ASSESSING THE ENVIRONMENTAL IMPACT OF FUTURE URBAN DEVELOPMENTS AT NEIGHBOURHOOD SCALE

J. A. Fonseca[1]; A. Willmann[1]; C. Moser[3]; M. Stauffacher[2]; A. Schlueter[1]

1: Architecture and Building Systems – Institute of Technology in Architecture – ETH Zurich. John-von-Neumann Weg 9. 8093 Zurich; 2: Transdisciplinarity Lab - Department of environmental systems science – ETH Zurich, Sonneggstrasse 33, 8092 Zurich; 3: Institute of Sustainable Development – School of Engineering – ZHAW. Technoparkstrasse 2, 8400 Winterthur

ABSTRACT

This paper presents the results of a two-year trans-disciplinary research project investigating opportunities and limitations of the Swiss 2000-Watt/1-ton CO_2 society vision for the transformation of industrial sites into liveable neighbourhoods. By involving local stakeholders we elaborated four plausible scenarios for the transformation of an industrial area in the city of Zug, Switzerland. Based on life cycle analysis methods and urban energy modelling, we estimated the carbon and energy footprint of every scenario due to construction, operation, retrofit and dismantling of buildings, production processes and logistics, commuting, and business flights. The results of our research present a comprehensive description of focal points of environmental impact in future forms of urban development and a description of the role of industry in a transition towards more sustainable urban environments. These are topics of high interest for decision makers involved in initiatives for the sustainable transformation of neighbourhoods such as the 2000-Watt Areale or alike.

Keywords: Urban transformation, environmental impact in neighbourhoods, 2000-Watt/1-ton CO2 society.

1. INTRODUCTION

New patterns of urbanization and population growth have induced the renewal and expansion of urban areas across the globe. A rising awareness on climate change and its effects on cities have suggested processes of urbanization focusing on improving the social, economic and especially the environmental performance of cities. In Switzerland, an environmental vision known as the 2000-Watt/1-ton CO_2 society calls for the reduction of 1/4 of every inhabitant's carbon foot-print by 2050. By acknowledging a direct relation between these targets and the environmental impacts of the built environment, a set of acupunctural projects at neighbourhood scale (2000-Watt Areale) have recently risen as part of physical initiatives to assess the implementation of this concept as potential role-model for sustainable development in Switzerland.

The concept of the 2000-Watt Areale has been widely analysed for residential and commercial areas in Switzerland [1]. For industrial areas there is a need for a congruent knowledge base that serves decision makers to understand the role of industry in the process of revitalization of urban areas and the applicability of the 2000-Watt/1-ton CO_2 society vision for this endeavour. The key question is: what are the opportunities and limitations of the 2000-Watt/1-ton CO2 society vision for the transformation of industrial sites into liveable neighbourhoods?

This question is analysed by means of a case study in the Swiss city of Zug. It consists of an industrial site of around 25ha undergoing a process of urban transformation. Siemens Building Technologies (SBT), a large manufacturer in the light industry sector, owns and predominately occupies the site along with several companies in the services sector. At the moment, there is no residential use on site.

In this paper, we present an assessment of the environmental impact of scenarios of urban transformation for this former industrial area. In section 2 we present key information about data collection, scenarios construction, and life cycle assessment (LCA) methods. In section 3 we present a comparison among scenarios and discuss the implications of these trajectories of development in relation to the 2000-Watt/1-ton CO_2 society vision and areas with industrial uses.

2. METHOD

2.1. Data collection and processing

We collected data of buildings, infrastructure, industrial processes, users and mobility patterns on site in order to set-up a baseline. Figure 1 presents a visual representation of this baseline or Status Quo scenario.

For buildings and infrastructure, we collected information regarding energy consumption and energy systems along with key characteristics of buildings (e.g. dimension, program and thermal properties). We evaluated retrofit options for existing energy infrastructure and buildings along with the potential for integration of renewable energy and waste heat [2].

For industrial processes, we gathered data about the production chain of two characteristic products of SBT and evaluated potential energy efficiency strategies [3].

For mobility, we conducted a postal survey in SBT (N = 1085, response rate 62%) and received data about users, distances, frequency, transport means, and willingness to relocate to the site [4].

2.2. Scenario construction

In order to assess the environmental impact of future states of urban development, we constructed plausible urban scenarios for the area of study in an interdisciplinary process. This processes consisted in a series of workshops including researchers from architecture, engineering, sociology, and psychology and representatives of SBT.

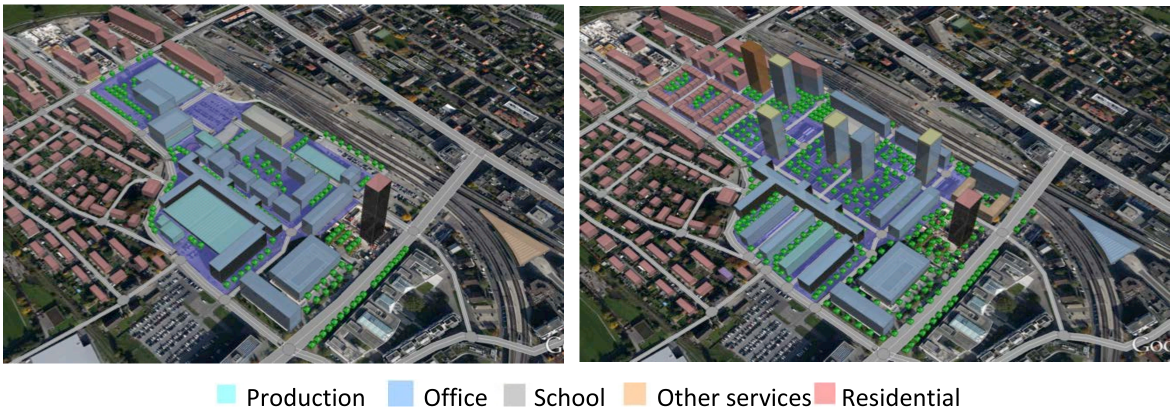

Figure 1 Status Quo and example of urban scenario, left: Status-Quo, right: High-End and Business. Image elaborated with CLM [5]

Following the approach of [6], four scenarios were developed from the combination of a top-down vision and different levels of variables such as mixed-use, building typology, target groups etc. The four scenarios are: **Business-as-usual** (**BAU**) (isolated development; no activities in the evening/during the night; little social life; a few new buildings; existing industrial production is kept; more office space); **Campus** (**CAMP**) (Innovation park; student housing; collaboration between science, little industry, and education; existing industrial production on site is kept; shopping possibilities for students; priced restaurants; nightlife); **High-End Business (HEB)** (Research and development; global companies; densification and high buildings; business hotel; luxury apartments; little industry; restaurants and nightclubs); **Urban Condenser (UC)** (lively city quarter, markets, family friendly, pedestrians and bikes, urban farming, small and local businesses; little industry; more residential areas). In Figure 1 we present a visual example of the HEB scenario.

2.3. Carbon footprint assessment

The carbon footprint of the area is assessed accounting to the shares of buildings and energy infrastructure, production processes and logistics and finally, commuting and business flights.

Buildings and energy infrastructure

The emissions due to construction, retrofit and dismantling of buildings in a scenario basis were computed by relating statistical data of the Swiss building stock [7] to the building's geometry [8]. For new scenarios, the emissions due to operation of buildings and related infrastructure were calculated with the multi-objective optimization approach of [9] assuming an equal balance between costs, emissions and efficiency.

Production processes and logistics

The emissions due to production processes and logistics of SBT are calculated for the supply chain of two representative products. For this we considered the life cycle of components, and processes of fabrication and distribution. We used SimaPro and ReCiPe Midpoint to carry out a detailed energy demand and a reduction potential analysis dissecting three main impact factors: transport distance, weight of product, and means of transportation. The emissions of other types of industry on site were calculated by correlating statistical data to the built area [3], [10], [11].

Commuting and business flights

We calculated the carbon footprint due to commuting and business flights following the recommendations of the standard SIA 2039. For this we took into consideration the data gathered in section 2.1 and estimated future states of trip generation of every target group (i.e. students, expats and families) considering both private and public transportation modes (i.e. Bicycle, pedestrian, public transport, aircraft). We considered only one-way trips to attribute 50% of the total emissions to the area. All factors relating the carbon foot print of a target group and transportation mode were obtained from [12]–[14] and the Ecoinvent database.

3. RESULTS AND DISCUSSION

Based on the approach of [14] we calculated target values of the 2000-Watt-society vision for the year of 2050. These target values are obtained for the dimensions of embodied energy, operation of buildings and mobility. As shown in Figure 2a, both, grey emissions and embodied energy in buildings will increase for every possible scenario at a maximum of 180% from today's levels. For the area of interest this level is still below its target values. For the Swiss average, we might assume that an urban transformation in this direction will tremendously increase its carbon footprint due to embodied energy.

For operation of buildings and industry, we found the expected performance of each scenario (Figure 2b) to slightly exceed its target values. The same statement is valid for the total emissions of the area (Figure 2d). We found this behaviour to be strongly related to technology efficiency rather than to industry operation, whose share is negligible in comparison to building operation (Figure 3). In consequence, we foresee that an increase from today's 14% to 20% efficiency of photovoltaic technology (considered the most optimal for every scenario in section 2.3) would allow the CAMP, HEB and UC scenarios to attain the target value of total emissions for the area.

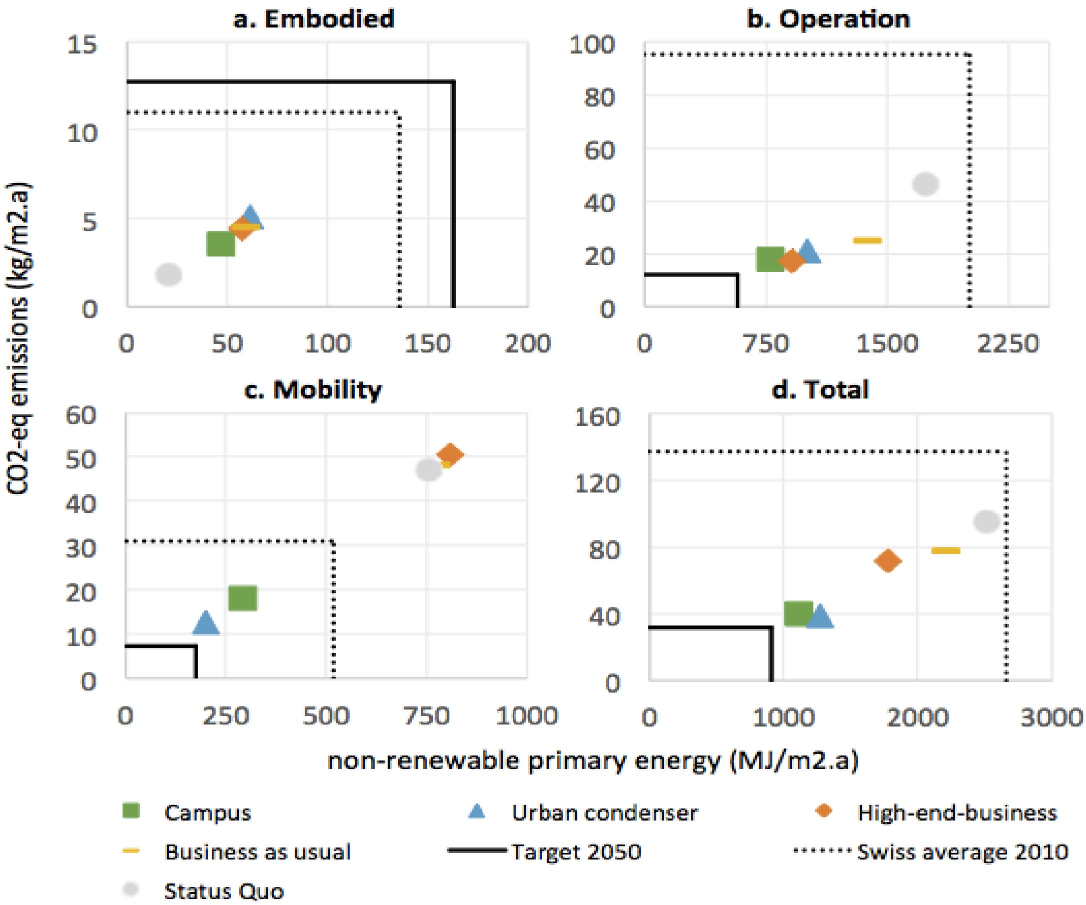

Figure 2 Comparison to short and medium term 2000-Watt/1-ton CO_2 society goals due to: a. embodied energy, b. building operation, c. mobility and d. total for the area

In terms of emissions due to mobility the panorama can highly change from scenario to scenario. In general SQ, BAU and HEB scenarios could potentially generate up to four times more emissions due to mobility than the other (Figure 2c). This behaviour is driven by top-level management positions and related business flights, which correspond to the highest share of total emissions in the area (Figure 3). As a consequence the Scenario HEB will be the most polluting one with 32% more emissions than today (SQ).

As shown Figure 3 the CO_2-eq emissions per scenario will decrease by 20% to 63%, the later coming close to the 2000-Watt/1-ton CO_2 benchmark of 75% (2 ton/p.a). As stated above, the highest leverage to attain this benchmark for the area of concern exists in the building sector, where despite the grey emissions of new buildings and infrastructure, energy and building technology allows to drastically reduce emissions. As in the total values of Figure 3, the predominant share remains in business flights whereas the lowest lie in logistics and industrial processes. The total emissions in the area can decrease up to 48% for a scenario with low business flights, or increase in 32% for the most demanding one.

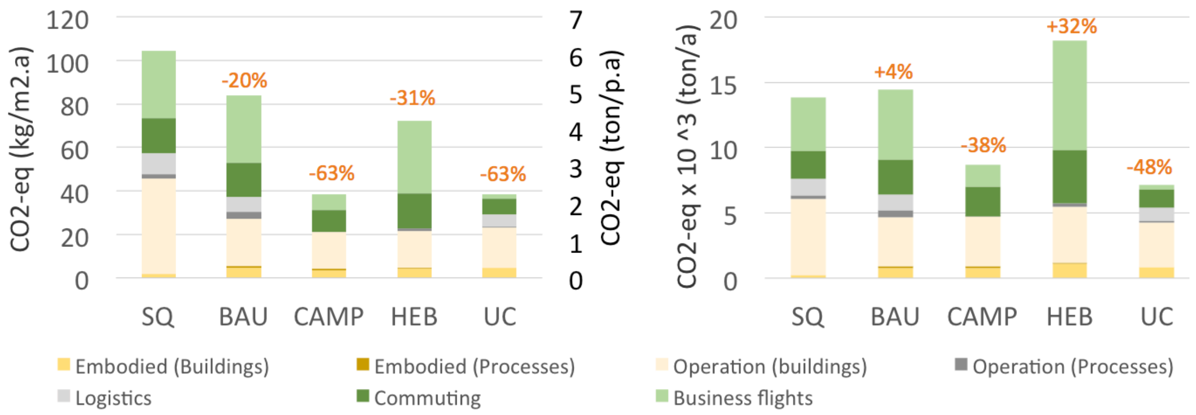

Figure 3 Variation in percentage of CO_2-eq emissions per scenario with respect to Status Quo, a. Left: Relative b. Right: Total

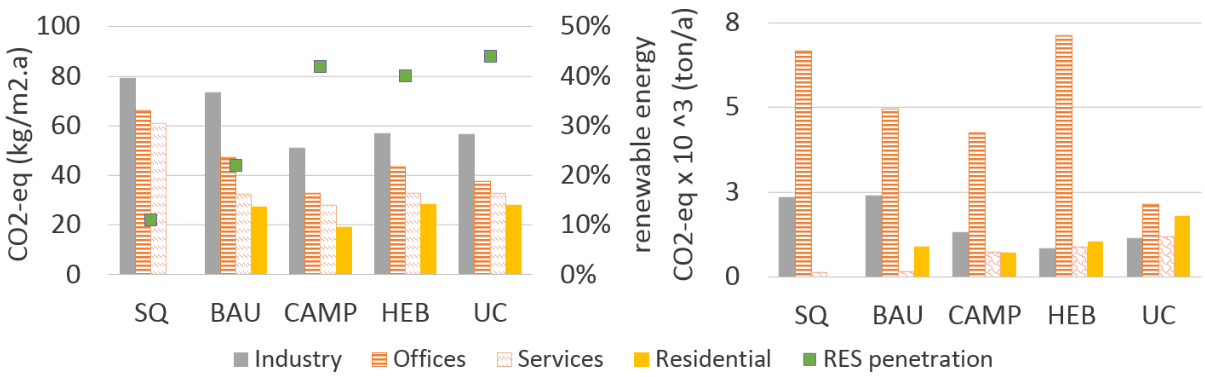

Figure 4 CO_2-eq emissions per building sector. a. Left: Relative values and penetration of renewable energy b. Right: Total

As depicted by the relative values of Figure 4, the CO_2-eq emissions of each sector decreases proportionally to the penetration of renewable energy resources in site. The highest leverage is found in residential, offices and services sectors while the lowest in industry. This behaviour is due to the relatively few energy efficiency alternatives found for industry on site in comparison to the other building categories [8]. In terms of total values, offices uses could predominantly increase the total carbon footprint of the area, what we found to be in line with current trends of high penetration of services uses in cities.

4. CONCLUSIONS

We presented a case study of urban transformation and assessed the expected carbon footprint of plausible urban scenarios. We compared their cross-sectorial (industry, buildings and transportation) and multi-dimensional (during construction and operation) environmental impact. We presented a comprehensive description of focal points of environmental impact as well as a description of the role of industry in a transition towards more sustainable urban environments.

For the case study of Zug, we described how, in relation to the different scenarios, the shares of embodied energy in buildings and operation of industrial sectors have the potential to generate the lowest emissions, whereas mobility in the service sector (business flights) potentially generates the highest. The existence of light industry itself does not jeopardize the future environmental performance of the area, but instead, it brings positive effects as a potential source of waste energy. In contrast top-management levels creates the highest share of emissions due to business flights. Technological advances in energy and building technology will represent a critical factor to attain the 2000-Watt/1-ton society goals.

In general, the series of assessment methods here before introduced are applicable to studies in any urban area with or without industrial use, as benchmarks can be easily changed. Further work could consider sensitivity analysis techniques for more detailed intra and inter scenario comparison.

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