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Green Public Procurement in Mission-Orientated Innovation Systems: Leveraging Voluntary Standards to Improve Sustainability Performance of Municipalities

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Abstract: Mission-oriented approaches such as green public procurement (GPP) are emerging as popular solutions for governments to tackle contemporary sustainability challenges. Voluntary standards are instruments that can be used in GPP to drive innovation toward sustainability goals. However, there exists a lack of understanding of how to theoretically situate and practically execute GPP and voluntary standards within missions-oriented innovation systems (MIS). To address this research gap, this paper investigates how voluntary standards can be used to help formulate and achieve missions for sustainable urban development (SUD) at the municipal level, followed by what role green public procurement can play in this process. To do so, it establishes a first theoretical synthesis of GPP and MIS. Next, focusing on the Municipality of Amsterdam, it conducts an empirical investigation of 95 SUD projects, of which 55 were public tender projects (in which the municipality is the landowner) and 40 were non-public tender projects (in which a private entity is the landowner), supplemented by stakeholder interviews. Based on this, it (1) conceptualizes six sustainability ambitions as missions and examines each for their formulation in terms of targets and associated standards (problem-solution diagnosis), and (2) it maps the various actors engaged in the process of implementing these missions through SUD projects, defining their positions and interrelations within the MIS at the municipal level (structural analysis). Conclusions and reflections are made regarding the relationship between changing standards and regulations over time, the potential for GPP to increase progress toward missions via use of voluntary standards in public tenders. Until programmatic approaches to measuring progress toward missions are fully implemented, the presence of voluntary standards is suggested as a potential metric.

Keywords: green public procurement; sustainable public procurement; mission-oriented innovation systems; green; ecolabels; voluntary standards; emissions; environmental; implementation

1. Introduction

Mission-oriented approaches are emerging as popular solutions to contemporary sustainability challenges, as seen in the United Nations Sustainable Development Goals (SDGs) [1] and the Horizon Europe R&D program of the European Commission [2,3]. As a contemporary framing of science, technology, and innovation policy, mission-oriented innovation policies (MIPs) such as these call for transformational change to sociotechnical systems [4]. Missions are challenge-based, urgent, and strategic goals [5]; rather than having a static focus on technological innovation, missions are emergent and evolutionary in nature [6], supporting experimentation and promoting stakeholder alignment and cooperation toward common goals. The challenges they tackle are complex, consisting of multiple stakeholders and requiring insights from many perspectives [7]. Governmental bodies are increasingly engaged in the use of missions to take societal challenges, like promoting a more sustainable society [8].

The Council of the European Union emphasizes “the crucial role that public procurement can play in the proper implementation” of the SDGs, and the “incorporation of these
goals to serve the public interest” [9]. One instrument that public contracting authorities can use to achieve such environmental missions is green public procurement (GPP), as purchasing that reduces environmental impacts across product or service life cycles [10]. As an innovation procurement mechanism, GPP is a tool that supports the uptake of eco-innovations by markets [11] and can be conceptualized as mission-oriented innovation policy (MIP) [12] and thereby offers a mission-oriented approach to furthering sustainable development progress. GPP stimulates the development, commercialization, and market penetration of products and services with the best environmental performance [10]. A core mechanism by which it does so is via the incorporation of voluntary standards and eco-labels into public calls for tenders, creating competition between potential suppliers that rewards those with the most sustainable products, services, or works. Voluntary standards (often referred to simply as “standards”) are documents that specify what (if any) is required by regulation [13] created through a process of standardization: the voluntary development of “technical specifications based on consensus amongst the interested parties”, Ref. [14] including industry, interest groups, and public authorities. Standardization can occur for de jure standards via different methods such as (1) via consensus processes at standards development organizations (SDOs) like ISO and its national member bodies (e.g., Stichting Koninklijk Nederlands Normalisatie Instituut [NEN] in the Netherlands and Deutsches Institut für Normung [DIN] in Germany), or (2) more closed or proprietary processes by various industry associations [15]. In comparison, de facto standards can be created by public procurers via specification in tender documentation [10]—this will be explored later in more depth, as it is the use of either de facto or de jure voluntary standards in GPP tender projects that can contribute toward achieving missions, as compared to non-tender projects where the relevant public authority does not have the authority to set requirements beyond those specified by regulation.

The European Commission encourages GPP, including through the availability of guidance for considering sustainability standards in public tenders. A variety of types of voluntary standards and eco-labels may be used in public procurement provided that they are “clear and ambitious” [16], based on “scientific information using a procedure in which stakeholders, such as government bodies, consumers, manufacturers, distributors and environmental organizations can participate” [17]. This paper considers GPP as being relevant to all types of innovation activities within an MIS, and therefore considers all types of voluntary standards used for their relation to furthering missions by their application in GPP tenders. Particularly for local contracting authorities, the close proximity between buyers, suppliers, and end users [18] can provide complementarities for mission-oriented approaches to achieve sustainability goals through the use of GPP. With over half of the world’s population located in urban centers, cities are a major contributor to greenhouse gas (GHG) emissions, while also having high potential to implement sociotechnical solutions to climate change mitigation and adaptation [19]. Municipalities could thereby benefit greatly from practicing mission-oriented GPP for sustainable urban development (SUD), where sustainability missions can be achieved through the incorporation of voluntary standards in public tenders [20,21] for public goods, services, and works. Currently, the European Commission is in the final stage of gathering stakeholder feedback on draft guidance for the public procurement of sustainable infrastructure, including co-creation of new solutions and recommendations [22]. This underscores the contemporary and international importance of the investigation of this paper.

However, methods for mission-oriented approaches for empirical study, and particularly in the investigation of public procurement projects, are still in their nascency. Progress toward achieving missions is currently limited by the lack of methods by which to systematically incorporate green criteria within SUD projects, at both the project and the program level, as well as across different municipalities. As applied to GPP, this can leave procurers and project managers without the necessary tools by which to translate high-level missions into sustainability aspirations within the procurement process and engage stakeholders in achieving these goals. In turn, practitioners can miss opportunities
to set the right demand to the market and to leverage the purchasing power of public procurement to its full potential. Theoretical understanding of these mechanisms is also limited, despite the practical implementation of missions across many policy domains. Of course, environmental policy approaches to public procurement and to greening private industry are nothing new—the Commission of the European Communities noted almost 30 years ago that “Member States (and their public authorities) have, increasingly, started to integrate environmental considerations into their public procurement practices” [23]. For example, the many European countries had implemented environmental management systems (EMS), and programs and methodologies to identify opportunities for improving emissions efficiency such Pollution Prevention Pays (PPP) in the Netherlands [24]. In a longitudinal review of GPP literature, Cheng et al. [25] found that the majority investigated GPP impacts, rather than any internal mechanisms of the procedure, and highlights the need for further research into the role of standards in GPP its innovation “spillovers”. The current analysis extends upon recognition of the importance of private-sector innovation, voluntary standards, and effective regulation by focusing on public procurement strategies, which include these elements—and, critically, multiple (types of) stakeholders—in mission-oriented approaches toward sustainability goals. Therefore, this paper poses the following research question:

“How can voluntary standards be used to help formulate and achieve missions for sustainable urban development at the municipal level?”

Narrowing in on any special potential for GPP in particular, this paper also poses the following sub-question:

“What role can green public procurement play in this process?”

This paper conducts an empirical investigation into the formulation of complementary missions toward SUD, and the implementation of these missions in SUD projects at the municipal level. In answering the research question, this paper presents a first theoretical synthesis of GPP and MIS, examining the deployment of voluntary standards in GPP by public contracting authorities to achieve sustainability ambitions. This comprises Section 2: Theoretical Framework. Next, in Section 3: Materials and Methods, a methodological approach is developed based upon this theoretical underpinning and empirically applied to a number of mission-oriented SUD projects within the Municipality of Amsterdam. The three main foci—problem-solution diagnosis, structural analysis, and voluntary standards and regulation—are present in the context of the case study.

Section 4: Results presents the results of these foci for the case study, breaking down the structural analysis into the resulting a) MIS and 2) the GPP process for SUD. Focusing on the Municipality of Amsterdam, the paper conceptualizes six sustainability ambitions as missions and examines each for their formulation in terms of targets and associated standards. Next, it maps the various actors engaged in the process of implementing these sustainability ambitions through SUD projects, defining their positions and interrelations within the MIS. Finally, it investigates the implementation of the sustainability ambitions themselves within 95 SUD projects, based on the presence of voluntary standards used to define the missions. A discussion of these findings is presented in Section 5: Discussion. Finally, in Section 6: Conclusions, reflections are made regarding the relationship between changing standards and regulations over time, and the potential for GPP as a mechanism by which to increase progress toward missions via competition induced by the use of voluntary standards in public tenders. Until programmatic approaches to measuring progress toward missions are fully implemented, the presence of voluntary standards is suggested as a potential metric.

2. Theoretical Framework

2.1. Missions and Innovation Systems

Mission-oriented innovation systems (MIS) are a recent approach to provide an analytical framework to analyze mission-oriented innovation policy (MIP). The MIS approach
may be conceptualized as a merging of innovation system theory and MIP. Hekkert et al. [5] defined MIS as a “temporary innovation system in which policymakers and other actors aim to coordinate innovation activities, with the objective of developing a coherent set of technological, institutional and behavioural solutions” [5]. Hence, MIS focuses on the innovation system surrounding goals that are set to complete a societal mission, or, in other words, the innovation system that becomes established via an MIP. MIS differs from other innovation system theories by focusing on the system around a problem rather than on that behind technological innovations, as does the technological innovation system (TIS). In addition, the boundaries of an MIS are set based on the societal challenge it tries to tackle, instead of the regional or national boundaries (RIS or NIS). Such systems perspectives for analyzing innovation processes also support demand-side innovation policies, facilitating analyses of interdependencies and interactive learning inherent to innovation procurement [26], of which GPP is a subtype.

Ideally, “missions” give a sense of both urgency and meaning’ while expressing values that citizens care for [5]. As discrete locales where practical change can be implemented toward grand challenges such as climate change, municipalities have close proximity between buyers, firms, and users which facilitates knowledge exchange toward the public procurement of innovative goods and services [18]. Uyarra et al. [27] refer to this knowledge exchange in the local ecosystem as “conversations” [27] in support of innovation procurement, as facilitated particularly by their close physical proximity. Intermediary roles to facilitate such knowledge exchange between buyers and suppliers can take the form of facilitating, networking, and brokering, as identified in the challenge-driven Startup-in-Residence (SiR) program of the Municipality of Amsterdam [28].

Central to innovation systems approaches such as MIS is the role of stakeholders in furthering the system as a whole through their various interactions that drive it. For the purposes of this paper, the definition of stakeholders by Freeman [29] is adopted, as a “... group or individual who can affect or is affected by the achievement of the organization’s objectives”. Recent analyses using stakeholder theory in GPP have subcategorized these into internal stakeholders and external stakeholders [30], with the former including the GPP project team and administration, and the latter including local government and the public. Focusing particularly on the role of external stakeholders in driving GPP practices, Lui et al. [30] used stakeholder theory to examine 142 local public sectors in China, finding that administrative stakeholders within the public sector can mediate effects of knowledge of GPP implementation policies and benefits. Investigating instead a wider variety of stakeholders, Rainville [31] examined the interactions of stakeholders across the procurement planning phase of a pilot project in the Netherlands, finding that stakeholder alignment is critical to a GPP project’s success and can be facilitated via intermediary stakeholders with various types of project-relevant skills.

2.2. Voluntary Standards in Green Public Procurement

The use of voluntary standards and eco-labels to support the procurement of sustainable solutions in GPP are means by which sustainability missions can be incorporated in practice. In addition, a demand-side innovation mechanism, the process of standardization establishes criteria beyond that which is required by law (if any), where the particular process contributes to the resulting standards’ legitimacy and credibility. Similar to missions and GPP, it engages multiple stakeholders, including firms and technical experts, toward increased levels of performance (more relevant to when the state of the art for a particular area of focus is at late-stage R&D, or once the product or service has been commercialized onto the market).

The voluntary standards resulting from standardization can be of many different types, often with a direct connection to the degree of technological and market maturity of a product or service being standardized (or the R&D process leading up to it). For example, standards for measurement, testing, and architecture can help guide the R&D process such as in a pre-commercial procurement (PCP) for more radical innovation [10].
For more incremental innovation such as through the public procurement of innovative solutions (PPI), variety-reducing standards can be used to limit horizontal product differentiation [32], whereas quality standards assist in requesting a minimum performance or desired functionality [10]. In comparison, and most relevant to off-the-shelf products or services and their diffusion effects on innovation, eco-labels are based upon information standards or product description standards [33] and convey information about a product or service to the consumer regarding environmental attributes [10]. Eco-labels can also be requested by procurers for suppliers to communicate quality attributes.

Not only the type of voluntary standard, but also how it is used, will influence the innovation and sustainability impacts of GPP. In tenders, including those for SUD projects, voluntary standards can be used in a number of locations and manners [34,35]. Methods for designing reward systems within the tender itself to facilitate sustainability performance in accordance to the voluntary standards include (1) requiring a technical standard within technical specifications that mandates adherence to the standard for the proposed solutions to be eligible, such as those specified in a municipal sewer plan, and (2) awarding points within the award criteria based on performance of the proposed solution to a particular standard, which could be made to be either mandatory or voluntary and the points system adjusted accordingly, such as efficiency specifications of the Nearly Zero-Emission Building (NZEB) standard. Additionally, incorporating voluntary standards into (3) contract clauses, such as sustainability performance standards for increasing emissions efficiency, is also becoming a more popular choice to share risks and benefits between procurers and suppliers over the course of what is usually a multi-year contract. Depending on the public procurement procedure used (open, closed, competitive procedure with/without negotiation, etc.), standards can also be used to define (4) increasingly strict selection criteria for groups of candidates between phases, such as pre-selection being on the basis of 35% “sustainability”, and the final selecting on the basis of 45%, with sustainability being clearly defined by specifications. Taken together, the set of voluntary standards used should orient the tender toward achieving the sustainability missions relevant to the contracting authority.

Management literature on the topic, focusing instead on influence of and on the supply-side with public procurement, has investigated the uptake of voluntary standards in connection with public tenders. Such investigation can be used to study both direct and “ripple” effects of GPP and innovation procurement, including wider market impacts and changes. For example, Blind, Polisch, and Rainville [36] found that firms engaging in standardization at SDOs, as well as those that undertook innovation activities, may have a competitive advantage in submitting tenders in the case of Germany, where, notably, construction has the highest procurement expenditure at 22.4% of all procurement expenditure. Similarly, and focusing particularly on GPP, Ma et al. [37] found a positive association between the uptake of environmental management system standard ISO14001, China environmental labeling and China Quality Certification Center (CQC) ecolabeling certification. Important findings of these micro-level analyses highlight factors that help contribute to company success in winning GPP tenders—and, more widely, being successful in markets affected by GPP. These include the role of upper management support in responding effectively to market pressure created by GPP [37] and engagement in strategic alliances including standardization [36].

2.3. Voluntary Standards in Missions

Voluntary standards can also be used to define missions, providing goals, potential solutions, or units of measurement, depending on the formulation of the mission and the particular (type of) standard used. Particularly for missions of public contracting authorities, with their close connection to citizens, voluntary standards developed via consensus processes—such as at standards development organizations (SDOs) may be most appropriate, as they convey instilled legitimacy via the science-based, multistakeholder process called for in the EU Procurement Directive [17]. One example of a standard used in MIP is the Leadership in Energy and Environmental Design (LEED) standard of the US
Green Building Council, which is comprised of a crediting system covering carbon, energy, water, waste, transportation, materials, health, and indoor environmental quality [38]. The use of the LEED standard in GPP, driven by “government green procurement policies”, led to greater uptake by private-sector developers and with a geographical clustering effect speaking to the local effects [20].

2.4. Local Green Public Procurement

In municipalities there can be close proximity between buyers, firms, and users that facilitates knowledge exchange toward the public procurement of innovative goods and services [18]. In contrast with regional or central contracting authorities, municipalities may tend to practice more direct procurement and engage with users [18]. While their size and potential lack of procurement expertise may hinder them in the procurement of innovation [18], they may be able to move with more agility than their larger counterparts, benefiting also from the information they can gather from local connections to inform more sustainable or innovative purchases (2017). This creates opportunities for intermediaries to facilitate knowledge exchange, such as studied by van Winden and Carvalho [28] in the Startup-in-Residence (SiR) program of the municipality of Amsterdam [28]. These interactions are central in the formulation of and progress toward missions. Policies and guidance for innovation procurement, such as in the most recent European Commission Guidance on Innovation Procurement [39], acknowledge the importance of such process-oriented procurement instruments in supporting inclusive and effective procurement planning. Methods for facilitating increased stakeholder engagement, such as user needs assessment and market consultation, are being captured based on best practice, refined, and propagated through European projects under the Horizon 2020 funding program, including eafip (European assistance for innovation procurement) and Procure2Innovate.

Conduct of GPP by municipalities can utilize this ease-of-interaction to stimulate the development, commercialization, and market penetration of sustainable products and services [10]. In this way, GPP serves as a demand-side mechanism in functionally specifying user needs and communicating them to the market to spur the development, commercialization, and/or diffusion of solutions to meet those needs [31], rather than via the conventional technology-push of demand-side innovation. Creating openness in procurement, such as through functional specification with ambitious performance requirements can lead to innovative solutions. This is in comparison with purely technological specification or “overspecification”. Functional specification is an output-oriented measure that coincides well with a mission-orientation approach. This enables the identification of process innovation in public procurement.

Incorporating voluntary standards alongside this functional specification is important to orient any innovative solutions for compatibility with existing infrastructure, surrounding knowledge, compliance and testing requirements, etc. [10].

3. Materials and Methods

3.1. Case Study—Missions of Amsterdam

The mission-oriented approach can offer a valuable contribution to achieve the desired mission of the Municipality of Amsterdam as it captures the need for transformative policy and includes a wide range of stakeholders [5]. As the unit of analysis for this paper, the Municipality of Amsterdam is a sustainability leader among Dutch cities, with actions in line with the Paris Agreement goals. With population growth and limited opportunities of outward development, there is increasing pressure on housing, public space, the road network, and public transport within the metropole. Climate change brings along an extra dimension to this challenge, making the municipality also responsible for climate change adaptation and environmental impact. To this end, the municipality pursues the challenge-based societal mission to build a city that will last for generations and that is developed sustainably—in other words, the mission to transition to SUD.
The overarching mission is translated into six missions, as ambitions or goals to guide practical implementation [40]. For the current analysis, the fifth and sixth themes are combined, five missions for assessment. Sustainability ambitions, as missions, are defined to set targets of various forms which the municipality aims to reach. These missions are often delimited by a certain time period and presented in measurable units, which are either quantifiable or quantifiable. A number of them include baselines for measurement, and some contain references to public policy. In a sense, the formation of the missions in this manner establishes broad de facto standards on behalf of the municipality as guidance for SUD projects. The missions are outlined as follows:

- **Sustainable energy and a natural gas free city**—Reduce CO\(_2\) emissions in 2050 by 90% of 1990 levels [41], in large part by stopping the use of natural gas by 2040 [42]. Measures include SUD for new buildings that use sustainable energy sources.

- **Cleaner air through emission-free mobility**—Increase air quality by reducing pollution from sources including mobility. Measures include environmental zones that prohibit the most polluting vehicles in the city, stimulating electric vehicles by increasing the number of charging points, and focusing on shared vehicles and making cycling and walking more attractive.

- **Climate adaptation**—Ensure that SUD projects are climate adaptive in response to and anticipation of weather trends such as heavier rainfall and longer droughts. Measures include giving more space to green nature areas, stimulating green or blue-green roofs and applying solutions for water storage.

- **Greening urban spaces and building nature-inclusive**—Support biodiversity, leisure and sports, promote natural cooling, and increase resilience to heavy rainfall through the use of green areas. Measures include improving and maximizing city nature in each SUD project.

- **Circular construction and waste and raw materials**—The Council of Amsterdam’s Strategie Circulair exceeds goals set in national missions, aiming to reduce the use of raw materials to 50% by 2030 and 100% by 2050, when all raw materials have to be reused [43]. Measures include focusing flexibility and modularity of building (materials), and the use of recycled materials. These fifth and sixth themes are related because if waste is reused through circular construction, fewer raw materials are needed. Therefore, these themes are combined.

### 3.2. Data and Methodological Approaches

A methodological approach is developed based upon this theoretical underpinning and empirically applied to a number of mission-oriented SUD projects, as a case study within the Municipality of Amsterdam. In lieu of any published guidance for the MIS approach, the method conducted here coincides with the first two steps of a conventional TIS analysis, namely, problem-solution diagnosis and structural analysis.

#### 3.2.1. Problem-Solution Diagnosis

First, problem-solution diagnosis is used to identify the missions themselves, with the research objective of defining the status quo by exploring what challenges need to be overcome, and what possible solutions exist by which to do so. Here, 95 projects were analyzed regarding their sustainability performance, of which 55 were public tender projects (in which the municipality is the landowner) and 40 were non-public tender projects (in which a private entity is the landowner; referred to by the municipality as transformation projects). Those SUD projects that result in a public call-for-tender can be conceived as GPP projects and therefore used to study the mechanisms of GPP in practice.

Available documentation from the most recent PLABERUM phase per project was analyzed since these contained the most recent agreements and updates on which and how sustainability targets were reached. Documents were collected manually, through direct request of involved personnel within the municipality. Depending on the PLABERUM phase a project was in, one or several documents were made available by the Sustainable
District Development (Duurzame Gebiedsontwikkeling; DGO) team to the researchers. These documents included preliminary documents from the municipality as framework for tender or non-tender projects (principal directives, project directives, investment directives, urban plans, and plot passports) and documents delivered by the developing party as part of their tender (building reports, sustainability reports, energy performance coefficient (Energieprestatiecoëfficiënt, EPC) reports, preliminary project designs, and definitive project designs). A list of indicators was developed together with the municipality and used to investigate the documents, resulting in concretization of six missions relevant to SUD at the municipality, including their goals and usage of any relevant voluntary standards or solutions, including in comparison to regulations (as previously noted, these six missions were reduced to five by combining those on circular economy and waste management). These indicators consisted of relevant variables per each mission (and sub-mission, where relevant), and methods for valuing these factors. The list of types of indicators identified per theme is presented in Table A2, Appendix A.2. These indicators also include particular voluntary standards (specifications, Table A2), which were used to identify whether and to what extend the projects examined had incorporated factors relevant to each of the missions examined. Finally, it is important to note that despite long project durations intrinsic to SUD, progress often happens quickly and, as a result, the analysis of this papers reflects one snapshot in time.

3.2.2. Structural Analysis

Next, structural analysis is used to determine composition of the MIS, mapping the network, stakeholders, institutions, and materiality. From the 95 projects that were analyzed in the first step, 36 cases were selected that were in the last phase of the PLABERUM process and where documents from all phases of the PLABERUM process were available. Five cases were chosen for further in-depth investigation—one from each district, namely North, East, Southeast, South and Centrum, and West and New-West (DGO, 2021). In total, 20 relevant stakeholders within the five cases were interviewed through semi-structured interviews. This began with two experts—an Urban Advisor and the Coordinator Sustainability and Sustainable Urban Development—who were interviewed about the general structure of the system around SUD projects. After each interview, the snowballing sampling method was deployed to identify other most-relevant stakeholders of the project, which led to 18 additional stakeholder interviews, comprised of the eight different types of stakeholders shown in Table 1 below. While the DGO of each of the five districts was interviewed, other stakeholder types were identified based on their relevance to that particular project.

Table 1. Overview of the stakeholders that were interviewed per district. The stakeholders that were interviewed were deemed most relevant in that specific project. Green cells show for which type of stakeholder was interviewed for each district.

| Stakeholder Type                        | East     | North | South | Southeast | West |
|-----------------------------------------|----------|-------|-------|------------|------|
| Sustainable District Development (Duurzame Gebiedsontwikkeling; DGO) | | | | | |
| Urban Planner (Stedenbouwkundige, SBK) | | | | | |
| Environmental Agency (Omgevingsdienst Noordzeekanaal gebied, ODNZKG) | | | | | |
| Land and Development Department (Afdeling Grond & Ontwikkeling, G&O) | | | | | |
| Project Manager (PM)                    | 2x **    |       |       |            |      |
| Engineering Department (Ingenieursbureau, IB) | | | | | |
| Leaseholder (land and/or building)       |          |   CPO * leader | Corporati Developer | |
| Architect                               |          |       |       |            |      |

* “Collectief Particulier Opdrachtgeverschap” (Collective Private Commissioning). ** Two project managers in the East district were interviewed.
The interview questionnaire was drafted, starting from a theoretical basis and together with assistance from the experts Urban Advisor and the Coordinator Sustainability and Sustainable Urban Development, and is available upon request because of its length. As an example, questions on structural components of the MIS included the following:

1. Who are the stakeholders? (A stakeholder is any group or individual who can affect or is affected by the achievement of the sustainability ambitions of the Municipality of Amsterdam for SUD.)
2. Which stakeholders are directly involved and actively engaged in the exploration phase of the PLABERUM process of SUD projects?
3. Which stakeholders are the most interdependent and how?
4. How do politics influence the development of SUD projects?
5. Which regulations have the most impact on the dynamics between the stakeholders?
6. Are there differences between the PLABERUM phases?
7. What do you expect to be barriers for achieving the sustainability ambitions of the Municipality of Amsterdam?
8. What factors or actors allow them to obtain the best sustainable results and what factors or actors constrain them and why?

Questions on achieving sustainability in SUD included:

9. How did you experience the implementation of the sustainability ambitions throughout the PLABERUM phases?
10. What directly hinders you from incorporating sustainability solutions in urban development?
11. In which PLABERUM phase did this barrier come up?
12. What are drivers when incorporating sustainability solutions in urban development?
13. In which PLABERUM phase did this driver come up?
14. What can the municipality do to stimulate the uptake of the sustainability ambitions in SUD projects?
15. What do you think about the standardizing the process of the development and application of the sustainability criteria?

In analyzing the interviews, first-order codes were derived from a number of diagnostic questions from TIS literature, with secondary codes emerging during the open coding process, resulting in 121 unique codes. Each interview was coded by a single researcher, and new codes were added to a shared document for cross-referencing. Axial coding was subsequently carried out using a merging of all the coded transcripts, allowing for the identification of relationships among the open codes and providing a conceptual overview. Next, the core variables were named and relating codes were identified via selective coding. Data was triangulated by five research personnel to uphold the validity of the work. During the open coding process, each interview was coded by at least two researchers to increase the validity of the coded results [44]. Cases were selected to represent each of the five geographical area within the city over which the DGO operates, thereby increasing the representativeness of results of the Municipality of Amsterdam, although generalizability of findings to other urban centers should be done with care.

3.2.3. Voluntary Standards and Regulations

Finally, voluntary standards and regulations are discussed in their own section, as they are developed via the interactions of stakeholders within the MIS structure (Section 4.2) and are oriented toward or comprise the missions set in the problem-solution diagnosis (Section 4.1).

4. Results

The first step, problem-solution diagnosis, showed that SUD projects perform relatively well in relation to the sustainability themes. In almost all PLABERUM documents, sustainability is an integrated theme. Quantification of this performance would have been valuable for future monitoring of SUD projects. However, due to a high variety in project
types, context and many different indicators per sustainability theme, it is too complicated to quantify the results. The second step, structural analysis, resulted in an overview of the MIS, including the materiality, institutions, stakeholders, and network. In addition, the stakeholders were mapped in a power-interest matrix to visualize which stakeholders are important in SUD projects.

4.1. Problem-Solution Diagnosis

For each of the six missions, a different set of solutions was implemented, consisting of a mix of regulations, voluntary standards, and innovative solutions. The current study applies MIS to determine the performance of the current SUD projects of the municipality with respect to their sustainability ambitions, and how to influence the incorporation of the sustainability ambitions in the transition toward SUD.

The first theme is sustainable energy. To tackle this problem, the Municipality of Amsterdam wants to build new projects natural-gas-free and invest in renewable resources. The main solutions implemented in this category are measured by the EPC and the Nearly Energy-Neutral Buildings (Bijna Energieneutrale Gebouwen, BENG). The EPC is an index of the energy efficiency of new buildings, which has been made stricter since 1990 up to a score of 0.4 in 2015. This means that the buildings have to use 40% of the energy that was used in 1990. In 2021, the EPC was replaced by the BENG. The BENG is determined by three different requirements [45], which are all expected to be above/below a certain value. The first requirement is the maximum demand of energy per m$^2$ floorspace per year, with a maximum of 50 kWh, which is calculated by the sum of heating and cooling. This can be reduced by optimizing the building through, for example, improving its thermal shell. The second requirement is the primary fossil fuel use per m$^2$ floorspace per year with a maximum of 20 kWh. Energy generated through renewable sources can be subtracted from the total sum. For example, energy systems as STES, city heat, or data heat reduce this. The third requirement is the minimum share of renewable energy in percentages, with a minimum of 70%, which includes the use of solar panels, wind energy, or hydroelectric power.

The second theme is cleaner air through emission-free mobility. A different range of pollutants from emissions cause severe and numerous health issues in cities all over the world [46]. Within Amsterdam the air quality is, on certain aspects, below the European standards and therefore policies are in place to tackle these issues [47]. The main solutions that the Municipality of Amsterdam focuses on are the hinderance or prohibition of the most polluting vehicles in certain areas of the city, the implementation of use of charging stations for electric cars, and the possibilities to share vehicles. Another main solution, restricted parking spaces and having no private parking spaces in the public space, means that newly built buildings need to realize either a parking space inside the building or no parking spaces at all. This theme also included indicators for sustainable construction logistics and the use of clean construction machinery.

The third theme is climate adaptation. Climate change will cause more severe weather situations [48]. The solutions for this category focus on the ability to adapt to these extreme conditions, like processing heavy rainfall, heatwaves, and droughts. This included solutions like green roofs, green facades, courtyards, water storage crates, and the minimization of paving. Furthermore, buildings must be able to process 60 mm/m$^2$ of rainfall every hour and green spaces should be present.

The fourth theme is greening nature urban spaces and building nature-inclusive. More research is pointing toward the importance of green within cities for human health, biodiversity, and to cope with extreme weather conditions [49,50]. Every project has a so-called ‘green standard’, which determines how much green should be included within the public area. Such general standards are often supplemented through extra criteria in tenders. Buildings are also expected to be nature-inclusive, which can be achieved through green roofs, green facades, high biodiversity in plants, or the inclusion of nest boxes for animals. In tenders this is measured and monitored using a point system.
The fifth and sixth themes, **circular construction and waste and raw materials**, are related because if waste is reused through circular construction, fewer raw materials are needed. Therefore, these themes are combined. For both ecological and economic reasons, it is important to decrease the waste flows from consumption and construction to prevent environmental depletion [49]. Circular construction and good waste management are important aspects to prevent this environmental depletion. The most important indicator in circular construction is the Environment Performance Buildings (MilieuPrestatie Gebouwen, MPG), which determines the environmental impact of the materials used in the new buildings [45]. Since 2018, the index started with a maximum of 1 and in July 2020, this maximum was set to 0.8 EUR/m\(^2\) gross floor area (bruto vloeroppervlak, BVO)/year. The goal is to lower this maximum gradually, until it is halved in 2030. Circular construction also includes the possibilities of dismountable parts, and flexible and adaptive building. For the theme of waste, different waste collection systems, like underground containers or pick-up services, were found, though all systems found included means to separate waste.

### 4.2. Structural Analysis

#### 4.2.1. Mission-Oriented Innovation System

The MIS includes many stakeholders who are involved and actively engaged in the process of pursuing the mission to build a city that will last for generations and is developed sustainably. Stakeholders were defined “as any group or individual who can affect or is affected by the achievement of the sustainability ambitions of the Municipality of Amsterdam for SUD”. Missions (see Section 3.1) are translations of sustainable development priority areas by the team Sustainable District Development (Duurzame Gebiedsontwikkeling; DGO) team set by the national government, provinces, municipalities, companies, and citizens within the Netherlands, developed via consensus process [51]. This exemplifies the Dutch Poldermodel, where the aforementioned stakeholders negotiate social-economic policy to reach a policy consensus and to coordinate its implementation amongst the involved stakeholders [52].

These stakeholders are divided into internal and external stakeholders, from which the internal stakeholders are subdivided into administrative and governing stakeholders. The latter sets the agenda within the Municipality of Amsterdam, installs norms and local regulations, and can start or stop new initiatives. Furthermore, they are bound by national regulations, which are set by the Dutch government, an external stakeholder. This network is shown in Figure 1. Short descriptions of the functions of the several stakeholders in the MIS of SUD projects are located in Table A1, Appendix A.

The **governing stakeholders** set the regulations that are then implemented by the administrative stakeholders. Within the SUD mission, all internal stakeholders fall under the Cluster Economic Services (Ruimte & Economie). Five departments were named to be important during the expert interviews, including the Engineering Department (Ingenieursbureau, IB), Area and Sustainability Department (Afdeling Ruimte & Duurzaamheid, R&D), Land and Development Department (Afdeling Grond & Ontwikkeling, G&O), Project Management Bureau (Projectmanagement bureau, PMB), and the Traffic and Public Space Department (Afdeling Verkeer & Openbare Ruimte, V&OR). The DGO team is the bridge between the policy-making department (Sustainability) and the urban development projects (Strategy), which are part of Area and Sustainability. DGO is part of the Strategy Department and brings the expertise of the implementation of sustainability policies, as well as reflection on long-term strategies. DGO also collaborates with the Project Manager (PM) and the Urban Planner (Stedenbouwkundige, SBK).
The external stakeholders include civilians, housing corporations, leaseholders (owners of the land and/or buildings), Vattenfall or Westpoort heat, Liander, Rijkswaterstaat (RWS), and the Environmental Agency (Omgevingsdienst Noordzeekanaal gebied, ODNZKG). Each external stakeholder has its own interests and expertise and collaborates with each other and with the internal stakeholders. Both the external and internal stakeholders are involved in mobilizing other MIS components, as they can, for example, choose to implement specific technological solutions (materiality).

Stakeholder decisions are influenced by the materiality—i.e., the available sustainability innovations that may be tendered—and many technological solutions are available for supporting progress within one or more of the sustainability themes. The materiality also influences, and is being influenced by, the institutions that are in place and the stakeholders involved. For example, new technological solutions for heating, such as a heat network or Aquifer Thermal Energy Storage (ATES), reduce the Nearly Energy-Neutral Building (BENG) and Energy Performance Coefficient (EPC) standards. Since 2020, BENG is the standard used by the municipality; previously used was the EPC standard. The standards are deployed within the award criteria of public tenders to award points to those tenders with BENG (or previously, EPC) above that currently set by regulation. For example, if national regulations demanded an EPC of less than 0.4, a tender could be drafted to allow administrative stakeholders to award points to every technological solution submitted that improves upon that EPC performance. Practically speaking, this would mean a technological solution submitted with an EPC of 0.2 received a certain number of points for this performance, whereas a competing solution with an EPC of 0.4 would receive no additional points for this heat efficiency criteria but would still be considered as eligible together with the other solution.

The governing stakeholders are directly involved in formulating—and are responsible for the governance of—the mission of SUD in Amsterdam. These stakeholders include the city council, the college of mayor and aldermen, and the city districts, which each have their own aldermen as well. They set the agenda within the Municipality of Amsterdam, install norms and local regulations, and can start or stop new initiatives. They are bound by national regulations, which are set by the Dutch government, an external stakeholder.

Importantly, the Urban Advisor, via the DGO, is responsible for coordinating/advising on SUD projects across five geographical districts [53]. For each district, several urban advisors play an important role in SUD projects. The process is iterative and consists of
four program components: knowledge development, advising, execution, and generating feedback and setting the agenda [49]. During each step, the Urban Advisor has a different role and collaborates with different stakeholders. The role of the Urban Advisor in each program component is shown in Figure 2.

![Figure 2. The role of the Urban Advisor during each program component of SUD projects [49].](image)

Overall, they are responsible for connecting sustainability policy at the municipality with concrete projects, translating policy into practice, and giving feedback to policymakers on what is not working.

4.2.2. GPP Process for SUD

All SUD projects go through the PLABERUM process (Figure 3), which aims to create clarity, diligence, and manageability of SUD projects across four phases. The first phase consists of an exploring study that decides whether starting a certain project is desirable. Phase two provides a feasibility study that explores how feasible it would be to carry out a project. Third, the design study researches the possibilities and costs of the SUD project. Finally, during the implementation phase, the execution of the project is enabled. Each phase results in a specific document and corresponding decisions. It is the various resulting PLABERUM documents of the numerous projects reviewed that informed the findings of Section 4.1, Problem-Solution Diagnosis, in this paper.

![Figure 3. The PLABERUM process at the Municipality of Amsterdam [54].](image)

4.3. Voluntary Standards and Regulations

There are many regulations set already that play a role within the MIS. For example, to unburden the sewer, the Rainwater Regulation forces SUD projects to be able to store at least 60mm/m² of rainwater during heavy rainfall. Given this, findings indicate that there are multiple factors that challenge the incorporation of voluntary standards, as sustainability criteria, in GPP to achieve missions. These include the high number and type of stakeholders engaged over the duration of a project, numerous standards available by which to measure and promote sustainability within any given missions, uncertainty
on where or how to include standards within the project planning process, the relative nascent of sustainability requirements, fragmentation across districts, and variability between individual projects.

The gradual strengthening of sustainability requirements in regulation means that eventually voluntary standards used in GPP will become law. For example, the lowering of Environment Performance Buildings (MilieuPrestatie Gebouwen, MPG) from 1 to 0.8 at the time of writing, and toward the end goal of 0.5. This allows for higher sustainability aspirations for non-public tender projects. Upcoming changes to legislation will facilitate the ability of municipalities to adapt policies to their own districts and give then more support in demanding improved environmental performance, together with a higher steering power from national authorities. The upcoming Omgevingswet (Environmental Act) was developed via input from all municipalities, and those with higher environmental aspirations could lobby for their missions to more strongly influence the act. Slated for implementation in early 2023, it is based on the National Environmental Vision (Nationale Omgevingsvisie, NOVI) for spatial planning over the next 30 years. Issues are crosscutting over districts, developed as a single vision for environmental policy in close collaboration with provinces, municipalities, water boards, and social parties. It covers the construction of approximately 1 million new homes, with missions involving the use of more sustainable energy, adapting to climate change, the development of a circular economy, and the transition to circular agriculture. Each municipality will develop its own Omgevingsvisie (Environmental Vision), and one Omgevingsprogramme (Environmental Programme) per subdistrict.

Referred to by one respondent as “a difficult new tool”, the Omgevingswet will simplify and merge the rules for spatial development to facilitate the beginning of construction projects, and as such will be the basis on which municipalities can increasingly refine or strengthen their sustainability requirements in SUD. This tool may accelerate the achieving of missions, particularly for non-tender SUD projects for which voluntary standards or GPP cannot be used to increase performance.

5. Discussion

Results indicate that the Municipality of Amsterdam is actively engaged in implementing sustainability ambitions, with sustainability becoming an integral part of project development throughout the city. The majority of PLABERUM reports analyzed include chapters describing and outlining the sustainability requirements and ambitions for the project based on some of the six sustainability themes. However, others excluded a particular sustainability chapter if the project team considered sustainability already integrated throughout the whole report. Often, not all six sustainability themes were included, or, if they were, not all specific requirements and ambitions were addressed. For example, a new building project might refer to the sustainable energy ambition, fully including each variable and potential value of the mission (see Table A2, Appendix A), and only partly to the greening nature urban spaces and building nature-inclusive ambitions, including whether a green standard was achieved, at what value and with what specification, yet neglecting to discuss any (sustainable) lot management plan or nature-inclusive features such as nest boxes. Though it may not be desirable to deliver detailed information about all six sustainability themes, considering the high contextuality of projects, the current documentation was found to be insufficient and overly complex regarding sustainability.

Still, during the analysis, many innovative sustainability solutions were identified to help move toward achieving the missions of the municipality. These innovative solutions address the environmental criteria determined by the municipality and sometimes went beyond what is legally required, serving as an (often de facto) voluntary standard. For example, the installation of solar panels combined with the use of highly insulating building materials can result in a building that is energy neutral or even energy positive, so that it can provide renewable energy to the grid. These types of solutions help to achieve the sustainable energy ambitions determined by the municipality to a large extent. Conversely, it also regularly occurred that a project only just meets the national requirements. Although
the national requirements are passable, they are almost never sufficient to meet the long-term municipal sustainability ambitions, as seen in the gradual strengthening of regulations over time.

This significant difference can partly be explained by looking at the two main types of projects: public tender projects and non-public tender projects. These types of projects have some key differences in the way that solutions for a sustainability theme are determined. For public tender projects, the municipality can engage in GPP to challenge the market by awarding points to project developers that deliver more sustainable solutions, generating competition between project developers, whereas for non-tender projects they are bound by regulation unless additional agreements are made. Hence, sustainability themes are often addressed in much more detail and go further in tender projects. Projects for which GPP can be conducted, where the municipality is the landowner, more often include a wider variety of voluntary standards. However, by no means are the sustainability ambitions for non-public tender projects less important, as this type of project is numerous, and the scale is often significant. In Amsterdam, only 20% of projects are tenders, whereas 80% are non-public tenders. While this reflects the greater impact of regulations on affecting the sustainability performance of technological solutions, it also suggests that in one-fifth of the projects voluntary standards have the opportunity to improve the sustainability performance even further. This creates space for GPP to reward companies with the best performance, creating both direct effects via implementation of these solutions as well as indirect effects through the market.

6. Conclusions

GPP allows for the creation of competitive environments that reward higher sustainability performance than any required by regulation, facilitated through the use of voluntary standards in public tenders that help to qualify, quantify, and guide sustainability improvements. In this way, voluntary standards serve as a linchpin between missions and concrete projects, and their presence, type, and means of use can be an indicator for tangible progress toward achieving missions. This may be particularly true in the absence of coordinated, outcome-oriented methods for assessing progress, such as widespread, routinized procedures to follow up on actual performance upon project completion.

For SUD projects where the municipality is not the landowner, private project developers must only adhere to public policy requirements. If these are perceived as the bare minimum in terms of sustainability performance, additional agreements between parties can lead to the incorporation of higher standards. Whether or not this is occurs depends on many aspects, such as on individuals employed for the project and on whether an area is appointed as a pilot area.

Progress toward missions is often requested across all districts of a municipality, for the city as a whole, such as by its alderman for urban planning and sustainability. However, this is difficult because of differences in organizing document sources, leaving it difficult to understand what is happening, with policies leaving room for interpretation that results in high variability between districts. To reduce variation between sustainability ambitions between districts, policies should be similarly approached in all documents. Due to the high influence that individual project members can currently have on project sustainability, standardizing processes are expected to create more clarity for project developers and facilitate interest in voluntarily increasing sustainability performance of non-tender projects particularly.

For the cases examined in this paper, and likely for many other municipalities globally, the processes for incorporating sustainability missions—as well as the sustainability missions themselves—are new. The use of voluntary standards in GPP is similarly novel; however, there is a growing awareness and understanding of the mechanism, where its practical implementation can feed into theoretical assessment, and vice versa. Studies on implementation of GPP to support missions can therefore lead to a greater scientific understanding of the interaction between sustainability missions and other themes is necessary.
to explore the potential trade-offs and unintended consequences of incorporating these missions—including via voluntary standards—into GPP. Providing means by which to improve the use of voluntary standards in tender projects is therefore recommended to increase competition for sustainability within suppliers operating in the construction sector and indirectly influence environmental performance within the SUD MIS.

Finally, the conclusions of this paper present opportunities for further research. Due to the high number of projects analyzed and the variance between these projects, it was not possible to go in-depth into the results of either subset of tender projects or non-tender projects. To derive meaningful results, this paper therefore focused on tender vs. non-tender projects, also to better highlight the role of voluntary standards and GPP within SUD projects as a whole and toward municipal missions that affected both project types. Since an in-depth look into the formulation and specification of voluntary standards within tendering documents themselves is valuable in providing greater understanding into the ways in which they are deployed in practice toward sustainability missions, future research should undertake this more focused investigation.

An extension of this limitation is the focus on the demand-side rather than any micro-level analysis of the supply-side. This paper focused on internal mechanisms within and across districts of a local public contracting authority practicing GPP and suggests that more purposeful and streamlined incorporation of overarching missions in the early stages of SUD projects—facilitated by the use of voluntary standards—can help assist in their achievement. Responses from—and interactions with—firms therefore lay outside of this paper’s scope, even though they contribute to the functioning of an MIS. As previous research has identified, and this paper also supports, GPP can create wider impacts by influencing products, services, and practices in individual firms toward more sustainable solutions. For this reason, it is recommended that follow-up research is conducted on both engagement with and influence of GPP projects on the private sector within MIS. An example of such work would ascertain whether firms engaging in tender or non-tender projects for SUD are incorporating voluntary standards and thereby increasing the sustainability of their products, services, and practices, including private managerial implications of doing so.

**Funding:** This research was funded by Horizon Europe project ‘DemoTrans’ (grant 101059288).

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Acknowledgments:** The author would like to thank the following individuals for their diligent research and analysis which comprised a large component of this study: Naomi Ruijtenberg, Nathalie Geerts, Mees Eringa, Luuk van Santen, and Joeri Pieterson. Sincere gratitude is also extended to the Department of Urban Planning and Sustainability at Gemeente Amsterdam, and in particular Vivien Laros and Valerie Deckers, for their support in conducting this study. We also thank the many interviewees for their valuable time, and the anonymous reviewers of this article for their helpful critique, which improved the manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest.
Appendix A

Appendix A.1 Solution Approach per Mission

Table A1. Short description of the functions of the several stakeholders in the MIS of SUD projects.

| Department                                                                 | Acronym | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-----------------------------------------------------------------------------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Land and Development department (Afdeling Grond & Ontwikkeling, G&O),       | G&O     | Shapes the growth and development of Amsterdam to reach its SUD project missions. Core tasks include preparing of land for construction and issuing it on long lease, real estate management, and financial-economic guidance and management of SUD projects.                                                                                                                                                                                                                                                                                                                                                               |
| SBK                                                                          |         | Researches potential developments for existing and newly developed urban areas, including public spaces                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Sustainable District Development team (Team Duurzame Gebiedsontwikkeling)   | DGO     | Develops an integral approach for SUD projects in which sustainable choices (environmental sustainability) are integrated as much as possible.                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Architect                                                                   |         | Design SUD projects, as commissioned by the leaseholder of the building                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Engineering department (Ingenieursbureau, IB),                              | IB      | The IB offers technical assistance whenever needed during SUD projects.                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| ODNZKG                                                                      |         | Grants permits and ensures that all parties comply with their legal obligations relating the environment, soil, and construction.                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Project Management Bureau (Projectmanagement bureau,                        | PM      | Responsible for the overall coordination specific projects, ensuring that regulations are met and budget is not exceeded.                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| CPO leader                                                                  |         | Leads the project and coordinates the demands of all members of the CPO                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Corporation                                                                 |         | Offers social housing; responsible for building and maintaining livable and affordable housing.                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Leaseholder                                                                  |         | Prepares and carries out major SUD projects. Engaged in the purchase of land or real estate at its own risk, in order to sell it after completion of the project.                                                                                                                                                                                                                                                                                                                                                                                                 |

Appendix A.2 Indicators per Theme

Table A2. List of types of indicators identified, including per phase, assignment type, and sustainability theme (mission).

| PLABERUM Process                                                                 | Plan Products                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phases                               | Plan Products                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 1. Exploratory study                 | 1. Principle directives/decision                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 2. Feasibility study                 | 2. Project directives/decision                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 3. Design study                      | 3. Investment note with SO (Sketch design), building envelope, plot passport                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 4. Execution/Implementation          | 4a. VO (Temporary design)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                     | 4b. DO (Definitive design)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|                                     | 4c. Selection Brochure                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

| Building assignment                  | Values                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Variable                             | Values                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| How many houses                      | Numbers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| How much GFA in m²                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
Table A2. Cont.

| Home type             | Social/rent/middle |
|-----------------------|--------------------|
| Rent/buy              |                    |
| Average surface apartment in m² |                    |
| Others functions      | Type of function: office/commercial facilities (catering, leisure, retail)/social facilities (such as education, care) |
| How much GFA in m²    |                    |
| Open–close ratio      | Percentage         |
| Canopies/sun protection| Yes No             |

**Specifications**

**Mission: Sustainable energy and a natural gas free city**

| Energy Use/Efficiency | Values                                                      |
|-----------------------|-------------------------------------------------------------|
| Energy Performance Coefficient (EPC) | Numeric |
| Nearly Energy-Neutral Buildings (BENG) | NZEB 1 (kWh/m²/year) |
|                        | NZEB 2 (kWh/m²/year) |
|                        | NZEB 3 (%) |

| Energy/Heat System | Values                                                                 |
|--------------------|------------------------------------------------------------------------|
| Heat supply        | Heat network (HT district heating), PV solar panels (numbers), data heat, TES (open soil system), closed soil energy system, aquathermal |
| Cooling            | City cold, TES, individual solutions (specify, e.g., air conditioning, ventilation, green roof, et cetera) |
| Heat saving/insulation | Shower heat recovery (yes/no) |
|                     | Façade material (wood, concrete, steel) |
|                     | Glass type (single, double, HR+, HR++, HR+++) |
|                     | Rd value facade, roof and floor (m² K/W) |

**Mission: Cleaner air through emission-free mobility**

| Variable            | Values                                                                 |
|---------------------|------------------------------------------------------------------------|
| Car charging stations | Type: private/semi- public/public |
|                     | Numbers per type                                                       |
| Modal split         | Parking places car/bicycle/scooter                                      |
| Share mobility      | Type: car/bicycle/scooter                                              |
|                     | Numbers per type                                                       |
|                     | Specifications                                                          |

**Air Quality**

| Variable                        | Values        |
|---------------------------------|---------------|
| Sustainable construction logistics | Yes/No Specifications |
| Clean construction equipment     | Yes/No        |
Table A2. Cont.

| Mission: Climate adaptation | Rain Resistance |
|-----------------------------|-----------------|
| **Variable**                | **Values**      |
| Water storage solution      | Location: public space/lot/roof |
| Type of solution (wadi, green roof, green-blue roof, rain barrel, . . . ) |
| Water storage in mm/m²      | Disposal        |
| Type: sewerage/soil infiltration/surface water/reuse |
| Further specifications      |                 |

| **Heat**                    |                 |
|-----------------------------|-----------------|
| **Variable**                | **Values**      |
| Solution                    | Location: public space/plot/courtyard garden |
| Type of solution (e.g., green facades) |
| Further specifications      |                 |
| Cool places                 | Location: public room |
| Distance to (m)             |                 |
| Surface (m²)                |                 |
| Shadow walking routes       | Location: public room |
| Percentage                  |                 |
| Further Specifications      |                 |

| **Drought**                 |                 |
|-----------------------------|-----------------|
| **Variable**                | **Values**      |
| Solution                    | Location: public space/lot/roof |
| Type of solution             |                 |
| Further specifications      |                 |

| **Water Safety**            |                 |
|-----------------------------|-----------------|
| **Variable**                | **Values**      |
| Solution                    | Location: public space, plot, roof |
| Type of solution (no sensitive functions ground floor, raising ground level, etc.) |
| Further specifications      |                 |

| **Mission: Greening urban spaces and building nature-inclusive** | **Green** |
|-----------------------------------------------------------------|----------|
| **Variables**                                                  | **Values** |
| Green                                                           | Location: public space/lot |
| Green type (lawn field, green roof, green facade, . . . )      |          |
| Surface (m²)                                                   |          |
| Specifications (ecosystem green/utility green/details)         |          |
| Green standard                                                 | Achieved (yes/no) |
| Achieved values                                                |          |
| Specifications                                                 |          |
| Management                                                     | Location: lot |
| Management plan (yes/no)                                       |          |
| Specifications                                                 |          |
Table A2. Cont.

| Nature-inclusive | Values |
|------------------|--------|
| Points system    | How many points |
| Type of solutions| Green/green-blue/brown roof (m²), green facades (m²), nature playground (m²), et cetera. |
| Nest boxes (numbers) | |
| Other (specify)  | |

| Missions: Circular Construction and Waste and Raw Materials (Raw) Materials |
|-----------------------------|--------------------------|
| Variables                  | Values                   |
| MPG score                  | Score in EUR/m² GFA      |
| Material usage             | Location: OR/building    |
| Type of material (wood/concrete/steel/ . . . ) | Quantities (m²) |
| recycled materials         | Location: OR/building    |
| Percentage                 | Specifications           |
| Lifespan                   | Lifespan materials       |
| Building Future-Proof      |                          |
| Variables                  | Values                   |
| Flexible/adaptive          | Plinth height (m)        |
| Mat 8 (score)              | Specifications           |
| Demountability             | Demountable parts (yes/no) |
| Waste                      |                          |
| Variables                  | Values                   |
| System                     | Standard collective underground collection system, separate above-ground GFT containers, VFG food waste shredder, indoor (roll) containers for glass, paper/cardboard and residual waste, combined collection (commercial and household waste), etc. |

| Particularities |
|-----------------|
| New sanitation/reuse of waste water, for example |

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