GERMANY

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1 OVERVIEW OF THE REGION

Characteristics of the Region

The Region of Bavaria is one of sixteen states in the Federal Republic of Germany. It is the second biggest state in Germany with more than 12.5 million inhabitants and with an area of 70,000 square kilometres. The state capital of Bavaria is Munich with famous cultural and architectural characteristics. Located close to the Alps and characterised by rural landscape Bavaria has developed a strong innovative region in recent decades. High-tech industries combined with historical way of life pave the way for the future development of Bavaria. Economic prosperity is founded upon innovative small and medium-sized companies and is reflected in an extremely high GDP of around €37,000 per capita and an employment rate of 75% in the year 2010.

The environmental and energy sector in Bavaria consists of many international market leaders, which have a proven long-term competitiveness in their fields, such as automotive industries. The recent global crisis intensified the need for a stable legislative framework, which secures and provides conditions for local value creation which are the focus of current Bavarian economic and energy policies.

Due to the federal organisation, every state has a sovereign constitution and is able to shape its own areas of legislation. This is particularly true for the energy sector, where local regulations for buildings and incentives for renewable energies have been established locally. With respect to these regulations and incentives, Bavaria is one of the leading regions in Germany.

Energy demand and supply of the Region
The region of Bavaria has a detailed energy strategy established by the Bavarian Government (2011). The goals and data within this paper, unless indicated otherwise, originate from this document. Total primary energy demand of Bavaria in 2008, as shown in *Table 1*, was 567 TWh and was mainly based on petroleum products, nuclear power and gas. Renewable energies amount to 10.1% with a strong growing trend (12.9% in 2010, Federal Working Group of Energy Balances, 2013). The total final energy consumption of Bavaria totalled 390 TWh in the year 2010 which was subdivided into three sectors: domestic sector with 181 TWh, commercial-industrial sector with 87 TWh, and the transport sector with 123 TWh (Federal Working Group of Energy Balances, 2013).

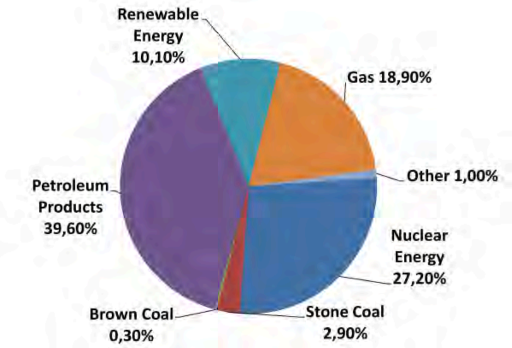

Figure 1 – Total primary energy demand of Bavaria in 2008 (100% = 567 TWh, Source: Bavaria Government 2011)

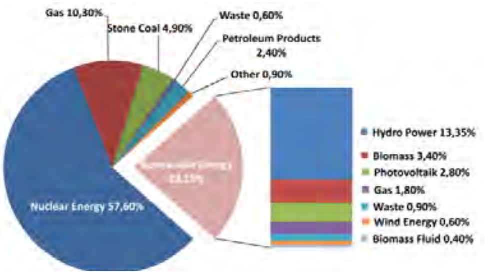

Figure 2 – Electric energy supply of Bavaria in 2009 (100% = 85 TWh, Source: Bavaria Government 2011)

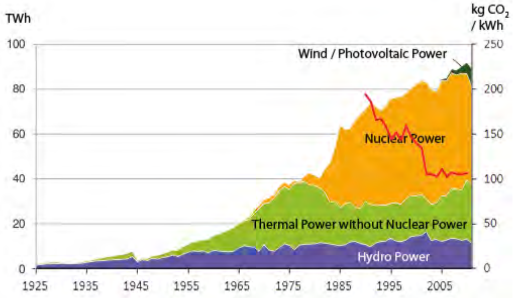

Figure 3 – History of the energy sources for electricity supply in Bavaria and CO_2 emissions including electricity imports from 1925 to 2011. The red line shows the kg CO_2 emission per kWh electricity. (Data / source: www.statistik.bayern.de)

The average CO_2 emissions amount to 6 tons per capita per annum (the national average for Germany is about 9 tons). This is mainly caused by the low-emission energy supply, as shown in *Figure 3*, resulting in very low GHG emissions for electricity from the grid at slightly above 100 g CO_2/kWh (the average in Germany in 2012: 546 g CO2/kWh, source: www.Umweltbundesamt.de). This low figure for Bavaria is a result of the high percentage of nuclear power and an increasing share of renewable energies. However, the phasing out of nuclear power is a challenge for a climate-friendly energy supply in the future. Bavaria leads Germany in terms of the use of hydro energy, solar energy, biomass, and geothermal energy. Furthermore, Bavaria has a good developed and modern gas infrastructure which enables petroleum gas to be a feasible substitute for nuclear power. In contrast, Bavaria does not have much coal-fired power. Coastal areas of Germany dominate the potential for wind energy.

2. CURRENT SITUATION: TARGETS RELATED TO ENERGY POLICY

Germany aims to decrease its CO_2 emissions by 40% until 2020 increasing up to 80% to 95% by 2050 compared to 1990 levels. Renewable energies are to achieve share of gross final energy consumption by 2020 increasing to 60% by 2050. For electricity consumption, the share of renewable is planned to be at least 35% in 2020 increasing to 80% in 2050.

Due to the fact that climate protection is a number one priority of the Bavarian Government, the region's policy is fully supportive to the Federal Governments climate goals. Bavaria faces the challenge of climate change. Bavaria had a total GHG emission of 80 million tons of CO_2 equivalents (6.4 tons per capita and year) in 2010 (Federal Statistical Office 2012) and aims to reduce CO_2 emissions to below 6 tons by 2020. That is only possible by extending renewable energies and increasing energy efficiency.

Until now Bavaria covers its energy consumption within its domestic boundaries; however, this could become difficult in the future as energy production depends more and more on renewable energies. Offshore wind farms and grid-connected PV systems located outside of Bavaria might offer a chance to solve this problem. According to policies, the government intends to keep Bavaria as independent as possible of energy imports. In the next 10 years, the aim is for renewable energies to cover up to 50% of the Bavarian electricity demand; that's double what is provided today. Regarding the share of renewables in final energy consumption, Bavaria aims at accomplishing 20% and thus excels the given EU goal by 10%.

Other Regional targets, barriers and drivers
One important measure in Bavaria is a significant reduction of heat demand of 20% for residential buildings and 15% for industry

by the year 2021. Furthermore, the renewable share in electricity supply should be increased to 50% by the year 2021. These regional targets have been initiated by the Bavarian Government and are clearly political goals. To achieve these objectives of climate protection, political goals and compliance are necessary together with a stable supply of climate-friendly technologies. The political framework accompanied by the German nuclear phase-out, which started in 2011 and shall be finalised in 2022, demonstrates a stronger shift to natural gas is exemplary for a European Energy Region and its transformation. Nevertheless, the increased CO_2 emissions through this intensified substitution of natural gas needs to be compensated by an efficiency increase in the areas of heating energy and mobility.

Bavaria will accomplish this by a massive investment in new cross-nation power lines, improved regional power grids and additional renewable power sources. Gas-fired power plants will replace old nuclear plants progressively. Furthermore, major improvements are required in the generation and usage of heat and energy usage for mobility. This should be supported by investments focussing on energy storage and innovative energy research projects.
A broad variety of renewable energies have to be promoted based on water, wind, solar, geothermic potentials etc. Therefore socially compliant, economic reasonable and environmentally compatible solutions are required.

In Bavaria solar irradiation is very high and suitable soil is available so that solar and geothermal energy sources could be used effectively. Due to German energy saving policies (‘Energieeinsparverordnung’, EnEV = energy saving ordinance and ‘Gesetz zur Förderung Erneuerbarer Energien im Wärmebereich’, EEWärmeG = law for the promotion of renewable energies for heat use) many new buildings use renewable energy sources. At present, there are about 500,000 solar collectors and 80,000 heat pumps installed in Bavaria. Additional instalments in existing buildings tend to be approx. 25,000 solar collectors and 3,000 head pumps per year. The Bavarian Government uses financial incentives and information campaigns to strengthen these numbers with an initiative called “Energiewende vor Ort” (local energy transition) which aims to encourage local and regional energy suppliers to multiply investments in renewable energy plants.

On the demand side, the building sector accounts for a major part of the energy demand and related emissions. The sector causes approx. 35% of the emissions and has a share of 40% of the total energy demand. Moreover, heat demand and domestic hot water account for 90% of these emissions. Although in the last 10 years reductions in demand have been realised, the potential of energy saving and respective emission avoidance has not been exploited. Demand by existing buildings is large due to high renovation costs and a lack of information on government funding available.
If the current trend continues, only 10% of the required 20% of savings will be realised; and it will not be possible to reach the 50% goal in 2050. Therefore, Bavaria is going to have to optimise the subsidies to promote energy-focused building refurbishment and to abolish legal barriers. For this reason, the government plans to increase the CO_2 retrofitting program of the KfW banking group by another 4 billion Euro. Furthermore, the programme will be extended in duration and applicability. Tax incentives are also planned to support the realisation of the energy saving potential.
The case study presented in the second part of the text deals with the delay of investments for the energy transition and its interrelation with economic and social factors.

Transport accounted for 38% of the CO_2 in the year 2010 in the region (Bavarian Office for Statistics). Based on a study by the European Commission, public transportation will increase by one third until the year 2030 in Bavaria which indicates the need for efficient, sustainable and climate-friendly systems of transportation. Within urban areas, this implies concentration of residential areas including decrease of soil sealing for motorised transport and better distribution of use in urban structures to avoid traffic, so that inhabitants can reach their everyday needs within short distance (“Stadt der kurzen Wege”, Short-distance city). Furthermore, a more widespread and optimised urban transport system enhancing bicycle and pedestrian traffic could transform traffic flows to more climate-friendly modes. Finally, it is essential for the economy in Bavaria to guarantee the security of energy supply especially for those, which develop future-proofed technologies next to competitive energy prices.

3. CASE STUDY: URBAN LABORATORY NUREMBERG WESTERN CITY

The impacts of global change are increasingly affecting cities and urban agglomerations. Economic, social, technological and ecological changes, such as climate change or the energy policy transformations in Germany ('Energiewende' = energy transition) impose significant challenges, which are of major importance for the existing neighbourhoods and communities in urban areas.

The interdisciplinary research project 'City Lab Nuremberg West' at the 'Technische Universität München' (TUM) commissioned by the City of Nuremberg investigated how the urban district Nuremberg Western City (*Figure 4*) dealt with these challenges. The main goal of the study was to establish long-term strategies for the development of a liveable and sustainable future for this urban district. The innovation of the study consisted of the energy planning for an urban structure to suit the local economic and social conditions of the district and to provide feasible strategies for different conditions. The main hypothesis of this approach was that a sustainable and energy-efficient urban area is only achievable taking into account social and economic aspects.

Figure 4 – District of Nuremberg Western City (Zitat) (Author: Isabell Nemeth)

An interdisciplinary team of scientists has been working together on the 'Urban Laboratory Nuremberg West' project. Knowledge of different working methods, levels of detail and references was crucial to create a base for the interdisciplinary collaboration of the various disciplines and work areas, such as urban planning, landscape planning, resource consumption and energy efficiency and transport planning.

Initial conditions and local situation
Located in the German state of Bavaria, the city of Nuremberg has a population of 500,000 inhabitants; the metropolitan region includes 3.5 million inhabitants. The district Nuremberg Western City connects Nuremberg to the nearby city of Fürth. It has 20,000 inhabitants in an area of 3.25 km^2. Nuremberg and particularly its the district Western City have been impacted by economic change since the 1970's when the labour market declined and the city's economy shifted from traditional manufacturing (metal, steel, and textiles) to other sectors including communications, energy technology, and consumer electronics.

As these economic changes occurred, former industrial sites and their related infrastructure have become increasingly marginalised. Analogue to the urban structures grown during industrialisation, the structures of energy demand and supply are complex. With respect to energy demand, there is a large range of building types reaching from farm houses with an age of several hundred years to highly energy-efficient new buildings. More than half of the residential buildings in the area of Nuremberg Western City was constructed before 1948. As a consequence, façades are decorative resulting in challenges with regard to the thermal improvement of the building envelope. Furthermore, as a result of the industrial history of the quarter, more than 50% of the heated buildings are non-residential, which may change depending on future development.

The loss of economic investment and the traditional manufacturing sector raises questions about the identity of the area and appropriate urban development goals. Along with the economic change and the associated job losses and increasing poverty levels in Nuremberg, planners must also grapple with pressing issues of sustainability and the related ‘Energiewende’, which requires a shift to renewable energy sources and the major renovation of existing buildings and infrastructure, such as water, energy and transport. Requirements of the energy transition, while benefitting the environment, may negatively impact already vulnerable population groups if the burden of their implementation falls on the poor.

Objectives and methods

The goal of the case study was to create a strategy for the sustainable redevelopment of Nuremberg Western City. The emphasis was placed on minimising the dependency on fossil fuels. The results of this ‘laboratory’ are expected to enable the city of Nuremberg to implement strategies for the future development that address the social, economic, and ecological aspects of sustainability, and are able to be implemented both at an individual neighbourhood as well as on a citywide and even regional level. Using this approach, the study will provide the city with feasible strategies for different situations of urban development. Furthermore, it is intended to analyse how this work can be applied to other post-industrial cities, regions and nations.

Long term focus

This study has a long-term focus until the year 2050, which distinguishes it from the usual techniques of urban energy planning which are typically more short term. This long-term approach and strategic planning are crucial with regard to economic feasibility and realisation of these measures such as the infrastructure of the city including energy systems, individual and public transport, as well as water supply and sewage systems. Particularly with regard to the development of key projects, sites and locations, long-term strategies are inevitable, as the short-term realisation of supposedly appropriate projects on specific locations might prohibit the future viability of sustainable projects in these locations. By the conducting this prototype research, the aim is to bring the innovation of long-term analysis and strategy development to the practice of urban planning. The horizon to 2050 is a significant innovation as usual integrated urban development plans (= Integriertes Stadtentwicklungskonzept, INSEK) only take account of a medium-term period in future.

To deal with the uncertainty involved with long-term planning, three alternative development paths for a plausible future were defined and examined. These development paths represent strategies towards a sustainable and liveable city dependent on possible economic development patterns, which are economic growth, economic standstill or economic decline. It is important to mention, that in each of these three visions the concept of a liveable city was taken as an indispensable element for the development. As part of the overall work of the Urban Laboratory Nuremberg Western City, these three development paths were analysed with regard to the functional aspects and the physical development of this part of the city, to the implications on the use of resources and to mobility and transport.

The modelling and the stochastic simulation of the long-term energy demand is based on the residential building stock, which was available as geo-referenced data describing the building’s footprints. The data also includes information on the height of the buildings and thus conform to CityGML Level-of-Detail 1. The use of the digital cadastral map shown in *Figure 5* allowed the identification how the buildings are surrounded by other built structures – an aspect that has a high impact on the energy demand. This was combined with information on the construction age classification in certain residential blocks, which allowed for the calculation of the specific energy demand with a satisfactory accuracy.

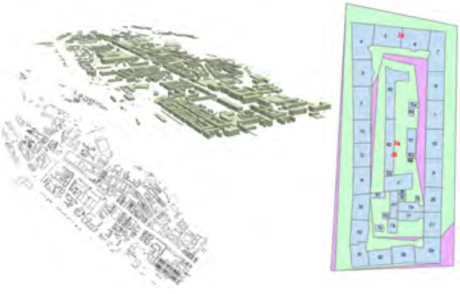

Figure 5 – Digital cadastral map of Nuremberg Western City (Zitat) (Author: Isabell Nemeth)

The energy demand of non-residential buildings was based on the determination of their function and from assigning specific energy consumptions according to their use. For both sectors, the model includes the energy consumption of all processes inside the buildings. In residential buildings, this is derived from the shape of the building; in non-residential buildings, the type of the company and its energy consumption determines the demand of process energy. Furthermore, the model includes retrofitting measures by a stochastic approach. The method assigns a probability to the different parts of the buildings to be renewed and energetically improved. With the exception of the limitation of a lack of information on the specific technical equipment of the heating system, this method allows to simulate the energy demand for the specific conditions with good approximation.

The sustainable and liveable urban district approach requires the integration of a very wide range of topics, such as economy, health, mobility, culture, identity, food supply, quality of the built environment and many other aspects. As this research project could not include all these topics, focal points were chosen, which cover the dimensions of sustainability with its main energy consumers in the domestic and the transport sector. Significant factors in the analysis include ‘functionality’, ‘energy and resource consumption’, ‘mobility’ and ‘urban quality’. It becomes apparent that many different sectors contribute to the emergence of a city worth living in, both in terms of content as well as in terms of the various administrative levels, such as the state, the city and the private level.

This intersectoral analysis and development requires an integrative systemic view.
The dependencies of the many individual aspects, related to the various sectors and disciplines lead to a complex system that needs consideration for a long-term urban development. To detect and investigate the dependencies of the various factors, a method of systems modelling was developed, which was based on sensitivity modelling described by Frederic Vester (2007). This methodology served to detect the influences between variables and trends of various sectors in an expert discussion at TUM and to map their effects. On this basis, a quantitative system model was developed and simulated. Experiments with this system simulation model served to examine the future development paths, their relation to the energy consumption and emissions, and their involved risks.
The stochastic modelling and simulation of the building stock in detail allowed to identify the key parameters to reduce the energy consumption and the interactions with other sectors, such as investments in building and the economic urban conditions.
The examination of these parameters by stochastic energy simulation and the systems modelling led to strategies for low energy urban regions.

System simulation and results
As result of the stochastic simulations, four major parameters controlling the retrofit of the building stock and its energy consumption and emissions were found. These parameters are the retrofitting rate, the quality of the building envelope, the type of energy sources, and the quality of the building technology, which are presented below.

The retrofitting activity of improving the building envelope has an essential effect on the reduction of the heat energy demand of the residential buildings. However, according to Diefenbach et al. (2010) the current retrofitting rate for buildings constructed before 1978 is approximately 0.8% p.a., which is far below the potential possible level. For a climate-neutral building stock, a doubling of the yearly retrofitting is assumed to be necessary. Therefore, in the simulation, the retrofitting rate was doubled and an increase of the energetical retrofitting was tested.

The parameter building envelope has already been significantly increased, driven by regulations (‘Energieeinsparverordnung’, EnEV = energy saving ordination). Therefore, increasing the rate of buildings envelope improvement is limited. Considering the retrofitting rate and building envelope, simulations show that the doubling of the retrofitting rate and an increase of the energetically improved retrofitting of 10% per 10 years using an energetic high-quality building envelope according to passive-house standard has the potential to reduce the heat demand of residential buildings by 44% until the year 2050 compared to 2012 in Nuremberg Western City.

The parameter energy source is particularly well situated in Nuremberg Western City. The area of the study contains a large district heating system. A high share of heat for this system comes from the biomass heating power plant, Sandreuth, which assists with a massive reduction of the emissions. The goal of reducing the emissions by 2050 requires an increased development of this district heating network. For this reason, the share of connected buildings until 2050 of 45% was increased to 65%. This eliminates the supply by coal, oil, and electricity for heat generation and thus massively decreases the emissions with respective effect on the air quality.

For the parameter 'quality of building technology', potential energy use is limited due to the wide-spread application of the condensing boiler technology and associated efficiency are already achieved. Therefore, the effectiveness of heat generation technology will not change a lot by 2050. Heat pumps are the only exception with their share in the heat supply of buildings is estimated to be 8 to 10%. However, for this quality of building technology, the potential of reducing primary energy demand and respective emissions is limited due to the use of the German electricity mix. Systemic interdependencies are of major importance. The potential to reduce energy consumption and emission is linked to other factors and parameters in the district. For example, the retrofit of a building's envelope requires economic investments in buildings. This leads to a need of economic activity to allowing the investments. These activities have impact on transport activities and further energy consumption as consequence; also, the potential for quality of life and of liveability of the urban structure accompanies economic activities and investments especially in the case of Nuremberg Western City.

The development of a model for dynamic system simulation of the period until 2050 serves to capture these interdependencies. Firstly the stochastic simulation of the building stock, allowed for modelling the dependency of the reduction of energy consumption

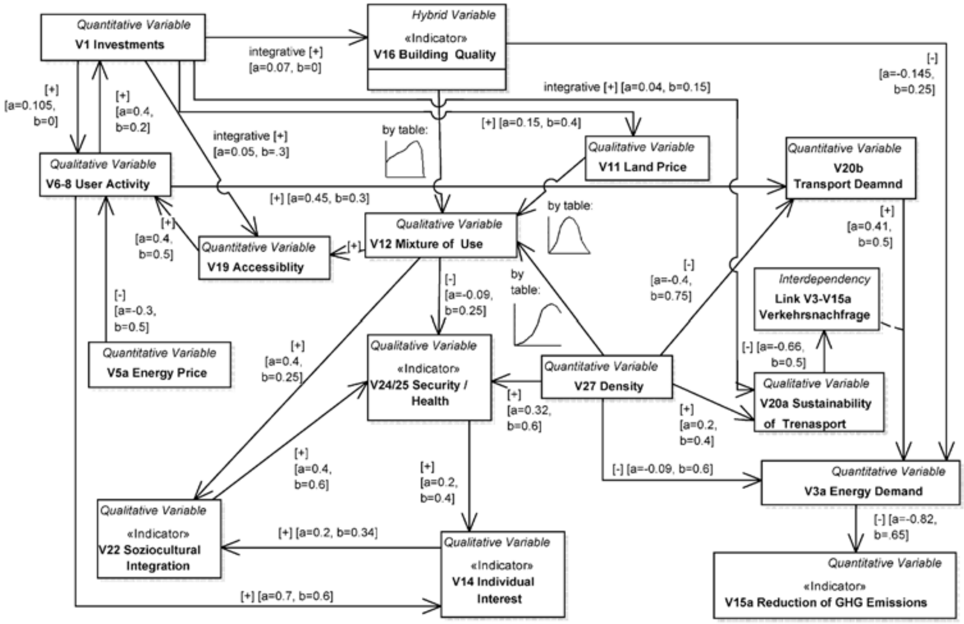

Figure 6 – Systems model of the interdependencies of the built environment and urban transport with the social and economic factors of sustainability

depending on investments in the building stock. Furthermore, well know studies, such as Kenworthy and Laube (1996) and Fischer (1985), and statistics of the City of Nuremberg (2012) served as a data source to develop the systems model and its quantitative interdependencies. *Figure 6* shows the partial effect structure used in the Nuremberg Western City project. All interdependencies shown in this figure are quantified either by the simulation or by looking up statistical data or by other studies that are comparable to Nuremberg Western City.

In most cases, linear dependencies described by a factor a and an offset b serve the modelling of these interdependencies. Only in some cases, such as the link of the building quality (V16) to the mixture of use (V12), more sophisticated functions serve for the modelling of the dependency; these functions are described by tables in combination with interpolation. The system model resulting from modelling all these interdependencies provides the base for the simulation described in the following text.

In the dynamic system simulation, different experiments were carried out to determine the behaviour of each of the three potential development paths under several circumstances and to learn more about sensitivities and risks of each of these development paths. *Figure 7* shows the baseline results (orange line) of the partial simulation made for the scenario “Knowledge economy hub”, which is an economic high-activity development path, together with an experiment (blue line). The purpose of this experiment was the examination what effect a delay of investments by ten years has on the development of the district. This experiment helps to assess the risk that the development path will fail due to delayed investments. Furthermore, it determines the sensitivity of the energy consumption in the development path to this risk.

In the results of the experiment shown in *Figure 7*, the dependence of the building quality (V16) on the investments (V1) is clearly shown. Building quality increases only in case of investments. These investments are based on economic prosperity. However, the user activity (V6 8) and the respective transport connected to this economic prosperity lead to energy consumptions (V3a) nearly levelling out the energy savings of retrofitted buildings. However, the increased user activity and a more pleasant built environment cause a significant better fulfilment of individual interests (V14), the inhabitants and working people are more content. Therefore, an economic sane state can lead to a more liveable urban environment.

Outcomes

The developed methods improve the energy efficiency of urban structures considering the interaction with its social and economic conditions and with the specific conditions of urban planning, which the application in the case study shows. This analysis provides a base to evidence that strategies are realisable within a specific urban environment. One important prerequisite for the delivery of the project was the close collaboration between the different involved disciplines at TUM and with the city of Nuremberg. Furthermore, the identification of interactions, interfaces and systemic interdependencies helped to understand the cross-sectoral behaviour of the urban structure and thus influences on its energy-efficiency and the emissions. Main barriers for the delivery of the project were regulations of data protection and data monopolies of energy suppliers. In summary, the project showed that the economic and social conditions of an urban quarter are important drivers of the energy transition. Furthermore, it is required to implement energy-efficiency and sustainability as specific measures in urban planning to enable their realisation.

4. CONCLUSIONS

Nuremberg Western City typically represents urban building stock in Bavaria. The structure is frequently found in non-centre districts. The age of the residential buildings is slightly higher with a higher proportion built before 1948. Furthermore, the building stock of the case study’s district is in a poorer condition compared to the Bavarian average. In contrast, the good energy supply infrastructure within the case study district, namely the high share of renewable heat energy from biomass, and the façade decoration, both reducing the potential of future energy efficiency measures, which partly reduces options of energy-efficiency measures, compensate for this potential bias. Therefore, a transfer of the case study to the region – limited to the urban structures – seems appropriate.

The method of combined systems modelling and simulation forms an integrative approach that is deemed necessary to model and plan a real energy transition for specific built structures. Due to the interdependencies of energy-efficiency and emissions on technological, social, and economic conditions, a cross-sectoral approach is required. The detailed stochastic simulation of the building stock and of its retrofitting process allows the correct determination of its energy-efficiency potential. The inclusion of investments in the building stock and further economic and social factors from other studies allow for the linkage to the relevant factors for urban structures. The abstraction and aggregation in a systems model lead to integrative conclusions. We think such a system-based approach is necessary to examine the sectors of urban structures in an integrative way, to assess potentials correctly and to develop feasible well-performing strategies for a sustainable and liveable built environment. This not only concerns cities of Bavaria or Germany but urban structures in general as many energy issues in cities have a multi-sectoral character.

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COST DESCRIPTION

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