Multicriteria analysis – identifying benefit optimized energy efficiency measures in public buildings

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Abstract

The general conditions for local authorities in Germany have changed fundamentally during the last decades. Not only do municipalities compete with each other for employment, prestige and competitive advantages, they also face increasingly higher demands by their citizens, for instance in the area of climate protection.

Therefore, every municipality has to consider various economic, social and ecological determinants in its decision-making processes. With respect to public buildings, an economically-oriented cost-benefit-analysis alone is not adequate due to a municipality's role as 'consumer and role model'. To identify measures with a broader benefit, a multicriteria analysis (MCA) has been used to analyze energy efficiency measures in public buildings for the city of Dortmund.

For several years Dortmund has committed itself to implement energy efficiency measures and improve the energy performance of its building stock. Nevertheless, a benchmark analysis still shows a high energy saving potential that cannot be tapped with the existing measures and instruments. Therefore, a package of measures has been developed in close cooperation with the city of Dortmund, ranging broadly from measures of energy efficient refurbishment and green IT to behavioural change of building occupants. In the MCA these measures have been assessed according to ten different criteria such as innovativeness, cost effectiveness, external costs, CO_2 reduction potential, local value or effort of implementation. Three different scenarios ('City as Role Model,' 'City as Homo Economicus,' 'City as Climate Protector') show different municipal perspectives.

The analysis has shown that the greatest benefit for municipalities, regardless of the municipal perspective, is yielded by measures such as voluntarily enhanced minimum standards for new or for energetic retrofitting of public buildings, the procurement of energy-efficient office equipment, the expansion of heat generation from renewable energies and the involvement of private capital in participatory projects like 'Solar&Save' (Berlo et al. 2007).

Introduction

Climate change is a global phenomenon. Therefore it has to be tackled primarily at an international and national level. However, the failed negotiations at the UN climate conference (COP 15) in Copenhagen or the results of the UN climate conference (COP 16) in Cancun, at which only a minimal goal could be agreed on, raise doubts that top-down climate policies can be effective. The difficult negotiations show that instruments for climate protection, which are binding under international law, reach their limits when they compete with national interests. For this reason it becomes increasingly important to understand climate protection as a bottom-up process. The significance of local authorities in this process has grown over the last few years. They have already been called the "great white hope" for global climate protection policy (Bielitza-Mimjähner 2007:89). Moreover, it seems obvious that ambitious climate protection goals cannot be realised without committed local authorities. Local decision makers are aware of their responsibility. In order to fulfil their function as role

model for their citizens and local businesses, they implement their own climate protection measures. This local commitment arises from the special role that municipalities play. On the one hand local authorities have to adapt to and pay for the effects of climate change such as hot spells, heavy rainfalls or storms. One the other hand municipalities compete with each other for employment, prestige and competitive advantages. Within this competitive framework, climate protection has become an important locational advantage.

The special role of local authorities was already mentioned in the Agenda 21 which was adopted in 1992 at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro. Chapter 28.1 of the Agenda 21 emphasizes the significance of cities and local authorities in implementing climate protection measures (United Nations Division for Sustainable Development 1992).

One important field of action is the public building stock. Measures to improve the energy efficiency, to exploit renewable energies or to use cogeneration do not only protect the climate. They also have considerable co-benefits such as increasing local value, positive employment effects or enhancing the image of a municipality. Moreover, such measures contribute to reducing the operational costs for buildings, increasing the value of the building stock and relieving the local budget.

Therefore, the question for municipalities is not whether investments in energy efficiency, cogeneration or renewable energies will be profitable. The real question is which measures offer the greatest benefits for the municipality within the framework of interacting economic, ecological and social factors.

To answer this question we examined the public building stock of the city of Dortmund. Based on a benchmark analysis of the current situation in Dortmund a package of measures was developed in close cooperation with the city of Dortmund. In a MCA these measures were assessed to identify those measures with the greatest benefit.

Case study Dortmund

CURRENT SITUATION

For several years Dortmund has been making an effort to implement energy efficiency measures and improve the energy performance of its building stock. Its activities, efforts and achievements were evaluated in comparison to other cities and municipalities in Germany with the help of a benchmark analysis. Within this context the benchmark instrument can be defined as an "environmental management tool that can provide a substantial contribution to the improvement of environmental performances by facilitating the identification of the gap between company performance and a given performance"(Bolli et al. 2001:12). The activities, efforts and achievements were assessed quantitatively as well as qualitatively. The evaluation considers activities that were introduced no later than spring 2010.

The quantitative benchmark analysis was based on data from the Ages GmbH, which has one of the largest databases for energy related parameters of non-residential buildings in Germany (Ages GmbH 2007). To qualitatively assess the achievements of the city of Dortmund in the last few years, a three-step procedure was developed that consisted of literature research, interviews with experts and a pretest. As a result, 23 packages of measures were identified that could ameliorate the energetic performance of a public building stock. Subsequently, for each one three possible stages of development were identified and described qualitatively. Stage three represents an exemplary implementation in comparison to other German cities. Figure 1 shows the 23 packages of measures and the evaluation of Dortmund's position within each package.

In 2008 the heat consumption of the public building stock in Dortmund amounted to 170 GWh. The total power consumption was 45.3 GWh. This resulted in CO_2 emissions of approximately 65,000 t, which corresponds to 3 percent of the citywide emissions. The analysis of the energy saving potential for each type of building showed that there is a, sometimes considerable, saving potential for almost every building type. If all these potentials were tapped, the heat consumption could be reduced by 49 percent and the power consumption by 63 percent. Further development potentials exist in the field of cogeneration and with regard to renewable energy sources used for heating.

In 1997 an energy management department was founded in the city of Dortmund. It provides an institutional framework to control, evaluate and improve the energetic performance of the public buildings. Over the last years the department has focussed on measures that promote behavioural change by building occupants (students, teachers, administrative staff members etc.). Measures such as 'missionE' or 'Aktionswoche e-Fit' are important examples (Funke et al. 2009). Accordingly the city of Dortmund achieves a high rating in the category 'User Behaviour'. Furthermore, the department has performed the typical tasks of a municipal energy management such as metering of energy consumption or central building control systems. With the foundation of the 'Konsultationskreis Energieeffizienz und Klimaschutz (KEK)', which was honoured at the 'European Energy Awards' (eea) with the 'Eurocities Award' in the category 'Cooperation'(eea 2010) , as well as the projects 'Solardachpool' and 'Solarfonds e.V.' the city of Dortmund successfully established platforms that enable different stakeholders and citizens to participate in the city's conceptual development. Despite the achievements of the last few years it is very unlikely that the estimated energy saving potential can be tapped with the existing measures and instruments. The data analysis in spring 2010 showed that the city of Dortmund does not have an adequate strategic plan, which is reflected in the lack of minimum standards for new or retrofitting of public buildings. Moreover the city of Dortmund lacks long-term goals and visions for the development of its public building stock. There are also deficiencies in the existing financing structure.

MULTICRITERIA ANALYSIS

Methodology

The results of the benchmark analysis raise the question which energy efficiency measures should be implemented to yield the greatest benefit for the city of Dortmund.

In regard to public buildings, a economically-oriented cost-benefit-analysis alone is not adequate for the municipality's role as 'consumer and role model'. Therefore, the city of Dortmund has to consider various economic, social and ecological determinants in its decision-making processes. In order to support "people to make choices according to their values in cases

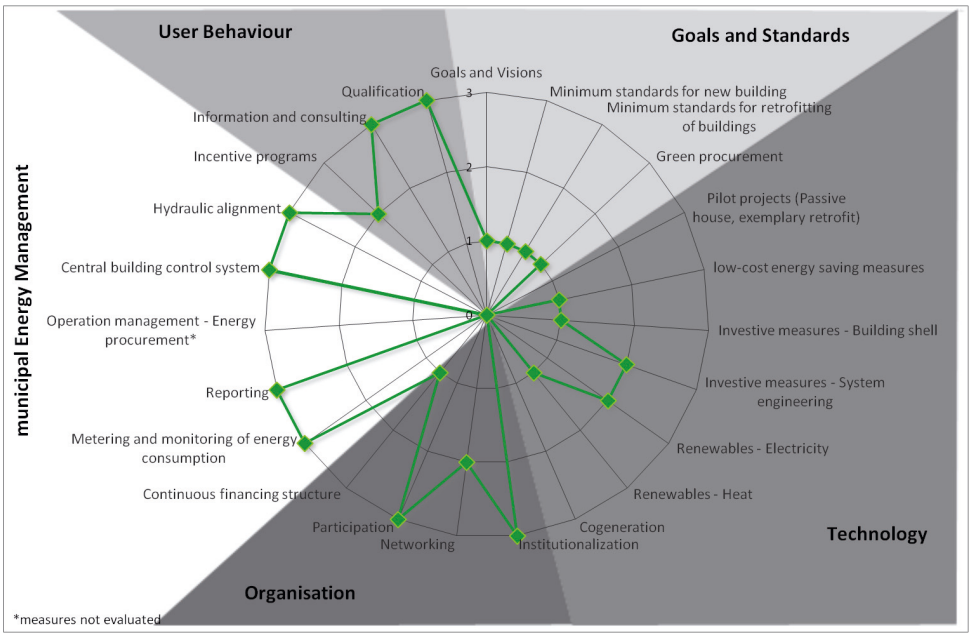

Figure 1. Evaluation of energy saving activities for public buildings in Dortmund.

characterized by multiple, no commensurate and conflicting criteria" (Bogetoft, Pruzan 1997) the research discipline 'Decision Aid' was developed. MCA is a well-known branch of Decision Aid and can be defined as "a type of decision analysis tool that is particularly applicable to cases where a single-criterion approach (such as cost-benefit analysis) falls short, especially where significant environmental and social impacts cannot be assigned monetary values. MCA method allows decision makers to include a full range of social, environmental, technical, economic, and financial criteria" (UNFCCC 2010).

The greatest advantage of MCA is that it simplifies complex situations. In practice, beyond a certain number of criteria, decision makers cannot take the entirety of information into account for their judgement. Therefore, each decision is characterized by subjectivity. MCA breaks down the components of complex situations and structures them so that it becomes possible to find solutions in a transparent way. With this method a broad spectrum of quantitative and qualitative criteria can be taken into consideration.

In close cooperation with the city of Dortmund a package of measures has been developed, ranging broadly from measures of energetic retrofitting and green IT to behavioural change of building occupants. The measures have been developed in order to tap into the shown energy saving potentials in the benchmark analysis. The most promising measures were examined with the above described MCA (cf. Table 3).

The methodical procedure will be presented in the following paragraphs (cf. also Figure 2).

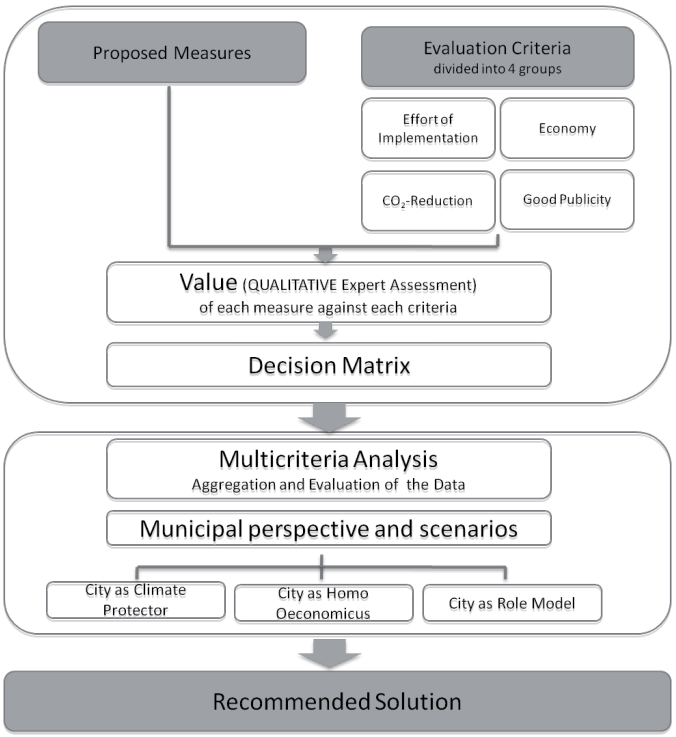

Figure 2. Methodology of MCA.

Evaluation criteria

To evaluate the proposed measures, ten evaluation criteria were defined. The criteria were designed to take a broad spectrum of economic and ecological determinants into account. Implementation efforts and publicity effectiveness are further criteria to consider (Table 1).

Eleven different experts subsequently assessed the evaluation criteria. The evaluation is based on an ordinal scale from one to ten with ten signifying the optimum. Each criterion and its minimum and maximum value were described qualitatively to ensure a transparent and comprehensible assessment. To make sure that the assessment represents different points of views, experts from various disciplines or contexts were selected. In addition to experts from science (University of Applied Sciences Ruhr-West) and policy advice (Wuppertal Institute, Ifeu, Ö-Quadrat), experts of municipal practice (Environmental Agency of Bochum, Düsseldorf etc.) were involved as well.

Table 1. Evaluation criteria.

Effort of implementation	Economy	CO_2 reduction	Good publicity
• Compatibility with existing administrative structures • Personnel resources • Financial resources	• Economic efficiency • Local value • External costs	• CO_2 emission reduction potential	• Innovativeness • Public perception • Spill-over effects

Table 2. Significance of evaluation criteria in designed scenarios.

	Effort of implementation			Economy			CO_2 reduction	Good publicity		
	Compatibility with existing administrative structures	Personnel resources	Financial resources	Economic efficiency	External costs	Local value	CO_2 emission reduction potential	Innovative-ness	Public perception	Spillover-effects
City as Climate Protector	5%	0%	0%	5%	10%	5%	60%	5%	5%	5%
City as Homo Econo-micus	5%	10%	10%	40%	0%	20%	0%	5%	5%	5%
City as Role Model	0%	0%	5%	5%	10%	5%	15%	20%	25%	15%

Municipal perspective and scenarios

The proposed measures differ according to their economic implications, their contribution to climate protection, the effort required for their implementation and their impact on public perception. Due to the existing financial constraints, the city of Dortmund will most likely not implement all of these measures. Therefore, policy makers will have to select measures with the optimum benefits. They cannot be relieved of this decision but the suggested scenarios can be helpful to them by illustrating different development paths and options for action. The following three scenarios have been designed:

- City as Climate Protector
- City as Homo Economicus
- City as Role Model

The three scenarios differ in regard to the significance or weight that is given to the ten defined criteria (Table 1). This means that in the scenario 'City as Homo Economicus' criteria such as 'Economic Efficiency' or 'Local value' are weighted stronger than in the scenarios 'City as Climate Protector' or 'City as Role Model'. On the other hand criteria such as 'CO_2 emission reduction potential', 'External costs' or 'Public perception' receive a higher weighting in the scenario 'City as Role Model' or 'City as Climate Protector' than in the scenario 'City as Homo Economicus'. The weighting of the evaluation criteria was based on expert assessments.

The described scenarios do not only represent different municipal perspectives. They can also be used as a kind of sensitivity analysis. If there are measures that receive good rankings in all three scenarios, there is a high probability that they will yield high benefits if the municipality implements them.

RESULTS OF MCA

Table 3[1, 2] shows the results of the expert assessment and the ranking of the proposed measures in the three different scenarios. The focus here is not on the ranking of each measure but rather on the general trends that can be identified. There are several measures that achieve a top ranking in all scenarios. It can be assumed that these measures will provide the greatest benefit regardless of the possible municipal perspective.

The analysis shows that the greatest benefit for municipalities is yielded by measures such as minimum standards for new or for energetic retrofitting of public buildings, the procurement of energy efficient office equipment, the expansion of heat generation from renewable energies (solar thermal, wood chips etc.) and the usage of private capital in participatory projects like 'Solar&Save' (Berlo et al. 2007). Proposed measures that

1. Procurement of energy-efficient office equipment: Several websites such as www.ecotopten.de or www.officetopten.de offer information about the most energy-efficient office equipement available on the market.

2. Public internal performance contracting: Public internal performance contracting (PICO) is a kind of in-house "third-party" financing or energy performance contracting scheme. One unit of the public authority, e.g. the technical department of a municipality, delivers the financial and technical energy efficiency service to another unit of the same public administration, and the remuneration takes place through cross payments of budgets, according to the saved energy costs, between these two organisational units (Irrek et al. 2005).

Table 3. Ranking of proposed measures and recommended solution.

Title of Measure	City as Climate Protector	City as Homo Economicus	City as Role Model	Recommended Solution
Voluntarily enhanced minimum energy performance standards for energetic retrofitting of public building	1	6	1	
Voluntarily enhanced minimum energy performance standards for new public buildings	2	2	2	
Expansion of heat generation from renewable sources	3	8	4	
Energy Performance Contracting with citizen's capital	10	4	3	
Procurement of energy-efficient office equipment (TopTen-Lists)	5	2	7	
Expansion of power generation from renewable energies	6	5	5	
Pilot projects (Passive house, Zero/Plus energy house)	12	1	8	
Pilot phase micro/mini-cogeneration	7	12	6	
Pilot phase Thin-Client	8	9	9	
Public internal performance contracting	9	6	11	
'Energy-saving scout'	11	9	12	
Energy-Performance-Contracting with external contractor	4	11	13	
Cooperation with Dortmund universities	13	13	10	

Recommended without reservation (top 4 ranking in at least two scenarios)

Recommended (top 6 ranking in at least two scenarios)

Recommendable with reservations (bottom 6 ranking in at least two scenarios)

Currently less recommendable (bottom 4 ranking in at least two scenarios)

received only low rankings can also provide a great benefit. However, it will most likely be harder to realise them against the background of the strong competition for limited funds. Therefore, the results of the MCA suggest that decision makers should focus on implementing the measures marked in light and dark grey (without cross hatching) in Table 3.

CONCLUSION

The MCA provides useful results. Those measures with top rankings have already been successfully implemented in various municipalities. So the methodology presented is a helpful instrument for decision makers to identify benefit optimized measures with only a small additional effort. However, the approach has some methodical limitations. Experts normally assess the proposed measure qualitatively based on their own experiences and knowledge. That means that the choice of expert can influences the result. Furthermore experts were generally chosen for their special knowledge about different techniques, programs or/and are already working on a municipal level, but external experts do not fully understand the local situation in Dortmund. On the one hand, this means that the results can therefore be applied to other cities, too. However, a lack of understanding of local circumstances in the city of Dortmund (or any city for that matter), may prevent the implementation of all attractive measures. Another consideration is that the results do not factor in possible positive effects that one measure might have on other measures. The building of a passive house as a pilot project, for instance, was only assessed as "Recommendable with reservations". However, successful implementation of this project may reduce existing constraints for the realisation of minimum standards for new public buildings. The MCA does not offer absolute results, but it provides food for thought and helps decision makers in their decision making process.

Outlook

In 2010, a group of consulting firms and scientific institutes have developed a climate protection programme for the city of Dortmund. The measures proposed in this paper are part of this concept. By implementing all measures of the concept it is estimated that the city of Dortmund will cut its CO_2 emission by 42 % by 2020 compared to 1990. Nevertheless, the city of Dortmund as well as other German municipalities will need political and financial support from the European Union as well as from the German federal and state bodies such as support programmes for energetic retrofitting to reach their ambitious long-term climate protection goals.

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