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COLLABORATIVE PLANNING FOR SUSTAINABLE URBAN INFRASTRUCTURE IN FRANKFURT AM MAIN

PLANOWANIE WSPÓŁPRACY ZRÓWNOWAŻONEJ INFRASTRUKTURY MIEJSKIEJ WE FRANKFURCIE NAD MENEM

Abstract

Infrastructure planning in most cities is a process of sectoral implementation which produces independent sectoral solutions to urbanisation issues. With the advent of sustainable practices, along with the challenges posed by climate change, cities are discovering important synergies among urban infrastructure sectors which are being used to reduce the urban footprint. In the need for sustainable infrastructure, the city of Frankfurt am Main, although operating in a sectoral manner, has learned from past experiences and has progressively developed a collaborative approach to infrastructure planning. This collaborative approach increases the possibilities for trans-sectoral projects and reduces the consumption of natural resources. This paper showcases interesting sectoral and trans-sectoral projects in the infrastructure sectors of energy, water, wastewater, solid waste and urban agriculture. The showcased projects have been selected from a study of 36 operational, programmatic and educational initiatives implemented by the city.

Keywords: collaborative planning, sustainable infrastructure, trans-sectoral projects, renewable energies

Streszczenie

Planowanie infrastruktury w miastach jest procesem wdrażania sektorowego, który przynosi rozwiązania problemów urbanizacyjnych. Wraz z pojawieniem się zrównoważonych praktyk obok wyzwań związanych ze zmianami klimatu miasta zaczęły odkrywać ważną synergię między sektorami infrastruktury miejskiej. Korzystając z wielu lat doświadczeń, architekci i urbaniści z Frankfurtu nad Menem stopniowo rozwijają swoją współpracę w planowaniu infrastruktury. Podejście oparte na współdziałaniu zwiększa możliwości projektów międzysektorowych i zmniejsza zużycie zasobów naturalnych. Niniejszy artykuł przedstawia interesujące koncepcje sektorowe i międzysektorowe w zakresie infrastruktury sektorów energii, wody, ścieków, odpadów stałych i rolnictwa miejskiego. Prezentowane propozycje zostały wybrane z 36 inicjatyw operacyjnych, programowych i edukacyjnych realizowanych przez miasto.

Słowa kluczowe: wspólne planowanie, zrównoważona infrastruktura, projekty międzysektorowe, odnawialne źródła energii

1. Introduction

Frankfurt am Main, 740,000 inhabitants in 2018, is a dynamic metropolis at the heart of the FrankfurtRheinMain Region in western Germany. The employment opportunities fuelled by financial services have not only created unexpected population growth in the city and the region, but also a series of challenges in terms of urban infrastructure provision and affordable housing to respond effectively to the needs of existing and new residents as well as commuters. The municipal departments in charge of infrastructure and urban planning have responded to these urbanisation challenges by implementing incremental collaborative planning processes, focusing the development of the city on sustainability, environmental protection and mitigation measures to cope with climate change.

This article is the summary of an ongoing empirical investigation into the planning process for sustainable urban infrastructure in Frankfurt and a recollection of the projects implemented by the city. The research examines five sectors of urban infrastructure provision, namely energy production and provision, water provision, wastewater management, solid waste management, and urban agriculture. This research about infrastructure planning and implementation in the city highlights the importance of project-driven collaborative planning processes, along with the involvement of a diversity of urban actors in the planning and implementation process. Likewise, the research identified some trans-sectoral infrastructure projects which increase the effectiveness of investment in urban infrastructure for the city. This paper will describe the most prominent projects, categorising them into practice-oriented, programmatic and educational. In the same way, for each category an abridged stakeholder analysis has been created to identify the typology of actors involved in the provision of urban infrastructure in Frankfurt.

The research sub-project *Urban Planning and Capacity Development* at the Frankfurt University of Applied Sciences is part of a larger research project: *Rapid Planning – Sustainable Infrastructure, Environmental and Resource Management for Highly Dynamic Metropolises*, funded 2014–2019 by the German Federal Ministry for Education and Research (BMBF). Frankfurt was selected as a reference city because of its size, population growth rate, and the city's position in the German and European economy. The project recognises Frankfurt as a good example of sustainable planning practices which have resulted in a good quality of life, providing urban infrastructure with a focus on environmental protection [9]. The research on Frankfurt as a reference city has two main objectives: to identify the urban infrastructure projects that promote sustainable development in the city, and to describe and analyse the planning system in Frankfurt with the instruments and processes utilised by the City Planning Department in the search for a balanced urban environment and a better quality of life in the city. This paper addresses the sustainable infrastructure projects; the analysis about the planning system can be found in the article *A flexible system for localised sustainable development* published in 2018 in the journal *Technical Transactions* [10].

2. Ambitious Sustainable Development Goals

Frankfurt has defined ambitious goals for urban development, following the guidelines of the German Federal Government and the European Union. The city applied for the *European Green Capital Award* in 2014 and, since then, has implemented a series of initiatives to increase and preserve the quality of life in the urban core. The submission of Frankfurt for the Green Capital Award was mainly based on three service provision sectors: energy performance, sensible water usage and e-mobility [6]. Although Copenhagen won the award in 2014, the nomination as a finalist served as the basis to promote more sustainable development projects and create a sustainable vision for Frankfurt. The city extended the scope of the green city vision to include other urban sectors, defining four core areas to promote sustainable urbanisation: *Economy and consumption, Sustainable mobility culture, Planning and construction in dense urban areas, and Climate and open spaces* [19].

Sustainable development has been a goal in all German cities for more than a decade, leading municipal governments to adopt formal environmental protection policies along with measures for the provision of sustainable urban infrastructure. Hence, simultaneous to the process of applying for the Green Capital Award, the city developed a sustainable energy concept following the national and international guidelines for urban sustainability. In the form of *Master Plan 100% Climate Protection*, this concept set specific sectoral goals for reducing the consumption of natural resources and decreasing the urban footprint of the city regarding energy production [12]. The research has shown that the implementation of sustainable infrastructure provision policies for reducing the impact on the built environment has resulted in the generation of trans-sectoral synergies among different infrastructure sectors while increasing the efficiency of investments in urban infrastructure for the city. The analysis of infrastructure provision programmes and projects in Frankfurt suggests that the concept of trans-sectoral synergies in the city has been increasingly permeating the infrastructure planning process for years; thus, a project-driven collaboration scheme has been developed which depends on formal communication channels among the relevant municipal departments for each project and agreement among public officials on a common sustainable vision for the future. Initiatives such as *Master Plan 100% Climate Protection* and *Frankfurt Green City* look at urban development in a holistic way, involving not only different sectors of urban infrastructure in the process but also different urban actors.

Figure 1 shows the involvement of the public actors in the different infrastructure sectors revised by the Rapid Planning research project in Frankfurt. The direct or indirect participation of diverse stakeholders in one specific sector illustrates the synergies between the sectors of urban infrastructure in Frankfurt; for each sector the key actor is a municipal department that controls the planning process and promotes trans-sectoral initiatives, as well as the involvement of other relevant municipal departments. As an example, energy provision projects are defined and controlled by the Municipal Energy Agency, which looks at implementing clean energy-provision technologies and reducing energy consumption. With these objectives in mind, the energy projects also involve the waste and wastewater

sectors by utilising waste products for the production of clean energy, i.e. cogeneration plants that produce energy and heat from biomass, household bio and solid waste, and sludge from wastewater treatment. These energy projects demand collaboration between public actors such as the Municipal Energy Agency, the City Planning Department, and the Environment Department. They also require cooperation with semi-public and private actors such as the waste management company (FES) and local community organisations, e.g. in the case of using the residues from the cogeneration process for compost.

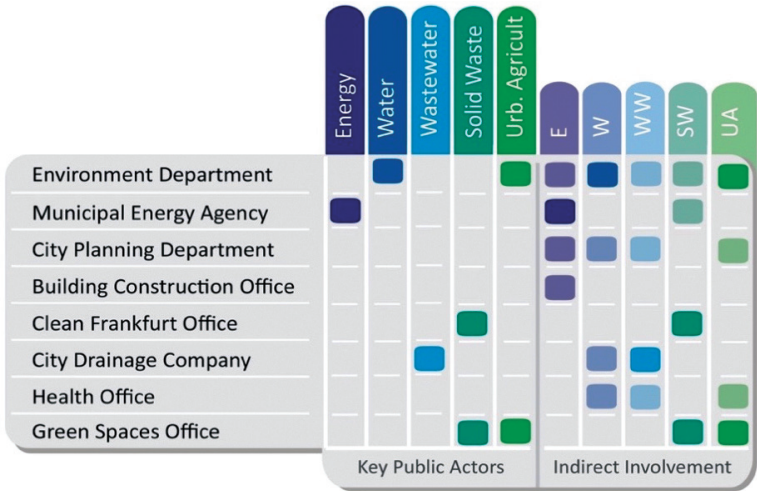


Fig. 1. Involvement of municipal departments and public stakeholders in the infrastructure sectors (source: Global Urbanisation Research Team FRA-UAS)

3. The Impact of the Energy Sector in Urban Planning

The establishment of ambitious environmental goals is based on the objective of providing the city with 100% renewable energy by 2050 [3, 13]. The methods used to achieve this objective are the transition from fossil fuels to renewable energy sources, along with raising awareness among the population and promoting the reduction of energy consumption in households and industry. Utilising new technologies for renewable energy reduces CO₂ emissions and is also closely linked to the depletion of natural resources in other sectors, e.g. energy, water, and a reduction in waste products going to landfills.

Renewable energies are changing not only the process and attitudes of planning for buildings and urban infrastructure, but also the perception of the city. These policies are collected in *Master Plan 100% Climate Protection*, which establishes the goals for the city. The Master Plan defines different scenarios for the provision of clean energies, as well as goals for reduction of CO₂ and consumption of fossil fuels in the city. It develops general guidelines for the public and the private sector in terms of energy planning until the year 2050 (Fig. 2).

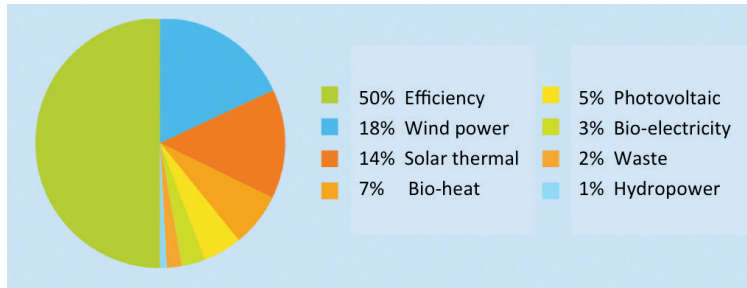


Fig. 2. Scenario of energy provision in Frankfurt am Main in 2050 [2]

3.1. Clean Energy Provision Strategies

The sustainability mandate of the city has led to the implementation of a diverse set of measures for the production of clean energy; examples include district cogeneration plants, encouraging the use of photovoltaics, bringing together diverse urban infrastructure sectors to reduce the city's input of resources and output of waste, and reusing biomass and solid waste products for the production of heat and energy. As a result of the climate change policies implemented in the country and the city in recent years, the use of clean energy has grown in the city and met 50% of the electricity demand in 2014 [15]. Technologies such as photovoltaics, thermal and wind power, and cogeneration from waste and biomass have become commonly used by public and private buildings, and these new technologies are now a possible source of income for households and businesses, e.g. photovoltaic panels on roofs and facades as private investment.

3.1.1. Solar Roof Frankfurt (Solardach Frankfurt)

A promotion programme for photovoltaic roof panels has been developed with the support of the semi-public energy company Mainova and the public housing company ABG Frankfurt Holding. Several systems have been developed and the company offers tenants an opportunity to purchase a share in photovoltaic plants. Photovoltaic systems help not only to produce environmentally friendly electricity and to involve citizens, but also to earn money for the citizens and for the city [3].

3.1.2. Cogeneration

Combined heat and power (CHP) generation systems are an efficient way of producing electricity and heat simultaneously using biomass or waste products. In CHP the residual heat that is generated in the production of electricity is used for heating purposes. The main advantage of cogeneration is that the system uses 90% of the engaged energy and saves up to 40% of primary energy, whereas in conventional power stations 60 to 70% of the primary energy is lost in production [3]. This process reduces carbon emissions and the carbon footprint of the city, and these power plants are lucrative and eco-friendly [27].

In Frankfurt cogeneration is an essential part of energy planning. The city is committed to the European *CHP goes Green* programme, which promotes the increased use of renewable energy sources from cogeneration. Frankfurt operates more than 200 decentralised facilities and has three major cogeneration-based district heating networks. In total they efficiently produce about 50% of the power and supply large parts of the city with heating, such as Frankfurt Airport and office buildings [3].

The design of cogeneration power plants in Frankfurt is linked to urban planning. The Municipal Energy Agency annually collects information about cogeneration processes and results. The analysis of these data, its impact and possible improvements are discussed with the operators of the power plants in order to improve the cogeneration process. The discussion and sharing of experiences between the involved stakeholders are very important for achieving the sustainable goals of the city.

3.2. Energy Planning beyond Provision

Programmes such as *Solar Roof Frankfurt*, *Energy Renovation*, *Ecoprofit* and *Frankfurt Saves Energy* are collaboration projects between the Municipal Energy Agency, the City Planning Department, the local economy, private households and organisations – all supported by effective public relations and run by external experts. These programmes aim to reduce energy consumption and provision costs while protecting natural resources.

3.2.1. Energy Renovation

The Municipal Energy Agency also functions as consultant for private homeowners who want to increase the energy efficiency of their homes. It provides guidelines for the energy-saving renovation of private buildings, information on legal requirements and planning and implementation measures for special features of historical buildings, information on better insulation techniques and guidelines for passive house components. Moreover, the city has various support programmes, among others from the City Planning Department and the KfW banking institute, that can help to finance renovations and modernisation measures related to energy retrofitting [3, 27].

3.2.2. Ecoprofit – Ökoprofit

Ökoprofit is a pillar of *Master Plan 100% Climate Protection* in the corporate sector and is directed at city companies and operational facilities which want to improve their ecological performance and profit from improved climate-friendly technologies and practices. The programme gives companies access to environmental and energy management systems which save costs, use natural sources, and reduce negative effects on the environment. Ökoprofit focuses on individual counselling, joint workshops and networking among participating companies [4].

3.2.3. Frankfurt Saves Electricity (Frankfurt Spart Strom)

Frankfurt Saves Electricity is a support programme offered by the Municipal Energy Agency, which combines environmental and economic benefits for its participants, e.g. Frankfurt's private households, companies, associations, and community centres, and the city as a whole. The programme helps small and medium-sized enterprises to analyse their energy consumption and implement energy-saving measures. The programme also offers a financial incentive in the form of a cash bonus reward depending on the amount of the households' electricity savings [5].

3.2.4. Passive Houses

Passive houses (Fig. 3) are energy efficient, requiring around 90% less energy than regular buildings. As one of the strategies to achieve the goals of *Master Plan 100% Climate Protection*, all city-owned buildings and other municipal projects must be constructed following passive house standards, and energy-efficient components must be used for new constructions or refurbishment work [16]. The city leads by example in the reduction of energy consumption by implementing urban development policies in which all public buildings adopt the passive house standard by utilising solar, wind, thermal, and insulation technologies. The city also promotes and encourages the use of renewable energy sources for private developers by providing advisory services. The decision of the municipality to take public buildings up to passive house standards has made Frankfurt a hub for passive houses in Europe.

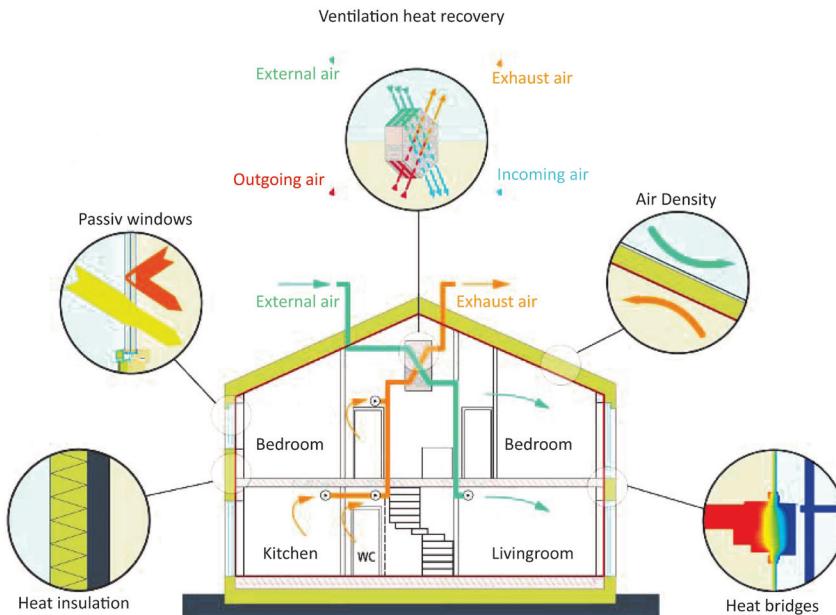


Fig. 3. The five basic principles of passive houses
(source: Passivhausinstitut, image modified by the Global Urbanisation Research Team FRA-UAS)

4. Environmental Protection and Climate Change Mitigation

The impact, participation and involvement of the city of Frankfurt on the region is regulated by the *Regional Authority (Regionalverband FrankfurtRheinMain)*, which comprises 75 municipalities in the metropolitan and surrounding area [11]. This institution's function is to create space for discussion and conflict resolution between municipalities, bringing them to agree on regional development policy in order to secure a good quality of life in the region. Regulations to protect green areas around the urban perimeter facilitate monitoring and quality control of the natural resources. These regulations also have a direct impact on the planning processes of the municipalities in the region, supporting efforts towards the conservation and protection of the environment.

4.1. Synergies between the Water Sector and Green Infrastructure

The strict federal regulations that the city must follow in the quality control of water sources demand the strong involvement of municipal departments in the management of provision, delivery, and collection systems. Therefore, the main actors involved in the water sector are the City Planning Department for definition of land uses, the Environment Department for control and monitoring of water quality, and Mainova, a semi-public service-provision company in which the municipality is the major shareholder. Other public and private actors are involved in educational and programmatic projects focused on raising awareness about the need to reduce water consumption in households or promoting new technologies for increasing the efficiency of water use in the industrial sector. The implementation of programmatic and educational projects, along with the improvement of technologies in the water sector, have resulted in a decrease of water consumption from 223 l/day per person in 1980 to 158 l/day in 2014 [28].

Water provision is a health-sensitive issue in cities and must be managed with the highest quality standards and specific legal regulations. The protection of aquifers demands the absence of polluting activities in the surrounding green areas; therefore, the implementation of water sector projects which involve other infrastructure sectors is difficult due to federal regulations and the health hazards of mishandling water sources. However, there is a clear relationship between clean water and the urban agriculture sector: responsible, pollutant-free, organic agricultural production should be coupled with water provision planning to protect aquifers whilst efficiently utilising the soil around the protection areas.

4.2. Wastewater Management, a Public Responsibility

Wastewater treatment is controlled to the highest standards in the city, which also implements new technologies and initiates trans-sectoral projects in order to reduce the output of waste products. Similar to the situation in the drinking water sector, the wastewater sector is regulated by federal laws which ensure that treated wastewater is free of harmful pollutants and can be delivered back to water bodies where the treated water infiltrates the

soil. However, in the case of wastewater the stakeholders are 100% public and, except for special agreements with neighbouring municipalities, the wastewater sector is concerned only with the collection, transport and treatment of wastewater within the city borders.



Fig. 4. Rainwater collection and infiltration areas in Riedberg District, Frankfurt am Main
(source: Global Urbanisation Research Team FRA-UAS)

The challenges of the wastewater sector are related to the flow rate capacity of the sewage system to cope with an ever-increasing flow from urbanisation growth. The sewage system in Frankfurt needs expansion and renovation; in the new developments, the city has implemented a separate collection system for rainwater in flood-prone green areas, facilitating the direct infiltration of rainwater into the soil [23]. Rainwater infiltration also reduces the flow of sewage water going into the system, thus reducing the need for expansion of the sewage system. Reusing rainwater and greywater for gardening or industrial purposes has also been promoted in the city in order to reduce the demand for potable water [21]. In the same way, the rainwater collection areas are also green public spaces which on dry days can be used for recreation and leisure for the community.

The inclusion of rainwater collection and infiltration areas directly in the urban design of new neighbourhoods in Frankfurt, such as the new north-western district of Riedberg [23], highlights the collaborative approach between the City Planning Department and the Municipal Environment Department. Both departments work together to introduce elements of environmental protection and climate change mitigation in planning procedures.

Designing usable green spaces that are also functional for rainwater infiltration in urban areas decreases the pressure on the wastewater collection system, while allowing the replenishment of aquifers in the surroundings.

4.2.1. Sludge Dewatering and Incineration Project

Additionally, as an approach to trans-sectoral planning and resource efficiency, the collaboration between the City Planning Department, the Environment Department, the City Drainage Company and the energy provision company Mainova has produced a trans-sectoral sludge dewatering and cogeneration project that combines the energy and wastewater sectors by producing electricity and heat from burning the sludge left by the wastewater treatment process, and thereby also reducing the waste going to landfills. Sludge incineration is one of the most environmentally friendly and economically effective methods of disposing of sewage sludge [14, 26].

4.3. Reducing, Reusing, Recycling for Waste Collection

The waste management process in Frankfurt focuses on four recycling processes: *reuse*, *recycle*, *transform* and *compost*. *Reuse* is based on the repair of large electronic appliances and furniture; these are collected and fixed or repurposed for further use. Waste products made out of plastic, paper and metal go through the *recycling* process, where they are sorted and sent to the processing station. *Transformation* or thermal recycling is coupled with CHP processes, turning residual waste products into heat and energy by means of incineration in cogeneration plants. Finally, the outputs of the thermal recycling and bio-waste are processed into *compost* to be utilised in agriculture and gardening.

In order to reduce the consumption of plastic bottles, a refund fee is included in the price of each plastic and glass bottle, which prevents plastic bottles from going into trash bins or littering public spaces. In the same way, many supermarkets have banned single-use plastic bags, promoting reusable bags for shopping.

4.3.1. Waste Collection at the Household Level

The main concept behind the charging system is financial incentives for environmentally friendly behaviour; properly separated waste and reduction allow residents to save money. In addition, the free collection of bulky waste on demand and the delivery of harmful substances to specific collection centres prevent illegal dumping and environmental damage. The Environment Department is officially responsible for controlling and monitoring waste management and street cleaning, while the semi-public waste management company, FES, provides the service and all the necessary equipment [18].

The waste collection services are provided by different companies associated with FES. The city finances the waste management operation with the fees charged to residents and businesses, which operate under two payment modalities: standard fees and variable fees. A resident or

business can choose between the fee modality, and these fees finance the collection services, the service vehicles, personnel, administration, as well as management of sorting, recycling and disposal services. The standard fee is a fixed amount paid by every household and commercial establishment in Frankfurt. With the standard fee, FES also provides waste disposal containers. The collection of bulky waste is included free of charge up to 13 times a year. The variable fee is charged according to the volume of the waste and the frequency of the collection service [18].

4.3.2. Waste Management, a Multi-Stakeholder Trans-Sectoral Opportunity

The waste management system is a good example of joint work between citizens and the private and the public sectors in Frankfurt. The collection and disposal of waste products rely heavily on educating citizens and involving them in the separation of waste products at source, e.g. bio-degradable or light packaging, paper, and residual waste, etc. Separation is the first step in the waste management process and is aimed at reusing or reducing the amount of residual waste going to landfills.

Besides the benefits for the environment, a good waste management system based on separation, and recycling attracts private investors. Waste management has become a niche for businesses making a profit from the recycling, reuse or repurposing of waste products. The involvement of the private sector provides an enterprise-like management style, increasing the efficiency and facilitating technological upgrades and collaboration with other sectors. Though the involvement of the private sector has proven beneficial for the quality of the service, the system of waste management in Frankfurt is still controlled by the municipality. The company and subsidiaries that provide the collection and disposal services (FES) are semi-public companies in which 51% of the shares are owned by the municipality. This ownership gives the municipality power over tariffs and waste management policies while allowing the company to function as a private enterprise [7].

The concept of reducing consumption is widely implemented throughout the environmental and infrastructure policies in Frankfurt. The emphasis on waste discrimination and reduction in consumption is evident in the educational programmes promoted by the city, raising awareness of the urban footprint and climate change. Consumption and the production of waste are reduced, while the reuse or repurposing of waste products is achieved through the introduction of new technologies and the involvement of several urban infrastructure sectors in waste management projects, e.g. cogeneration and composting. Furthermore, the development of cogeneration technologies has allowed the city to introduce a trans-sectoral vision in terms of the production of sustainable energy on the scale of a city district, reducing the amounts of waste products going to landfills as well as the need to bring in energy from outside the city boundaries.

4.4. Urban Agriculture for Environmental Protection

The urban agriculture sector in Frankfurt is directly dependent on the resources that the FrankfurtRheinMain Region provides. The municipality has developed a system of green infrastructure surrounding the urban perimeter called the *Frankfurt Green Belt*, which is

connected to other green spaces in the region, such as the *Regional Park FrankfurtRheinMain*. Within the Green Belt a multiplicity of uses for green areas coexist, e.g. urban parks, forestry, brown field redevelopment, agriculture, environmental protection and recreational areas. The *Frankfurt Green Belt* brings to the city biotic benefits related to species and biotypes as well as abiotic benefits related to climate, soil, water, and air. Likewise, the green infrastructure creates spaces for recreation, improved environmental qualities, and the generation of economic income from agriculture, forestry and catering industries [24].

4.4.1. Collaborative Approach for Green Infrastructure

Frankfurt's approach to urban agriculture requires the collaboration of different municipal departments as well as the Regional Authority. The *Regional Land Use Plan (Regionaler Flächennutzungsplan)* prepared by the Regional Authority establishes, among others, the areas for urban expansion, residential, industrial and agricultural use, as well as environmental protection [24]. The City Planning Department defines more detailed regulations for land use in the city, including specific planning instruments in order to minimise the impact of urban growth on the environment. In the same way, the Environment Department performs programmatic, educational and monitoring functions and is in charge of promoting programmes and projects to protect urban and rural green areas.

4.4.2. Impact of City Planning in the Urban Agriculture Sector

Land, whether urban or rural, is not a renewable resource and growing cities need to address the problem of urban expansion and growth in a sustainable way. Therefore, the city explores many variations of policies and regulations to reduce the impact of urbanisation on the natural environment while providing the necessary conditions for citizens to experience a high quality of life [22]. One example of policy innovation is the *Compensation Areas* policy, which includes different land use typologies, including protection of existing green areas and redevelopment. In this way, the policy covers not only agricultural land, but also the water and wastewater sectors, thus helping with the protection of water reservoirs and control of water bodies [25].

5. Characterisation of Infrastructure Initiatives in Frankfurt

The research and analysis of projects, programmes and activities implemented in Frankfurt within the main five sectors of urban infrastructure suggest three categories of initiatives, in accordance with the objectives and purpose of the programme or project. These categories are: practice-oriented, programmatic, and educational initiatives.

5.1. Practice-Oriented Projects

As the name suggests, practice-oriented initiatives are projects aimed at the provision of public services to residents. Evidently, a large proportion of the initiatives implemented in Frankfurt are categorised as practice oriented, since the main purpose of urban infrastructure planning is the provision of the necessary public services to sustain a good quality of life. Thus, the ambitious sustainable development visions adopted by the municipality have driven the different municipal departments towards innovative technological approaches to improve the efficiency of service provision in the city. The initiatives implemented in Frankfurt have a high degree of technological complexity, exemplified especially by the proliferation of projects in the renewable energy sector.

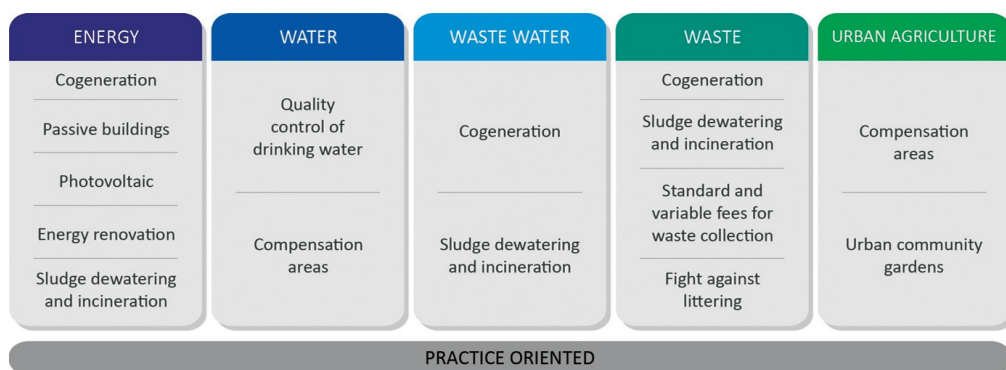


Fig. 5. Practice-oriented initiatives in Frankfurt (source: Global Urbanisation Research Team FRA-UAS)

The research results show an increasing number of projects in the energy and waste sectors. As a reason for the amount of projects in the energy sector, the research suggests rapid advances in technologies for the production of clean energies from renewable resources, along with the need for cities to reduce their ecological footprint. Reducing the carbon footprint requires changes in the production of energy by means of cogeneration, sludge incineration, and photovoltaics projects; reduced consumption through the promotion of passive buildings; increased efficiency in household appliances and industrial processes; and better housing insulation to reduce heating costs through energy retrofitting.

Similarly, the solid waste management sector is directly dependent on technological advances for the separation, recycling, and incineration of waste products, awareness of which has been created by the environmental policy in Germany. This collective consciousness, combined with a waste-collection fee based on product separation and individual needs, has resulted in less waste going to landfills and more efficiency in the waste management process.

For health reasons, the water and wastewater sectors are heavily regulated in Germany. In the case of water provision, the main projects are in place to protect the aquifers and water reservoirs from natural or artificial pollutants and to monitor the quality of water that reaches the end consumer. Therefore, there are few projects in this sector and they are very tightly

controlled by the Environment Department. In the case of wastewater, the challenge is in the effective collection, treatment and disposal of black water from households and industrial processes, and in promoting the reuse of rain and grey water for irrigation and non-potable purposes in households. Due to the high level of monitoring and control needed for the management of wastewater and the lack of this sector's attractiveness in terms of financial profits, the wastewater sector is 100% planned, implemented and monitored by public agencies; it is thus the only completely public sector in Frankfurt.

The urban agriculture sector is focused on promoting the use of non-developable green urban areas for the creation of community gardens. The main objective of the community gardens is to bring the local population together and raise awareness about environmental issues. Outside the city, the urban agriculture sector works in protecting agricultural land and balancing the loss of green areas inside the city with protected green spaces around the city such as the Green Belt and the City Forest.

Technological advances have played a crucial role in making sustainability policies feasible and facilitating the participation of different actors, from public to private and to citizens, in the provision of urban infrastructure with a focus on protection of the environment. The environmental focus is driven by the need to reduce consumption of natural resources, while shifting from the use of fossil fuels to renewable energies, as illustrated by the proliferation of energy-related projects and the evolution of waste and wastewater management processes in Frankfurt.

5.1.1. Semi-Public Companies for Public Service Provision

Trans-sectoral infrastructure planning and implementation requires the participation of diverse stakeholders and collaboration between municipal departments, along with a clear distribution of functions for the coordination of planning and execution processes. The research identified a specific collaboration scheme for the provision of public services in Frankfurt between the municipal departments and the private sector: while

Service Operators

- Energy & Water: *Mainova AG – Stadtwerke Frankfurt am Main Holding Group*
- Housing: *ABG Frankfurt Holding Group*
- Waste: *FES – Frankfurt Disposal and Service Company*
- Wastewater: *City Drainage Frankfurt Company*
- Cogeneration: *Müllheizkraftwerk Frankfurt GmbH/AVA*

the infrastructure planning process is the responsibility of the municipality through the City Planning Department, the Environment Department and the Municipal Energy Agency, the operation of services and connection to the end user are often managed by semi-public companies that allow the municipality to control tariffs and ensure fair costs of public services. In order to retain control of the service provision, these companies are publicly owned with a minimum of 51% of shares held by the City of Frankfurt, but they are managed in a business manner, with the municipality having the main voice in the reinvestment of profits.

These semi-public companies are bringing efficiency and innovation to the city, as well as extending their scope

Fig. 6. Operational companies in Frankfurt

from one single sector to implementing trans-sectoral infrastructure provision projects such as the increasing joint collaboration between the energy and waste sectors. The use of new technologies for the production of energy from waste products is leading the trans-sectoral thinking in the city. These two sectors are showing increasing opportunities for collaboration and are even involving other sectors like agriculture in the trans-sectoral energy production process.

The wastewater sector is the only sector that is completely managed by the municipality through the public City Drainage Frankfurt company. Wastewater does not attract private investment and the federal and state regulations for the management of wastewater requires high degrees of control and monitoring, which is more feasibly achieved directly by the municipality. Sanitation and treatment of wastewater is crucial for public health and sustainable environments.

5.2. Programmatic Experiences

Programmatic experiences are the projects and programmes aimed at promoting behavioural change and sustainable practices within the city and among urban residents regarding the consumption of natural resources. These initiatives are found among every sector of urban infrastructure initiatives and are formulated by the different municipal departments, with specific policy objectives for each of the sectors. The scope of initiatives is broad: promotional programmes for the use of renewable energies, e.g. *Ökoprofit* [4, 17] and *Sensible Water Use* [20]; improving ecological performance in the private sector and obtaining profit from climate-friendly technologies; advisory services for businesses and social projects such as *Cariteam*; training the long-term unemployed population to become energy-saving advisors and assistants for low-income households [1]; and social projects such as *Ffmtipptopp*, whose aim is to improve cleanliness and have a social effect that enhances citizens' awareness and creates new jobs for the unemployed through training [8]. Municipal departments or agencies advise citizens and the private sector on infrastructure-related issues in order to achieve the ambitious sustainability goals proposed by the city, e.g. energy efficiency, reduction of water consumption, flood prevention etc.

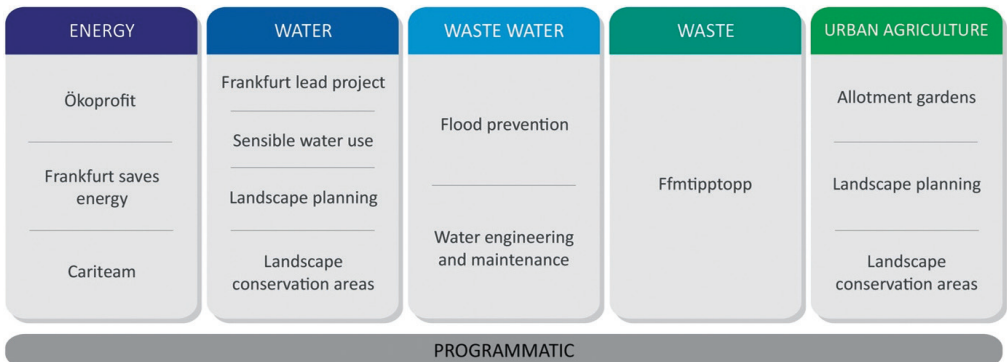


Fig. 7. Programmatic initiatives in Frankfurt (source: Global Urbanisation Research Team FRA-UAS)

5.2.1. Public Actors as Consultants for the Private Sector

The stakeholders involved in the programmatic initiatives are public departments and agencies focused on advancing the ambitious policy goals set by the municipality. Their responsibility is the formulation of policies, programmes and regulations in order to lead the city closer to achieving its sustainability objectives. The specific role of these public actors in the programmatic projects is to act as advisory boards to the City Magistrate and the City Council in the formulation of public policies, providing practical and professional feedback for decision-making. This advisory responsibility extends also to private investors and citizens in cases of urban development or building improvement.

The main municipal departments responsible for programmatic initiatives are the Environment Department, the Municipal Energy Agency, and the City Planning Department. These departments are in constant communication in order to plan and find opportunities for multi-sectoral collaboration, and to make urban development planning more efficient. Usually, the role of general programme coordinator is fulfilled by one of these three departments in accordance with the main characteristics of a given project, and it is this coordinator which invites the relevant stakeholders from other municipal departments or external actors from other infrastructure sectors to be involved in the project.

Programmatic Stakeholders

- Environment Department
- Municipal Energy Agency
- City Planning Department
- Building Construction Department
- Clean Frankfurt Office
- City Drainage Frankfurt am Main
- Health Department
- Green Spaces Department

Fig. 8. Programmatic stakeholders in Frankfurt

The Environment Department is intensively involved in the implementation of urban policies focused on environmental protection, with an essential role in the definition of regulations and the monitoring and control of the quality of the green infrastructures in the city, i.e. protection of greenery, agriculture fields and aquifers. It is also involved in the energy sector by raising awareness about the need for renewable forms of energy and the importance of climate protection in the city and the region. The emphasis of Frankfurt's public policy on sustainable development highlights the importance of the Environment Department as an advisory body as well as in the formulation of projects and programs. Therefore, the Environment Department is one of the most involved – both directly and indirectly – municipal departments in projects

developed by all sectors of urban infrastructure.

The City Planning Department is the municipal organisation in charge of steering the urban development vision in the city, regulating the expansion, development and redevelopment of urbanisation, defining densities, plot coverage and heights, along with the urban requirements for each infrastructure sector. The involvement of the City Planning Department in the infrastructure sectors is indirect; its role resides in producing urban development plans with regulations and guidelines which are later used for the implementation of urbanisation and other development projects.

A common characteristic observed in these initiatives is the multi-sectoral collaboration approach; diverse municipal departments and agencies are involved in the infrastructure

planning process in terms of defining the regulations for land use, consumption of natural resources, and coordination of multi-sectoral programmes. Although most municipal actors are involved directly and are responsible for only one specific sector of urban infrastructure, the collaboration approach suggests their indirect involvement in programmes and activities outside their specific sector. In this sense, the research has identified a project-driven collaboration nature in the infrastructure planning processes in Frankfurt.

5.3. Educational Experiences

Educational or promotional experiences are focused on raising awareness and educating citizens in consumption-related issues, while promoting a sense of place and commitment to helping the city achieve its sustainability goals.

These experiences exhibit a strong sectoral approach and are generally developed by one municipal actor. These educational projects are mostly aimed at young residents, who later pass on their knowledge at home. The emphasis on educating young people requires easy-to-understand topics, therefore these projects, although they may have a trans-sectoral background, are usually executed by one single actor in order to facilitate their implementation. However, the education of the public has had a trans-sectoral impact in the consumption patterns of the population, resonating among the energy, water, wastewater and waste management sectors. This trans-sectoral impact has helped the city achieve milestones and partial goals in the reduction of resources, as well as transitioning from fossil fuels towards clean and renewable energies.

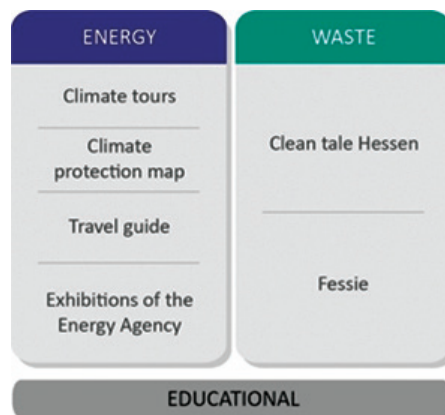


Fig. 9. Educational Initiatives in Frankfurt (source: Global Urbanisation Research Team FRA-UAS)

The responsibility of promoting sustainable urban development, clean energy, and reduced consumption starts with the City Magistrate and the City Council by enacting urban policies which direct the development of the city towards a more environmentally friendly approach. The municipal departments, i.e. the Municipal Energy Agency, the Environment Department, and the City Planning Department, are the three main stakeholders in the

implementation of sustainable urban policies in the city, and, as such, they have cooperated in bringing the city infrastructure towards new approaches which make the achievement of the ambitious goals of the city feasible.

6. Conclusions

The main programmes and projects in each infrastructure sector in Frankfurt highlight trans-sectoral planning practices within the city administration. These trans-sectoral practices have emerged from the need for coordination and communication between municipal departments. The analysis of Frankfurt's infrastructure sectors suggests that the concept of trans-sectorality in the city has been permeating infrastructure planning processes for years, thus resulting in a project-driven collaboration scheme. Depending on the specificities of a project or programme, the relevant stakeholders come together to design effective multi-sectoral approaches.

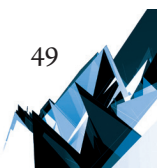
Trans-sectoral projects are becoming more necessary in order to achieve the environmental goals set by the municipality. Initiatives such as *Master Plan 100% Climate Protection* and *Frankfurt Green City* approach look at urban development in a holistic way, involving different sectors of society through public-private partnerships, engagement of private actors, and operational stakeholders as semi-public actors. The diversity of stakeholders is complemented by a multi-sectoral approach that involves two or even three urban infrastructure sectors for large infrastructure projects. For example, in the energy sector projects are looking at utilising waste products and biomass and reducing the consumption of natural resources, i.e. by cogeneration from household waste and sludge from wastewater treatment. These energy projects demand trans-sectoral collaboration between the Municipal Energy Agency, the City Planning Department, the waste management company, and community organisations in the case of by-products from cogeneration that are used for compost.

Moreover, when examining the experiences in Frankfurt, it can be observed that the energy sector leads the implementation of environmentally friendly projects; however, the Municipal Environment Department and the City Planning Department are also involved in most urban infrastructure projects and sectors, either as advisors, coordinators (as is the case of the Municipal Planning Department for large infrastructure projects), or monitoring and controlling the quality of the environment and the products delivered by the infrastructure projects.

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