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Resource Management as Part of Sustainable Urban District Development

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Abstract: Rising urban populations, limited natural resources (following the German Federal Environmental Agency, natural resources are resources that are part of nature. They include renewable and non-renewable primary raw materials, physical spaces (surface areas), environmental media (water, soil, air), flowing resources (e.g., geothermal, wind, tidal and solar energy) and biodiversity. It is irrelevant here whether the resources serve as sources for producing products or as sinks for absorbing emissions (water, soil, air)) and climate change require a new approach to urban planning. Recently, international, European and national programmes, concepts and framework documents have been created to promote the implementation of measures for more sustainability, resource efficiency and climate resilience in urban districts. In the funding measure of the German Federal Ministry of Education and Research's "Resource-Efficient Urban Districts for the Future-RES:Z", twelve funded research project networks are dedicated to understanding the impacts that urban districts have on the resources of land, water and material flows, as well as the resulting impacts on urban green spaces and energy issues. By considering the different resources involved, it is shown that the optimisation of their use cannot take place independently of each other. This may even lead to conflicting goals. Use conflicts can be recognised at an early stage and measures can be tailored to the specific neighbourhood context when applying an integrated approach that provides a common view on all of the aforementioned resources. Special attention is paid to solutions which create numerous benefits i.e., multifunctionality. The RES:Z funding measure utilises living labs for the research on and implementation of solutions. This lays the foundation for a sustainable transformation of urban districts and the basis for further research.

Keywords: resource efficiency; urban districts; sustainability; multifunctionality; sufficiency

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1. Introduction

According to United Nations estimates, the global urban population currently amounts to about 4.5 billion people, which corresponds to about 57% of the world's population. In 2030, around 60% of people will live in cities, and by 2050, the proportion is expected to rise to over 70% [1]. Cities already exhibit a high demand for resources and energy; cities currently consume up to 75% of the energy generated worldwide [2] and are also responsible for around 75% of global resource consumption [3]. There is much potential for implementing resource efficiency in urban districts as well as many opportunities for the development and testing of resource-saving measures. The district level is suitable for the implementation of the following sustainable approaches: efficiency, effectiveness and sufficiency [4]. In addition, districts are an ideal urban scale to address the existing challenges—this includes not only measures of material flow management but also the behaviour of people. The building sector influences several areas of life and is connected to other sectors. In order to be successful, sustainability strategies have to be implemented according to the present living conditions in the respective districts. By being the link between the single-building and citywide perspectives, responsible legislative authorities should better address the urban district level. On the district level, measures can be realised in combination with each other in order to enable new potential synergies [5].

In addition to the central goals pertaining to the economic and prudent use of available raw materials, water, land and energy, resource efficiency in urban districts also includes other aspects such as quality of life. Against the backdrop of increasing extreme weather events such as heat waves or heavy rainfall, the creation of a liveable microclimate in urban districts is increasingly becoming a central focus of residents, municipal administrations and higher-level ministries. For example, the greening of urban land plots and building facades, together with intelligent rainwater management systems, can improve the microclimate considerably. This paper will focus on the central role of an integrated approach for the resource-efficient design of urban districts, which takes into account all resources.

Various national and international approaches and concepts already exist to promote and achieve resource efficiency in urban districts. These include, for example, the Sustainable Development Goals (SDGs) of the United Nations and the resulting aspects of European and national guidelines and initiatives, such as the "European Green Deal", the German Resource Efficiency Programme III, the German Climate Protection Act (2021) and the New Leipzig Charter (2020), all of which are relevant for the urban district scale.

In order to support the resource-efficient development and design of urban neighbourhoods, the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung-BMBF) is funding twelve interdisciplinary and transdisciplinary collaborative projects under the title "Resource-Efficient Urban Districts for the Future—RES:Z". The twelve projects address the fields of urban material flows, water infrastructure systems and land use in urban areas. The projects include the active involvement of more than 20 model municipalities and leading research institutions. The aim of the funded joint research projects is to develop new implementation-oriented concepts for the sustainable use of resources at the urban district level and to test them on-site, as well as testing the transferability of the results to other cities and communities. The funding measure RES:Z also focuses on indicators for visualising and measuring the impact of the solutions. The results of the collaborative projects not only contribute to the resource-efficient design of urban districts, but also promote the climate-resilient and climate-mitigating design of cities.

2. Legal and Policy Framework for Resource-Efficient Urban Districts

For several years, resource management has been a top issue on the policy agenda. The following section introduces different policy programmes and initiatives which impact resource management in urban districts.

The United Nations 2030 Agenda, with its 17 Sustainable Development Goals (SDGs) [6], formulates political objectives for global sustainable development related to economic, social and ecological aspects. In particular, the implementation of Sustainable Development Goal 11, "Sustainable Cities and Communities" [7], can make an important contribution to the local implementation of resource-efficient urban districts.

Around 16 tonnes of materials are consumed in the European Union (EU) per capita per year—of which 6 tonnes are accumulated as waste [8]. Therefore, a long series of resource-relevant programmes were released in the last 20 years at the EU level, starting in 2002 with the Sixth Environmental Action Programme (which included priority areas such as natural resources), followed by the Thematic Strategy on the sustainable use of natural resources in 2005 [9], the Raw Materials Initiative in 2009 [10], the Roadmap to a Resource Efficient Europe in 2011 [11] and the Seventh Environmental Action Programme in 2014 [12]. Furthermore, the "European Green Deal" presented in December 2019 set the course for greenhouse gas neutrality within the European Union. The European Green Deal is a roadmap of measures that, among other things, aims to promote the more efficient use of resources through a transition to a clean and circular economy and to achieve the climate neutrality of all member states by 2050. With regard to the building sector, the European Green Deal primarily takes into account the issue of energy- and resource-efficient construction. For this, a "renovation wave" is planned that is primarily aimed at improving the energy efficiency of buildings [13].

With the New Leipzig Charter (2020), the Member States of the European Union aim to play a worldwide leading role in the "transformation of societies" on the basic principles of "circular economy, digitalisation, renewable energies and sustainable mobility". Urban quarters, being the most directly lived and experienced scale of urban life for residents, are to contribute to achieving this goal by becoming "real laboratories for innovative projects" [14].

The European Union supports innovative approaches to urban district development with the "Urban Agenda", the "New European Bauhaus" initiative and the "Next Generation EU" reconstruction fund. President of the European Commission Ursula von der Leyen, for example, demands: "I want Next Generation EU to trigger a European renovation wave and make our Union a pioneer in the circular economy. However, this is not just an ecological or economic project: it must also become a new cultural project for Europe." [15–17]

At the national level, the German Resource Efficiency Programme (ProgRess) [18], which was first launched by the German government in 2012 and is updated every four years, most recently in June 2020, sets out goals, guiding ideas and approaches for protecting natural resources. Even though the focus here is not exclusively on urban districts, the following measures are planned for the building sector, which also apply to this scale:

- Promotion of resource-saving building products with a low CO_2 impact,
- Increasing the use of renewable raw materials and the proportion of recycled materials in the building sector,
- Further expansion of sustainability assessments in the building sector,
- Further development of the assessment criteria for sustainable construction standards for the use of natural resources,
- Promotion of the use of recycled building materials in public building projects and
- Promotion of selective deconstruction for the extraction of secondary raw materials.

Progress also focuses on the important role of municipalities. On the municipal level, large quantities of resources are required, such as building materials, water and energy. Hence, the undertakings of local politicians, administrations and municipalities—such as urban planning of districts—all play an important role in reaching resource efficiency in urban districts [19]. This is supported by the coalition agreement of the new German government, which has been in office since the end of 2021, and which includes the following measures:

- Optimisation of building facades.
- Optimisation of technical systems for the generation and supply of renewable energy in buildings, including district solutions.
- Amendment of the tax, levy and apportionment system to simplify and strengthen tenant electricity and district concepts [20].

The amended Climate Protection Act came into force in August 2021. It stipulates that Germany should become climate-neutral as early as 2045. In 2022, the energy-efficient refurbishment of buildings and the installation of energy-efficient heating systems are to be promoted by means of an emergency programme. According to the amended Climate Protection Act, greenhouse gas emissions in the building sector must be reduced to 67 million tonnes of CO_2 emissions by 2030, i.e., by two-thirds compared to 1990 (210 million CO_2 emissions) [21].

The flagship report of the German Advisory Council on Global Change (WBGU (WBGU = Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen)) from 2016 outlines the special challenges and opportunities faced by cities from the perspective of the necessary transformation towards sustainability. One of the core recommendations for transformative action fields is to link urban design to sustainability and adaptability. It is stated that low-carbon urban and city district planning needs locally adapted urban planning strategies that observe not only the respective geographical and cultural context, but also the technical possibilities of implementation and maintenance [22].

In 2020, the German Advisory Council of the Environment (SRU (SRU = Sachverständigenrat für Umweltfragen)) published a new environmental report [23]. This report highlights the enormously important role of districts for climate change and resource efficiency. One chapter of the report describes districts as an important strategic as well as implementation level—the district level helps to address these challenges. Different issues—such as the construction of buildings or infrastructure—can be considered jointly to find environmentally friendly solutions. With regard to the challenges of climate change and resource protection, the report states that planning, administration and funding structures are currently not sufficient to achieve the relevant potentials of the district level [24].

In 2020, the "Bauhaus der Erde" was initiated. Its objective is to transform the built environment, and its aspiration is to break the mold of conventional construction and catalyse systemic change in the building sector to promote sustainability and inclusiveness. Therefore, the initiative works on alternative models of built and urban environments at the building, district and city scales. "Bauhaus der Erde" also has an international view. It builds up a new network, for example to Africa. In this context, Mrs. Mathai (Vice President and Regional Director, World Resource Forum Africa) refers to the following: "*As cities go, so goes the planet! It is estimated that cities are responsible for 75 percent of global CO_2 emissions, with transport and buildings being among the largest contributors. In Africa the urgency is even greater—a majority of the infrastructure needed for the next 50 years has not yet been built...!*" [25].

In Germany, the focus on "district refurbishment" during the past decade was on traditional urban refurbishment actions and energy-efficient urban renovations through the Kreditanstalt für Wiederaufbau (KfW) (The Kreditanstalt für Wiederaufbau is one of the world's leading promotional banks. On behalf of the Federal Republic of Germany and the federal states, KfW has been committed to improving economic, social and environmental living conditions across the globe since 1948 (https://www.kfw.de/About-KfW/, accessed on 1 March 2022)). In 2020, the German Advisory Council on the Environment stressed the importance of the "neighbourhood" planning level for implementing energy transitions and resource protection measures, as well as for the synergies between water, energy and open spaces. However, this requires "new governance approaches that involve local actors and a further development of funding geared to this" [26], p. 405.

The necessity of bundling resource efficiency at the urban district level and combining the expertise of different disciplines is repeatedly demanded by municipalities and supported by position papers of the leading associations. In the position paper "Heat and Drought in Cities and Municipalities", the German Association of Cities and Municipalities calls for far-reaching climate adaptation measures which require the "integration of the expertise of different disciplines" [27]. Clear accents are also being set on the sectoral side. With positions such as the "Water-conscious Development of our Cities" published in 2021, the German Association for Water, Wastewater and Waste (DWA Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V.) promotes the multifunctional utilisation of water resources. DWA calls for multifunctional uses in neighbourhoods to increase the soft location factors of the area, which also support improvements in the urban quality [28].

3. Resources in Urban Districts

Figure 1 shows the levels of consideration in which the planning of urban districts takes place. There is a high potential to reach a sustainable and efficient handling of resources in the context of these levels—especially if they are already considered holistically and are integrated into urban planning and development processes.

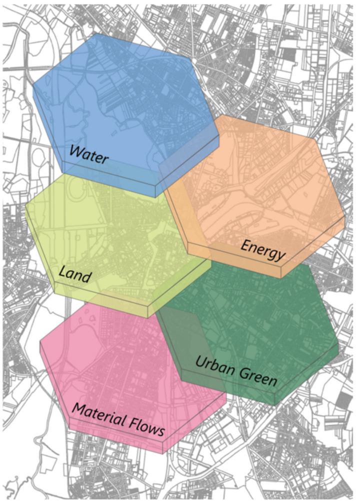

Figure 1. Levels of consideration in resource-efficient urban districts (authors' elaboration).

Urban districts are the place where various urban functions such as housing, services, commerce and transport are located and where potential and conflict coexist. Integrated concepts for district development have established themselves as a practicable steering instrument in municipal practices in recent years [29]. While integrated concepts for the city as a whole often have a strong sectoral focus and formulate long-term perspectives, district concepts are mostly cross-sectoral and implementation-oriented [30]. This is also associated with the expectation that resource efficiency can be decisively promoted at the district level. Experience gathered from energy-efficient refurbishment actions shows that this can indeed be successful. Since 2011, the Kreditanstalt für Wiederaufbau (KfW) has been promoting a neighbourhood and resource-oriented approach as part of its funding programme on energy-efficient urban refurbishment—climate protection and climate adaptation in districts [31]. The program is considered to be most successful when combined with co-financed neighbourhood management. Above all, the energy use of construction measures and buildings is one of the main triggers of resource consumption. The construction and building sector is responsible for 38% of worldwide CO_2 emissions. The district approach to action is mentioned in the UN report several times (for example, district cooling and heating) [32]. Since 1 April, 2021, the new thematic fields of green infrastructure and water-sensitive neighbourhood design, digitalisation and climate-friendly mobility have been included in the funding [33]. Thus, the task for researchers and practitioners is to show ways to create resource-efficient urban districts.

A key issue to be addressed will be the anchoring of multifunctionality. Multifunctional land use overlaps and addresses different demands for use of the same space. Current and future urban development trends such as a growing urban population, increasing land use pressures and the expected climatic changes increasingly require such solutions. This also fits with the 15-Minute City approach, according to which residents of a district should be able to meet most, if not all, of their daily needs within a short walk or bike ride from their place of residence [34]. The 15-Minute City approach is not a radically new idea since it utilises long-established planning principles [35].

Existing problems of urban development, e.g., traffic conflicts, urban heat stress, energy supply, resource consumption (e.g., construction materials), land use and flooding or impairment of the green space along streets, will increase significantly in the near future. The task of future-oriented urban development is therefore not only to develop land uses side by side, but to link and combine them for multifunctionally (i.e., to "designate" them for several simultaneous uses) and thus to be able to develop them with regard to different interests and their land uses and functions. In increasingly dense cities, the neighbourhood and street space present a large space reserve for the provision of open space and the qualification of the residents' quality of stay in the living environment. The concept also harbours potential for flood protection and a decentralised energy supply, strengthening biodiversity and the use of recycled materials [36].

In order to structure the necessary sectoral management of multifunctional uses, interdependencies must be analysed. The following sections first deal with the resources of land, water, urban greenery and materials in urban districts, which are to be highlighted analogously to the BMBF funding measure. Further connections to ecosystem services and energy aspects are established.

3.1. Land

The resource of land in neighbourhoods and districts is a fundamentally scarce and, above all, non-replicable commodity; the very nature of the resource of land requires that it be used prudently and sparingly. The utilisation of land for building purposes is linked to the destruction of natural soil functions. The use of land is subject to conflicts between economic, ecological and social considerations. These are to be weighed against each other. Resource-efficient urban districts must:

- Use existing space sparingly,
- Use brownfields or conversion areas for the development,
- Use potential for promoting sufficiency,
- Increase the density of housing without restricting the quality of life, as proposed, for example, in the framework of double internal development (dense urban structures as well as qualitative green spaces) and
- Exploit the multifunctionality of land use.

This is also confirmed by the requirement in the German Sustainability Strategy 2021 to reduce the land take to less than 30 hectares per day by 2030 [37]. Actually, this goal will not be reached anytime soon, as around 52 hectares of new land are currently being designated as new settlement and transport areas every day in Germany [38].

Special attention should be paid to the type of land use. While recreational areas such as city parks or public gardens can make a positive contribution, for example, by improving the urban climate or helping to cope with heavy rainfall events, the construction of new buildings or new traffic areas requires soil sealing with mostly irreversible impacts. This usually leads to these areas being impermeable to precipitation and the natural soil functions being destroyed. Possible social consequences include a reduced quality of life for the residents of an area. Economically, the follow-up consequences of these sealed areas must also be taken into account.

Land is a scarce good. Therefore, the consequent application of inner development to urban districts and cities is required. With a view to natural resources, existing urban structures need a qualitative re-densification to support existing targets [39]. As a possible measure against land taking, a sustainable urban settlement policy which prioritises the inner development of neighbourhoods can be pursued. Inner urban development aims to make use of the existing brownfields, gaps between buildings and vacancies in the urban fabric instead of sealing previously undeveloped land for new buildings. Measures related to de-sealing and renovation concepts, especially when applied to the management of vacant brownfield land, can greatly support the land-efficient development of urban districts [40]. Furthermore, the district level is appropriate for the implementation of the sufficiency approach. An example is the Hunziker Areal (housing cooperative "mehr als wohnen") with 370 apartments in the city of Zurich, which has adopted the 2000-watt-society objectives [41]. For this, behavioural changes were initiated to reduce resource consumption. Land sufficiency and energy efficiency are achieved in the district by using different sharing models in common and public spaces [42]. The living space per person in the Hunziker Areal is 32 m^2, whereas the average amount in Switzerland is 44 m^2. Resource consumption is not just triggered by population growth but also by lifestyles.

Another good example of a compact district developed on a conversion area is the Aspern Seestadt in Vienna. It includes a new centre with 25,000 residents and up to

20,000 jobs [43]. The main elements of the masterplan were: high-density constructions, diverse and multifunctional uses, short distances within the district and qualitative public spaces. The aimed-for urban structure essentially demands a high building density. Further, the planners of the Aspern Seestadt also include other sustainable approaches such as avoiding motorised traffic, an energy-saving city quarter layout, the use of geothermal energy and material management [44].

3.2. Material Flows

The construction sector caused approximately 231,000 tonnes of construction and demolition waste in 2019; this corresponds to about 55% of the total waste generated [45]. Urban areas are therefore enormous "material sources" which are expected to increase in the future due to the creation of new infrastructure and living spaces [46]. The construction sector also has a high demand for resources—e.g., construction material, energy and water. In Germany, around 517 million tonnes were removed as mineral raw materials in 2015 [47]. The construction sector also uses around 2.6 million tonnes of plastic every year [48]. The extraction of raw materials for building purposes sometimes has a detrimental environmental impact. For example, the operation of gravel pits and quarries, as well as lime mining, destroy existing ecosystems and water tables. The processing these resources undergo for later use as building materials, such as cement or metals, also requires large amounts of energy and thus contributes significantly to the emission of greenhouse gases. Besides the reduced use of primary raw materials, a further solution to this problem can be found in the recycling of building materials and thus in the substitution of primary raw materials with secondary materials being reused for new purposes.

The city of Zurich's "resource strategy" sets a focus on the recycling and re-use of materials. In the resource strategy, capabilities for recycling building materials are to be developed in order to process material flows from demolition through to intensified clean-up activities and the replacement of buildings [49]. To support the implementation of the objectives and measures outlined in the resource strategy "Building in the City of Zürich", the Seven Milestone programme was developed [50]. The use of recycled building materials is also possible on the district level.

On the other hand, the substitution of environmentally problematic building materials such as concrete, cement or steel is possible. The use of timber or other natural materials as construction materials is a chance for the building sector—including on the district level. Timber is a good material for CO_2 storage. The city of Munich has already developed the "Prinz Eugen District" as an ecologic model district by using wood as construction material. More than 600 apartments were built [51]. In addition, the city of Berlin is planning the new "Schumacher District", also on a conversion area and with around 5000 apartments constructed by using timber [52]. The Schumacher District is expected to become a model residential district for urban timber construction. The objective is to transform Europe's building culture towards a bio-based, circular economy. The use of timber as construction material is also a step towards a circular economy, because the material can be easily reused.

The city of Stockholm used an integrated approach for the development of the district of Hammarby-Sjöstad (11,000 apartments). The planning of the area and its buildings were to be aligned with the principle of natural cycles—"*The natural cycles should be closed at as local a level as possible*"; "*Energy should be derived from renewable sources, and as far as possible obtained from local sources*" [53]. As part of an environmental programme, an eco-cycle model was developed—the metabolic flows of Hammarby Sjöstad were reduced as a result of the integrated system [54]. The model was consequently developed as part of a cooperation arrangement between the municipal organisations of Stockholm Energi (now Fortum), Stockholm Vatten AB and Stockholm's waste companies. The Hammarby model takes an integrated planning approach and considers cross-sectoral material flows in order to produce synergies. The overarching objective for the district is to be "climate neutral" by 2030. Experience and knowledge were used in Stockholm for the development of the new district of Royal Seaport. An eco-cycle Model 2.0 was developed; the primary objective of the eco-cycle model was to contribute to drawing attention to and explaining important connections and synergies between resource flows [55].

Not only the efficiency of materials but also that of energy must be taken into account in order to develop resource-efficient and sustainable urban districts. Since about 25% of German energy consumption is attributable to private households, the carrying out of energy-efficient building renovations is an important field of action [56]. Due to the long use of buildings, it is of the utmost urgency to reduce the energy consumption per residential unit or per square metre of floor space [57] and thus to achieve long-term energy efficiency. The level of the urban district is also the key for increasing the redevelopment rate of buildings. A long use phase of buildings saves the consumption of natural resources. The concept of municipal energetic re-development plans is an important instrument for planners on the district level [58].

According to the German Council of Environmental Advisors (2020) [26], pp. 452–453, additional potential for environmental and climate protection can be tapped at the urban district level. However, this requires far-reaching adaptation measures with regard to buildings and infrastructure in cities in order to achieve an urban energy transition and the careful use of natural resources (material flows and especially land).

3.3. Water and Urban Greenery

The resource of water and the topic of urban greening are closely intertwined on the district scale. They play an important role in the resource-efficient planning and design of urban districts, both in new buildings and in structural re-densification. Water-related considerations and green neighbourhood development are both indispensable in the context of creating a healthy and social environment for the urban population facing the demands of climate change mitigation and climate change adaption.

To achieve resource efficiency in urban districts, water must be considered a multi-functional resource. On the one hand, water plays a part in the natural environmental balance as the basis of various ecosystem functions and thus makes valuable contributions to urban society. On the other hand, water must also be understood as a risk factor (e.g., flooding risks during heavy rainfall) when planning construction.

Climate change impacts our everyday life, which is why adaptation is an increasingly important area of activity for local governments. Therefore, natural water management has been a central part of urban planning processes in several districts. For example, the city of Bochum's Feldmark district, with 1000 residential units, shows new paths to climate change adaption in urban planning [59]. During the planning process of the new district, several measurements with a focus on climate change were already discussed and included, for example, aboveground waterways to drain rainwater, the retention and storage of rainwater or the connecting of green spaces.

Another good example for the implementation of sustainable approaches is the ecovillage in Hannover. It will be a model project, providing affordable living space for around 900 people, while at the same time being future-oriented, sustainable, affordable and community-supporting [60]. One of the most specific features of the ecovillage, and its guiding principle, is sufficiency. Its motto is that to possess more one must share more. This represents a highly flexible approach that, here, is not only preached but also practised [61]. Everything is built from wood, and the sealing of land is being minimised as well. Biodiversity is promoted, and greywater and rainwater are treated and cleaned with the help of a plant-based sewage treatment system. After being directed into a biotope-like lake, it seeps away and evaporates, or serves the residents for watering their gardens.

Green urban infrastructure can be created primarily through vegetated facades, green rooftops, parks and gardens, as well as vegetated courtyards. Green spaces support the fundamental regulation of water levels in neighbourhoods through natural infiltration, storage and evaporation. In addition, they offer a variety of other functions. Not only do green spaces promote a healthy microclimate in neighbourhoods by mitigating the urban heat island effect through increased evaporation capacity, they also serve as a buffer against the consequences of heavy rainfall events through increased soil infiltration as well as contribute to air filtration, all the while supporting biodiversity. In addition, they improve the location quality for residents by serving as areas for recreation and social encounters as well as participation [62].

An integral consideration and application of water and land resources is reflected in the use of blue-green infrastructure. According to the definition of the European Commission (2013) [63], blue-green infrastructure is a strategically planned network running through a city, consisting of urban green spaces and urban aquatic ecosystems. In terms of design, green infrastructure can take the form of retention roofs or combined green and water facilities such as infiltration beds or tree trenches.

Water and green spaces can provide so-called ecosystem services in urban districts, i.e., services provided by nature which may also benefit residents. Ecosystem services are currently divided into four main categories. The provisioning function of ecosystem services provides people with products from the ecosystem, such as raw materials, water and food. Regulating and maintaining services mitigates environmental stresses, which also benefits the residents of an area through increased resilience, for example, by microclimate regulation of temperature and humidity. In addition, ecosystems also provide cultural services, which usually take the form of intangible benefits such as recreation or education.

3.4. Resources in the Urban District: Interactions, Conflicting Goals and the Public Interest

The resource-efficient and sustainable urban district claims to optimise the use of each individual resource. A desired side-effect of optimisation is the interaction between the resources under consideration, which can lead to the generation of several positive effects; this can be seen in the example of blue-green infrastructure explained above. On the other hand, resources in urban districts are in competition with each other, and conflicts of objectives can arise. This particularly affects the resource of land but can also be seen in aspects such as the energy efficiency of buildings vs. the affordability of housing, land consumption vs. acceptable settlement density or in competing demands for green spaces vs. mobility-oriented land use.

One possible approach to reducing competition for land in urban districts, which is also used in the Environmental Report 2020 of the German Advisory Council on the Environment, is an integrated approach within the framework of the urban structure. This includes, in particular, the designation of multifunctional land uses. In addition, a land-saving building typology which promotes compact architectural solutions, as well as different uses within a building or neighbourhood (mixed use), can contribute to the efficient use and management of the resource of land in neighbourhoods [26], pp. 436–437. Transparency related to all planning options should be ensured in order to be able to properly weigh them against each other. Specially developed indicator sets which evaluate the various impact dimensions on a site-specific basis can serve as an aid for the decision-making process.

The high resource consumption of cities as described above leads to the fact that municipalities will have to attach a greater importance to resource efficiency in their urban district planning in the future. For the broader goal of a sustainable urban district, social aspects must also be taken into account; in short, the sustainable city of the future is oriented towards the well-being of people. In his book "Cities for People", author Jan Gehl describes as a basis for planning activities that the city must be experienced at the speed of a pedestrian rather than from a vehicle. The city should be measured by the criteria of liveability, safety, sustainability and health [64]. This also applies in particular to the district as a sub-unit of the city, where life and daily encounters take place.

The position paper "Cities for People" published by the German Association of Cities in October 2021 calls for better framework conditions for liveable, crisis-resistant, innovative and modern cities [65]. The health, well-being and prosperity of residents, good local amenities and the overall satisfaction of residents are thus in the public interest—and all this from the perspective of affordability, i.e., the public budget on the part of the municipality and affordable housing on the part of residents.

The overall result is that the management of resources in urban districts must be thought of in terms of the residents, who should live and feel comfortable in the neighbourhood. Ideally, public spaces are available for community activities in the urban districts. Gardens and parks serve as places for local recreation; at the same time, green spaces or urban vegetation can help store rainwater and improve the microclimate through evaporation and shading. The use of greywater and solar energy as well as the reuse of building components or the recycling of building materials complement the concept. The resource-efficient way of thinking can thus simultaneously increase the resilience of the districts to climate change; residents benefit, for example, from higher water availability, milder temperatures and better flood protection. For the planning of urban districts, a comprehensive integrated approach is indispensable, taking into account different human interests and the conflicts of resource use described in Chapter 3. There is no exclusive ideal solution, but rather an optimum balance must be found for the conditions in each district. In the interest of the residents, they should therefore be included in the planning processes.

4. Expected Results from the Funding Measure

As part of the BMBF funding measure "Resource-efficient urban districts for the future (RES:Z)", a large number of innovative solutions are being developed for the resources of land, water, greenery and building materials in urban districts.

The *NaMaRes* project is developing a web tool to assess de-sealing potential as well as greening and other potential for roofs, facades and yards in existing urban districts. The data for the analysed areas which are potentially suitable for de-sealing measures are openly accessible data from official administration sources to be used for research purposes. To assess the ecosystem services of private yards and urban green spaces, these data are supplemented in the project by a detailed GIS-based mapping of private land parcels. The assessment of roofs and facades includes the current as well as the potential usage of photovoltaics and solar thermal panels, as well as rain water collection. For the evaluation of the areas, a set of indicators was compiled for the whole district under study which, in addition to the costs/necessary investments of implementing the improvement activities, also takes into account, for example, the savings related to municipal rainwater fees, the potential public funding of such measures, the potential for urban heat island reduction and CO_2 fixation, or the potential for reducing air pollutants. The next step is a comparison of different options/improvement measures, in order to decide which measures have the greatest leverage to reach the set goals in the district under study [66]. The *R2Q* project develops the "ResourcePlan" as an integrated (i) legal and (ii) planning instrument to support the efficient use of natural resources in urban districts. As a legal instrument, the ResourcePlan integrates solution strategies and planning goals into existing formal and informal instruments of municipal action. As a planning instrument, the ResourcePlan evaluates the resource efficiency of sectoral resource management of (i) water (ii) building materials, (iii) energy and (iv) land. The conceptualisation of the ResourcePlan as well as the development of additional software tools, application guides and information materials are completed in transdisciplinary exchanges between municipal stakeholders (the City of Herne and eight associated municipalities) and scientists. The final results will be the key element of the new German norms "Resource efficient districts" [67]. In the *RessStadtQuartier* project, various tools are being developed to support municipalities in the use and recycling of building materials for neighbourhood development projects. The tools, a GIS-based building material cadastre, a waste management tool and a resource efficiency tool, provide data on the types and quantities of materials to be expected in the buildings, but also, for example, on the CO_2 footprint occurred over the buildings' life cycle, and help in particular to evaluate refurbishment and demolition activities in the new construction of buildings. The data basis for the building material cadastre is formed by official geographical data, which were supplemented with synthetic building-related data. In addition, data from municipal offices, for example surveying and building supervisors, and data from residential building statistics were integrated into the tool. With the help of special algorithms, district-specific values for material quantities, CO_2 balances or refurbishment requirements can be calculated based on the building type and age class. With the help of a bidirectional interface, data can, on the one hand, be extracted for the Building Information Model (BIM), and on the other hand, be further fed into the cadastre [68].

In addition to planning aspects, some of the projects also deal with the design of areas that focus strongly on urban green infrastructure and water management. For example, the *Leipziger BlauGrün* project is planning and supporting the development of one of the first water and energy efficient districts in Leipzig. The project is developing innovative technology solutions in co-designing blue-green infrastructure with the city authorities. The guiding principles for the technology evaluation and legal framework recommendations will be transferable to comparable new districts as well as existing districts throughout Germany. For this purpose, planning tools and multicriteria assessments of neighbourhood developments for their integration into urban land use planning are being developed. The application in the project "Leutscher Freiladebahnhof" will avoid nearly all rainwater flow into the (already overburdened) urban canalisation system [69]. The *GartenLeistungen* project investigates the environmental performance of urban green spaces and provides well-founded information for political decisions. The project evaluates the multidimensional relevance of urban gardens, parks and green spaces for urban society. To this end, material flows and ecological and social impacts are quantified using a set of analytical instruments that are developed and evaluated together with relevant urban stakeholders. In collaboration with the cities of Stuttgart and Berlin, as well as with further stakeholders, the instruments developed are applied to specific case studies [70].

In this context, the *TransMiT* project has set the path for a fundamentally new approach to stormwater management. An innovative and resource-efficient urban drainage concept was developed and conceptually tested that enables the quality-based drainage and treatment of urban rainwater through the smart use of existing infrastructure. The transformation takes place at the operational level through the increased integration of measurement technologies, optimised operational concepts and forecasting models. Constructive measures are only considered if they are necessarily required. By implementing the quality-based drainage and smart distribution of rainwater flows in existing discharge and treatment pathways, the target-oriented use of existing infrastructure can be achieved. In *TransMiT*, the stabilisation of integral processes was achieved through the further development of a district-based participation process into a process flow within the administration, on the basis of which district-specific, cross-sectoral catalogues of measures (the prioritisation of measures) can be drawn up, which in turn form the basis for further sectoral, object-related planning by the municipal administration [71]. In the *BlueGreenStreets* project, street spaces are to be designed as future-proof multi-talents, especially with a view to linking urban greenery to flood protection. A special and innovative contribution to this is made by the planning and construction of so-called tree trenches, a technique in which planted trees are combined with infiltration systems. On the one hand, this allows high amounts of precipitation to be channelled during heavy rainfall events and, at the same time, creates a water reservoir for the tree, which it can draw on during dry periods and can also generate a positive microclimate effect in the urban district. To prove this effect, bioclimatic analyses of street spaces are carried out. In addition, a toolbox is being created in the project that brings together all the aspects investigated with the aim of developing multi-coded street spaces [72]. The project *Straße der Zukunft* is also concerned with the future design of street spaces and applies its research findings in two model districts. The focus in a newly developing district is on mobility. Therefore, the demands for mobility and the behaviour of the users are being recorded in order to link the different forms of mobility and thus optimally design mobility offers in the urban district. A second real laboratory takes up the topics of climate change adaptation of urban districts and a water-sensitive urban development with a focus on selective precautions against heavy rainfall and the potential for heat and longer dry periods. In practice, the street space is tested as a water reservoir by installing a cistern. Further, a comparison of different types of street transportations (cars and bikes) is being undertaken to measure the differences in water (street water runoff) and air quality [73].

Innovative technical approaches are also being researched further. In the *VertiKKA* project, a multifunctional façade module is being developed that combines the provision of energy through foil photovoltaic modules and the vegetation of walls, thus allowing for evaporation and the improvement of the microclimate to take place. Further, the module uses and treats sourced greywater. Initial research results on a demonstrator in Weimar show that the module generates benefits on various levels in addition to energy generation and greywater utilisation: the photovoltaic modules arranged in front of the plants protect them from damage caused by extreme weather events such as storms. The plants themselves grow more slowly with an opening angle of 45° for the PV foils, but their vitality remains unaffected. Due to the lower plant growth, the maintenance effort is reduced. Finally, the modules improved the thermal balance of the building in winter by increasing and stabilising the temperatures in front of the façade, thus improving the heat transfer coefficient. The measurement data are supplemented with a model to simulate the microclimate. In addition, sustainability assessments were carried out, and a working paper on legal framework conditions was prepared [74]. The *IWAES* project is investigating how an infrastructural coupling of the cooling and heating requirements of various consumers in urban districts can be achieved and how existing residential water infrastructure can be made usable for the storage and withdrawal of heating and cooling energy. The innovative goal is to use thermal hybrid ducts for the distribution of waste heat within an urban district. Current results have shown that such ducts, when activated as heat sources and sinks, can be further developed into a heat and cold transport system (hybrid duct network) between houses and blocks within the district by modifying and supplementing their hydraulic components. Its practical implementation, including its integration into the urban development processes, is being tested in a model quarter in Stuttgart. Using various simulation tools and models, the influences of different parameters on resource efficiency are to be mapped for the study area and evaluated by means of indicators [75].

The *OptiWohn* [76] and *BoHei* [77] projects both focus on the research of more efficient (residential) space designs. The *OptiWohn* project aims to improve sufficiency in the use of existing buildings by focusing on residential options. Initial results show that the willingness to live in more sufficient living arrangements is greater than expected. Fifty per cent of the respondents to a questionnaire can imagine communal living on a smaller area of land than their current living situation. In order to put this into practice, *OptiWohn* is developing modules for an advisory and support service and is testing them in three cities. The goal is a nationally applicable support programme for land-efficient housing. Urban development with the re-densification of an existing and inhabited neighbourhood poses special challenges for urban planners. The BoHei project, which deals with the redevelopment of a neighbourhood with typical pre-war and immediate-post-war buildings in the south of Heilbronn, therefore focuses on the participation of residents in the redevelopment planning by means of surveys, workshops and participatory actions. When considering the question of how many people can and should live in the neighbourhood in terms of the optimal use of resources and a liveable environment, the concept of "common-good-oriented density" was developed. In a density workshop, different development scenarios for the BoHei district were simulated. In addition, a zero-waste strategy for building materials and concepts for water management were developed. With the help of a regulator plan, the use of resources is to be optimised in neighbourhood planning, and the resulting conflicts of objectives are to be solved in a neighbourhood-specific manner. In accordance with the residents' wishes, community activities were carried out that use the open spaces in the neighbourhood. For example, participatory gardens were created, and a car-sharing service was installed.

5. Summary and Conclusions

In this article, the possibilities for the resource-efficient (re)design of urban districts were examined in more detail. Against the backdrop of the legal and political framework, the article describes the possibilities and necessity of resource-conserving action in the urban environment. The results of the 12 funded RES:Z research projects provide approaches to solutions for urban districts of the future, which focus in particular on the topics of land use, water and material flow management.

Water, energy, land, urban green and material flows were chosen as the relevant aspects of consideration for resource-efficient action. It was explained that resource efficiency is possible and necessary at the different levels of consideration. By means of supplementary practical examples, it was shown that the implementation of resource efficiency in cities is feasible and has already been tested and shown to work, at least in partial aspects (e.g., Stockholm).

The task now is to implement these tried and tested measures together with the new solutions, for example from RES:Z, in Germany as well. If, as envisaged in the coalition agreement, 400,000 new dwellings are to be built in Germany per year, it will not be possible to build in the traditional way, as this clearly contradicts the land use targets. Moreover, the focus should not only be set on building with the right materials, but also on using fewer resources and achieving better results. Another example is that new green elements in the city can only be operated sensibly if water management methods in the form of water storage, greywater use and evaporation are included in the planning.

All this requires integrated planning. The urban district is the right benchmark to address the changes in the best possible way.

Integrated urban planning requires, on the one hand, the cooperation of all actors at the city level in order to be able to provide the necessary data, and on the other, identifying as well as coordinating responsibilities so that important goals may be reached. Currently, instruments are needed which analyse and evaluate the specific urban district data and thus provide the basis for decision making in order to accelerate and simplify the planning processes.

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