Building Physics

4 Energy saving - Sustainability

ir. I.M. Kuijpers-Van Gaalen, DGMR, Arnhem

Klimapedia, August 2022

8

Energy and energy performance

ir. I.M. Kuijpers-van Gaalen MBA

Approximately 40% of the total yearly energy consumption in the Netherlands is used in buildings. The building practice has a great need for predicting and calculating the various elements of energy use of buildings. This makes sense, because besides the environmental need to reduce energy use, energy costs money. Using less energy will result in money-saving. This means that when a company or consumer is considering the purchase of a new boiler or lighting, they should also consider the energy use of this device. The financial investment in such a device, after all, goes beyond the initial investment: the energy itself also has to be paid each year. And the aggregate costs of this over the years could be even higher than the purchase price.

8.1 Energy use

It is very difficult to predict energy use in practice. Buildings are dynamic and people do not always behave as expected. Before we go into the way in which energy use can be predicted, it is important to make a distinction between the various items of energy use existing in a building.
The main distinction is between building-related energy use and non-building-related energy use. These two main groups can then be further divided.

- Building-related energy use: the energy which can be attributed directly to the building itself. This includes:
  - energy use for climatising the building (heating, ventilation, cooling, humidification);
  - energy use for lighting the building (lighting and emergency lighting);
  - other building-related energy uses (tap water and auxiliary energy, for example for pumps).
- Non-building-related energy use: the energy which cannot be directly attributed to the building itself. For example:
  - office equipment (servers, computers, printers, coffeemakers, TVs, fridges, washing machines);
  - process energy, the energy use which belongs to processes. In most office buildings, schools and homes, this share is very small or zero, but in for example an industrial building or a swimming pool, the share of process energy is often significant.

Non-building-related energy use

Here, we mainly focus on the building-related energy use, because this is the area of attention of the building physicist. We will briefly provide a guideline for calculating the energy use of processes and of equipment, such as servers and computers. Predicting the energy use of industrial processes is very complex and varied and falls outside the scope of this book.

In order to map out the energy use of machinery, the following data need to be collected:

- P_{full} = full load capacity of the machine in watt;
- P_{part} = partial load capacity of the machine in watt*;
- $P_{stand\text{-}by}$ = the stand-by capacity of the machine in watt;
- t_{full} = the number of hours per year the machine operates on full load;
- t_{part} = the number of hours per year the machine operates on partial load;
- $t_{stand\text{-}by}$ = the number of hours per year the machine is in stand-by mode.

* Partial load = the power required to have the machine operate on ‘half power’. In many cases, if a machine can be only turned ‘on’ (full load) or ‘off’ (= 0 or stand-by), you do not need this value.

The energy use of the equipment (in kWh) is calculated by using the following formula:

$$E_{equipment} = \frac{P_{full} \cdot t_{full} + P_{part} \cdot t_{part} + P_{stand\text{-}by} \cdot t_{stand\text{-}by}}{1000} \text{ [kWh]}$$

In order to calculate the total non-building-related energy use, you make an estimation for all machines in the way shown above and you find the aggregate:

$$E_{non\text{-}building\text{-}related} = \sum_{i=0}^{n} E_{equipment,i} \text{ [kWh]}$$

Clearly, the difficulty lies in estimating the number of hours per year a machine operates or is in stand-by mode. In general, you will notice you tend to overestimate this. Equipment is turned off more often than you might think. For example due to holidays, illness, bank holidays and appointments elsewhere.

Building-related energy use

In order to predict the building-related energy use of a building, a model will have to be made which includes all parameters that influence building-related energy use. These are constructional data, climate data, installation data and the data concerning the actual usage of a building. This type of calculations can generally not be performed by hand. A variety of software packages have been introduced for this purpose.

These software packages can be divided into static models and dynamic models.

The static models are simple models which could be performed by hand, albeit with some effort and help of Excel. A static model assumes many parameters to have fixed values (static). This makes the calculation simpler and it will therefore take less time to perform it. The level of accuracy, however, will also be lower. A static calculation makes use of a simplified outside climate: for each month, a fixed average outside temperature is used. Based on the average outside temperature, the energy use for heating or cooling is calculated. The building parameters, as well as the use are often represented by a fixed value in a static model (for example an average yearly efficiency), while in practice these values may fluctuate.

In dynamic models, it is attempted to simulate the actual use of the building as much as possible. This means the input will be extremely detailed. It is possible to indicate how the building is used, how many people are present and what the climate settings are on an hourly basis. The outside climate, including the sun load, is available in the model on an hourly basis.
In the dynamic model, it is calculated from hour to hour what the expected inside temperatures and energy uses will be. The model also takes account of what happened in the building in the preceding period. If, for example, it has been warm for a couple of days, the building will be heated up. It will then take more energy to cool down the building, since the structure itself is also heated up (thermal mass). The dynamic model takes account of these effects.

Still, a dynamic calculation is not always better than a static calculation. If certain input parameters are unknown when performing the dynamic calculation, and the person performing the calculation 'takes a guess', the quality of the static calculation could be higher. And if the input for the dynamic calculation is the same as for the static calculation, there will be little difference between the static and dynamic calculation. Dynamic calculations are only of any use if sufficiently detailed information is available about the building and the use of the building.

Comparing measured energy uses

Once a building is in use, it is interesting to see how the energy use develops over the years. Does it increase or drop? And is it possible to see whether a given energy-saving measure actually results in a reduction in energy use?

Simply comparing the energy uses of two years with each other will result in incorrect analyses. One year may after all be colder than the other and this has an impact on energy use for heating. It is therefore desirable to correct the actual energy uses for heating for climate influences to be sure of an objective comparison. You can do this by utilising a 'degree day correction'.

The point of departure is: if the average outside temperature is higher than the average inside temperature, the boiler does not need to be turned on. If the outside temperature is lower, the boiler needs to go on and degree days need to be counted. There are degree days when, during an entire day, the average temperature is lower than the heating threshold of 18 °C (the reference temperature generally used in the Netherlands above which heating is not necessary). Above the threshold of 18 °C, there are no degree days.

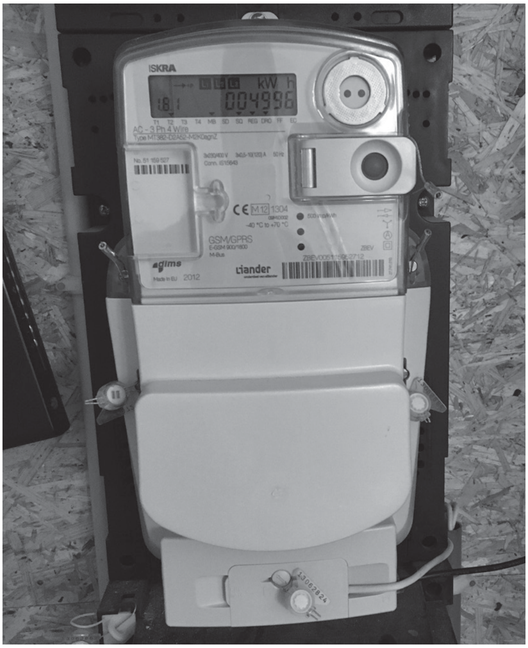

Figure 8.1 Energy meter in a home. Both the gas and electricity use can be read at distance.

The term degree days is confusing, because it does not refer to days. A degree day is a measure for the amount of energy required to heat a building. A degree day is calculated as follows: reference temperature of the heating threshold (18 °C) – the average temperature of that day. Every day it is registered how many degree days there are that day.
If the average temperature on a given day is 11 °C, that day has (18 – 11 =) seven degree days. If a day has the average temperature of 20 °C, the number of degree days is zero (you can't have negative degree days).

We also have the term weighted degree days. For weighted degree days, account is taken of the fact that buildings are also heated by sunlight and that the boiler needs to deliver less energy. Depending on the season, the number of degree days is multiplied with a weight factor. The weight factors are:

- 0.8 in the months of April to September;
- 1.1 in the months of November to February;
- 1.0 in the months of March and October;

We generally use weighted degree days when comparing energy use over a number of years, so that the influence of sunlight is included. To determine the total number of weighted degree days over a time period, the (weighted) degree days of the separate days are added.

Example

In 2013, 1000 m^3 was used on heating in a home. The number of weighted degree days in 2013 is 3094 (De Bilt). Gas use in 2014 was 800 m^3. The number of weighted degree days in 2014 is 2418. Gas use dropped significantly, but is this due to the climate or because actually less gas was used?
By calculating the gas use per degree day for each year, we can clarify this.
2013: 1000 m^3/3094 degree days =
0.323 m^3/degree day
2014: 800 m^3/2418 degree days =
0.331 m^3/degree day

When we work out the energy use of 2014 to reference year 2013, we find a use of 0.331 m^3/degree day = 1024 m^3. In other words: in comparison to the reference year, use in both years is practically the same. The drop in gas use is caused by the fact that 2014 was a milder year than 2013.

Counting up degree days is not something you have to do yourself. There are a number of websites available which let you determine the number of degree days in a given period. The basic details are collected by the KNMI (Royal Dutch Meteorological Institute) and tables of degree days can be found on their website.

Note: the degree date correction is only performed for the gas use for heating. Gas use for tap water must first be subtracted from gas use for heating, because the gas use for tap water does not depend on the climate. These same calculation can of course also be performed for buildings with district heating or electric heating (heat pumps), but then the calculation must be done with GJ or kWh instead of m^3 gas.

8.2 Energy savings and financial analyses

The nice thing about calculating energy is that you can also work out energy savings and financial savings. In practice, this is often done to make investment assessments. The question is: will we make back the investments we put in during the lifetime of the device or the building?

There are various ways to make these calculations. We will illustrate the two most common methods: the simple payback time and the net present value method.

Usually, this type of financial analyses is done in order to make a choice. This means that the additional investment of the one option is scrutinised in relation to the other. This additional investment must be paid back within a certain period through the lower energy costs. In order to be able to make a calculation, we do not only need the (additional) investment costs, we also need to know the costs of energy, interest and maintenance to include them in the calculation.

Simple payback time

The calculation of the simple payback time SPT is, as the name suggests, simple. This calculation looks only at the additional investment of a given choice and it is calculated in how many years this additional investment will be recovered. The method does not take into account any costs of interest, maintenance, etc.

Example

An entrepreneur is considering changing the lighting of his premises. He has the choice between placing traditional fluorescent lighting or led lighting. He does not like the additional investment of led lighting, but he has also heard led is more economical. To get a first idea of the numbers he quickly finds out the simple payback time with the formula:

$$\text{SPT} = \frac{\text{additional investment}}{\text{yearly savings on energy costs}}$$

The additional investment amounts to € 10,000 and he saves 18,500 kWh per year on the more economical led lights. Based on his energy price for electricity (€ 0.15/kWh) he calculates that the investment is recovered in 10,000/(18,500 · 0.15) = 3.6 years.

The lighting has a much longer lifespan than 3.6 years. He therefore decides to purchase the led lights, as he will after all start making money on them after 3.6 years.

In general, entrepreneurs want to recover their investments in the short term. A payback time of five to seven years is still acceptable. If it takes longer than that, entrepreneurs often think the risk to high as they cannot see into the future that far ahead. For a private or non-profit organisation this turning point can be a little further into the future, since they are in a more stable market.

Net present value

The calculation of the net present value is somewhat more complicated. In this calculation more components are included than in the simple payback time, and account can be taken of variable costs per year. The net present value method looks at all future cash flows (such as interest, maintenance costs and energy costs) which are associated with the investment currently under consideration. These future cash flows are expressed in their present value.

In order to work out the net present value (NPV) you need the following details:

- the initial investment (INV_0);
- the yearly cash flow, consisting of costs and profits for energy, maintenance, energy, etcetera;
- the discount rate (r), or the interest of the loan to finance the investment with;
- the time period (t) you want to calculate the NPV over.

The formula for calculating the NPV is:

$$NPV = \sum_{t=1}^{n} \frac{\text{yearly cash flow}}{(1+r)^t} - INV_0$$

The first term in the formula calculates the yearly cash flow back to the value in the first year (at the start of the project). So you calculate the first term for every year separately, whereby the cash flow can vary for each year. For year 1, you calculate the term with $t = 1$, for year 2 with $t = 2$, etc. The initial investment (INV_0) has already been found for the current value, so this does not have to be worked out again, which is why it is outside the aggregate sum.

For investments in energy conservation, there is often a choice between two options which have to be compared. The NPV will then have to be calculated for both situations and the option with the highest NPV can be selected. An alternative is to look at the additional investments and the savings (so just the difference between the two options need to be regarded), so that only one calculation has to be performed. In that case, you will have to test whether the NPV is larger than zero, because then the additional investments can be compensated by the savings. This is elaborated in the calculation example below.

Example

Let us again consider the situation of the entrepreneur who has the choice to install either led lighting or fluorescent lighting. The additional investment for led lighting amounts to € 10,000. The yearly energy saving is € 2,775 and he estimates maintenance will cost him € 1,000 less on a yearly basis. He uses a discount rate of 7%.

year	additional investment (INV_0)	yearly savings on energy costs	yearly savings on maintenance costs	total yearly savings	total yearly savings made current with savings $(l + r)_t$
0	€ 10,000				
1		€ 2,775	€ 1,000	€ 3,775	€ 3,528
2		€ 2,775	€ 1,000	€ 3,775	€ 3,297
3		€ 2,775	€ 1,000	€ 3,775	€ 3,082
4		€ 2,775	€ 1,000	€ 3,775	€ 2,880
5		€ 2,775	€ 1,000	€ 3,775	€ 2,692
6		€ 2,775	€ 1,000	€ 3,775	€ 2,515
7		€ 2,775	€ 1,000	€ 3,775	€ 2,351
sum of the present value of the savings					€ 20,345
additional investment					€ 10,000
net present value					€ 10,345

Figure 8.2 Calculation example of the net present value of a led light project

The net present value is clearly positive. So also from a financial point of view it is better to invest in led lighting than in fluorescent lighting.

8.3 European energy performance legislation

Reducing energy use is one of the main objectives of the European Union (EU). Because 40% of our energy is used in buildings, the EU has introduced legislation to make sure that buildings will start using less energy.

An important part of this legislation is the Energy Performance of Buildings Directive (EPBD, directive 2002/91/EG). This directive was first published in 2002 and forces all EU countries to improve their building regulations and to introduce energy certificate regulations for buildings. The directive was amended in 2010 and refined into the EPBD Recast (directive 2010/31/EG).

The main points from the EPBD 2002 directive:

- There must be a calculation method which can work out the integrated energy performance of a building. The directive establishes which requirements this method must observe. For this purpose, the NEN 7120 standard was formulated in the Dutch Buildings Decree. This standard meets the requirements in the EPBD directive.
- Minimum requirements must be set for the energy performance of new buildings. This is implemented in the Netherlands by setting requirements of the energy coefficient (EPC) of new buildings.
- For existing large buildings which have to undergo drastic renovations, minimum requirements must be set to their energy capacity in order to encourage reduced energy use in these buildings. In the Netherlands, this is laid down in the Building Decree.
- When selling or letting a home or building, an energy label must be available, so that the new occupant or owner can form a picture of what the possibilities of making savings are.
- Boilers and air-conditioning systems in buildings must be regularly tested in order to prevent these systems from functioning below their optimum level.

In the Netherlands, the requirements from the 2002 EPBD directive have been translated into laws and legislation. This legislation is accommodated in the Building Decree, the Energy Performance of Buildings Decree (BEG) and the Buildings Energy Performance Regulation (REG).

The EU published a revision of the EPBD Directive in 2010. This revised directive is designed to force countries to take steps in the further reduction of energy use in buildings. The EPBD Recast includes the following requirements which must be laid down in the legislation of all EU member states:

- New buildings must be ‘nearly zero energy’ as of 2021. The government must play a leading role in this and as of 2018 only ‘nearly zero energy’ buildings may be bought, rented or built by the government.
- More stringent requirements must be laid down regarding insulation (R_c) of the building shell for drastic renovations and the replacement of insulation materials.
- Member states must introduce sanctions for non-observance of the directive. Fines, for example, for not having an energy label.

Legislation in the Netherlands

Several laws and regulations exist in the Netherlands which have to ensure that the country meets the obligations from the EPBD Recast. It is laid down in the Building Decree that new buildings and buildings which are to be drastically renovated are properly insulated. This is established by placing demands on the R_c values of facades, floors and roofs and the U values of windows and doors. It has also been established that the buildings as a whole must be energy efficient. This means they have to meet the energy performance requirements (EPC requirements) which are laid down for each designated use. In section 8.4, we will explain the structure of an EPC calculation and which aspects play a part. Section 8.5 will briefly deal with the energy label for existing buildings.

In 2021, the legislation in the Netherlands will also have to be revised, so that here too we will meet the requirements for 'nearly zero energy building'. In section 8.6 we will briefly discuss what this means.

8.4 Energy performance of new buildings: the EPC calculation

The energy performance of new buildings is regulated in the Building Decree. The Building Decree includes energy performance requirements and a basic requirement of opaque parts (R_c) and transparent parts for new buildings (*U* value).
New homes, residential buildings and utility buildings must meet the energy performance requirements from the Buildings Decree. Per designated use there is a single energy performance requirement (EPC value), which must not be exceeded. The energy performance of a building is calculated using NEN 7120. The energy performance is expressed in the Energy performance coefficient (EPC). The basic principle is this: the lower the EPC value, the more energy efficient the building is.

The energy performance is an integrated energy efficiency requirement. This is intended to achieve that buildings have a minimum energy efficiency at an architectonic and installation level. How exactly this is realised and which measures are taken, is at the discretion of the parties in the construction process.
Higher energy use due to a 'poor boiler' with low generation efficiency, for instance, can be compensated by additional insulation in the facade. In order to ensure that the building as a good basic insulation quality, limits have been set in the Buildings Decree to the minimum requirements of the insulation of walls, roofs and floors. This is also referred to as 'safety net requirements'.

Basically, the energy performance requirements say that the total energy use of a building as a whole may not exceed the allowed maximum. The Building Decree lists the energy performance requirements for various designated uses. When the level of the EPC requirement per designated use was determined, account was also taken of the fact that some designated uses require more energy than others. A hospital for example will require more energy than an office, because a hospital is open 24 hours a day and usually is somewhat warmer.

An EPC calculation is formulated before the building is actually built. The ultimate use of the building is not yet known at that time. In order to work on the EPC anyway and to keep the requirements equal for all users, the energy performance standard assumes a 'standard occupancy behaviour'. Because of this standard occupancy behaviour, the energy use calculated by means of the energy performance standard does not represent the true energy use of the building! After all, the true energy use strongly depends on the behaviour of the users. The energy performance calculation is a so-called static calculation (see section 8.2).

Although the energy use should be calculated according to the energy performance standard, the standard by itself is not a design tool for determining the required performance of ventilators and/or cooling units for example.

The NEN 7120 standard should not hinder innovation. This is why an appeal can be made to the principle of equivalence in the Buildings Decree for energy-saving measures which have not yet been included in the standard.

Upon lodging the application for a construction permit, it must be shown that the EPC requirements are met. This means that in an early phase of the design process, besides choices concerning the actual construction, choices for climate installation and lighting must also have been made.

Elements of the EPC calculation

The calculation of the EPC looks at the building-related energy items. The non-building-related energy use is therefore left out of the equation. As mentioned above, the building-related energy use based on the energy use of standard occupancy behaviour is calculated. The EPC calculation is therefore a standardised calculation for the (assumed) energy use of a building. In the EPC calculation, the energy use is converted into the primary energy use.

The calculation takes account of the various energy items. These items are assigned a letter in the energy performance standard. The letters for energy items originate from a European standard and are used in all EU countries. When you come in contact with a French standard, you will find the same assignments of letters (derived from English terms):

- heating (H);
- humidification (hum);
- cooling (C) or summer comfort (SC);
- dehumidification (dhum);
- warm tap water (W);
- ventilators (V);
- lighting (L);
- auxiliary energy (aux) for the various energy items, this mainly refers to pumps;
- self-generated energy, such as the results of solar cells or CHP (deduction item).

EP_{tot}/EP_{admin} and EPC

Basically, the total typical primary energy use of a building in an EPC calculation (EP_{tot}) is worked out by finding the sum total of all calculated primary energy uses of all the items listed above. This total primary energy use is then compared to the energy budget (EP_{admin}) which depends on the size, shape and designated use of the building. The energy budget includes the EPC requirement of the designated use.

When a building has multiple designated uses, it is tested whether EP_{tot}/EP_{admin} is equal to or smaller than 1 for the purpose of the building permit. If a building only has one designated use, for example a home, EP_{tot}/EP_{admin}, is usually not used, but EPC is instead calculated by means of:

$$\mathrm{EPC}_{\mathrm{building}} = \mathrm{EPC}_{\mathrm{Building\ Decree}} \cdot \frac{EP_{tot}}{EP_{admin}}$$

This is basically the same, but causes some confusion in practice. Therefore, make sure you know whether people are talking about the EPC or the EP_{tot}/EP_{admin}. The term EP_{tot}/EP_{admin} is popularly termed the Q/Q. This term is from the predecessor of the NEN 7120 (the NEN 2916).

Example

A home has an EP_{tot}/EP_{admin} of 0.85. The EPC requirement for homes is 0.40. The EPC of this home is $0.40 \cdot 0.85 = 0.34$. The EPC therefore meets the requirements because the EPC is smaller than 0.40. This was already obvious from EP_{tot}/EP_{admin}, because it is smaller than 1.

From energy needs via energy use to primary energy

To be able to calculate EP_{tot}, a similar calculation is performed for each energy item, with the primary energy ultimately being calculated from energy needs. We here describe the basic design of the calculation, so you can get a clear idea of the calculation method.

The calculation for each energy item is divided into three steps each time.

1 First the energy need is calculated.

2 Then it is decided how much energy must be supplied to the building to cover this energy need.

3 Finally, the amount of energy supplied is converted into primary energy. Primary energy is the amount of energy derived from fossil fuels. In this calculation, all energy losses which occur, from extraction of the oil or gas to the delivery to a building are included. Especially when generating electricity, much energy loss occurs, since the efficiency of power station is not very high (approx. 40%).

We will explain this system based on the calculations for heat. For other energy items a similar method applies. Figure 8.3 shows this principle in the form of a diagram

Energy need

The energy need for heating is determined by performing a transmission calculation. This calculation takes account of the shape, the size, the thermal insulation, thermic mass, internal heat load and the amount of sunlight that enters the building. Account is also taken of the amount of ventilation air which must be heated and of course with the outside climate. In brief, you could say that the energy need of a building is the sum total of the amount of heat you need in each room during on year in order to keep the room at the desired temperature.

Supplied energy

The next step is to determine how much supplied energy ('on the meter') is required to supply this heat to the building. This concerns the various losses which occur before the gas is converted into heat at room level:

- In the building itself, energy losses occur between the central heating boiler and the rooms. We call this distribution and delivery losses. Consider for example energy losses through (poorly) insulated heating pipes running under the floor. The boiler will have to generate more energy than just the energy need. The energy lost in transit from the central heating boiler to the rooms will also have to be supplied by the boiler.
- In addition, the efficiency of the central heating boiler itself plays a part. Inside the boiler, (small) energy losses occur via the chimney due to the combustion of gas.

Primary energy

The final step is calculating the amount of primary energy that is needed to supply the required amount of energy to the building. A number of losses may occur:

- Transport losses. These are the losses between the building and the location where the energy is generated. For gas, these losses are zero, but for district heating these losses do indeed occur. Consider for instance the heat losses of the transport pipes located in a residential area and the electricity use of the pumps necessary to pump the district heating water from the central plant to the buildings.
- Conversion losses. These too are limited: the gas extracted from the ground can be used in buildings without any major conversions. This is different for electricity. Electricity is produced inside a power station by burning gas or coal for example. Much energy is lost during this process and this is set off in the conversion of energy use into primary energy.

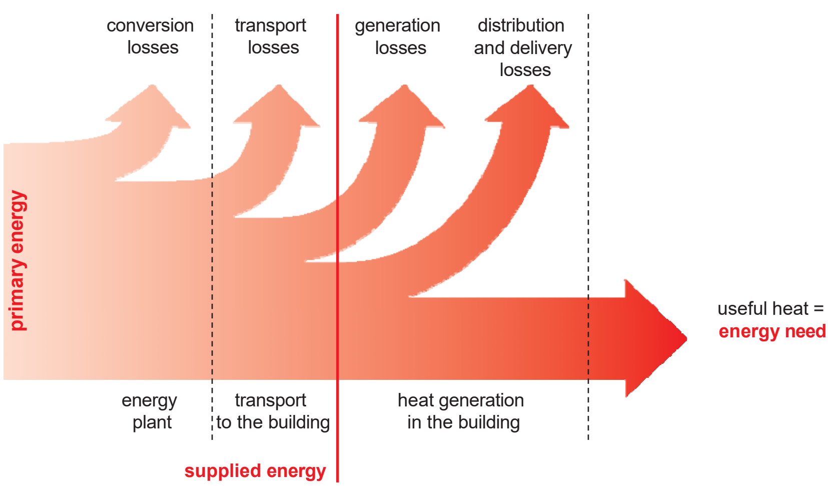

Figure 8.3 Schematic representation of calculating the primary energy use from the energy need.

For calculating energy use into primary energy use, you can use the following rule of thumb:

- 1 m^3 natural gas (on the meter) = $35.17\ MJ_{primary\ energy}$ (the combustion value of gas)
- 1 kWh electricity (on the meter) = $3.6\ MJ_{on\ the\ meter}/0.40 = 9.0\ MJ_{primary\ energy}$

The central (average) generation efficiency of electricity in the Netherlands is approx. 40%. If all 'bioenergy' is included (burning of biomass or use of biogas), this efficiency is approx. 47%. By deploying sustainable energy, the efficiency will increase in the future. For all energy items included in the EPC calculation, the above calculation is usually performed, whereby a calculation is performed which works out the primary energy use based on the energy need and the supplied energy.

A special item is the energy generated on the own grounds. Consider for instance solar boilers (see figure 8.4), PV cells and the electricity produced by combined heat and power. This energy is immediately set off as a deduction item (because of PV the amount of electricity to be supplied to a building becomes lower).

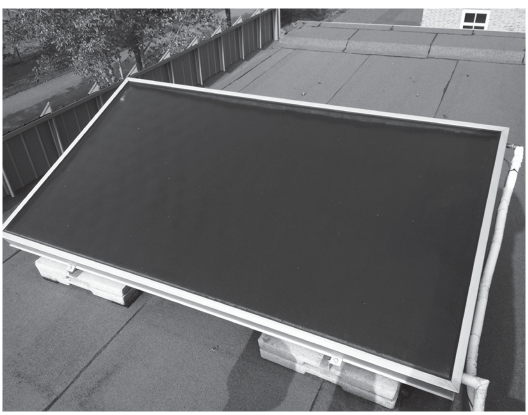

Figure 8.4 A solar boiler on the roof of a home sustainably generates warm tap water (partly)

Performing an EPC calculation

An EPC calculation cannot be done manually as the calculation is too complex for this. There are a number of computer programs available, which can help you to perform these calculations. The way this is done is described below.

Schematizing the building

You start by making a diagram of the building. The complete geometry of the building must be entered into the software. The building must be divided into different fields with designated uses. The structural and installation parameters are then assigned to these fields. Basically, the calculation is divided into many small calculations which are added together by the end of the calculation.

Structural input parameters

Subsequently, the structural input parameters have to be entered. This means that the following details have to be available:

- R_c value, U value, g value of the outer walls, roof and floor, including the surface areas of the different parts;
- orientation and level of shading of the windows and facade elements;
- thermal mass of the building;
- infiltration characteristics of the building (such as the type of facade).

In order to properly enter the structural input parameters, consultation with the architect will need to take place.

Installation input parameters

For the installation characteristics, many details concerning installation need to be entered. The list below is not exhaustive, but does provide you with an idea about the details you have to collect.

- Heating:
  - type, efficiency and capacity of the central heating boiler;
  - supply temperature of the heating system;
  - presence of (un)insulated pipes and ducts;
  - auxiliary energy of the central heating boiler;
  - presence of any (additional) circulation pumps.
- Cooling units (if present):
  - type, efficiency and capacity of the cooling installation;
  - supply temperature of the cooling system;
  - auxiliary energy for cooling.
- Warm tap water (W);
  - type of tap water appliance;
  - pipe lengths of the tap water appliance to the bathroom/kitchen;
  - diameter of the pipes;
  - presence of a shower heat recovery system (including efficiency).
- Ventilation:
  - type of ventilation system (natural ventilation, balanced ventilation, etc.);
  - flow rate of the ventilation system;
  - efficiency of heat recovery;
  - ventilator capacity.
- Humidification system (if present):
  - type of humidification.
- Solar boilers (if present):
  - surface areas and orientation of the solar panels;
  - type of solar boiler;
  - auxiliary energy for the solar boiler system.
- PV system (if present):
  - surface areas and orientation of the PV system;
  - watt peak capacity of the PV system.
- Lighting (input only required for utility buildings - for residential buildings fixed values apply which cannot be adjusted):
  - installed power for lighting;
  - type of lighting control.

In order to properly enter the installation input parameters, consultation with the installation consultant or contractor will need to take place.

Final result verification

When all details have been collected and entered, it needs to be verified whether EP_{tot}/EP_{admin} meets statutory requirements. If it doesn't, additional measures will have to be taken in consultation with the architect and the installation consultant. The building physicist can advise in this since he has knowledge of both installations and structural solutions.

8.5 Energy efficiency of existing buildings: the energy label

It is established in the EPBD that existing buildings need to be provided with an energy label when the building changes owner or tenant. An existing building's energy label is calculated in a similar way as the energy performance of a new building. The calculation of the energy label is therefore also a static calculation based on a standardised occupancy behaviour of the users of the building.

The energy label of a building can vary from an A-label to a G-label. A G-label means that there are many possible ways of implementing energy-saving measures in a building. In a building with an A-label, most energy-saving measures have already been implemented.

8.6 Nearly zero energy buildings

As of 2021, all new buildings will be 'nearly zero energy'. The first question on your mind will probably be: 'what is nearly zero energy'? During the period 2015 - 2020, all EU countries will define the exact meaning of nearly zero energy buildings in their country. The EU has recorded in the EPBD Recast which preconditions these buildings must meet.

A nearly zero energy building must meet three separate requirements:

- A maximum energy need requirement per m^2. Only the energy needs for heating, cooling and lighting are considered.
- A maximum primary energy use requirement per m^2. Only the total primary energy use is considered here, so including all energy items and energy generation.
- A minimum requirement concerning the share of renewable energy. This will encourage that part of the energy use in a building is covered by the renewable sources (such as wind, solar and geothermal energy).

For the Netherlands, the arrival of nearly zero energy buildings means that at that point we must say goodbye to the EPC as indicator for the performance of a building. For construction, this means that a new way of designing energy efficient buildings will develop. It is possible in EPC to compensate poor insulation of the shell with a great heating system: as long as the total EPC remains below a certain value. This is no longer possible for these buildings: all three requirements must be met. It will become increasingly important to limit the energy need (first requirement). This will result in new concepts and design solutions in buildings which will show many similarities with the solutions used in passive building.

8.7 Passive building

The EPC calculation method was introduced in the Netherlands in 1995. A result of this introduction is that the market parties started designing buildings which score well in the EPC method. This mostly means that rather many installations are present in those buildings, and less attention is given to applying high-quality insulation materials or sun-oriented building. We also refer to this as ‘active building’: the installations ensure the building is energy efficient.

The opposite of active building is passive building. Passive building is popular in countries surrounding the Netherlands, and also in the Netherlands some passive buildings have been realised.

Passive building is characterised by the following (fixed) principles:

- A passive building is very well insulated. This means R_c values of 8-10 m^2·K/W and the application of triple glazing. The first step is to reduce heat loss.
- A passive building has sufficient thermal mass which can be used to store heat and stabilise the temperature in the building.
- Passive buildings have a balanced ventilation system with heat recovery possibilities.
- A passive building has a southern orientation with large windows facing south and smaller windows facing north. During the winter, the sun is low and therefore heats the building with free solar heat. In the summer, the sun is high in the sky. This high sun can be easily kept out by making use of overhangs and sun blinds. This way, a passive building profits from the sun in the winter, and can easily keep out the sun in the summer.
- A passive building also has internal zoning. This means that rooms where heat is desirable are located on the south. These are living rooms, nurseries and suchlike. Rooms which produce heat, or which do not require heat face north. These are kitchens, stairwells, storage areas, garages and suchlike.

Passively built homes are often additionally provided with a solar boiler and or solar cells for generating sustainable energy.

9

Sustainable construction

ir. I.M. Kuijpers-van Gaalen MBA

Sustainable construction means that homes, buildings and other structures are developed and used with respect for people and the environment. Sustainable construction does not just concern energy-saving in homes and buildings, but also includes:

- the use of sustainable materials with take account of the environment and the health of residents and users;
- a healthy indoor environment due to good ventilation which prevents moist, mould and accumulation of hazardous substances.
- sustainable demolition, where materials can be used again (reuse and recycling);
- responsible use of water;
- respect for the environment;
- prevent raw materials for construction from being depleted.

Sustainable construction is therefore a very broad term.

There is a number of models and systems with which you can 'measure' the sustainability of a building. In this chapter, we will briefly address the two main models used in the Netherlands: BREEAM-NL and GPR. It is beyond the scope of this book to discuss the models in great details; for this, we refer you to the internet site of the models in question.
Besides BREEAM-NL and GPR, the American model LEED is also used in construction projects on occasion. LEED can be compared with BREEAM-NL, although its main focus is on the American market. For more information on LEED, we refer you to the website of the US Green Building Council, the party which develops LEED.

9.1 BREEAM-NL

BREEAM-NL is a method with which the sustainability of new buildings, existing buildings, areas and demolition projects can be assessed in its entirety. BREEAM-NL is derived from the international BREEAM model developed in England by BRE. In the Netherlands, BREEAM-NL is managed and developed by the Dutch Green Building Council.

BREEAM-NL has three different quality marks:

- BREEAM-NL New building and Renovation;
- BREEAM-NL In Use;
- BREEAM-NL Demolition and Dismantling;
- BREEAM-NL Area.

BREEAM-NL New buildings and Renovation

With BREEAM-NL New buildings and Renovation, new developments and large-scale renovations can be assessed on sustainability performance. BREEAM-NL New buildings and Renovation can be used for offices, retail, schools, industrial buildings, homes, meeting and accommodation facilities, and data centres.
Buildings are assessed on nine different sustainability items. The items are indicated by a three-letter code, derived from the English term of the sustainability item.

- Management (MAN). This theme includes aspects such as the lay-out of a sustainable construction site, notification of neighbours and ensuring correct completion of the building.
- Health (HEA). Daylighting, view, high-quality lighting, air quality, thermal comfort and acoustics are items included in this theme.
- Energy (ENE). For example, energy-efficient designs, installing additional meters, implementing renewable energy and using energy-efficient appliances are covered in this theme.
- Transport (TRA). In this theme, public transport and basic facilities, transport plans, and pedestrian and cyclist safety play a role.
- Water (WAT). This is not just limited to the use of water, but, for instance, also the reuse of (rain)water.
- Materials (MAT). This theme pays attention to the origins and environmental impact of the construction materials.
- Waste (WST). This category does not just assess limitation and separate collection of waste during construction, but also during the operational phase.
- Land use and ecology (LE). Reuse of land and respect for the plants and animals present at the construction site form part of this category.
- Pollution (POL). Within this theme group, various aspects of pollution are dealt with, such as light pollution, pollution due to refrigerant leakages and noise pollution.

The nine sustainability themes are subdivided into credits. For each credit a certain number of points can be scored if it is shown that the requirements of this credit have been met.

In order to determine the final score of a project, first the separate scores of each sustainability theme are determined in relation to the maximum score. In the final score, each category has its own weighting factor: management 12%, health 15%, energy 19%, transport 8%, water 6%, materials 12.5%, waste 7.5%, land use & ecology 10% and pollution 10%. This leads to a final score expressed in stars in combination with an English mark ranging from pass to outstanding.

stars		score
★	pass	≥ 30%
★★	good	≥ 45%
★★★	very good	≥ 55%
★★★★	excellent	≥ 70%
★★★★★	outstanding	≥ 85%

Figure 9.1 BREEAM stars and scores

BREEAM-NL In Use

Sustainability is more than just erecting a sustainable building. As soon as the building is completed, it will start being used, and then it will be important to pay attention to a sustainable and conscious use of the building. In order to clarify this, BREEAM-NL In Use was developed. This allows the sustainability performance of an existing building to be monitored. As with BREEAM-NL New buildings and Renovation, assessments are made on nine sustainability categories: management, health, energy, transport, water, materials, waste, land use & ecology and pollution. These credits are, of course, adapted for existing structures. BREEAM-NL In Use also makes a distinction between three elements:

- asset: the sustainable performance of the building;
- management: the level of sustainability at which the building is managed;
- use: the sustainable use of the building.

As is the case with New buildings and Renovation, the final score of an In-Use assessment is also expressed in stars and an English mark ranging from pass to outstanding.

BREEAM-NL Demolition and Dismantling

In order to encourage parties to contribute to the circular economy, BREEAM-NL Demolition and Dismantling was developed. Demolition projects are assessed on eight different sustainability categories: management, health, materials, energy, transport, water, land use & ecology and pollution. For BREEAM-NL Demolition and Dismantling too, the final score is expressed in a number of stars and a mark ranging from pass to outstanding.

BREEAM-NL Area

The BREEAM-NL Area assess not just the sustainability performance of a single building, but of an entire area. Area developments are assessed on six sustainability categories: area management, synergy, sources, spatial development, wellbeing & prosperity and area climate. For BREEAM-NL Area too, the final score is expressed in a number of stars and a mark ranging from pass to outstanding.

9.2 GPR

In comparison to BREEAM-NL, GPR is a more accessible model with which to map out the sustainability of buildings and urban development areas. The GPR has a high level of freedom and flexibility; the model is les rigid than BREEAM. GPR is an originally Dutch model, which was developed by W/E consultants commissioned by the Tilburg Municipality. The abbreviation GPR refers to Gemeentelijke Praktijk Richtlijn: Municipal Practice Guideline.

The GPR currently distinguishes different modules:

- GPR buildings;
- GPR urban development.

In addition, a number of associated modules are available which will not be discussed here. For these, we refer you to the GPR website.

GPR Buildings

The name says it all: GPR Buildings lets you measure the sustainability of buildings. Not just new developments and large-scale renovations, but also existing structures can be assessed with GPR. GPR Buildings can be used for homes, offices, schools, places of business, accommodation facilities, meeting facilities, shops and healthcare-related real estate. In addition, there are so-called GPR Specials for railway station buildings, sports buildings and swimming pools.

GPR Buildings assess buildings on five themes: energy, environment, health, quality of use and future value.

- Energy. In this theme, the philosophy of the trias energetica is leading. The results for energy performance calculations play an important role in this theme. A number of additional criteria have also been included which are not covered by the energy performance calculations.
- Environment. The environmental impact of (construction) materials and the assessment whether renovation is more sustainable than new development is considered in this theme. In this theme, attention is also given to limiting water use in buildings.
- Health. The objective of this theme is realising healthy buildings to live and work in. Consider for example limiting noise pollution, sufficient fresh air, comfortable ventilation and sufficient daylight.
- Quality of use. In this theme, it is encouraged that designers think about the quality of use of buildings. The aim is to make buildings appropriate, accessible, functional, of good technical quality and in a safe living environment. GPR Buildings offers insight into the extent to which a building or design meets the requirements of the target population.
- Future value. Empty buildings and unattractive residential neighbourhoods are a social and financial problem. They have not been realised futureproof at the time they were built. For construction or renovation of buildings, it must be taken into account that the function and amenity value of the area may change in the future. A high score on this theme, a building can be adapted to changing user requirements or law and legislation without great expenditure or wasting of materials.

In general, GPR uses menu selections (for the themes health, quality of use, and future value) and the results of calculations which have to be made anyway in the context of building permits (such as the EPC calculation). A score is determined for each theme (from 0 to 10). No overall score is determined as is the case for BREEAM. It is possible that a building scores 9 for energy and 7.5 for future value in GPR.

GPR Urban Development

Not just the sustainability of a single building is assessed with GPR Urban Development, but that of an entire area. Area developments are assessed on five sustainability categories: energy, space and supply; wellbeing and health; practical value and future value. For GPR Urban Development, too, a score of 0 to 10 per theme is given.