ID 1317 | VISUAL INTERACTIVE SUPPORT FOR CROSS-DOMAIN SIMULATION AND NEW INFORMATION FLOWS IN EARLY STAGE PLANNING PROCESSES

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ABSTRACT: For the development of urban areas within existing urban systems, which concentrate on sustainable ways of energy supply and therefore essential cooperative planning processes, interactive software systems holding digital city models can enable visual driven support. The offered visual support provides a communication basis for the interdisciplinary actors within these complex planning processes. Within an interdisciplinary research project a visual planning and decision support system, named the 'URBEM-Visualization', has been developed. This system allows to geographically pinpoint information of urban systems within a multi-dimensional city model. Thus, it offers multi-scale and cross-domain handling of information within different calculation scenarios regarding energy supply. Based on a development area in Vienna, located at the train station "railway station Vienna West", which offers high potential for a sustainable agglomeration and the use of built grid infrastructures, a "planning test run" is evolved. Within this planning test run, new designs of housing developments and different possibilities for the electrical and thermal energy supply related to building energy demands are evaluated, analyzed and visualized. Based on this planning test run the paper exposes how visual interactive decision support strengthens the cooperation of the interdisciplinary planning team as well as the planning process. Furthermore, this interdisciplinary consolidation facilitates a rethinking process, changing historical driven top-down planning processes. It shows how visual output of simulation data regarding energy supply networks allows the design of new feedback-loops of information flows and how this can supply decision makers in early stage planning processes.

KEYWORDS: decision support tool, visualization, cooperative planning process, cross-domain grid simulation

1 INTRODUCTION

1.1 MOTIVATION

The United Nations forecast of 2014 shows a population of 8.5 billion people up to 2030 (United Nations, 2014) on the earth. The forecasts also report about 60% of the population in 2030 (Statista, 2017) will live in cities worldwide. Due to this rapid growth of urban agglomerations worldwide, planners are facing complex tasks for setting up plans, measures and actions to gain sustainable development within urban settlements in a resource-conserving manner. Against this background, urban development within defined city limits is a constructive approach to reduce soil sealing, arising damages of the soil function as well as the possibility to use existing supply infrastructures in the fields of mobility and energy. This can cause a reduction of CO2 emissions due to energy savings in construction, maintenance and usage. The formula 'Inner development before external development' by Bernd Scholl proclaims to reduce further settlement spread and declares to improve the quality of the built stock (Scholl, 2007: 3).

In practice, this ambition means a big challenge for planners and complex planning processes. Within these processes, the cooperation of interdisciplinary domain experts, the connection of domain specific calculation and simulation models as well as the spatial visualization of their outcomes has to be structured and handled. For the support of planners facing the mentioned needs, a digital spatial visualization provides a communication base.

Furthermore, the visualization allows to create multi-scale system overviews as well as long-term simulation and analysis of the impacts based on performed actions. If the visualization is embedded in a digital environment, it enables decision and planning support.

Within the doctoral college URBEM (Urban Energy and Mobility systems) conducted from 2013 to 2016 at TU Wien (cf. Bednar et al., 2016) the URBEM-Visualization prototype has been developed. The URBEM Visualization constitutes a web-based planning support system. This approach focuses on a test run, the ‘URBEM-Planning and Development Run’ (UPDR), using the URBEM-visualization as a decision and planning support tool for a sample region located in Vienna which holds high potential for redensification. Within the UPDR interdisciplinary domain experts simulated outcomes for the technical infrastructure grids within this region and focused on following questions for the energy supply: Which short- and long-term effects do occur regarding the analyzed thermal and electrical supply systems? How can knowledge, which evolves through this calculations influence early spatial planning processes and help to endeavor sustainable urban developments?

1.2 STATE OF THE ART

Inward development means an interdisciplinary analysis and the participation of cross-domain expert planners. In turn, this interdisciplinary planning process needs a definite frame. Scholl promotes a planning method called “test planning” which features a flexible framework and forces progress in complex planning processes (cf. Scholl, 2011: 336). A test planning process is structured in multiple levels and offers a practical application for the communication of sketched and refused decisions with various stakeholders (cf. Scholl, 2011: 340ff). Thus it allows to handle and structure the key tasks within a planning process.

Beside structuring planning and decision processes, visual multi-dimensional and quantitative foundations enable feasible support. Especially for cross-domain collaboration, a visual format with spatial pinpointed information outputs allows interdisciplinary overlay for analysis, clarification and verification of calculation models. CAD based software developments (GIS, BIM) for planning and decision support, game engines with CAD model implementations (cf. Forster et al., 2015a) or web based interactive multi-dimensional visualization formats (cf. Forster et al. 2015b) depict a feasible basis for spatial planning purposes and support. Beyond the visual interpretation of information, the mentioned systems interlink different databases and data structures to become simulation tools. To assure efficient progress during planning processes, the visual support must depict dynamic data flows between database, calculation model and spatial interpretation environment. Schleicher describes an operating system representing a flexible work-platform, which structures data and initializes data flows between calculation models and visualization (cf. Schleicher et al., 2016a). Based on this the URBEM Smart City Application (USCA) can be set up and enables holistic calculation flows between domain specific models on various spatial scales (cf. Schleicher et al., 2016b).

1.3 OVERVIEW

Within the interdisciplinary expert team URBEM a holistic application, the USCA (cf. Schleicher et al. 2016) was developed. This embeds domain and scenario specific simulation models and a strategic visualization tool, the ‘URBEM-Visualization’ (cf. Forster, 2016: 93-114). The URBEM-Visualization depicts an interactive 3D city model and allows interlinking the generated and implemented spatial objects with simulation outcomes from domain models within the USCA. Therefore, the ‘URBEM-visualization’ allows to geographically pinpoint information, the simulation of planning actions as well as their analysis and validation. This enables decision and planning support for detailed analysis of complex planning problems within an interdisciplinary context.

With this approach, we demonstrate a strategy for analysing energy supply options in early design stages within a cross-domain context. Thereby it targets to exchange linear top-down planning processes towards effective cyclical planning processes. This aspired cyclical planning routine is driven by the interdependency within a problem solving process. Precisely this means, that the development of solutions for a problem in planning is giving birth to new ideas by analyzing their resulting impacts. Simultaneously it means to analyze the root cause of the base problem.

In planning practice a holistic sustainable development in urban regions regarding energy supply and associated climate protection results in the need of interactive data links between domain experts. Analytical data visualization is one possibility to deal with the challenging gaps between these involved agents. Furthermore, it facilitates the explanation of pure numerical information. We assume that data visualization can lead to break linear processes and generates feedback loops dynamically within modern problem solving processes in planning. The UPDR is verifying this assumption.

The paper gives a short insight in two domain specific simulation models for electrical and thermal energy grid infrastructures as well as presents the web based visualization technology developed within the PhD course URBEM. It shows the data flows between these models and a strategic set up for an exemplary test run based on a specific development region with high potential in Vienna. The test run allows to show the necessity of loosening top-down planning processes for the raising challenges of the future energy supply of buildings, which is coherent with ambitious climate protection policies, mostly coming along with infrastructural investments and demand for long-term decisions.

This paper was already published within a chapter of the doctoral thesis “Strategic spatial visualization in the context of the inward development of urban settlements, energy and mobility systems” (cf. Forster, 2016: 115-134).

1.4 CASE STUDY REGION

In Vienna, the sites at the main train stations of the city (North, South and West) and alongside their esodic and near rails have an inherent potential for new urban developments. Due to the renewal of the station buildingand the infrastructure policy of the Austrian Railway Association (ÖBB), Vienna’s western train station “Wien Westbahnhof” and the belonging region has changed since 2014 after Vienna’s main train station was developed at the former southern train station areal. Thereby necessary tracks for the movement of travelers and freights as well as many buildings used for infrastructure and administration purposes did become unused at the western train station. Thus, these areas hold new potential for inner developments.

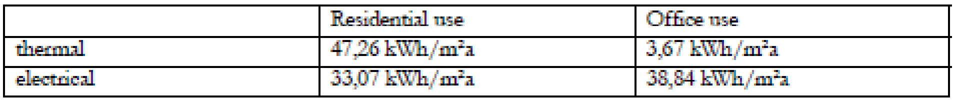
The area is located centrally within the city and is well accessible with public transport. New ‘inward developments’ which target to create sustainable and worth living space are strongly connected to secure supply of thermal and electrical energy. In this area the UPDR simulates prototypic housing designs regarding different approaches for long-term supply of thermal and electrical energy.

2 METHODOLOGY

2.1 METHODOLOGICAL FRAMEWORK

The first methodological step within the UPDR was the analysis of spatial constructional possibilities within the area beside the rails. A master plan for the research area, placed alongside the north and south sides of the rails, has been elaborated (see Figure 1).

The master plan in Figure 1 represents a base for the extrapolation of gross floor spaces and the definition of the utilization of these spaces. Thereby following assumptions (cf. Ziegler, 2016) for thermal and electrical energy demands for the building supply in 2015 are made:



	Residential use	Office use
thermal	47,26 kWh/m^{2}a	3,67 kWh/m^{2}a
electrical	33,07 kWh/m^{2}a	38,84 kWh/m^{2}a

Table 1: Assumptions for thermal and electrical building energy demand

Beside the underlying definitions for potential building developments and floor space utilizations, the existing supply networks set the main input for the cross-domain simulations.

Figure 1: Elaborated master plan for the research area “Wien Westbahnhof”; Source: own illustration.

Depending on the available grid infrastructures within the focus area, five electrical and thermal supply alternatives (including combinations) have been identified:

	Electrical energy supply	Thermal energy supply
Alternative 1	Electrical energy	Electrical energy
Alternative 2	Electrical energy	District heating
Alternative 3	Electrical energy	Gas
Alternative 4	Electrical energy	Photovoltaic
Alternative 5	Electrical energy	Photovoltaic combined with thermal storage

Table 2: Analyzed building energy supply alternatives within this approach

The cited supply alternatives are simulated for the time period 2015-2045. Therefore, a “business as usual” (BAU) scenario with the assumption of decreasing thermal energy demand (space heating and domestic hot water) is defined with 28% up to 2045 in comparison to the initial year 2015 (cf. Fritz, 2016: 77). This assumption considers impacts of investment decisions on Vienna’s building stock (base year 2008) caused by building owners. It includes efficiency actions (thermal renovation / heating system exchange) concerning energy demand as well as the rising population. In terms of electrical energy an assumption of a rising demand of 1,26% up to 2025 in comparison to the base year 2015 has been taken. Additionally the scenario considers additional decentralized power supply (Photovoltaic) by 100 Megawats up to 2045 in comparison to 2015. This assumption is based on the sustainability strategy (cf. Wiener Stadtwerke, 2016) of the Wiener Stadtwerke Holding, Vienna’s biggest energy supplier.

The mentioned scenario assumptions are fundamental elements. They allow long-term effect analysis to verify the supply safety and the evaluation of necessary reinvestments in future. Thereby especially necessary grid upgrades based on rising degrees of capacity utilizations determine additional accruing costs.

In addition and assembling on the housing development assumptions for the focus area, the existing electrical, thermal and gas grid infrastructure needs to be extended. Therefore, realistic new configurations of pipelines and cables are determined. Figure 2 shows a scheme of the necessary new grids, which depict the spatial fundaments for the thermal and electrical grid simulation models.

Figure 2: Assumptions for the extension of existing energy grid infrastructures; Source: own illustration.

2.2 SYSTEM STRUCTURE AND SETUP

The main setup for the UPDR are the simulation models for the determining capacities within the electrical, thermal and gas grid as well as the visualization environment. These models are embedded in the USCA. The models are the ‘processing units’ for forecast and visual outcome presentation. They are interlinked which do in turn enable dynamic flows of data for interactive visual requests operated in a planning process by various stakeholders. Figure 3 gives a diagrammatic view of the technical setup and linkage of models to obtain mutual data exchange for the cross-domain simulation outcomes. It illustrates a sub set of implemented simulation models within the whole USCA, which explicitly describe the active components for the treated problem within this approach.

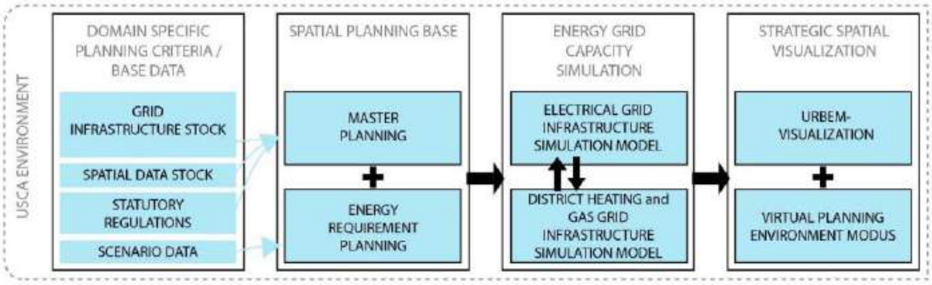


Figure 3: Technical setup of the USCA for energy supply simulation within the test run; Source: own illustration.

2.3 THERMAL ENERGY CALCULATION MODEL

Current developments of the European energy markets are influencing the operation strategy of heat suppliers. Especially providers of district heating systems fed by conventional heat production (i.e. CHP) have to react with appropriate measures to these changes. The integration of thermal storages, decentralization of the heat production, changing heating technologies or adjusting the temperature of district heating networks make it necessary to be able to simulate and analyze existing and future designs of district heating systems. Therefore, a simulating tool for flow networks is developed in Matlab®.

In order to achieve comparable conclusions about operating behavior of district heating systems, it´s essential to create a corresponding model including all its main components like pipes, pumps, storages and valves. The basic idea of the created numerical model is the combination of a steady state hydraulic and a transient thermal calculation of the district heating network (see Figure 4). The results of the iterative hydraulic calculation are the pressure and velocity distribution of the pipe network. These pressures and velocities are serving as Input-parameter of the thermal calculation. To simulate the thermal behavior of the district heating network a discretized one dimensional pipe model is used. The discretization is done by the Finite-Volume-Method and the resulting equation system can be solved explicitly or implicitly. In case of gas networks, only the steady state hydraulic calculation is applied. A common way to define the topology of networks is the usage of a node-edge matrix. This so called incidence matrix is generated automatically from given GIS data.

The result of the combined thermo-hydraulic calculation is the distribution of pressure, velocity and temperature of the flowing water in the entire district heating network. Furthermore it´s possible to calculate the heat and pressure losses of each pipe and subsequently doing exergy analysis. The introduced simulation tool serves as basis for analyzing and optimizing different designs of heating networks, which can be used to support economic analysis from a technical point of view.

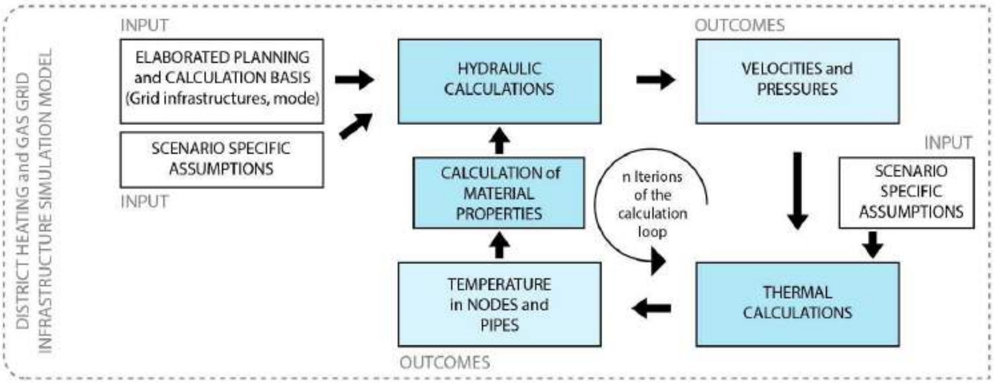


Figure 4: Setup for the district heating and gas infrastructure simulation model; Source: own illustration.

2.4 ELECTRICAL ENERGY CALCULATION MODEL

Power grid models are able to provide statements about reliability, network utilization, and possible overloads considering operational limits within the network. Increasing decentralized generation (e.g., photovoltaic systems), decentralized storage systems and combined energy networks are some of the reasons for defining new operation requirements in future power grids.

In this approach, the model (see Figure 5) describes a medium-voltage power grid with characteristics of an urban area. Short electric line lengths and high load densities are some properties of urban power systems. The input data for the model consist of geographic positions for electric operational equipment used within a specific service area. Handling this large amount of network data needs a powerful data processing platform, in this case Python®. Power flow simulations using the model are implemented in a modified version of the package pypower[1]. The Newton-Raphson algorithm used in pypower for power flow calculations is altered by building the Jacobian matrix only for the first iteration. Therefore, simulation time within the model reduces to a minimum compared to other power calculations approaches. The reason for this is the characteristic of an urban power grid where voltage drops or rises can be neglected due to the short electric line lengths combined with the high load density. In addition, optimized network calculations considering results obtained by the simulation model for thermal energy infrastructures are performed to minimize equipment utilizations inside the energy supply network.

The obtained results show future line utilizations comparing base year calculations with scenarios considering increasing integration of renewables, demographic change and changes in cooling and heating demand served by electric energy. Hence, the developed simulation tool allows network utilities to make future investment decision regarding changing requirements within the power grid.

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[1] https://pypi.python.org/pypi/PYPOWER

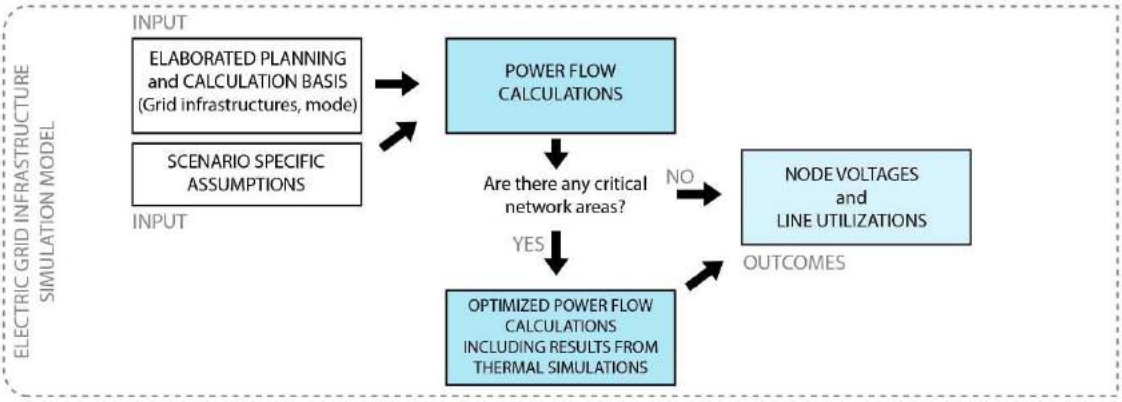

Figure 5: Setup for the electrical grid infrastructure simulation model; Source: own illustration.

2.5 SPATIAL VISUALIZATION OF THE CALCULATION OUTCOMES

The virtual visualization environment of the USCA depicts a user interface for future developments and for assumed scenarios. It holds the 3D model and triggers the calculation outcomes to gain cross-domain views. Figure 6 shows the web-based spatial visualization environment, the “URBEM –Visualization”, which embeds a planning environment for the elaboration and testing of possible construction works within an urban space.

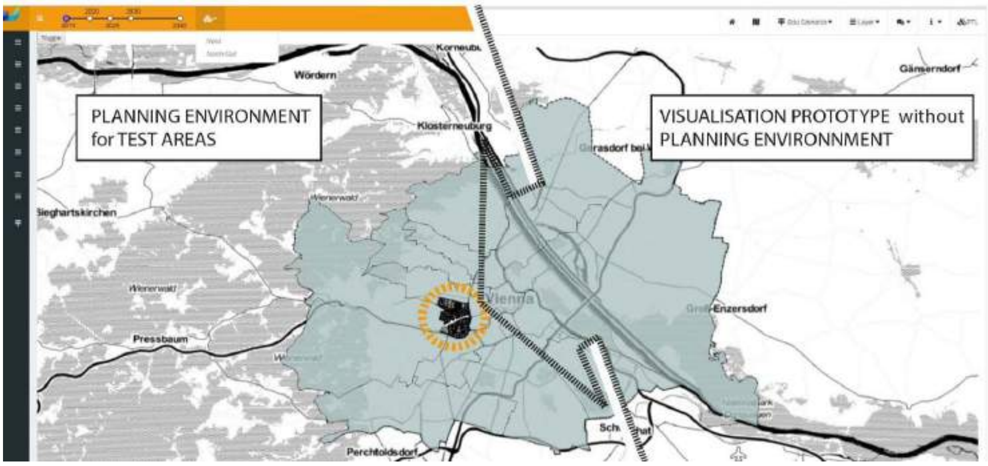

Figure 6: Visual web-based appearance of the interdisciplinary decision and planning support tool, the ‘URBEM-Visualization’; Source: own illustration.

The URBEM-Visualization enables the dynamic generation of multi-dimensional objects and interlinks them with outcomes from domain expert models via identification numbers. Thus, the calculation outcomes are geographically pinpointed and map overviews are designed. These overviews provide the basis for orientation, analysis and communication for input parameters and assist to locate, control and set the ‘regulation screws’ within complex spatial systems. Long-term trends for various frame conditions can become iteratively deliberated.

3 RESULTS

For the determined energy supply alternatives the simulation outcomes are represented in Table 3. Table 3 shows the simulated electrical and thermal supply alternatives to cover the predicted building energy supply within the development area up to 2045. Based on the simulation models for electrical, gas and district heating grid capacities the UPDR shows the need for combined supply technologies to cover electrical and thermal energy supply.

Supply Alternative	2015	2030	2045
Alternative 1	X	X	X
Alternative 2	✓	✓	X
Alternative 3	✓	✓	X
Alternative 4	-	X	X
Alternative 5	-	✓	✓

Table 3: Results for the simulated energy supply alternatives

The calculated numeric outcomes of the grid infrastructure models are processed and visualized within the 'URBEM-Visualization'. Figure 7 - Figure 9 present the visual calculation outcomes. Figure 7 shows an alternative when the predicted building energy demand within the analyzed area is covered only by electrical energy (without the usage of energy storage technologies). Furthermore the figure points out that no area-wide service is available. Due to this fact some transformer stations are colored red which means that the utilization exceeds their limits.

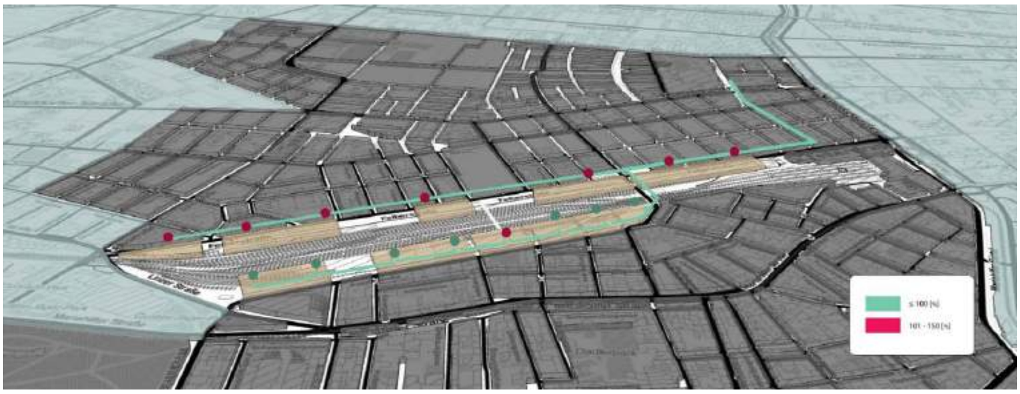

Figure 7: Visualization of capacity loads based on the electrical grid infrastructure simulations for 2030; Source: own illustration.

The extension of the gas or district heating grid infrastructure in addition to the electrical grid infrastructure provides two more energy supply alternatives. Figure 7 shows the energy supply within the urban development area with electrical energy and district heating. All capacities used therefore are in a valid scope up to 2045. All capacity loads in pipes and knots are lower than 100%. The legend for the electrical grid infrastructure is the same like in Figure 8.

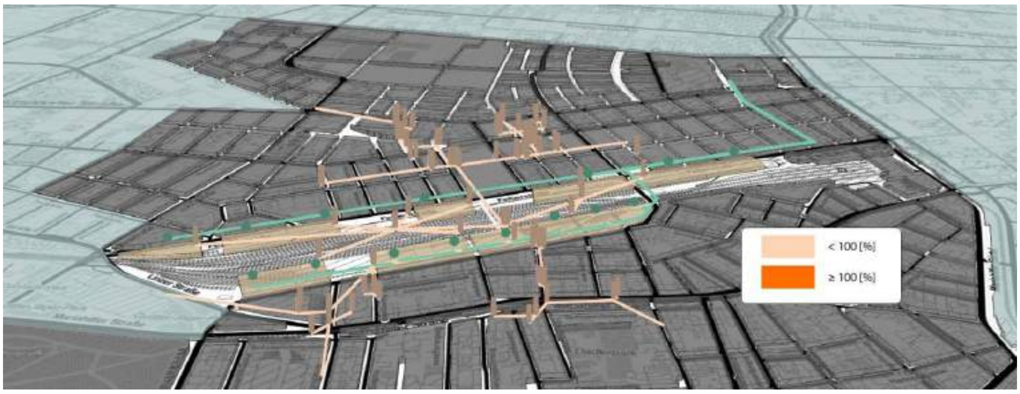

Figure 8: Visualization of capacity loads of the electrical and district heating grid infrastructure based on simulations for 2030; Source: own illustration.

One further valid supply strategy for the building energy supply offers the combination of photovoltaic technologies and thermal storage technologies. This combination causes a pure electrical supply for the development zone. Figure 9 shows this supply alternative.

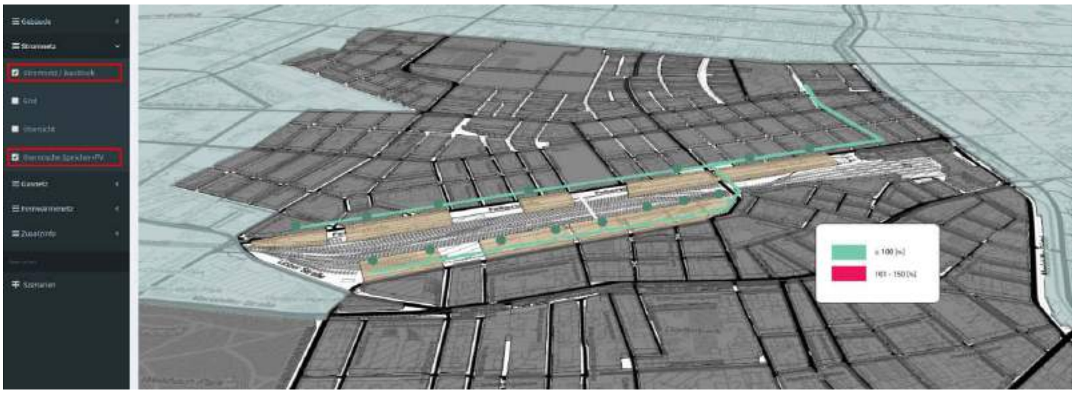

Figure 9: Visualization of the capacity loads of the electrical grid infrastructure based on simulations including photovoltaic and thermal storage technologies for 2030; Source: own illustration.

Based on the presented holistic knowledge for electrical and thermal long-term area-wide energy supply within the development area ‘Wien Westbahnhof’ new input is available for the early design stages. The decision of an energy supply technology, especially the decision for the thermal energy supply is an essential parameter besides caused constructional necessities. The commitment about the used energy supply option allows to establish the necessary agents of the planning world as well as to define and include chronological impacts and imperatives. Furthermore it enables the analysis of caused impacts spatially. Thus, it depicts an initialization for further iterative design on larger and smaller scales. The approach shows a method to fit the design of grid infrastructures within early design phases. The dynamic incorporation influences the entire planning process and initiates further iterative feedback loops between both, the planning process phases and the involved stakeholders. Figure 10 presents a showcase for initiated feedback loops involving the infrastructure grid development.

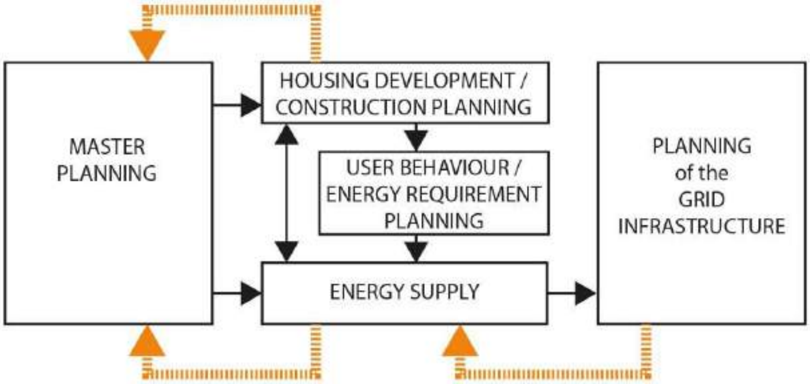

Figure 10: Possible feedback loops within planning process phase sequences; Source: own illustration.

It visualizes a practical multi-phase planning process for multi-scale urban developments. The black arrows show the historical mainstream links and information flows between the individual planning phases. The orange ones present new initiated information feedbacks, which enable impact control and active influence on various planning levels (scales) supporting decisions made by interest representatives.

4 CONCLUSIONS

The interdisciplinary URBEM-Planning and Development Run (UPDR) points out that the URBEM Smart City Application (USCA) concept is a convenient environment and tool to trigger, guide and handle complex planning processes. Thereby the participating agents from the various domains depict the most important parts within the process. The respective domain knowledge is essential for the analysis and interpretation of the implemented information. Furthermore, the explanation and interpretation of the visual outcomes allow setting and testing of new actions. So the URBEM-Visualization within the USCA provides a useful administration environment.

The UPDR shows the need of knowledge about input and outcomes for the decision process to gain and understand interactions within the cross-domain planning purposes. In general, communication is the central topic within the UPDR and the URBEM-Visualization provides a visual base unit concerning this matter.

The survey of energy supply alternatives within the UPDR demonstrate increasing flexibility in planning for future urban developments based on the provision of combined spatial overviews. Thus, new adjusted views provide the finding of comprehensive domains “Hubs”, based on the understanding of interdisciplinary connections. These hubs boost more and more importance to gain sustainable strategies of land use and to combine cross-domain possibilities for energy and mobility subsystems as structures for an urban overall system.

In praxis, supply technologies influence architectural arrangements. The predefinition of an energy carrier technology for a development region in early planning phases can become a general condition within architectural competitions. Housing developers and planners have to cogitate about useable storage technologies. This opens new ways for decentralized energy supply in the building sector.

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ID 1331 | REGIONAL PLANNING RESPONDING TO CLIMATE CHANGE

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ABSTRACT: Climate change, although defined with global and long-term scales, has currently caused substantial impacts to many local places. Even though wide efforts are being made to ameliorate the future environment, increasingly frequent extreme events due to the changing climate have been rather unbearable to many places and population. The integration of mitigation and adaptation efforts becomes a critical issue, so that improvement is available to both current and future, both local and global conditions. Spatial planning for urban regions demonstrates unique potential of promoting this integration. With the review of existing studies, we lead the mitigation-adaptation integration to the topics of regional planning and policy mobilities, for which regional governance is proposed as the appealing innovation in climate governance.

KEYWORDS: Climate change, Mitigation, Adaptation, Regional planning, Policy mobilities

1 INTRODUCTION

Climate change is essentially defined as the potential long-term increase of the global average temperature, which, along with the many associated issues, has gained prodigious international attention and controversy (IPCC, 2014). The social response to climate change is usually conceptualised as either mitigation or adaptation, which has formed a dichotomy (Biesbroek et al., 2009; Bulkeley, 2013). This dichotomy indicates that the two parallel lines of practice addressing climate change have no need to heed each other. However, the implicit (hard-to-recognise, yet sometimes fundamental) conflicts between these two types of efforts may hint total failures of the overall effort (Laukkonen et al., 2009).

Although the different characteristics of mitigation and adaptation would necessitate a certain degree of division, the integration of them is to ensure the total effect, which is the efficacy of our general response to climate change, because, after all, it is climate change that sits at the core where either mitigation or adaptation is born (McEvoy et al., 2006; Wilbanks and Sathaye, 2007). We propose this integration as a specific point to joint climate change concern with spatial planning which is striving to justify its role in addressing climate change (Campbell, 2006; Davoudi et al., 2009). The finding of researching in the literature on spatial planning narrows down to a scale-sensitive conceptual model which embeds mitigation and adaptation in a cross-scale framework (Howard, 2009). The key potential of integrating mitigation and adaptation is to take into account a full range of spatial scales. This conceptual model suggests a mode of mitigation-oriented adaptation as the most desirable integration of mitigation and adaptation, which would also be the most effective response to climate change. Moreover, compact urban form and green open space are recognised as important elements constituting the spatial planning approach towards mitigation-oriented adaptation, for which we propose further research on regional planning. At last, policy mobilities is briefly reviewed to demonstrate its relevance and competence in searching for effective form of regional planning responding to climate change. The expectant contribution is not only an advocacy of planning in the multi-disciplinary context, but also a proposal of some very effective tactics. The following three sections before conclusion will thus unfold the dichotomy between mitigation and adaptation, a scale-sensitive model integrating mitigation and adaptation, and policy mobilities.