Energy savings in new built houses; not the reality but the reference situation determines the amount of savings

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Abstract

All over Europe the building regulations include energy saving components. In the 1980s and 90s most building regulations set levels for individual building components and installations. However, combinations of such measures and other energy saving techniques became increasingly important for the achievement of the desired energy performance. Today many EU Member States use a single integrated energy performance measure to set an energy efficiency standard for new buildings. In their plans to generate energy savings almost all EU Member States include increased levels of energy efficiency for new buildings in their National Energy Efficiency Action Plans. But for calculating these energy savings one cannot compare the new with the old situation. So a reference situation has to be defined to which the energy use of a new building can be compared.

This paper presents several reference situations that could be used for the energy saving calculations for newly build houses and illustrates these by examples for the Netherlands. It shows what the consequences are of the selection of each of these references and how this will result in different (calculated) energy savings. In addition the dynamic of the reference situation will be presented and the pros and cons of a static and a dynamic approach will be illustrated with an example. The paper concludes with a proposition for the baseline in the harmonised reporting system of the ESD and the consequences of the proposed choice.

Introduction

After the oil-shock in the 1970s more attention has been given to insulation and most building regulations set levels for individual building components and installations. All over Europe building codes included energy savings components. Today, with the increased need for energy efficiency, combinations of energy saving techniques are increasingly important. In many EU Member States this stimulated the use of a single energy performance measure to set a standard for energy efficiency of new buildings. With the energy Service Directive[1] (ESD) the EU also pushes forward to achieve better energy efficiency. This directive requires Member States to draw up programmes to improve energy efficiency. Each Member State is obliged to provide an overview of its strategy for achieving the targets in a National Energy Efficiency Action Plan (NEEAP). Most EU Member States include increased levels of energy efficiency for new buildings in their actions to generate energy savings. But for calculating these energy savings a simple comparison of the new and the old situation is not possible. Therefore a reference situation has to be defined to which the energy use of a new building can be compared.

This paper presents several reference situations that could be used for the energy saving calculations for newly built houses and illustrates this by examples using data for the Netherlands. It starts with a short introduction of the Dutch building code and the calculation of the building related energy use. Different options for the use of references are presented and discussed using different measurement methods and baseline constructions. We will demonstrate how these choices affect the calculated energy savings. From the results some recommendations will be put forward.

Table 1. EPC value and its adjustments

Implemented	1995	1998	2000	2006
EPC value	1.4	1.2	1.0	0.8

The Dutch building code, a short overview

Since the oil crisis of 1973 the Netherlands has included measures in its building regulations to improve energy efficiency. In order to further stimulate insulation, in the years that followed the building code became more stringent with respect to energy losses of walls, windows roofs and floors. Much energy could also be saved by using more efficient installations for heating and cooling. Rather than prescribing exactly what type of materials and installations should be used in the building construction, the Dutch government decided to use an integrated energy standard and leave the choice on how the standard could best be met to the constructors. This standard, the Energy Performance Coefficient (EPC), was introduced in December 1995. Its initial value was set at 1.4 for dwellings. In the years that followed the norm and was subsequently tightened (see table 1).

The norm prescribes that a standardized energy use must be calculated on the basis of constructional and energy-technical properties of the dwelling for heating, cooling, hot water, ventilation, pumps and lighting under normalized conditions (occupation, indoor temperature, weather). The relation between EPC, characteristic energy consumption, floor area and loss surface of the envelope is stated below.

Equation 1

$$EPC = \frac{Q_{pres;tot}}{(330 \times A_u + 65 \times A_{loss})} \times \frac{1}{C_{epc}}$$

Where

EPC = energy performance coefficient (no dimension)
$Q_{pres;tot}$ = characteristic energy use (calculated primary energy use) (MJ)
A_u = conditioned floor space (m^2)
A_{loss} = loss surface of building envelope (m^2)
C_{epc} = adjustment factor with respect to NEN 5128[2] (no dimension)
330; 65 = weight factors (MJ/m^2)

The EPC-value is an indicator of the energy efficiency of a building. Because the amount of floor space and the exposed area of the building envelope are taken into account in its calculation, this means that different types of houses with the same EPC value will differ in energy consumption. The information required for the calculation of the EPC-value is specified in the design plan of the house. A building permit is issued only after the local authorities have approved the design and have checked its conformity with the norm.

Harmonized evaluation methods

The Energy Service Directive of the EU prescribes that each Member State will take measures to promote and ensure an increase in energy efficiency of 1% per year, resulting in 9% avoided energy use in 2016, the end of the ESD period. The results of the measures taken by the Member States to meet this requirement must be reported not only using top-down methods, but also for a considerable proportion using bottom-up procedures. Each Member State has forwarded a National Energy Efficiency Action Plan (NEEAP), in which it describes what measures will be taken to achieve this objective.

The NEEAPs of many countries include measures to increase the level of energy efficiency for new buildings. However, for the calculating of these energy savings one cannot compare the new with the old situation. The reference situation to which the energy use of a new building shall be compared has to be given careful consideration. Furthermore, the calculated energy savings must be comparable across Member States. For this reason, an EU-taskforce set out to develop harmonized bottom-up methods to measure the amount of energy saved, the EMEEES project. For new residential buildings this effort has resulted in a proposed methodology for the bottom-up evaluation of energy efficiency gains[3].

Since there are large differences in type and availability of data between Member States (MS), the EMEEES project usually devise methods on three levels of difficulty, reflecting increased precision, but also requiring higher levels of data availability. First level methods work with estimation using EU-wide reference values for the measure under scrutiny and require minimum evaluation efforts. The second level works with MS-specific reference values (following harmonized rules) and requires intermediate evaluation efforts, using well known techniques for data collection and estimation. The third level works with measure specific values (following harmonized rules), requiring enhanced evaluation efforts and specific measurements.

In the case of evaluating the energy efficiency effects of more stringent building codes, a level 1 evaluation method based on European default values is not applicable since the differences in energy consumption of dwellings in the European Union is too great between countries. The highest level of evaluation (level 3) is possible only if individual properties of newly built dwellings are known. In all cases the energy consumption associated with a specific (type of) dwelling is by definition calculated, using some model that separates and normalizes the energy consumption associated with heating, cooling, ventilation, pumps, etc.

The EMEEES proposal

In the harmonized method for the evaluation of energy efficiency improvement in new residential buildings as a result of more stringent building codes, the EMEEES proposal has taken into account several complications. For these complications the method uses default values. For non-compliance with the building code the standard value is 10%, the autonomous development of energy efficiency by the market is set at 0% and the rebound effect is set at 0%. Furthermore the proposed method uses a static baseline at the year the building code was

Table 2. Types of dwellings and their energy consumption

TYPE	1 Detached house (kWh/m²)	2 Semi-detached (kWh/m²)	3 End-House (kWh/m²)	4 Town-House (kWh/m²)	5 Apartment (kWh/m²)	6 Gallery flat (kWh/m²)	7 Apartment/flat (kWh/m²)
EPC = 1,4	204	195	196	179	171	168	170
EPC = 1,2	175	167	168	154	146	144	145
EPC = 1,0	145	139	140	128	122	120	121
EPC = 0,8	116	112	112	103	98	96	97
Space (m²)	170	148	124	124	91	112	102

first implemented, but no earlier than 1995. Finally a time lag of two years is taken into account for a new building code to take effect in actual production. For the calculation of avoided energy use, using an overall energy performance standard the calculation is according to the formula:

Equation 2

$$\text{TNFES} = \sum_{i=1}^{c} (UFED_{0i} - nc \times UFED_{1i}) \times n_i \times (1 - re)$$

Where

- TNFES = Total Net Final Energy savings (MJ)
- $UFED_{0i}$ = Unitary Final Energy Demand for a standard dwelling in class i, under baseline conditions, per annum (MJ)
- $UFED_{1i}$ = Unitary Final Energy Demand for a standard dwelling in class i, under the building code to be evaluated, per annum (MJ)
- re = Rebound effect (default = 0) (no dimension)
- i = Class of dwelling (1 thru c) (no dimension)
- nc = Non-compliance parameter (default = 1,1) (no dimension)
- n_i = the number of units in class i no dimension)

Note that the non-compliance factor is not applied to the reference energy demand. But throughout the years non-compliance with the regulations has existed, therefore also in the reference year. If the non-compliance factor is accordingly placed outside the brackets, this would result in higher savings!

Methodology and data

REFERENCE DWELLINGS

For the calculation of energy savings the unitary energy demand of a standard (type of) dwelling can be used. In this case the dwelling is the main unit. Alternatively the energy savings can be calculated using the amount of m² of conditioned floor space in combination with the energy consumption per m² for a standard (type of) dwelling. The choice depending on the data availability. For this paper we will make use of reference dwellings for which energy use per m² is documented. These dwellings can be seen as a good representation of the different categories of dwelling as they are built in the Netherlands nowadays.

There are six reference dwellings. The last category is merely the simple average value for apartments and gallery flats. It was created for convenience reasons, because our research data only have one category for apartments and gallery flats. We opted for this solution because the energy use per m² for the categories 5 and 6 is very similar for both these categories. Note that the variance of the characteristic energy use for the different types of dwellings is limited in comparison to the variance of the conditioned floor space. An overview of types of dwellings and their energy consumption is given in table 2.

PRODUCTION DATA

The annual production figures for residential buildings are obtained from Statistics Netherlands[4]. They are broken down by ownership i.e. privately owned verses rental dwellings and by type i.e. houses verses apartments/flats.

DISTRIBUTION OVER TYPES OF DWELLINGS

For the distribution of newly built dwellings we made use of a large scale survey called “Woon Onderzoek Nederland (WoON)”, which was conducted by the Department of Housing (VROM)[5]. This survey has collected data on a sample of some 40.000 dwellings in the Netherlands. From this source information was obtained about the distribution over the different standard types for the cohorts built in 1995 thru 2005. Furthermore the average conditioned floor space could be calculated for each type of dwelling.

Figure 1 shows the average size of newly built homes in the years 1995-2005. A steady increase of the amount of floor space in newly built dwellings is clearly visible. For apartments and flats the increase in these years was about 20%. On average the increase was about 7% for all newly built dwellings.

Alternative ways to calculate the energy gains

The proposal for a harmonized methodology provides Members States with guidelines for the calculation of energy gains as a result of more stringent building codes. However the choices made in the EMEEES-proposal are as yet not finalized by the Commission. In its conception there were discussions on topics as baseline, non-compliance, rebound effect and unit. Choices made on either of these topics may have a severe impact on the outcome. Furthermore, even within the outlines as given in the proposal, Member States have a choice with respect to type of data, the unit and the number of categories to be used in the calculation of their energy gains. We will now illustrate what impact such choices can have on the outcome.

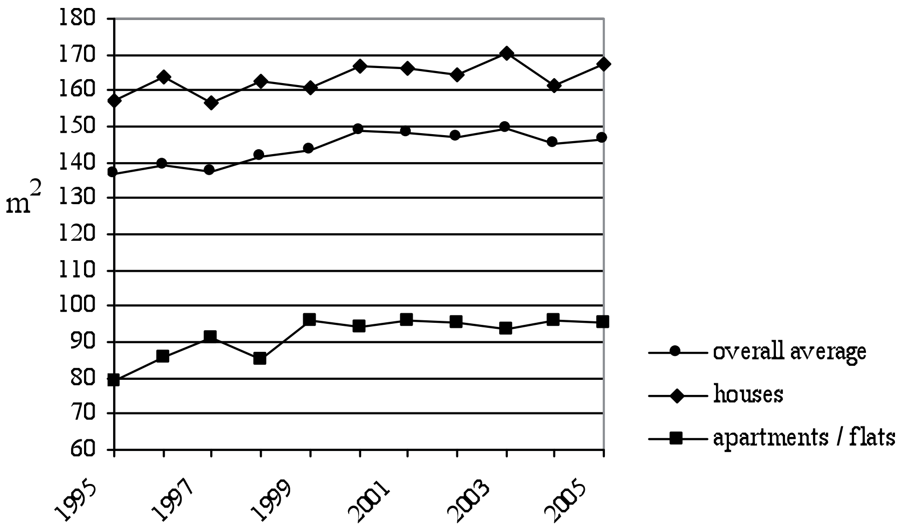


Figure 1. Average size of dwellings (1995-2005)

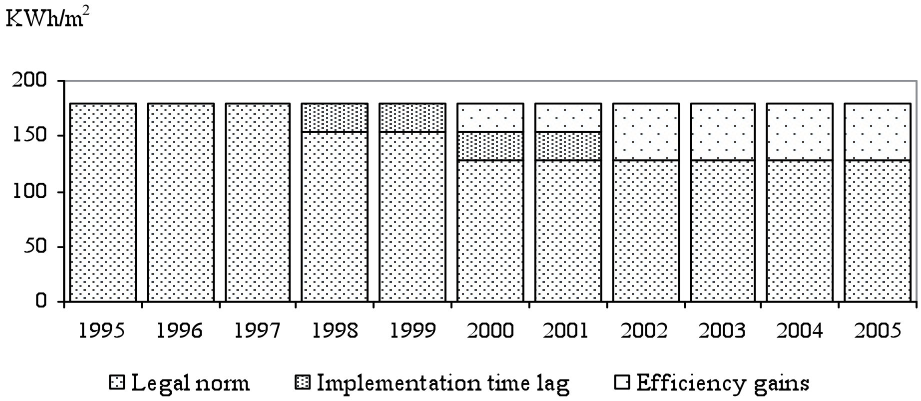


Figure 2. Baseline with introduction of the norm of 1995 as a starting point

BASELINE IN THE DUTCH SITUATION

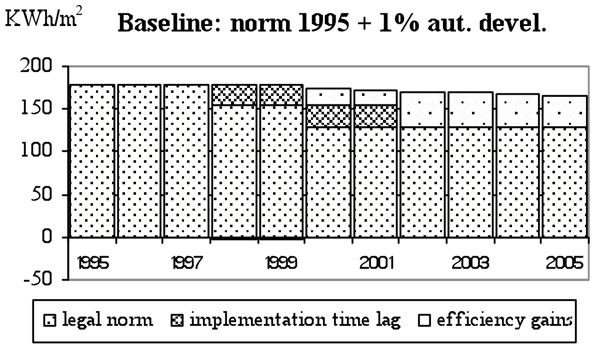
For a long time the Dutch building code has set standards for the use of construction materials in order to stimulate the energy efficiency of new buildings. In the beginning the focus was mainly on the building envelope, hence on insulation measures. Gradually other important elements came into play, such as installations for heating and hot water. Since 1995 the building requires that a newly built house meets in integral energy efficiency norm. This norm was adjusted in January 1998 and again in January 2000. The last adjustment dates from January 2006.

Since the introduction of the norm as such does not constitute a more stringent building code, the first efficiency gains can be attributed to the tightening of the norm in 1998. Because it takes about two years before the new norm results in production of dwellings that meet the new norm, these efficiency gains only start to materialize in the year 2000 (see figure 2). The energy gains are measured against the amount of energy that would have been used by the same number of houses (per standard category) under the 1995 building code, or alternatively the same amount of conditioned floor space per standard category.

UNITS AND THE NUMBER OF CATEGORIES

To illustrate the impact of the unit and the number of categories we calculated the energy savings achieved since 1995 up to and including the year 2005. For the calculation of energy savings the following approaches were evaluated using a simplified form of formula 2 from the EMEEES proposal, i.e. without the 10% non-compliance factor. In these calculations the baseline was chosen as shown in figure 2.

1. In this approach one standard category of dwellings is used. A type 2 standard dwelling was used as the reference as it best fitted the average. In this approach the unit used in the calculation is the dwelling, meaning that the energy consumption of the standard dwelling is multiplied by the number of newly build dwellings to calculate the energy consumption.
2. As above, but now two categories of dwellings are used. The type 5 standard dwelling was selected to represent all newly built apartments and flats. The second category represents all other dwellings. For this latter category a type 2 standard dwelling was used.
3. As in the second approach, but now using the energy demand per m2 and the amount of m2 floor space to calculate the energy consumption. This means that the energy



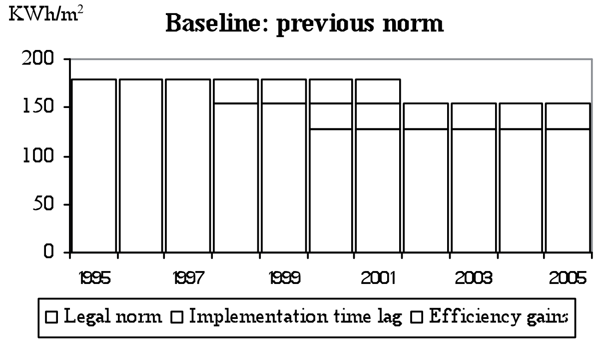


Figure 3. Alternative baselines

Table 3. Eight alternative ways to calculate energy savings

alternative	baseline	norm	# categ.	unit	addition	2005 savings/yr	% diff.	cumulative savings	% diff.
1	static	1995	1	dwelling	-	1,99	3,8%	9,80	2,7%
2	static	1995	2	dwelling	-	1,72	-10,4%	8,60	-9,9%
3	static	1995	2	m^2	-	1,93	0,9%	9,65	1,1%
4	static	1995	5	m^2	-	1,92	0,0%	9,54	0,0%
5	static	1995	5	m^2	nc 10%	1,44	-25,0%	6,43	-32,6%
6	static	1995	5	m^2	fixed floor space reference	1,29	-32,5%	6,59	-30,9%
7	dynamic	1995	5	m^2	AD 1%	1,40	-27,0%	7,39	-22,6%
8	dynamic	Pre-vious	5	m^2	-	0,96	-50,0%	5,81	-39,1%

consumption of a dwelling in a specific category now varies with the amount of floor space.

4. As in three, only now using 5 standard types of dwellings (1, 2, 3, 4 and 7).

In table 3 the results of the calculation of energy gains according to the different approaches are presented. The first approach resulted in calculated energy savings of 2.0 PJ per year in 2005. The second approach introduced an extra category. This resulted in 1.7 PJ of calculated energy savings per year in 2005. The 3rd approach allowed the energy consumption to vary with the floor space. Calculated energy savings came out to be 1.9 PJ per year in 2005. Calculation as described in alternative 4 also resulted in 1.9 PJ energy savings per year in 2005. Since this last the calculation according to alternative 4 is the most refined (i.e. has the most categories and allows the energy consumption to vary with floor space). We assume that this approach has rendered the most accurate results. This approach is used as the standard against which the other alternatives are measured. Thus comparing the alternatives 1 and 2, the introduction of an additional category did not render more accurate results. This can be explained by the fact that when using the dwelling as a unit, the outcome depends heavily on how well the reference dwelling fits the average in its category. In the first alternative this fit was very close, but in the second the reference dwellings were small compared to the average dwelling size of the two categories used. In variation 3 this result was corrected very efficiently using m^2 floor as the unit. The addition of 3 more categories in alternative 4 only resulted in a very minor adjustment.

These results illustrate that it is preferable to take m^2 as a unit rather than a dwelling. A second advantage is that an increase (or decrease in floor space in newly built houses over the years is incorporated in the calculations. On the other hand, if the dwelling is chosen as a unit, this does not necessarily render bad results, provided that the reference dwelling fits the energy use of a dwelling in its class fairly well. A close fit to the average amount of floor space in the relevant category is the dominant factor for this last condition. In general these alternatives 1, 2, 3 and 4 produced very similar results. Taking the alternative 4 as a reference point, the maximum deviation was 10.4%.

BASELINE AND CORRECTION ISSUES

We will now turn our attention to some known disturbances such as non-compliance and the rebound effect. Furthermore we will present some approaches where the baseline changes over time, i.e. using the 1995 legal norm and an autonomous development of energy efficiency of 1% per year and an approach where the reference situation is the previous legal norm.

The following alternatives were evaluated:

5. As in the 4th approach, but introducing a non compliance parameter of 10% as in the EMEEES proposal.
6. As in the 4th approach, but fixing the floor space for the reference situation at the 1995 level.
7. As in the 4th approach, but introducing a 1% autonomous development of energy efficiency.
8. As in the 4th approach, but now the previous norm is taken as a reference rather than the norm of 1995.

The results in table 3 show that the general impact on the calculated amount of energy gains of the approaches 5 through 7 is considerably greater than then for alternatives 1,2 and 3.

- In the 5th approach we can see that the factor for non-compliance that was introduced in the formula as proposed by EMEEES takes away 25% of the energy gains
- In the 6th approach the increase in floor space over time is viewed as a special case of the rebound effect, the so called market or dynamic effect (Gottron, 2001)[6]. In this example the impact on the outcome of calculated energy gains amounts to roughly one third of the energy gains in the 4th approach.
- In the 7th approach a factor for the autonomous development of energy efficiency by the market was introduced. The value of 1% is of course arbitrary. In fact, many specialists point out that there is a market failure with respect to the implementation of energy efficiency measures for (domestic) buildings (for example Clinch and Healy; 1999)[7]. Evaluation of this approach reveals that the introduction of such a parameter on the calculated energy gains has a considerable impact on the outcome.
- In the last approach, the reference value for the new norm is not the norm in a base year, but the norm imposed in the previous building code. This seems a logical reference. In this example using this baseline halves the calculated energy gains. This is so because it eliminates savings from earlier policy steps. Since there is consensus over the fact that measures for energy efficiency of buildings have a very long savings lifetime (that is can be counted as savings for a very ling time), the use of this baseline would be in conflict with this consensus. Also it would be to the disadvantage of the Member States that have already actively carried out policies with respect to energy efficiency in domestic buildings. For these reasons we think it is preferable to use a baseline with a fixed base year.

Discussion

In this paper we explored several approaches to calculate energy savings due to more stringent building codes. According to the EMEES proposal for the bottom up evaluation of the resulting energy gains, EU Member States are free in their choice of the unit want to use in their calculations (i.e. dwellings or m^2). Furthermore, depending on data availability they may use a single category of dwellings (average) or many. What are the effects of the choices made by the Member States? Do they result in a lack of inter-comparability of the energy efficiency reports? To shed some light on this question we presented some different approaches (1 through 4) with respect to the unit and number of categories used in the calculations. Another issue is how the impact of the choice of unit and the number of categories used in the calculation of energy gains compares to the impact of different assumptions regarding the baseline and the correction factors used in the calculations. To answer this question we also evaluated some plausible assumptions regarding non-compliance (5), rebound effect (6) and the baseline (7 and 8).

Evaluation of these approaches 1, 2, 3 and 4 showed that the variation in the outcome was limited and in these examples was never more than 10.4%. Not the number of categories determines the accuracy of the outcome, but rather how well the properties of the standard dwelling fit the characteristics of the dwellings in a category. For the fit the amount of floor space seems more important than the characteristic energy demand. The use of m^2 as a unit is therefore to be recommended because it adjusts for deviations of the reference category from the actual amount of floor space in a dwelling.

The evaluation of approaches 5, 6, 7 and 8 shows that the choice of the baseline and the correction factors have a much greater impact on the calculated energy savings than the choices with respect to the measurement. The impact of each of these approaches was 25% or more.

Glossary

EMEEES	Evaluation and Monitoring for the EU Directive on Energy end-use Efficiency and Energy Savings
EPC	Energy Performance Coefficient
ESD	Energy Service Directive
NEEAP	National Energy Efficiency Action Plan

Notes

1 Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:114:0064:0085:EN:PDF

2 Correction factor to enable comparison of EPC values after norm (and calculation of EPC) heas been changed.

3 Evaluation and Monitoring for the EU Directive on Energy End-use Efficiency end Energy Services (2008); http://www.evaluate-energy-savings.eu/emeees/en/evaluation_tools/bottom-up.php

4 Statistics Netherlands (CBS); http://statline.cbs.nl/StatWeb/publication/?DM=SLEN&PA=37263ENG&D1=2,4-9&D2=0&D3=4,9,14,19,24,29,34,39,44,49,54,59,64&LA=EN&VW=T

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6 Gottron, F., (2001). "Energy efficiency and the rebound effect: Does increasing efficiency decrease demand?" Congressional Research Service. Report for Congress (RS20981). The Library of Congress. July 30, 2001.

7 Clinch, J.P. and Healy, J.D. (1999). "Domestic Energy Efficiency in Ireland: Correcting market Failure", Environmental Studies Research Series (ESRS) Working Paper 99/05, Department of Environmental Studies, University College Dublin.