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Criteria for energy efficient urban planning

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Abstract: Many cities today are committed to increase the energy efficiency of buildings and the fraction of renewables especially in new urban developments. However, quantitative data on urban energy performance as a function of urban density, building compactness and orientation, building use and supply options are rarely available during the design of new cities or early scenario analysis for existing city quarters, making it difficult for cities to effectively evaluate which concepts work today and in the future. The paper proposes a methodology to assess the energy demand and supply options as a function of the availability of geometry, building standard and use data. An automated procedure was implemented to identify each building´s geometry and volume and transfer the information to a simulation tool, which then calculates heating demand and solar energy generation on roofs and facades. The simulation include shading calculations for each segment of the façades and roofs and thus allows a very detailed quantification of the urban energy demand.

By applying the methodology to a case study city quarter designed in an urban competition in Munich, it can be shown how the urban design influences the energy demand of the quarter and which fractions of renewable energy can be integrated into the roofs. While the building insulation standard and use are the is most important criteria for building energy efficiency (with an impact of more than a factor 2), the exact geometrical form, compactness and urban shading effects influences the energy demand by 10 to 20%. On the other hand, the detailed roof geometry and orientation influences the possible solar coverage of electricity or thermal needs. Zero energy city quarters with solar resources alone are only possible when all available building surface areas are fully optimized and do not need to fulfill other requirements such as providing roof gardens, terraces or others. Combinations with other more centralized renewable resources such as deep geothermal, solar or biomass heat or cogeneration plants are often necessary to achieve zero energy balances.

Keywords: urban energy system design, energy assessment tools, 3D city modelling

Introduction

Sustainability certification schemes have recently extended to the urban level, mainly to improve awareness and publicity for the developers. Simple assessment rules rules prevail to evaluate a city quarter performance. Haapio (2012) analyses existing assessment tools for urban communities, namely the Japanese system CASBEE for Urban Development, the UK certification scheme BREEAM Communities and the US rating scheme LEED for Neighbourhood Development. In all three rating schemes, infrastructure aspects dominate the criteria with 24% (BREEAM), 32% (LEED) oe 45% (CASBEE) weight, while ressources and energy only amount to 14-18%.

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For a more quantitative evaluation of a city quarter energy performance, a more precise buildig typology or simulation based approach has to be chosen. A review paper on urban energy models clustered urban simulation papers in six categories, ranging from technology, building and system design to urban climate, policy assessment and trasnport (Keirstead et al, 2012). While detailed physical models dominate the technology and building simulation tools, the system design models are mainly optimisation tools with very simple component and building models on a district scale with the goal to minimize costs for energy infrastructure and building effiency.

Between simple certification schemes, local energy planning tools and detailed individual building simulation there is still a knowledge gap of how the design of an urban quarter affects the energy performance and the potential for renewable integration.

In this paper a methodology is developed and implemented to analyse under which conditions a city quarter can cover its building energy requirements with renewable sources and which data needs to be available to seriously assess energy demand and production. Transport energy is excluded from the analysis, as it requires completely different modelling tools for the demand evaluation and as renewable fuels are most likely to be produced more centrally than on the urban surface itself.

For a case study in Munich/Germany criteria were proposed for urban energy efficiency in the early design and competition stage of a new city quarter and the analysis of a neighbouring existing city quarters, which was used for the model validation. In a second stage, more detailed quantitative analyses of building block clusters are done to show the influence of urban structure on energy performance and renewable integration potential.

Criteria for energy efficient city planning

To assess the energy performance of city quarters or entire cities, criteria have to be defined as important characteristics for evaluation. Often criterias are grouped in categories of urban assessment, such as infrastructure, transportation, energy and resources. As the goal of this work was to analyse assessment methods only for urban energy, criteria were developed for the energy performance category only. Related to the criteria are corresponding indicators, which describe the quantitative measurements to evaluate the performance.

As the main energy related criteria, four categories were established based on an analysis of many low energy city quarters:

- the integral energy concept with the criteria of innovation and highlight projects
- the induced energy demand with the criteria of urban and building compactness
- the solar access with main orientation of the buildings, minimizing shading and placing low consumption districts furthest away from the district heating plant
- the renewable supply with efficient renewable heat distribution and photovoltaic panel integration in buildings

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For the four categories, indicators were developed, which are partially qualitative, but try to include quantitative information as early as possible in the analysis process.

Case Study Munich Freiham Urban planning competition

The city of Munich/Germany plans a major expansion to the west of the city named Freiham to be developed during the next 30 years. The urban extension has a total area of 350 ha with a northern part of mainly residential buildings and a southern part with mainly business, shopping and the city center. Comparably high renewable heating fractions of 90% will be obtained by a deep geothermal heating plant, while electricity production relies on decentral photovoltaics. An urban planning and landscaping competition for the first stage of construction in the Northern section of Freiham has taken place in 2011. The criteria and indicators were analyzed to evaluate the energy performance of the urban plans.

The analysis showed the limits of assessing energy performance based on paper plans still typical in urban competitions. Many criteria such as urban and building compactness could only be estimated, as well as solar access and mutual shading of buildings, as these required data were not provided by the participating urban planning offices. For the residential sector, the list of criteria and the maximum achievable number of points are shown in Figure 3 together with the result analysis of the 14 competition contributions. From the 1000 total points the best proposal reached 765 points, the worse 250 points.

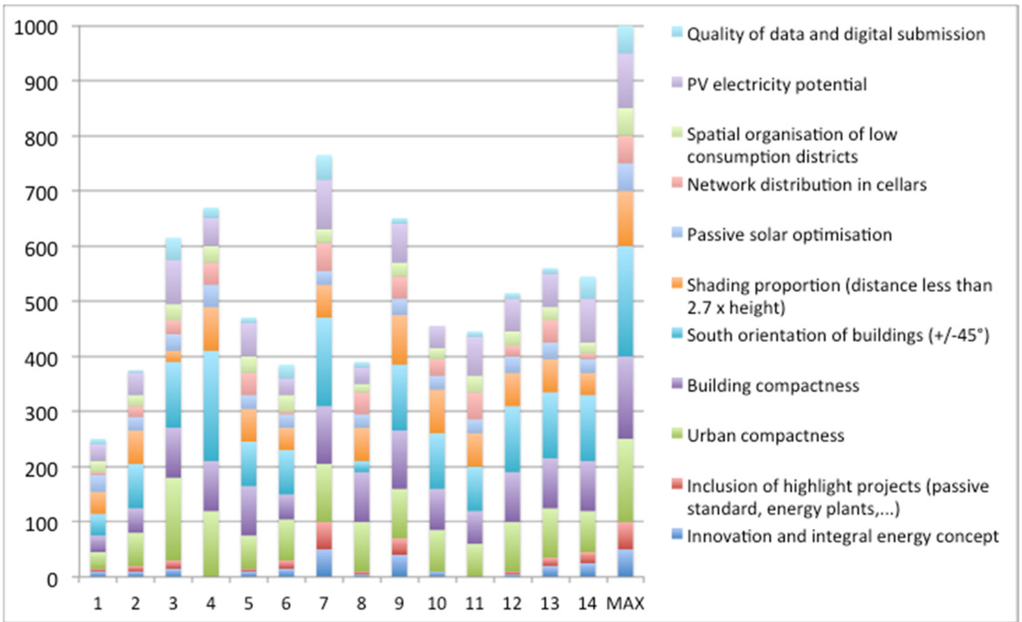

Figure 3: Maximum number of points achievable for each criterium in the right column and results for the 14 submitted competition proposals in the residential area.

The proposal number 1 finally won the urban competition, mainly due to the fact that it corresponded best to the urban planning idea of a green garden city, not for its energy concept.

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Building cluster analysis for detailed impact evaluation of urban form on energy demand, renewable supply and building costs

To quantitatively analyse the influence of the urban form on building efficiency, renewable integration potential and building costs of several building energy standards, one of the clusters of the winning urban plan with multi-family buildings was selected for a detailed analysis. Four different urban forms were developed with the planning office west 8 and subsequently simulated. All concepts (nearly) have the same floor space number (GFZ) of 1.4. The variants can be distinguished into open block edge (B) and (closed) block edge types (C). Another difference was the roof structure: Compact flat roofs (B.2, C.2) compared to roofs with roof terraces and corresponding roof structures (B.1, C.1). For each form three building energy standards were calculated. EH 70 corresponds to 70% primary energy demand compared to the legal standard EnEV 2009, EH 55 to a maximum of 55% and the most efficient standard EH 40 to 40%.

The combination of the four cluster variants and their three building energy standards were converted into a 3D city model. This model allows a computerised procedure for calculating the heating energy demand according to DIN V 18599 and to determine the influence of higher building energy standards through thicker walls on net floor area losses (and reduction of the marketable area) and building costs. Additional, options of photovoltaics usage were analyzed to determine the possibilites to cover the electricity demand with clusterwide self produced electrical energy.

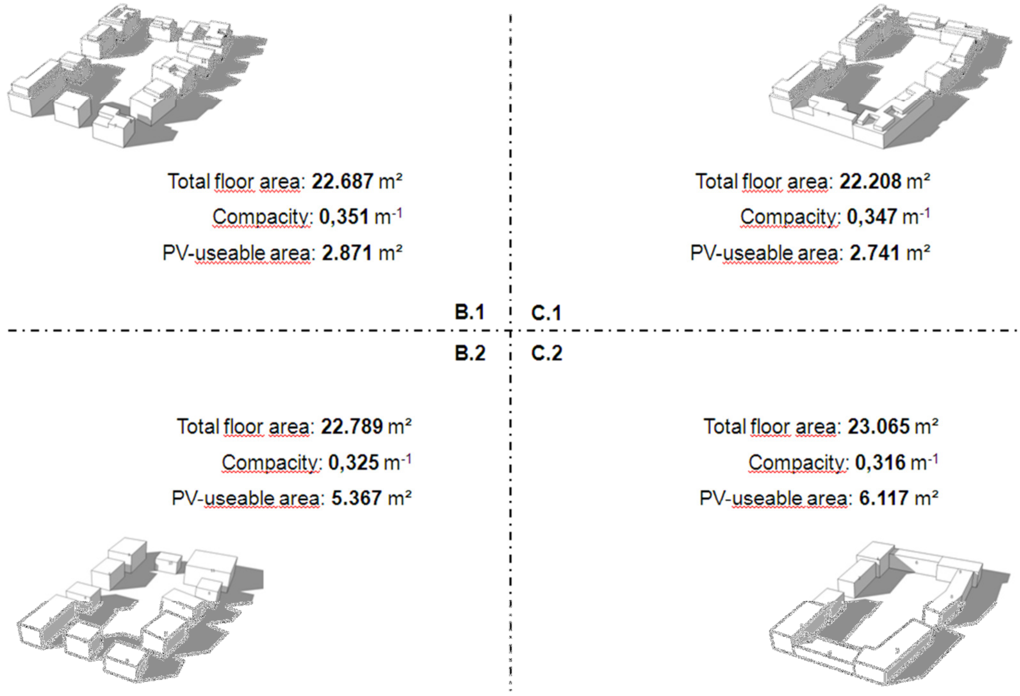

Figure 4: Considered building und urban form variants

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Results for heating demand and costs

The heating demand was simulated using the monthly energy balance method described in DIN V 18599-2 and implemented in the simulation environment INSEL (www.insel.eu). The results showed that the urban form was less important for the heating demand than the building compactness. With more compact buidings, the demand decreases by about 10% (heating demand difference between variants *.1 and *.2), while the detailed urban form (B.* versus C.*) only changes the overall demand by 1 to 2% (see Figure 5).

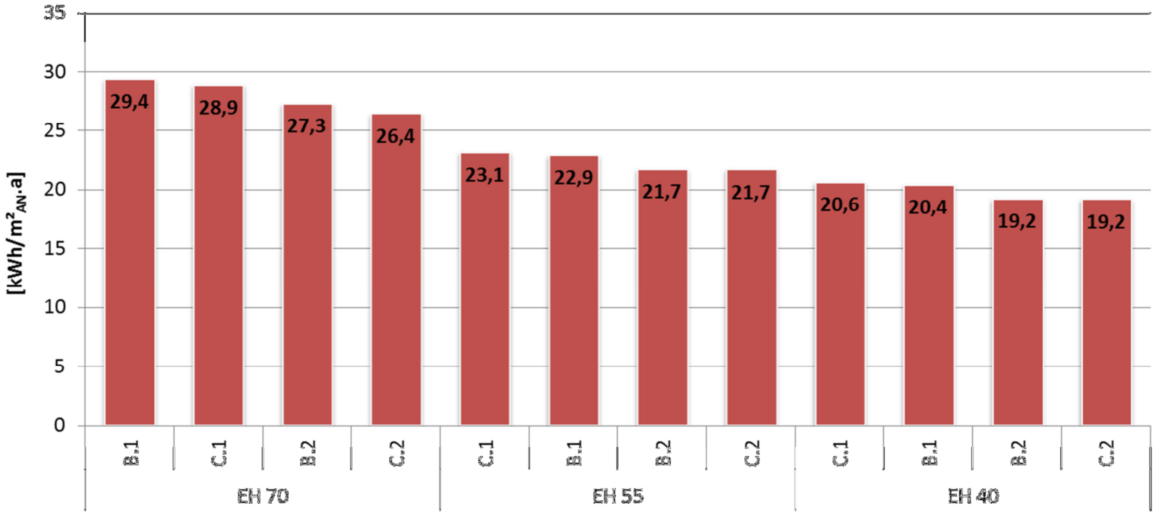

Figure 5: Comparison of specific heating demand of all cluster forms for three different building energy standards.

Building compactness and building costs are closely linked. According to Figure 6, additional building costs for more efficient energy standards can nearly be offset by an optimized cluster form. For example, the building costs for combination B.1/EH 70 are comparable to cluster form C.2/EH40. That is why the optimisation of the cluster form represents an important step towards reduction of building costs.

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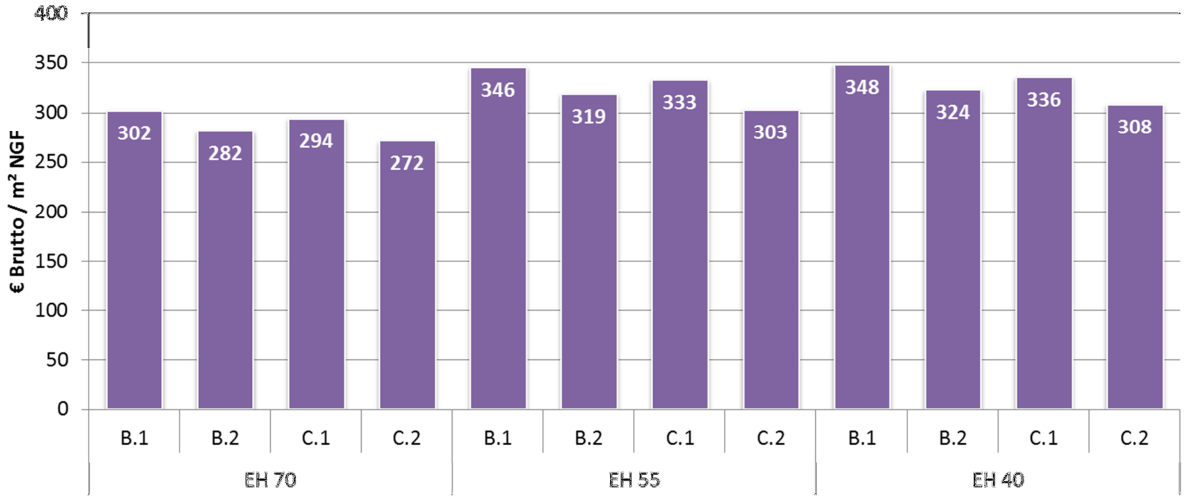

Figure 6: Comparison of building costs per m² net floor area

PV potential and coverage rate of self-produced electricity

By planning a construction site or cluster, the fact that roof structures and roof terraces increase the heating demand of a building in principle or increase the costs to eliminate these disadvantages should be kept in mind. Moreover, roof structures minimize useable area for PV modules. However, the question of roof area usage must also consider aspects of higher levels of housing quality through roof terraces or roof greening.

For all cluster forms a PV potential study was undertaken. Within this study two different possibilities of PV installation (FDA = flat roof with inclined PV modules) and PDD = mono-pitch roof) have been investigated. The analysis is based on polycristalline silicon modules with 15% efficiency and 10% electrical system losses. To calculate the electricity coverage rate for each cluster form, a household-specific electricity demand of 20 kWh/m² was assumed.

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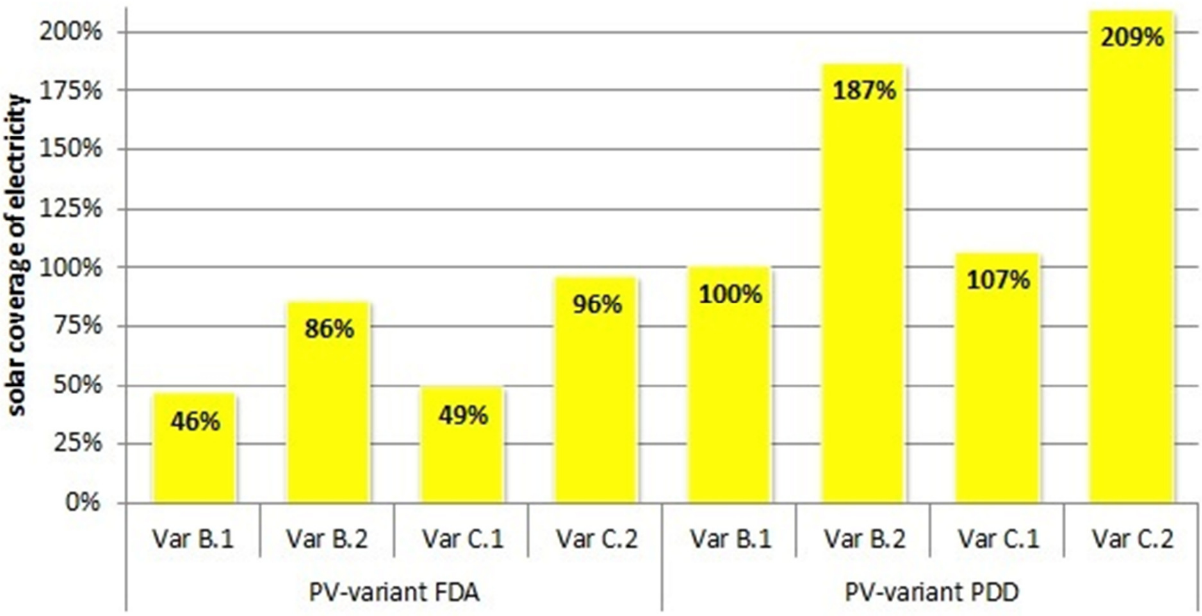

Figure 7: Clusterwide PV potential and coverage rate of self-produced electricity

As shown in Figure 7, the installation of PV modules on mono-pitched roofs (PDD) could cover the electricity demand for all building variants. Yields of inclined PV modules on flat roofs (FDA) are low compared to the PDD-installation and can not cover the complete cluster electricity demand.

Conclusions

The paper presents a methodology to evaluate the energy performance of urban quarters at different stages of design and analysis. While mainly developed to compare urban planning competition results for a large city extension in Munich/Germany, it can also be applied to existing city quarters with scenarios for rehabilitation and energy infrastructure improvement. The main goal was to establish an accurate energy performance prediction method to compare urban development types.

The analysis of today´s urban planning competition assessment showed that only a very general evaluation of an urban design´s energy performance is currently possible and estimated energy performance is rarely taken as a major criterium in urban competitions.

The detailed cluster analysis emphasised that it is very important to analyse the detailed building form, as the loss of building compactness increases the energy demand for heating by 10-20% while it reduces the integration potential of renewables by more than 50%. Different urban forms for otherwise compact buildings only influences the heating demand by 1-2%. Costs and building compactness are closely linked and additional costs by higher building standards can be compensated by more compact structures. The cluster analysis also showed that 100% or more PV electricity can only be generated if mono pitched roofs are fully covered with photovoltaic modules.

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References

Haapio, A., Towards sustainable Urban Environments , Environmental Impact Assessment Review 32 (2012) 165–169

J. Keirstead, Mark Jennings, Aruna Sivakumar (2012) A review of urban energy system models: Approaches, challenges and opportunities,Renewable and Sustainable Energy Reviews 16 (2012) 3847– 3866

LEED 2009 for Neighborhood Development Rating System, Created by the Congress for the New Urbanism, Natural Resources Defense Council, and the U.S. Green Building Council (Updated April 2012)