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Building Scenarios in Urban Energy Transition: A trans-disciplinary method for integrated spatial energy design

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Abstract: Within an energy transition process in the urban environment, a successful implementation of strategies requires the capacity of communities to develop and explore various visions and make decisions within an uncertain and complex context. To achieve a reduction of energy demand and to introduce technologies for production, storage and re-use of energy, different scenario types have been applied in energy and spatial planning in order to explore future pathways supporting and guiding decision makers. These are often used to compare the energy performance of different possible solutions and technological measures, underestimating physical and local spatial components to support integrated design processes, where spatial and energy urban systems can create a synergy for a better performance.
This paper describes the elaboration and the application of a transdisciplinary Design Oriented Scenarios (DOS) method for energy transition strategies, which is being developed within the framework of the JPI Urban Europe research project 'SPACERGY'. The DOS method, employed in the Hochschulquartier in Zurich, Switzerland, combines normative, descriptive and explorative components. It aims to help decision makers in a complex multi-actor process by setting common 'internal' transition objectives, sharing and creating a multidisciplinary common ground, and exploring alternative spatial and energy performative visions.

Keywords: Scenario, Living Lab, energy transition, urban design, Zurich

Introduction

This paper develops a new methodology on scenario building within a Living Lab approach to achieve Energy Transition towards a low carbon urban environment. Scenario tools are already recurrently used in urban planning and design, in circumstances where it is important to take a long-term view of techno-social developments and related strategies. It is also useful when there are a limited number of key factors influencing appropriate strategies, and a high level of uncertainty about such influences (van Timmeren et al., 2011). Scenarios build plausible views of different possible futures for relevant actors based on groupings of certain key social, spatial and environmental influences and drivers of change. The result is a limited number of logically consistent yet different scenarios that can be considered alongside each other (Ibid).

Although in recent years scenario planning and scenario modelling have become more common (Schoemaker, 2004; Mehaffy, 2015), particularly in support of visioning processes (Lemp et all, 2008**;** Bartholomew 2005), a Living Lab Approach (LLA) implies the necessity of far-reaching interdisciplinary integration and active participation of the different actors. In the reconfiguration of urban areas, a number of actors is involved with different ideas of the future. What is needed, is a scenario based method that allows to set common objectives and explore alternative future pathways, while helping the construction of common, so-called 'desirable visions'. Despite a certain level of uncertainty, it can also be used in evaluating the effects of decisions taken.

To meet this demand, and the necessity for coordination of design, research and planning to realize a energy-sensitive approach in Energy Transition processes, a method is being developed in the JPI Urban Europe SPACERGY project for a main Living Lab, the Hochschulquartier in Zurich, Switzerland, alongside two other Living Labs in Bergen and Almere. The main objective of the SPACERGY project is the elaboration of new toolsets and guidelines to implement energy efficient urban development. Within the first analytical phase, the main goal was to identify social, political and economic components to determine potential trajectories for the development of the energy concept of the different study areas. Furthermore, the exploration of energy-spatial strategies to guide robust design choices and processes of implementation requires the creation of a solid and common knowledge basis. For these reasons, scenario building is considered as a 'process related' tool, with a triple role to explore and describe possible future conditions and to guide spatial-energy decisions to address the national and urban energy goals.

In the following sections, the new scenario method, which allows to define common visions within a multi-actor Living Lab (LL) approach, is described. In the first part the general framework is set, starting from different classifications of scenario types commonly used. Next, new scenario methods will be constructed in relation to energy transition objectives. In the last part the evaluation and testing in the Zurich LL, will serve to improve the theoretical basis as well as the developed method.

What type of Scenario model?

Two fundamental definitions of scenarios can be distinguished, reflecting different epistemological views (van Notten et al. 2003; Rikkonen and Tapio 2009). The first is by Kahn & Wiener (1967) who define scenarios as built sequences of hypothetical events. The second is by Rothmans & van Asselt (1997) who see scenarios as descriptions of alternative images of the future, created from models that reflect different perspectives on the past, present and the future. According to these definitions, different types of scenario methods have been described in literature and applied in different contexts (Amara 1981, Borjeson et al. 2006, Dreborg 2004, Carsjens 2009, Sager-Klauß 2016).

In urban planning and design, scenario types can be classified according to content and objectives, as well as processes and methods. According to Manzini et al. (2008) a main distinction concerns Policy-Oriented Scenarios (POS) and Design Oriented Scenarios (DOS), where POS deals with the macro-scale and political decisions, and DOS are envisioned as tools in design processes. DOS, Manzini et al. claim, "should propose a variety of comparable visions to create inspiration for designers" and contain various proposals for a concrete plan, or a global vision which pictures the effect of the implementation, and which explains the main possible effects and general benefits, for example in terms of sustainability, economics, and social wellbeing. Another classification for types of scenarios regards the objectives on which these are built. According to Borjeson et al. (2006) scenarios are classified in three types : Predictive, Explorative and Normative. While predictive scenarios relate with the concepts of probability and likelihood, explorative scenarios have the aim to explore developments considered as possible to happen. Very often these take a starting point in the future, and are elaborated with a long time horizon to allow more profound changes. Concerning normative scenarios, the focus is transformed from visions into objectives and the possibility to reach a certain target set. The interest in this case is on a desiderable future situation and how this can be realised. Moreover, Rotmans et al.(2000) distinguish between normative (prescriptive) scenarios and descriptive scenarios. This last category describes, by using a deductive thinking process, how the future might unfold by applying known process dynamics or by similarities with other processes or experienced situations.

Project objectives and selection of scenario type

In the SPACERGY project, the selection of the type of scenario is based on the main objective: the building of a conceptual and methodological toolset to guide the design and urban development (including its technical systems) of the LL to achieve a successful energy transition. Although DOS are identified as useful tools to guide the process of design and identify visions in the specific context of urban transformations, these are often developed as a designed research product, without the involvement of stakeholders. In particular, concerning the field of energy planning and design, DOS have been associated with the visualization of energy footprint at larger scales, as explorative instruments, and for informing planning strategies. Therefore, in the context of Energy Transition towards a carbon free society, as Sager-Klauß (2016) states: "to start a process of energy transition in small and medium communities, guiding principles based on energy should be integrated in the urban development concept on a broad basis", while the process of envisioning should be developed by creating joint discussions with these communities and by including all relevant actors.

The main question thus became: What type of scenario model is needed in the Living Lab approach and how to improve the DOS approach for use in the LLs ?

Within the SPACERGY project the scope of scenarios intended as a tool is based on the aims:

- to collect knowledge by multi-disciplinary experts and actors and to understand drivers which influence the urban development (DESCRIPTIVE);
- to explore possible internal energy-spatial integrated development (EXPLORATIVE);
- to understand how to achieve national and urban objectives set for the energy-spatial transformation (NORMATIVE). For this reason, it is considered a hybrid DOS.

Scenario based process design and method

For the definition of a new framework for the hybrid DOS, following the scopes in a LL approach, the method merges in different phases characteristics of descriptive, explorative and normative scenario models in the procedural structure. Furthermore, the procedure inserts employment of techniques and activities which facilitate the interaction between scientific partners/researchers expert in different fields, together with municipality administrators as well as technicians. The scenario building itself is structured in three main phases, involving the following activities:

1) Preparation: i) Actors, energy policy, energy objectives and key drivers of change are identified, highlighting the role of planning instruments and main challenges and constrains for urban transformation. ii) A scenario matrix is developed taking in account the main factors of uncertainty.

2) Workshop: i) The scenario matrix is discussed and validated. ii) The participants divided in four heterogeneous groups describe and present the four visions according to the matrix. iii) The four visions are discussed for robustness and confronted

3) Evaluation and implementation: The multidisciplinary research team assesses the outcome, extrapolates the impact factors for a decisional and spatial integration, discuss the consistency, and plan possible modified implementation phases.

The resulting design scenarios will be assessed on their energy performance with a simulation model in a later stage (not described in this paper).

Case Study in Zurich

The hybrid DOS, after a first application in the LLs of Bergen (N) and Almere (NL), has been improved and applied in the Zurich LL to the case study area of the 'Hochschulquartier' (HQ). The HQ represents one of the most important and challenging urban transformations within the city of Zurich. In the dense and central area, the transformation of the university district is meant to create an internationally competitive location for knowledge and health. Here, the interests and demands in terms of space, energy and transportation of three key stakeholders, ETH Zurich (ETH), the University of Zurich (UZH) and the University Hospital of Zurich (USZ) have to be considered and coordinated along with existing residential functions.

The transformation plan increases the usable floor space by 40%, and includes a variety of interventions: retrofitting the large existing building stock, building extensions, and the allocation of built volume on currently unused areas to increase the building density. Another key objective, which however might be more difficult to achieve, is to realize synergies and create a liveable urban district, exploring options to share the use of common functions and spaces (such as services, restaurants, cafeterias, housing etc.) and introduce new land use types.

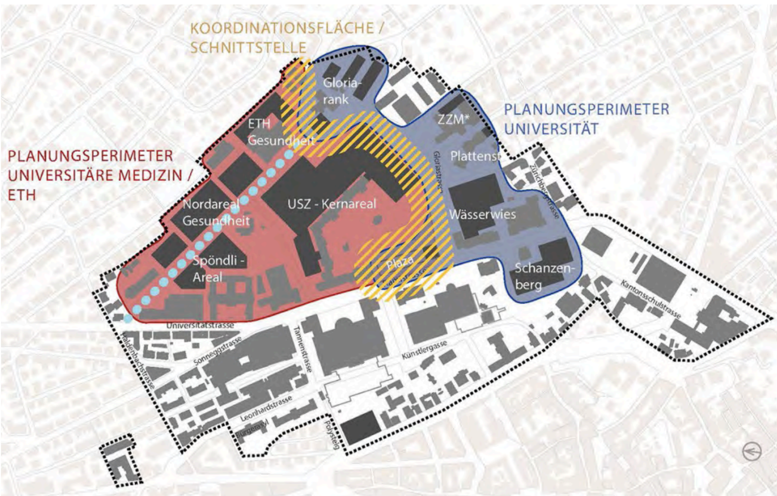

Figure 1. HQ Masterplan 2014. Hochschulgebiet Zurich-Zentrum Schlussbericht Vertiefungsthema Energieversorqung (2015)

These needs have to be balanced with the use of green spaces that are of great relevance for the area already, while the spatial transformation also has to go hand in hand with new energy solutions and set strict goals regarding energy performance. In this already challenging situation of high competition between different functions and their spatial use, the additional challenge is to meet the 2000 Watt Society urban goals. Furthermore, at the other (higher) administration levels, the energy policy commits to a challenging switch in the energy mix from nuclear power production to renewable energy generation by 2050. The HQ transformation takes this into account, although the potential to employ new energy sources and infrastructures has to be tied to a century-old distribution network as well. Besides, it also needs to comply with the varying demands of the new developments in terms of quantity, quality (temperature) and dynamics.

A master plan approved in September 2014 (EBP, 2014) provides a first outline for renovating the structural and operational infrastructures of the site over the next 30 years. For the city of Zurich, the area represents not only one of the most challenging tasks in the near future but is also supposed to serve as an incubator and demonstrator for a new inclusive planning process that connects the relevant actors and leverages synergies. Due to its complexity, integration of spatial development, energy planning and mobility is crucial for the success of the transformation in the end.

Figure 3. View of the design project developed by Team Gigon / Guyer, in the design competition in 2015

First results of the hybrid DOS method applied in Zurich LL

In this context of highly different interests and spatial competition, the development of scenarios is of fundamental importance to explore future options for the integration and tuning of energy and spatial measures. This section describes the results obtained by applying the hybrid DOS method to Zurich.

Development of a Scenario Matrix

Based on a Scenario matrix (Figure 3), four Scenarios were developed. The 2x2 matrix is built on the two most critical aspects which impact the transformation in the HQ: (i) the composition of energy measures that can be applied in the area to buildings and to the urban fabric, and the degree of integration regarding both and (electric) mobility concepts; and (ii) mix in spatial functions and use, inversely related to the demand of transport in terms of number of trips.

The horizontal axis of the matrix relates to different spatial frameworks in terms of mixed functions and the levels of homogeneity/heterogeneity in the use of the public spaces. The consequence of multi-functionality directly affects the transport demand. The reason is that the availability of space for leisure, facilities, residential purposes and flexible use of the space of the campus 24/7 reduces the number of trips outside the area for the community. This dynamic is also valid for students/users that in the actual situation have to move to others clusters in the city to have the same utilities.

On the vertical axis, the scenario moves from a condition in which the different energy measures for generation, re-use and reduction of the demand are strongly integrated, to a less integrated portfolio of energy measures, where the supply is guaranteed by centralised systems and infrastructures. These measures largely refer to the configuration and composition of the urban fabric and moreover to the integration of electric vehicles in the area for energy storage purposes and as an alternative for traditional transport solutions.

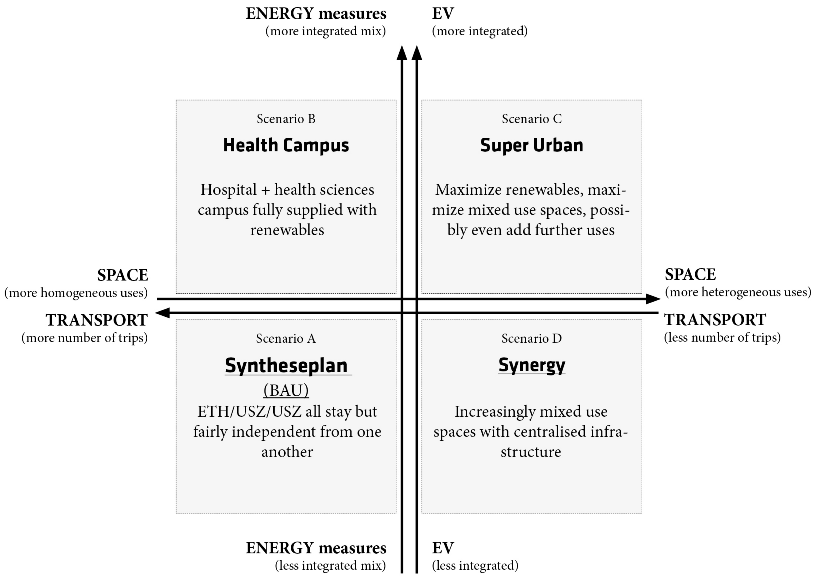

Figure 3. Scenarios matrix for the HQ

Description of the four scenarios

Scenario ‘Synthesesplan’(SP): This scenario is based on the actual vision of the project for the HQ. The scenario depicts a future according to the prescription of a plan where the three institutions ETH, USZ, UZH separately develop their spatial plans, without any integration of uses. The assumption is that each of the institutions realises an extension, increasing the total built volume in the area. Regarding mobility, according to the new long term urban transportation planning, bike and pedestrian pathways are improved, while there are no relevant changes regarding car use. The amount of green spaces increases, however the nature of the area is not drastically changed, neither are they developed to proactively support outdoor comfort or microclimate conditions. The overall energy demand rises slightly. Regarding energy supply, the HQ is connected to the urban energy grid, linked to the existing energy power plants at the canton and national level. At the city level it consists of large system components and centralized infrastructures using waste heat from the main incinerator station and use of existing heat exchange potential from the river water. The only measures available to increase the energy performance in the area embrace the possibility of reducing energy demand by high-tech construction materials. Electricity demand is not covered by local or on-site generation.

Scenario ‘Health Campus’(HC): This scenario is based on the tendency of homogeneity in use of the area where functions remain mixed but spatially clustered with a higher proportion of use related to health functions. At the same time, in the spatial transition, the HQ reduces its greenhouse gas emissions to the minimum, maximising the use of technologies to store energy generated by renewable sources, and using highly efficient distribution systems and building materials to diminish heat loss. Electric vehicles (EVs) are integrated in the local energy system. The total demand for transportation increases as the hospital attracts more users. Green spaces do not change in terms of footprint, but will be upgraded into more integrated and more shared high quality green spaces. In terms of functions, it is aimed for high integration of pedestrian and shared high quality green areas and increased permeability of the area. Building functions are more integrated, with a focus on health. Energy demand is rising, but, in terms of energy supply, a mix of different sources and technologies for production is created. Focus is put on finding complementary functions to exchange excess heat. This scenario is considered the more extreme case, with the highest energy demand for the area, and where energy solutions in the hospital complex will be less dependent on existing energy infrastructures.

Scenario 'Super Urban'(SU): The SU vision embraces a synergetic mix of functional use and shared spaces during daytime, combined with a high mix of distributed energy solutions. This scenario implies further political decisions. Focus is put on multi-functionality and highly integrated and liveable solutions, with a combination of residential building, amenities and offices, optimized for balancing the energy demand. The aim is a 24/7 liveable area, which is pedestrian (and bike) friendly and has an increased overall accessibility. Thus, internal accessibility increases, while external accessibility focuses on its connection with the city centre, through public transportation, sharing of devices and dynamic services. Green spaces are multifunctional in use. As a result of multi-functionality and interaction, urban form is of increased importance, with emphasis on the building-street interface to achieve liveable public spaces. The urban form supports walkability in terms of street-scape quality and intervisibility. Energy demand is based on a high level of occupation focusing on demand reduction strategies, and complementary internal balancing in time. Energy supply builds upon reuse of waste flows at the level of the area, optimization of (distributed) renewable potentials, and thus including storage (matching demand and supply). Energy systems are integrated at the scale level of the area.

Scenario 'Synergy'(SY): The SY scenario builds on a mix of functions, where the main difference with SU is that the energy supply is more conventional with centralised infrastructures and less distributed sources. It focuses on a better functional integration of use compared to the SP, and less on energy supply, which employs renewable sources at a larger scale-level, with limited production in the area. As for transportation, focus is less on the integration of new solutions, and rather on improvement of existing public transport systems, and better tuning with pedestrian and bike-based mobility. Regarding energy demand the SY scenario builds on better integrated means to decrease the energy demand, and a functional mix to increase the overall effectiveness (joint energy footprint of mobility and use of space). Green spaces are multifunctional and well integrated with the built environment. Also in this vision, as a result of multifunctionality, characteristics of urban form such as compactness and connectivity play an important role to achieve spatial and energy integration.

Discussion

A numerical analysis of the energy performance of the four descriptive/qualitative scenarios will be carried out in a second stage of the SPAGERCY research, providing the final assessment for comparison of the scenarios on a quantitative base. However, some preliminary conclusions can be drawn and factors of influence can be found by extrapolating the partial results presented in this paper.

The deductive construction of the four scenarios highlights the connections between the cooperation of types of land use and the availability of space for energy production. Where the integration of functions balances the energy demand, this also potentially decreases the competition for space. Furthermore, the introduction of microclimatic measures needs some more elaboration in the construction of a knowledge basis, since it seems there is little awareness among the participants about the benefit from an energy perspective. Regarding mobility, a numerical model should distinguish between internal and external mobility both for mode of transport and calculation of the numbers of trips.

Conclusions

The application of the DOS method has showed its capacity to support complex multi-actor process of spatial-energy transformation by helping in setting common transition objectives, sharing and creating a multidisciplinary common ground, and exploring alternative spatial and energy performative visions. In the evaluation phase of the method and its application in the Zurich LL, the four visions have been considered a fundamental contribution for the body of information and knowledge developed, and consistent in terms of description regarding the relations between the energy impact factors and processes. Quantitative indicators will be used in a second phase to calculate the balance between energy demand and on site production (normative value).

The authors and the other researchers involved in the process point out that the relatively limited number of actors that participated in the workshop can not be considered sufficiently representative. The difficulties regarding the involvement are related with a variety of cognitive limitations in dealing with uncertainty and complexity in scenario building, pointed out by Schoemaker (2005). In the case of Zurich, the high political sensitivity regarding the area, the request to discuss possible futures in a small setting and unusual framework in this context were the key elements that led to limited participation of the invited actors.

For this reason, a new phase has been planned to involve more stakeholders in the evaluation of the visions developed during the workshop by experts, making use of a interviews method. This additional implementation part in the hybrid DOS method is planned for the coming months, and aims to overcome the described shortcoming.

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