7. Public Transit	Prioritize development near public transit.	% of new development within 500 m of transit	100%	100%	

8. Car Control	Put in place measures to cap car use. Limit parking where there is good transit.	NA	NA	Yes	Parking norm for the area was set to 0.55 cars per apartment unit and that was lower than the normal parking norm in the city (set at 1.0).
9. Green Buildings	Construct high quality, resource efficient buildings.	MOHURD green building standard	≥ 70% 1-star; 20% to 40% 2-star; 5% to 15% 3-star	NA in Sweden	Buildings are classified according by 4 classification systems: Environmental Building, Green Building, LEED, and BREEAM. The average energy use for buildings in Hammarby is 113 kWh/sq.m./year.

10. Renewable and District Energy	Every project should analyze the potential for district energy.	NA	NA	Yes	Hammarby boasts an impressive integrated district system. This includes district wide energy in the forms of heating, cooling, electricity, and biogas (for some 1000 household stoves).
	Look for opportunities to use local sources of renewable energy.	% of electricity from locally-generated renewable sources	5% to 15% for residential areas	Approximately 50.5%	
			2% to 5% for commercial areas	50% of energy is recovered from waste	
				0.5% rooftop solar used for heating supply not	

				district heating	
11. Waste Management	Classify waste for its best use. *	All buildings should have waste sorting facilities, enabling all waste to be sorted	100%	100%	In Hammarby, there are by Swedish definition no waste classification facilities. However, there are systems in place to allow for source separation of waste.
	Composite organic waste.	% of waste composted	30-50%	Food waste: 35% of total household waste by weight 50% of waste is separated and about 90% of the separated food waste is converted into biogas	Most organic solid waste used as an energy source. None is composted.

	Resource efficiency.	% of waste recycled or reused	35-50%	33% material recycling 50% used for energy	Overall picture of waste usage: 0.7% Landfill 1% Hazardous waste 33% Material recycling 16% Biological treatment** 50% Energy recovery
12. Water Efficiency	Avoid water waste.	% of water use subject to metering	100%	100%	
	Conserve fresh water on supply side	% of water used should be from rainwater or recycled wastewater	20-30%		Storm water from roof tops and non-street surfaces is collected separately from storm water that falls on the streets. Non-street storm water is led through open water

ways in the area into the surrounding lake water system. Street storm water is purified before being channeled into the freshwater system.

* In a Swedish context this would be referred to as source separation of waste to enable best treatment.

** Waste goes to biological treatment which utilizes its component nutrients for plant cultivation and also utilizes its energy content (GlashusEtt, 2007).

Kritika Singh

Towards a Positive Energy District

NTNU
Norwegian University of
Science and Technology