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REVIEW OF EXISTING ENERGY PERFORMANCE CALCULATION METHODS FOR DISTRICT USE

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ABSTRACT

The Dutch building environment is responsible for 40% of the total energy consumption, which makes exploration of the possibilities to save energy in the built environment relevant. Because of a lack of calculation methods and techniques at district level it is difficult to determine which design variant has the best results for energy saving and CO_2 reduction. In this paper a review of the existing energy calculation methods at building and district level, considering the advantages, disadvantages and applicability is given.

INTRODUCTION

Energy saving is needed to achieve CO_2 targets and delay running out of fossil energy sources. All sectors of industry need to take appropriate action to reduce the use of fossil energy. In the Netherlands, the built environment is responsible for 40% of the total energy consumption [1]. This makes exploration of the possibilities to reduce energy in the built environment relevant. More and more designers realize this and incorporate energy saving techniques and construction methods in their designs.

Housing associations renovate large scale projects (districts), accelerating energy reduction in the existing building stock. At the scale of urban neighbourhood, district systems become economically feasible and renewable energy technologies are more economically attractive [19].

The review of existing energy calculation methods is part of a PhD-project. The objective of this research is to develop a district evaluation model based on energy performance to support housing associations in choosing the optimal renovation solution. A new district energy calculation method will be developed, based on existing methods.

DISTRICT ENERGY PERFORMANCE CALCULATION

Average energy consumption

To determine the aspects to take into account in the energy performance calculation at district level, the average energy consumption and CO_2-emissions of objects like houses, streetlights, and transport are examined. The average energy use of the Dutch housing stock in table 1, considering energy needed for heating, hot water and appliances [2], has the largest contribution to the energy consumption in a district. The amount of CO_2-emissions produced by transportation strongly depends on the type of transport and the travelling distance. The transport CO_2-emissions in table 1 are based on an average household consisting of 2,3 persons [22]. The amount of electricity needed for streetlights, given per house [3], is small compared to the other objects.

Table 1 Average energy consumption and CO2-emissions in the Netherlands per year

ASPECT	OBJECT	CONSUMPTION	CO2-EMISSIONS	YEAR
House	Electricity	3346 kWh	1,9 ton	2004
	Gas	1736 m^3	3,1 ton	2004
Transport	Car	15.500 km	3,0 ton	2008
	Public transport:		0,2 ton	2008
	- train	894 km		
	- bus, tram, metro	409 km		
	Airplane	1300 km	0,8 ton	2008
Streetlights	Electricity	150 kWh	0,085 ton	2001

Aspects to take into account

The previous paragraph showed that houses and transportation are the most important aspects to take into account for evaluating the energy consumption and CO_2-emissions in a district. Existing energy performance calculation methods consider mainly an average household with a certain user behaviour, therefore the actual and calculated energy consumption can differ. The SAVE project measured large variations between the energy consumption of different households living in the same house types [4]. Therefore the new district energy calculation method will evaluate besides the building systems, building construction and district systems, the households and their transport.

REVIEW EXISTING ENERGY CALCULATION METHODS

To find an existing energy performance calculation method to implement, a review of existing methods at the building and district level is made. For each existing method the range of application, availability of the input data and consideration of the input variables mentioned in the paragraph 'Aspects to take into account' is examined. This section gives per calculation method a short explanation and description of the advantages and disadvantages. Table 2 shows an overview of the reviewed existing energy calculation methods.

Table 2 Overview energy calculation methods and tools

	RANGE OF APPLICATION				**INPUT**				
	LEVEL		**BUILDING TYPE**		**INPUT**	**INPUT VARIABLES**			
name	B	D	new	existing	availability	B constr.	B system	household	D system
EPA	+	-	-	+	+	+	+	≈	≈
EPN	+	-	+	-	+	+	+	-	≈
GPR	+	-	+	+	+	+	+	-	≈
BREEAM	+	-	+	+	≈	+	≈	≈[1]	-
LEED	+	+[2]	+	+	≈	≈	≈	-	-
NABERS	+	-	-	+	≈[3]	+	+	+	+
BASIX	+	-	+	-	+	+	+	-	-
CASBEE	+	+[4]	+	+	≈	+	+	-	-
EPL	-	+	+	+	+	+	+	≈	≈
GreenCalc	+	+	+	+	+	+	+	≈	≈
SUNtool	-	+	+	+[5]	≈	+	+	+	+

[1] choice of appliances
[2] LEED-ND
[3] ≥ one year of consumption data needed
[4] CASBEE-UD
[5] depends on data collection

+ = yes
− = no
≈ = limited
B = building
D = district

Building level

EPA (NL)

The calculation method EPA (Energy Performance Advice) is used to compute the energy performance of existing dwellings and commercial and industrial buildings. An online tool [23] can be used for a rough calculation. To obtain an energy certificate (required since January 2008) the EPA calculation needs to be performed by an official third party.

EPA considers the building type, useable floor area, building envelope, thermal insulation and building systems for heating, hot water, ventilation and solar energy. The resident's behaviour in this model includes only the energy consumption for heating and domestic hot water. The output EI (energy index) is a score for the energy performance and determined by the total energy use divided by the building envelope and useable floor area.

Advantages

- EPA is a simple method that gives a rough indication of the energy performance;
- a limited amount of, not too detailed, input data is needed;
- parameters considering the resident's behaviour offer opportunities to take the household into account.

Disadvantages

- not all currently used systems are implemented in EPA like cooling and wind energy;
- district systems are implemented, but the question is how well these represent the reality. Looking at the efficiency of the heat pump, there is no difference between individual and district systems. And the amount of houses connected to the district system are taken into account, but the length and insulation of the pipes are not taken into account.

EPN (NL)

According to Dutch building regulations new dwellings and commercial and industrial buildings require a maximum energy performance coefficient (EPC). Designers are free in choosing solutions to comply with this maximum. The calculation method for the EPC is described in the energy performance standard (EPN).

EPN considers the useable floor area, building envelope, building mass, thermal insulation and building systems for heating, hot water, ventilation, solar energy, cooling and moistening. A standard resident's behaviour is assumed. The EPC is determined by the total energy use divided by the building envelope and useable floor area.

Advantages

- EPN is a practical, not too complicated method, with a limited amount of input data;
- a linear relation between the EPC and primary energy use enables the prediction of possible energy savings;
- EPN makes comparison of energy performance among different buildings possible.

Disadvantages

- the calculation method is less suitable for energy-low buildings because the reliability of the method decreases when the EPC approaches zero [21];
- district systems are implemented, but the question is how well these represent the reality. District and individual heat pumps have a corresponding efficiency. And the amount of houses connected to the district system are, in contrast to EPA, not included, but the length and insulation of the pipes can be taken into account.

GPR-Gebouw (NL)

Gemeentelijke Praktijk Richtlijn (GPR), roughly translated 'municipal practice guideline', can be applied to new and existing dwellings, offices and schools. It is used to set sustainability ambitions and to assess and optimize designs. Besides energy, the aspects material, waste, water, health and comfortable living are considered.

The aspect energy looks at the energy performance, energy demand reduction and measures directed at the future. The first issue assesses the EPN results. The two other issues consist of measures like wind energy, energy efficient elevators and user manuals. The total score is converted in a scale of 5 – 10 (5 corresponds to the building requirements).

Advantages

- GPR is a simple and fast sustainability assessment tool;
- the aspect energy connects to existing energy performance calculation methods (EPN, EPA);
- to reward low-energy measures that are not (yet) mentioned in GPR, a design can earn points with self filled in innovative measures.

Disadvantages

- the total score is determined by summing up measures. Therefore likely positive and negative effects, as a result of a combination of measures and contradictions with other interests, do not influence the total score.

BREEAM (UK)

The Building Research Establishment Environmental Assessment Method (BREEAM) is used to assess new and existing residential, commercial and industrial buildings. The method considers among others: energy transport, water and material & waste. Based on the awarded points, a building is rated on a scale of: Pass, Good, Very Good or Excellent.

The aspect energy, which counts for 20% of the total evaluation, awards the achieved CO_2-emission rate, building envelope performance, drying space, internal & external lighting and eco-labelled white goods. The assessment is a mixture of performance-based and feature-specific criteria [13]. Actual consumption figures may be used where available [13].

Advantages

- BREEAM is a simple and fast assessment method;
- the aspect energy also accounts for internal and external lighting and appliances;
- BREEAM-International, specially developed for buildings outside the UK, is adjustable.

Disadvantages

- separate tools are needed to assess the performance-based criteria like the CO_2-emissions;
- the method is originally developed for the United Kingdom and therefore not automatically suitable for other countries.

LEED (VS)

The US Green Building Council developed LEED (Leadership in Energy and Environmental Design) to encourage and accelerate global adoption of sustainable green building. LEED considers the aspects: sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality. Different versions of LEED are available to assess new constructions, existing buildings, schools, homes, hospitals and even neighbourhoods. Based on the total score, the following certificates can be obtained: Certified, Silver, Gold or Platinum.

LEED consists of a long list of measures rewarded with points. Without weighing, the total score is determined by the sum of all awarded points. The aspect energy in the new construction version (LEED-NC) considers the energy performance with regard to a reference building and the percentage of renewable energy. These values need to be calculated with the simulation program DOE-2 or BLAST. Other items are: enhanced refrigerant management, measurement & verification and green power.

Advantages

- LEED looks at a wide range of sustainability issues;
- the rating system (LEED-NC) is an understandable and easy to use system.

Disadvantages

- simulations (DOE-2 or BLAST) are needed to answer the performance-based criteria. Knowledge about these advanced simulation tools is needed;
- LEED is based on US Building guidelines and therefore less appropriate to use in other countries. For instance, the rating system assumes every building has air conditioning. And points are rewarded for measures that do not fulfil building requirements in Europe;
- the checklist of measures makes LEED less appropriate for the early design stage.

NABERS (AUS)

The National Australian Built Environment Rating System (NABERS) is used to determine ambitions and to measure and assess the environmental load of existing dwellings and offices. NABERS considers the measured energy and water consumption for a whole year (energy/water bill), the building construction, occupation schedule, number of occupants and computers and material use and reuse. With a special tool on the NABERS website, the thermal comfort, indoor air quality, noise, lighting and office arrangement can be evaluated.

NABERS compares the input with a reference building. The final score is represented in a scale of 1 – 5 stars. And more detailed output is possible like the energy consumption and CO_2-emissions per year.

Advantages

- NABERS is an online, easy to use tool;
- just a small amount of input variables result in an indication of the environmental load.

Disadvantages

- the tool only applies to existing dwellings and offices in Australia. The Australian reference buildings and climate make it not applicable for other countries;
- NABERS is focussed on the evaluation of the current situation therefore a separate tool is needed to determine the possible improvements;
- evaluation is possible after obtaining one year of energy and water consumption data.

CASBEE (JP)

CASBEE, which stands for Comprehensive Assessment System for Building Environmental Efficiency, is used to determine the environmental performance of Japanese buildings. The CASBEE versions Pre-Design, New Construction, Existing Buildings and Renovation offer possibilities to assess the building in several design stages. The assessment tool considers two categories. The quality category (Q) evaluates the improvement in living amenity within the building site boundary. And the loadings category (L) which evaluates the negative aspects of environmental impact which go beyond building site boundary.

CASBEE uses a very complex weighting system to compute the score for the three sub categories of Q and L. To determine the total score, the Building Environmental Efficiency (BEE) method is used. BEE divides the total quality by the total loadings. Finally the BEE score is translated in a C, B-, B+, A or S rating, where S is the highest score (high quality and low loadings).

Advantages

- CASBEE is implemented in Excel, which is for most people familiar and easy to use;
- the tool can be downloaded for free after registration on the website;
- a wide range of issues are considered.

Disadvantages

- it is a time consuming assessment method (3 – 7 days for a new building);
- the performance criteria lack a description how to measure or obtain these performance values. This can lead to inconsistency;
- CASBEE does not provide a score per subcategory;
- the assessment tool is designed for Japan and showed only 37 similar components compared to BREEAM and 44 un appointed parts [17].

District level

EPL (NL)

EPL, which stands for the Energy Performance of a Location, is a government instrument used to set ambitions, monitor and compare the energy performance of districts. It takes multiple new and/or existing buildings into account including the energy supply, transport & generation and the energy consumption of streetlights, drainage and appliances.

The EPL considers the energy performance results from EPN/EPA, appliances, utilitarian energy use and the energy source. The total score is represented in a scale of 1 – 10, where 6,6 satisfies the building regulations and 10 corresponds to a zero-energy district.

Advantages

- new district as well as existing districts can be evaluated;
- EPL also takes the utilitarian and appliances energy consumption into account.

Disadvantages

- the energy consumption for appliances depends on the usable floor area which is a rough indication and could differ al lot with the actual situation;
- our energy consumption for appliances keeps growing [2], but the EPL model still uses the same appliances factor (since 1998);
- only the building construction & systems and the energy source influence the EPL score;
- not all currently used low-energy techniques can be taken into account, like wind energy.

GreenCalc+ (NL)

GreenCalc is a Dutch software tool which implemented among others the EPA, EPN and EPL models. The software is used for a building or location to set sustainability ambitions and to assess & compare the environmental load. GreenCalc considers the materialization, energy performance, water efficiency and transport.

The software tool computes the environmental load based on the CO_2-emissions for heating (m^3 gas) and electricity (kWh). This is compared to a reference building to compute the environmental index which can be used as a benchmark. The location index compares the results to a self made reference and can not be used as a benchmark.

Advantages

- GreenCalc+ is applicable for new as well as existing buildings/districts.

Disadvantages

- the implemented EPA and EPN calculation methods are out-of-date versions which could lead to wrong energy performance predictions and a limited application of new techniques like self-regulating ventilation supplies;
- the environmental index can only be used as a benchmark when the results are compared to a reference building. This reference building is not always a good reference for your design. A benchmark for districts is not (yet) possible.

SUNtool (EU)

Project SUNtool (Sustainable Urban Neighbourhood modelling tool) is an EC funded research project. This project holds the development of an early decision making tool for sustainable urban design. SUNtool contains occupant's behaviour, daylight, heat flow, micro climate and plant & equipment models.

The user starts with choosing the global location (in Europe) which selects the climate data. SUNtool supplies default values which can be intervened for residential and office buildings in CH, CZ, FI, FR, GR and UK. Next the geometry is defined for each building. HVAC descriptions may be refined and additional plant items can be selected. SUNtool returns an overview of the performance of the site, each building within the site and how the site's performance compares within previous scenarios.

Advantages

- using the default values, a quick simulation is possible;
- the tool is applicable for a number of European countries;

- SUNtool shows results at the district and building level and offers the possibility to compare different design variants.

Disadvantages

- to understand the (simulation) results, a certain experience is required;
- in case of a different location and building & system design, refinement of a lot of default values is needed;
- only rectangle designs can be evaluated because of the simple 3D drawing tool.

CONCLUSION

Limitations energy performance models

A lot of the reviewed methods use a list of measures to assess the energy (and/or environmental) performance. This is a quick method but seems to be more appropriate to evaluate designs afterwards [21]. Almost all of the evaluation tools have different versions per building function. Only the district tools EPL and SUNtool seem to be able to combine houses with for instance offices.

Among the methods the aspects taken into account differ (see table 2) but also the extent of these aspects is not the same. For instance the aspect household in BREEAM and EPA. The first one looks at the energy labels of the appliances and efficiency of internal and external lighting. While the latter considers the influence of the household on the heating load (average inside temperature, ventilation rate, internal heat production) and domestic hot water use (amount of residents).

Most of the models are developed for a specific country. This is clear from the aspects taken into account, the performance criteria, climate file and reference buildings. This makes these tools less appropriate for other countries. The SUNtool contains default data of a couple of European countries but is still limited in its use in other (European) countries. The assessment methods that compare the results with a reference building are less reliable when your building is not alike.

Utility energy performance models

The review of existing energy performance calculations is part of a PhD project. The objective of this PhD-project is to develop a district evaluation model based on energy performance to support housing associations in choosing the optimal renovation solution. A new district energy evaluation method will be developed based on existing energy performance methods. These existing methods should be designed to assess existing houses and take the aspects building construction, systems, household and district systems into account. To support the housing association in the early design stage of the renovation project, a quick and simple evaluation is preferred. The evaluation model will be, in the first place, used by Dutch housing associations. But adaption possibilities are desired to apply the evaluation model in other European countries.

A combination of the EPA and EPL model and the SUNtool seem to fit the best in the new district energy calculation method. It takes all the aspects into account, offers possibilities to implement household profiles, looks at existing houses and needs a limited amount of, not too detailed, input data.

FUTURE WORK

To complete the review, the existing energy performance calculation methods should also be applied in a case study. At the Eindhoven University of Technology several (master) projects are on now, examining energy performance rating tools. These research projects apply the rating tools in a case study considering dwellings, offices and industrial buildings at the building as well as at the district level.

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