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‘*effort*’ (energy efficiency on-site) – a new method for planning and realization of energy-efficient neighbourhoods under the aspects of sustainability

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Abstract

To meet the challenges of climate change requires the commitment towards a climate-friendly energy production as well as an increased effort for climate-friendly energy use. In order to produce a noticeable reduction in greenhouse gases, it is necessary to increase the share of renewable energy and energy efficiency use in all sectors of consumption. The necessary result can only be achieved in the long term by the inclusion of as many households and businesses in our towns, cities and communities. The crucial spatial unit of this energy-efficiency urban redevelopment has become apparent based on present knowledge of the neighbourhood. Within the system relationship between building and city, lies the major energy optimization potential on a neighbourhood scale – in the sense that maximum energy efficiency may be grouped together in the spatial unit.

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effort is a tool that enables the planning of the optimal mix of energy supply in connection with a spatially and functionally sustainable development of the neighbourhood (‚Integrated Neighbourhood Concept'). All necessary indicators are brought together and linked to a GIS-based model. A total of 142 indicators (23 indicators sets) were selected from the specialist fields of: resources, ecology, mobility, architecture, urban planning and energy and building technology. These indictors appear essential for a sustainable neighbourhood development and allow for an easy, valid evaluation of development scenarios. The evaluation of sustainability occurs within the dimensions of: ecology, economy and social issues, all spatially stored evaluation criteria/indicators can be combined and clearly vizualised with the assistance of the specially developed ‚*effort*–Sun'. The foundation of the simulation of development scenarios forms an integrated objective discussion that leads to a spatial and functional model. This means that the prognostic potential of renewable energies in the neighbourhood can be determined. The model and energy potentials lead, in turn, to the derivation of specific measures that can be catalogued and used for future reference. The selection of measures is based on the respective classification regarding the degree of sustainability which is fulfilled. Three variations are defined: basic-measures, excellent-measures and a so-called theoretical optimum. A prognostic state description of the rebuilt neighbourhood can be done by simulating the effects of the measure packages. The significant innovation of this interdisciplinary planning tool results from the degree of severity of analysis and planning, and from the combination of building planning and urban planning in the field of energy-efficient urban redevelopment. The included method of sustainability assessment can also be used for certification of neighbourhoods.

The term *‚effort'* is the German abbreviation for *‚Energieeffizienz vor Ort'* (Energy efficiency on-site). The project is supported by the German Ministry of Education and Research.

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Keywords: energy-efficient neighbourhoods; modeling energy- and material flows; ecological and social aspects; sustainability indices

1. Introduction

The increasing implementation of the sustainability concept, the inevitability of the adaptation of climate change strategies, and not least the rejection of nuclear energy in Germany has led to the so-called *'energy revolution'*, which encompasses a broad swath of society. The implementation of this energy transition is ensured by law and aims to increase the share of renewable energy in the electricity supply to 80 % by 2050.

The building sector has the highest energy usage and the greatest potential for savings, this national energy plan can only be achieved with an energy-efficient urban redevelopment on a significant scale. The savings in primary energy and a substantial reduction of the heat requirement in the building sector are a key content. This will be achieved through the decentralization of power and an increasing energy modernization rate of at least 2 % pa.

Energy-efficient urban redevelopment involves substantial intervention in our surrounding environment. The energy transformation processes as well as the change of the urban climate could considerably affect the various habitats, the quality of life and human health in the neighbourhood. Both the socio-spatial and cultural aspects must be taken into account as components of sustainability as well as the protection and enhancement of environmental concerns. Today, there are no engineering planning solutions for such comprehensive tasks. *‚effort'*, the German initiative project, has given itself the goal of developing such planning solutions.

2. The Neighbourhood – the focus of the energy-efficient urban redevelopment

effort is a tool that can plan each related neighbourhood with an optimum and sustainable mix of energy supply *(‚Integrated energy concept')*. It can define the energy and environmental efficiencies of neighbourhoods, urban areas or small communities (including rural communities), it can develop strategies to reduce CO_2 emissions and actual implementation in a sustainability-based engineering design can be worked out. The expected effect of a high increase in efficiency is derived from the role of the neighbourhood as the ultimate spatial unit of energy-efficient urban redevelopment: Within the system relationship between building and city, a major energy optimization potential is seen in the scale of the neighbourhood. In addition, the top-down process (urban concepts and funding) is combined with bottom-up activities from the inhabitants (Figure 1). The term *‚neighbourhood'* is understood more as an energy senseful summarizable spatial unit than an urban structure.

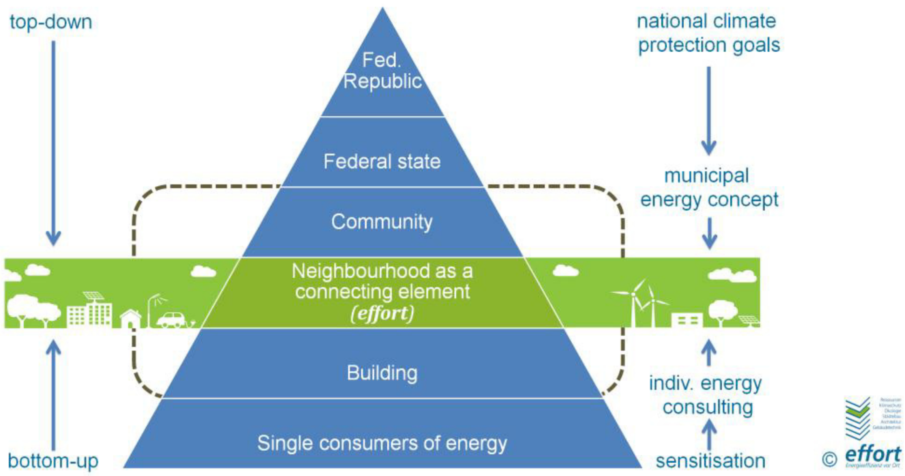

Figure 1. The neighbourhood seen as a linking factor between higher-level plans/concepts and building-related energy efficiency measures.

3. The requirement for systemic approaches and interdisciplinary preparation of the development teams

Until now there have been no methodological principles that lead from potential analysis to sustainable implementation strategies or even to the planning of energy-efficient neighbourhoods. In practice, most energy solutions for application come from those that are currently being advertised or are heavily funded or seem to be proven solutions. Planning and consulting services on the topic of energy conservation, climate protection and city development are either to global; based on the governance of entire cities, or to sectorally aligned for the neighbourhood, for example, only focus on energy or urban planning. For an optimized, sustainable energy supply, the energy potential is systemically considered focusing on site-specific conditions (land use, building and room structure, ecology, social aspects, the development potential of trade and industry, transport infrastructure, historic preservation, building culture, demography, etc.) and integrated to find specific solutions. The conditions meet here in a multicausal conflict structure of interacting fields of action that are mitigated or resolved only in complex balancing processes (Table 1). Measures of sustainability will be their level of economic, environmental and social dimensions.

Table 1. Examples of action and stress fields in the energy-efficient neighbourhood redevelopment

Decentralised energy supply	⟷	Interests of major suppliers
Use of potential renewable energy	⟷	Erratic funding policy
Optimisation of supply in the neighbourhood	⟷	Selfish individual interests
Demographic change (shrinkage)	⟷	Increasing land use
Social planning	⟷	Segregation
Increase in value	⟷	Investment
Area energy management	⟷	Conservation of the cultural landscape
Energy efficiency of the building	⟷	Aesthetics in construction
Internal compression	⟷	Urban ecology and climate
Land-use change	⟷	Local climate change
…		*etc.*

effort stands out when compared to other concepts because of its interdisciplinary, complexity and its consistent implementation of the sustainability principle through transdisciplinary practice application. Project partners are specialist engineers, who have complained about the lack of interdisciplinary solutions and promote a sustainable energy-efficient urban redevelopment.

The *effort* team members have experience with interdisciplinary approaches, including the revitalization of contaminated brownfield sites while taking in account urban planning and environmental and energy aspects, and working together with experts from the USA (US-German Bilateral Group, visit: www.smarte.org). The `optirisk`® method has been developed [1] as a guide for integrated site development in the United States, and a pilot project in Portland (OR) has been realized.

The research partner, Nordhausen University of Applied Sciences, developed the Space Time Energy Model (STEM) that up until now was the only tool with a systemic approach to spatiotemporal. It is an energy analysis of a model space and has been tested on a local and regional scale [2]. STEM takes into account all energy parties (housing, employment and mobility) and energy forms (electricity, heat and fuels).

4. Development of the *effort* tool

The methodology involves bringing together all necessary indicators for an integrated neighbourhood concept into a GIS-based model and establishing causal links. The demand on the spatial resolution exists in a balanced object and calculated level of consideration. This enables GIS action planning to take place and their effects can be determined on all other indicators. A variety of special tools has been developed for the evaluation of the individual sets of indicators, as well as the derived action plans. The degree of sustainability of the output target as well as the planning target/final state can be read just like the CO_2 balance read. The degree of sustainability of the actual and of the final state can be read as well as the CO_2 balance.

4.1. Indicators and indicator sets

For the implementation of the *effort* method, the involved departments defined: resources, ecology, mobility, architecture, urban planning, and energy and building technology to create an inventory of the neighbourhood. The derived action packages as well as the determination of the degree of sustainability have defined appropriate indicators. Indicators were selected which are essential from the view point of their respective disciplines for an integrated neighbourhood concept and which allow the different forms to be evaluated in a descriptive yet simply manner. These 142 indicators were grouped into 23 sets of indicators to improve their manageability. The sets are listed in Table 2.

Table 2. The indicator sets in *effort*

Building services technology	Architecture	Urban planning	Mobility	Ecology	Resources
1 Primary energy quality 2 Energy consumption 3 Potential of renewable energies 4 Energy infrastructure	5 Level of renovation - actual state 6 Heating demand – actual state 7 Use of redevelopment potential – actual state	8 Building culture and city image 9 Appearance 10 Building density 11 Usage intensity 12 Diversification 13 Basic structure	14 Public transport 15 Road traffic system 16 Regional structures	17 Quality of habitat and biodiversity 18 State of local water resources 19 State of the groundwater 20 Air quality	21 Population structure and development 22 Financial potential 23 Identity

Within these indictor sets the individual indictors were weighted (‚*vertical weighting*'). Table 3 shows an example of the composition and weighting of two of the 25 indicator sets:

Table 3. Example of the composition of an indicator set and its internal vertical weighting. Below is an example of the weighting for the sustainability dimension of ecology.

Indicator set	Indicators	Weighting *"eco"*
Primary-energy-quality	Cumulated energy expenditure	2
	Cumulated energy expenditure, share of renewable	2
	CO_2 equivalent value	3
	Energy costs	1

Indicator set	Indicators	Weighting *"eco"*
Habitat-quality and diversification	Ecological functionality	3
	Pollution	2
	Susceptibility to erosion	1
	Habitat/usage	2
	Green number	3

4.2. Sustainability assessment

effort assesses the sustainability in three dimensions; environmental, economic and social issues. It is measured by using a degree of fulfilment, which is why a specific reference value has been established for each set in each dimension of sustainability. The fulfilment levels enable the three dimensions of sustainability to be mapped out in their actual state. The weighting of the individual sets against each other allows for a prioritization of the dimensions (‚*horizontal weighting*'). Therefore, crucial potentials or deficits can be highlighted. The visualization is done with the *effort-Sun* I (*the effort-sun of sustainability - status*), in which all spatially stored and evaluation criteria/ indicators are combined.

4.3. Target definitions and model for the neighbourhood

The determined degrees of sustainability through the individual sets of indicators enable an overall degree of sustainability of each neighbourhood to be determined. The dimensions of sustainability flow equally into the overall evaluation, other cases (for example taking into account any special needs of clients) can be weighted later.

The result of the actual state assessment is divided and displayed in three classes or levels (a fulfilment level up to 60 %, between 60-80 %, and between 80-100 %). These classifications are in turn assigned as target definitions, which are defined according to the actual state and the specific conditions.

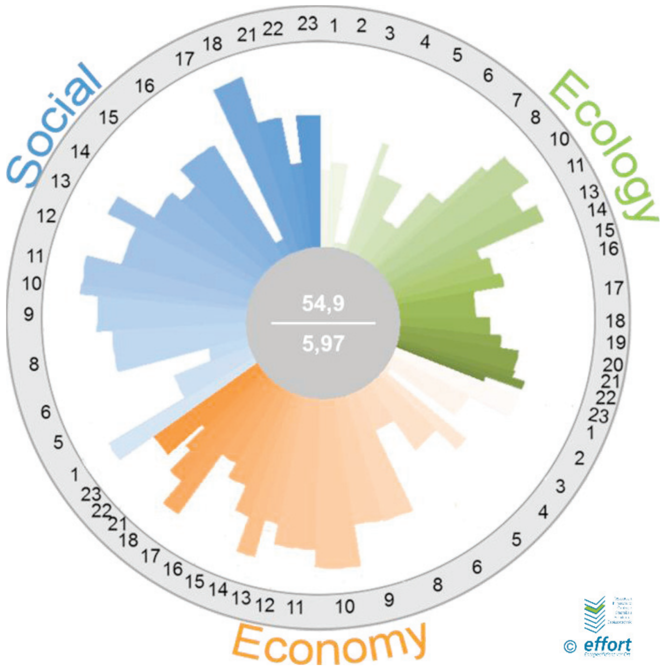

Figure 2. The *effort*-Sun I (Review of the actual state of a real neighbourhood in the city of Wiehe, Thuringia) The numbers on the diagram indicate the set numbering of indicators from Table 2. The numbers in the central circle indicate the degree of sustainability (in %) and the CO_2-emissions in tons of CO_2 per capita per annum.

The target definitions of the sets are subject to a hierarchy: targets for the implementation of energy efficiency measures or energy-efficient redevelopment are set first. Even if, in the target definitions not all sets of indicators are considered equal, then a deterioration ban is given to all sets (with the aim of improvement).

A specific model for each neighbourhood is derived from the partial targets of the individual indicator sets; this then defines the framework for future neighbourhood development. In addition, it should be noted that the future continuance and structure of buildings and open spaces will be determined by the population and the economic forecast. The realizable potential of renewable energies can be determined based on the defined model and its future spatial structure.

4.4. Derivation from measures

The model provides the prerequisite for deriving measures. These are stored in a catalogue of measures geared to the particular arrangement of the sustainability fulfilment level of the corresponding indicator sets. Three measure variations have been defined (Basis-variation, excellent-variation and theoretical optimum) and the relative effects of each link directly to dependent indicators in the three dimensions of sustainability. As well as the targets, the measures are subordinated into a hierarchy and the impact of each measure is tested directly on the dependent indicators, in order to meet the deterioration ban.

4.5. Integrated neighbourhood concept - the foundation for engineering design

A prognostic state description of the energy-efficient redeveloped neighbourhood can be visualized using ‚*effort*-Sun II' (*the effort-sun of sustainability – final state,* Fig.3), after the representation of the effects of the measure packages on the indicators has been carried out. If necessary the result, or the process may be readjusted manually. The results show the level of sustainability which can be achieved in an integrated neighbourhood concept when utilizing the energy-efficient potential of the neighbourhood. The involved engineering disciplines can develop implementation scenarios and plan a coordinated neighbourhood redevelopment on the basis of the catalogued measures.

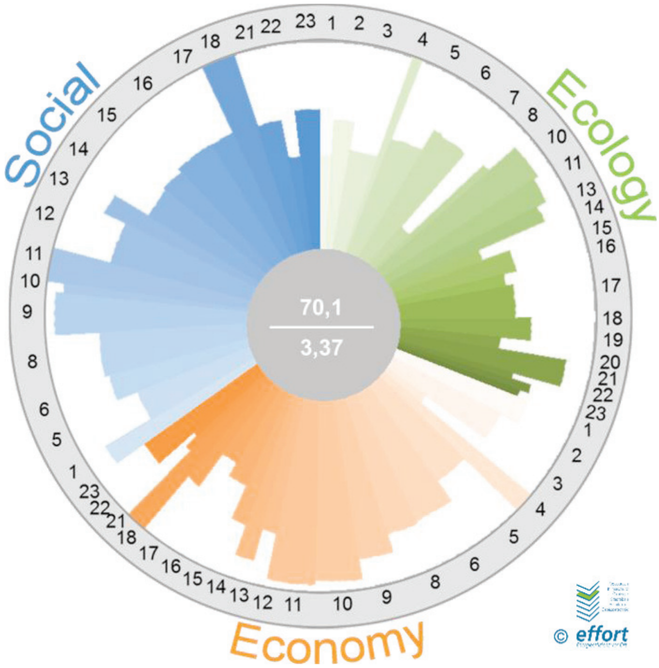

Figure 3. The *effort*-Sun II (final state of the neighbourhood in the city of Wiehe, Thuringia)

5. The work with *effort*

The validation of the method was based on four model neighbourhoods until April 2015. The authors gained experience in the collection of data in the field, the implementation into the GIS model and the derivation of integrated measure packages for engineering design. The procedure of a permanent critical assessment was subject to verification. Since the indicators of real neighbourhoods may have a differentiated relevance, their weighting may be managed more flexibly and further indicators may be consulted. In particular, the links between the sets of indicators are adjustable.

effort considers, in contrast with existing tools and approaches, detailed and concrete consumption and requirements and shows the potential energy. This interdisciplinary planning tool is groundbreaking due to the degree of severity and the possible consideration until the property-level. The maximum depth of planning can, of course, only be achieved if the required data is actually made available. Generally, however, the tool is so designed that the estimate option of the individual indicators values can be used. Engineering expertise is still required here.

Using *effort* is more costly in some neighbourhoods as compared to conventional procedures, when comparing market prices for integrated neighbourhood concepts. However, when the investment amounts and the object of planning energy-efficient neighbourhoods are viewed in full, *effort* provides a new quality, transparency and cost certainty that justifies the higher planning costs. Perhaps some procedural steps can be simplified after further validation.

The method of the sustainability assessment should be used for the certification of neighbourhoods. The increase in public demand for a high sustainability in recent years has transferred more and more to the owners and investors. Construction companies voluntarily comply with certifications, knowing that a high level of sustainability increases the marketability.

6. Outlook

effort is a new and promising tool for the development of sustainability-based integrated neighbourhood concepts. It supports the expertise of the engineers involved, by combining their skills into a complex tool that enables the implementation of a systemic view in the planning.

Within the next year, the authors wish *effort* to develop into a tool that is routinely used. This article should act as a spring board and build cooperation and application opportunities with partners in the USA and other countries.

References

[1] K. Roselt, I. Quaas, A. Homuth, A. Thor, Recommendations for action for optimization of redevelopment concepts for environmentally burdened sites - Guide for communities and planners.-Jena 2012. download under www.optirisk.de

[2] D.D. Genske, L. Messari-Becker, Energetische Stadtsanierung und Klimaschutz, in: Bauphysik-Kalender 2013: Nachhaltigkeit und Energieeffizienz. Published 2013 by Ernst & Sohn GmbH & Co. KG.

[3] P. Droege, D.D. Genske DD, A. Ruff, M. Schwarze (2014), Der BAER-Atlas als integriertes Modell und regionales Werkzeug. in: P. Droege (Hrsg) Bodensee-Alpenrhein Energieregion. Oekom-Verlag, München:19-125 S