Zurich, June 15-17 2016
Sustainable Built Environment (SBE) Regional Conference

Expanding Boundaries:
Systems Thinking for the Built Environment

ENERGY AND THE CITY: INVESTIGATING SPATIAL AND ARCHITECTURAL CONSEQUENCES OF A SHIFT IN ENERGY SYSTEMS ON DISTRICT LEVEL IN A SUMMER SCHOOL

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Abstract

This paper presents the approach, methods and results of an international summer school, InduCity, conducted at the ETH Zurich in collaboration between the Chairs of Architecture and Building Systems and Architecture and Urban Design. The objective of the summer school was to study potential interactions between future renewable energy systems and urban design and development. While transforming a former industrial site into a sustainable mixed-use urban neighbourhood, participants investigated the reciprocal relationship between modes of energy demand, supply and storage, and the built morphology and qualities of public space. Contrasting the common process of developing the energy concept on district level after designing the urban form, we established two different holistic transformation narratives, each equipped with a focused energy strategy to imply an energy driven design. For narrative one an introverted urban form was combined with a decentralized energy network whereas for narrative two a more flexible and open urban structure was combined with a local and autarkic energy supply. After analytical work, students engaged in design experiments based on energy harvesting strategies and established new programs and types of public space linked to different energy generation and storage technologies. The strategies operated on multiple levels: from urban growth scenarios driven by energy policies to urban morphologies defined by energy balance and building typologies developed according to storage technologies, to the design of public spaces inspired by energy storage. The design process and its results reveal conspicuous impacts of the energy supply strategies on the building, neighbourhood and district scales of urban development. The applied methodology proved very suitable for the prevalent teaching task of designing sustainable city quarters, and can be applied easily to other sites and tasks.

Keywords:

Energy; Urban Design; Sustainable City Quarter; Renewable Energy; Architectural Teaching

1 INTRODUCTION

To meet the goals and challenges of global reduction of the carbon footprint [1], Switzerland focuses on the environmental performance of cities. Initiated in 2008, the 2000-Watt/-1t CO_2 society calls for a reduction of ¼ of every inhabitant's footprint by 2050. On district scale, the so-called "2000-Watt-Areale", a set of punctual projects all over Switzerland, have been established and analysed over the last years [2].

Research on energy efficient communities mainly concentrates on urban economics, density, transportation and the building envelope [3]. However, the question of the relationship between city texture and energy consumption has not been answered sufficiently yet [4]. Ratti proved that the overall variation of energy

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consumption on urban geometry is very little. The ratio of passive to non-passive zones, the surface to volume ratio and the glazing ratio with orientation have been analysed and it was shown that the relevant design indicator for energy consumption on an urban level is passive zoning [4].

The InduCity research project, carried out by the authors, has proven that the type and mixture of functions has a significant impact on primary energy (PEN) and carbon emissions (CO_2) on district scale. Furthermore, for the case study under research, infrastructural upgrades on district energy supply systems provided a higher impact than building retrofit [5], [6]. Energy efficiency measures and the increase of share of renewable energy sources are prior challenges for urban planning in developed countries [3]. Hence, due to its type-specific energy consumption energy infrastructure as well as building use will become relevant parameters for urban and architectural design.

In contemporary architectural education environmental sustainability is often considered as an addition to the architectural design rather than an integrated prerequisite [7]. This is reflected in the current educational approach of design studios: Environmental design is mostly taught in parallel course work instead of being integrated in the design task and the design process. The InduCity summer school aimed to alleviate this shortcoming by integrating energy as a design parameter within a design studio set up (Figure 1).

This paper details the curriculum of the summer school in section 2.1, the essential data background in section 2.2, the scenario narratives in section 2.3 and results on the task and the teaching approach in section 3. It further discusses lessons learned and provides an outline on future courses applying the explored teaching methodology in section 5.

2 INDUCITY SUMMER SCHOOL

2.1 Curriculum

Organisation

The InduCity summer school took place from 17th to 26th of June in 2013 at ETH Zurich. It was a collaboration between the Chair of Architecture and Building Systems - Prof. Arno Schlueter (A/S formerly SuAT) and the Chair of Architecture and Urban Design – Prof. Kees Christiaanse. 16 students mainly from ETH Zürich and EPFL participated, ranging from bachelor level to doctoral students including exchange students from UPC Barcelona, NUS Singapore and ETSA Valencia.

Scope

The InduCity summer school aimed to explore the impact of energy as a design parameter within the disciplines of urban design and architecture.

Structure

Fig 2 displays the two-fold teaching structure analytical and narrative to introduce energy as a design parameter. The site was analysed regarding topology, transport infrastructure, public space, morphology and program, actor networks, regulations and projects, energetic synergy potential and renewable energy sources. The urban design development was based on combining the themes in two predetermined narratives and focusing on energy.

The twofold method of analysis and narrative as an iterative design development was crucial for students to learn about the site in question, tools for urban design and how to implement designs based on quantitative and qualitative aspects of energy.

Continuous student output was key for reflection and integration of analysed themes and designing narratives (Figure 2). Critical input and feedback by means of student presentations for selected guests from different fields i.e. urban design, architecture and energy sciences stimulated continuous design development.

Sequence

An introduction with lectures by both hosting chairs was followed by a site visit of the Siemens Areal in Zug, Switzerland. The students were tasked to explore and document the site and its buildings in order to get an understanding of the context of the summer school topic. Based on the site visit and further research students would then analyse in groups of two the different themes and present their findings. Additionally, selected speakers were invited to introduce the research project InduCity and its findings, energy technologies and their applications, geo-information systems and how to represent energy. The different analytical themes and the students were then combined into two pre-defined narratives, entitled ‘Campus’ and ‘Urban Condenser’ (UC) (Figure 2). The design development entailed representing design interventions in plans and models, mapping energy potential and its relationship to the design proposal which was presented to selected guests in the middle of the summer school and at the end of the summer school. The interim review helped students to clarify and how to further develop the proposals regarding urban design and energy. Lectures and an open discussion with guests and experts were critical for the design development. A final presentation would conclude the summer school and offer the possibility to reflect on the design proposals.

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Fig.1: Studio work mode.

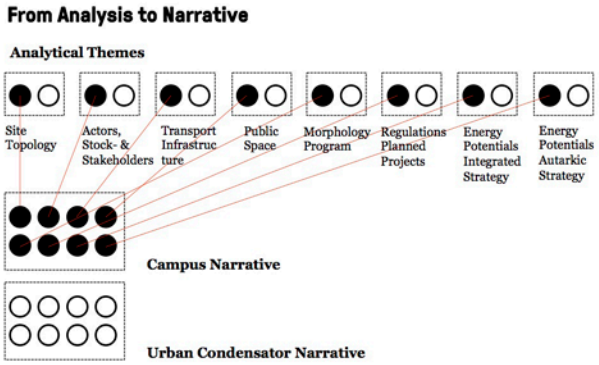

Fig. 2: Sequenced group work approach [8].

2.2 Data Background

InduCity research project

Based on the results of the research project InduCity, students were provided with data of the status quo and data for future scenario calculation. The data regarding status quo contained information on buildings, infrastructure, industrial processes, building uses and mobility patterns to set a base line energy consumption data [6]. Examples are shown in Figure 3 and 4. In addition, a carbon footprint methodology had been developed to assess the scenarios within the 2000-Watt/ 1t CO_2 society framework. [5]

Established on a cross-sectional (industry, buildings and transportation) and multi-dimensional (during construction and operation) comparison of the resulting environmental impact [6] of four possible scenarios at the site derived from the InduCity research project, we provided the two scenario narratives with the lowest overall carbon footprint for the summer school. Scenario construction during the research project was carried out according to [9]. Additionally, the data of the status quo was provided [5]. Regarding design parameters, i.e. density, program etc. and energy related decisions, both narratives were opened up to allow the students to own the scenarios by developing a group-specific scenario definition. For this reason and as the research project InduCity was lacking an urban design analysis, students had to carry out this analysis first to specify their approach.

Fig. 3: Masterplan Status quo [8].

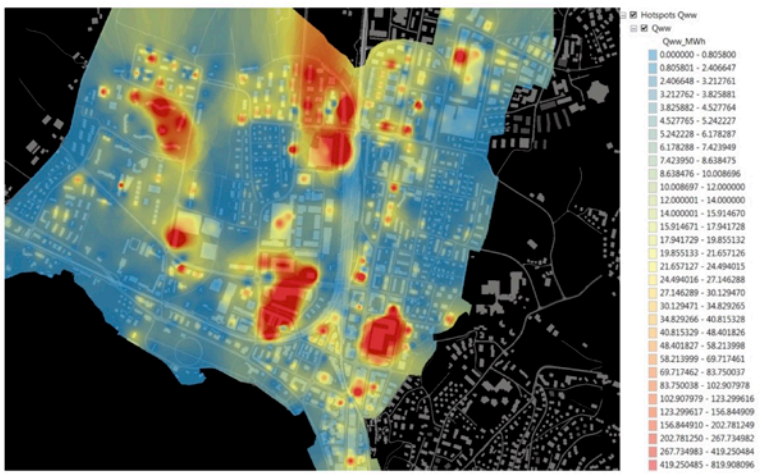

Fig. 4: Domestic hot water demand of the district by building [8].

2.3 Narratives

Key aspect of the iterative design development was the transformation of analytical themes into two synergetic narratives. The narratives serve as framework each with a specific scenario for future urban development scenario and energy supply. The aim was to explore how energy would influence urban form and vice-versa.

Students were tasked to implement a design proposal for each of the two narratives. The 'Campus' narrative assumed an urban form with a clear boundary towards the surrounding context. The programming emphasised the function of centrality. It focused on offices, research and education, complemented with high-end housing and maintaining some existing industrial program. The scenario assumed a few

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large-scale actors and underscored the centrality by developing the site vertically to increase densification. The centralised urban form would be counteracted by a decentralised energy strategy connecting to and exchanging with the urban context and neighbouring buildings to explore versatile strategies of renewable energy supply.

The 'Urban Condenser' narrative assumed an urban form with a less strict boundary and a stronger mixing with the urban context. The programming emphasised complementing the urban context. It focused on multi-generational housing. Utilising the large-scale structures of the former industrial program as mixed-use and multi-purpose open structures allows for small and fragile actors to occupy and develop flexible programming. To explore the possibilities arising from an energetic alliance based on a manifold community, this narrative was tasked with a centralised energy strategy.

Summarizing, the approach consisted of representing the narrative's potential, formulating a vision and a strategy for both the urban form and energy. The representation of the application would in turn display the spatial consequence of energy and the city.

3 SUMMER SCHOOL RESULTS

The students working on the 'Campus' narrative informed their campus vision with programmatic synergy of the two main identified actors, a university and the existing industrial corporation (Figure 5). They also explored recreational potential for its program of education and industry in the adjacent urban context and nature identifying many attractive opportunities. It included existing sports facilities and infrastructure as well as nature recreation areas nearby the lake and forests. The renewable potential analysis resulted in an overlap of local resources with recreational areas. The urban strategy was to connect the recreational areas and renewable energy resources with the 'Campus' through a cohesive element, a green infrastructure. A continuous tree structure inside and outside the 'Campus' serves as a spatial entity, a recreational space that can be harvested for renewable resources as shown in Figure 6.

Students working on the 'Urban Condenser' narrative proposed a mixed-use city quarter focusing on housing and places for exchange. The aim was to maintain most of the existing structures but change their programming. An energy network initially balances the diverse demand and supply. The urban strategy is based on a policy tool to manage the urban development potential on site according to its energy balance. It mandates small-scale energy infrastructure like production, storage and increased efficiency to potentially impact and benefit further planning. It combines measures for energy and buildings, from existing structures to future transformations for an incremental development complementing its urban context. Details on the policy framework can be found in Figure 7 and 8. Future transformation mandated by the development policy would incrementally increase housing. New buildings are self-sufficient and thus support their own demand. If necessary, they complement remaining existing and reused buildings.

The application of the summer school structure outlined in 2.1 allowed an iterative design development by students with a sufficient degree of flexibility. The students were able to explore on one hand how the availability of resources and energy supply systems can determine urban growth and urban form as in the 'Urban Condenser' narrative. On the other hand, designing urban space for trees as a cohesive element emphasizes the significance of renewable energy sources within the city. By integrating these elements into the public realm, buildings and streets literally have to make space for energy sources. Conclusively, both results can be synthesized in spatial responses individual to the narratives.

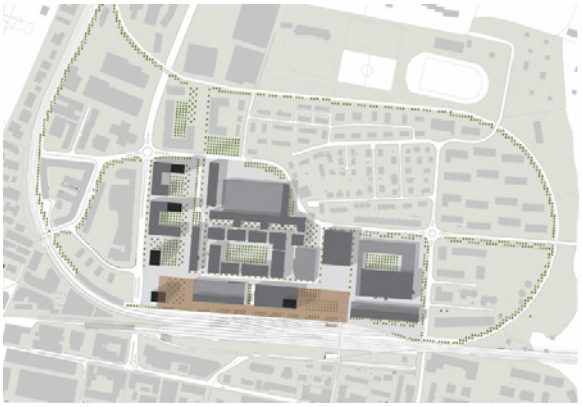

Fig. 5: Campus: Masterplan including tree [10].

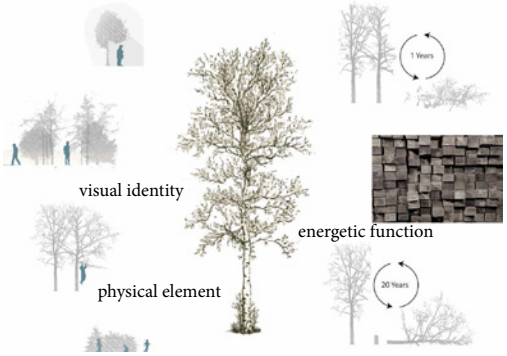

Fig. 6: Campus: Trees as cohesive element [10].

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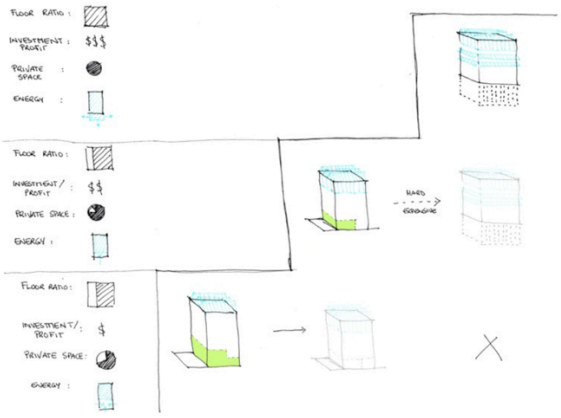

Fig. 7: UC: Set of rules for development [11].

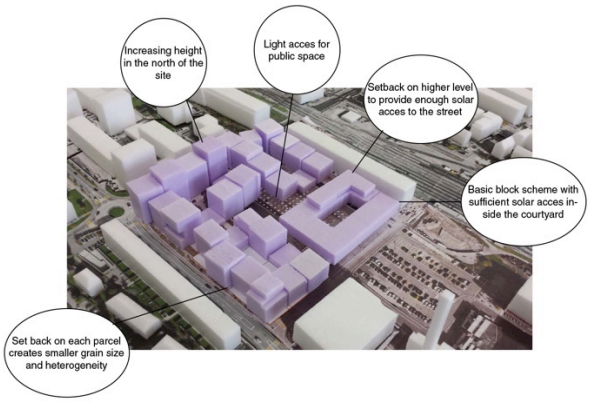

Fig. 8: Spatial development according to rules [12].

4 SUMMARY

This paper summarizes the summer school InduCity conducted in 2013 at the ETH Zürich focusing on combining energy as an urban design parameter and utilising real energy data and models from a parallel research project. The participating students engaged the selected site in a design studio environment. They analysed key urban design and energy potentials to develop two future proposals. The two proposals are based on two narratives each with a specific framework on programming, energy systems and urban form. The student's analysis was supposed to inform their iterative design development by combining urban design and energy. The results found two distinct translations of design including their spatial consequences. The 'Campus' featured a 'green infrastructure' combining recreational and renewable energy infrastructure and potentials. The 'Urban Condenser' featured a 'policy' mandating an incremental development including the possible reusing of existing structures and new energy self-sufficient housing. The InduCity summer school therefore successfully displayed the relationship and spatial consequence of energy and urban design through means of design and specific design proposals.

5 DISCUSSION AND CONCLUSION

The InduCity summer school has explored the impact of renewable energy systems on urban form. In both scenarios new planning tools were developed. Within the 'Campus' narrative it mainly impacts the public realm, in the 'Urban Condenser' narrative the energy balance will determine growth and density of the built environment.

The key limitation to the level of investigation was the duration of the summer school being only ten days, however promising results were achieved. This could be expanded to greater detail in a setting such as a full-semester course. In addition, any quantification of renewable energy potentials, harvesting and storage was based on simplified calculations. Assessment to the 2000-Watt-society as carried out within the research project was not possible. Students would need to be provided a better calculation tool that can iteratively calculate the current energy status during the design process such as provided by the CEA tool. [13]

The method of the summer school was limited to renewable energy, urban design and schematic architectural design. According to the BESQoL-method [14], this approach could benefit from being broadened by varying factors as movement, economics and human capital and quality of life to gain a more holistic view on the site, especially its shortcomings and potentials to not only improve PEN and CO_2 emissions but quality of life by urban redesign.

6 ACKNOWLEDGEMENTS

The continuing support in preparation and implementation of the summer school by Daniel Kiss, Chair of Architecture and Urban Design – Prof. Kees Christiaanse is gratefully acknowledged. Furthermore, the contributions by Dr. Michael Stauffacher, Dr. Corinne Moser, Fabienne Hoelzel, Prof. Dr. Stefan Kurath, Martin Haas, Adrian Altenburger, Markus Schaefer, Dr. Peter Kiefer and Stefano Grassi are gratefully acknowledged. Participating students in the InduCity summer school were: Albert Achammer, Anne Charlotte Astrup Chauvaux, Daniela Bolli, Juliana Felkner, Sara Vima Grau, Niklaus Haller, Arpad Hetey, Maryam Jafarbegloo, Nan Jiang, Mattias Frederik Josefsson, Orkun Kasap, Li Fang Lee, Franscisca Molina, Nicolas Pierret, Michael Andreas Reisinger and Vera Schmidt. This summer school was supported by Climate KIC.

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7 REFERENCES

1. IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

2. Kellenberger, D., M. Menard, S. Schneider, M. Org, K. Victor and S. Lenel, Arealentwicklung für die 2000-Watt Gesellschaft: Leitfaden und Fallbeispiele, Bern, 2012.

3. Madlener, R., and Y. Sunak, Impacts of urbanization on urban structures and energy demand: What can we learn from urban energy planning and urbanization management? Sustainable Cities and Society 2011. 1: p.45-53.

4. Ratti, C., N. Baker, and K. Steemers, Energy consumption and urban texture. Energy and buildings 2005. 37: p. 762-776.

5. Fonseca, J. A. and A. Schlueter, Method and data analysis for assessment of local energy potentials for urban transformation: a case study of a mixed use city quarter, in CISBAT 2013, 2013, pp. 649-654.

6. Fonseca, J. A., A. Willmann, C. Moser, M. Stauffacher and A. Schlueter, Assessing the environmental impact of future urban developments at neighbourhood scale, in CISBAT 2015, 2015, pp. 457-462.

7. Altomonte, S., Environmental education for sustainable architecture. Review of European Studies 2009. 1: p. 12-21

8. Willmann, A. S. Cisar, D. Kiss, K. Christiaanse and A. Schlueter, Reader. Energy and the city. InduCity summer school. ETH Zurich. 2013.

9. Gausemeier, J., A. Fink and O. Schlake, Scenario management. An approach to develop future potentials. Technolog. Forecast. Soc. Change 1998, 59: p. 111-130.

10. Achammer, A., A. Astrup-Chauvaux, J. Felkner A. Hetey, M. F. Jofesson, F. Molina, V. Schmidt and S. Grau Vima, Indu-Lab Zug. Final presentation: InduCity summer school, ETH Zurich. 2013

11. Willmann, A. S. Cisar, D. Kiss and A. Schlueter, Report: Energy and the city. InduCity summer school. ETH Zurich. 2016.

12. Fang Lee, L., N. Pierret, M. A. Reisinger, D. Bolli, M. Jafarbegloo, O. Kasap, N. Haller and N. Jiang, Urban Condenser. Final presentation: InduCity summer school, ETH Zurich. 2013

13. Fonseca, J. A., D. Thomas, A. Willmann, A. Elesawy and A. Schlueter, The city energy analyst toolbox part I: Demand and LCA modules, in SBE16, 2016 (forthcoming)

14. Sassi, P., Chapter: Built environment sustainability and quality of life (BESQoL) assessment methodology. In: Engaging stakeholders in education for sustainable development at university level. 2016, Springer Verlag, Switzerland, p. 21-31.

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