Environmental/energy performance of Buildings, recording operational energy use in EPB (MPG)

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Client: Stichting National Environmental Database
Project Leader: John Drissen

Author(s):

LBP|SIGHT
David van Nunen
Hilko van der Leij
Jeannette Levels-Vermeer

1 Contents

Standards

EN15804+A2	NEN-EN 15804:2012 + A2 (2019) *'Sustainability of construction works - Product environmental declarations - Basic rules for the product group construction products'*
ISO 14025	ISO 14025:2010 "Environmental labels and declarations - Type III environmental declarations - Principles and procedures"
ISO 14044	ISO 14044:2006 "Environmental management - Life cycle assessment - Requirements and guidelines"
Assessment Method	Environmental Performance Assessment Method for Construction Works, version 1.1 March 2022
NEN-EN 15978-1:2011 (Draft)	Sustainability of structures – Assessment of the environmental performance of buildings – Part 1: Environmental performance
NTA 8800:2022 (nl)	Energy performance of buildings - Assessment Method
Level(s)	A common EU framework of core sustainability indicators for office and residential buildings. Publication version 1.1, January 2021.
Level(s) indicator 1.1	Use stage energy performance. User manual: introductory briefing, instructions and guidance (Publication version 1.2), July 2021.
Level(s) indicator 1.2	Life cycle Global Warming Potential (GWP) User manual: introductory briefing, instructions and guidance (Publication version 1.1), January 2021.

1. Introduction

Stichting NMD considers it desirable to provide insight into material-related carbon emissions and carbon emissions from use stage energy in equal units and to consider these in conjunction in order to ensure a measurable target range for construction industry carbon emission reductions.
Stichting NMD therefore endorses that stated in Annex III of the proposal for EPBD IV[1]. The proposal states that a building's energy performance should be expressed not only in terms of energy use (kWh/yr) but also expressed as a calculated Global Warming Potential performance.

Annex III of the EPBD recast proposal includes a direct reference to EN 15978. This standard explicitly states that energy use should be divided according to energy carrier(s), (i.e. grid electricity, supplied gas, thermal energy, etc.) and this must be reported. Annex III of the EPBD IV recast proposal refers to the LEVEL(s) framework for assessing a building's elements and technical equipment.

Using product cards for energy carriers and by having knowledge of the energy carrier per connection enables the standardised energy use according to NTA 8800 to be expressed in 19 impact categories in line with the Assessment Method for the environmental performance of construction works. The environmental impact of energy savings can then be compared with the environmental impact of the energy-saving measures of additional building materials and/or construction work installations.

This report investigates how building-related energy use should be defined and applied in the context of the Assessment Method, aligned with EN 15978 and the LEVEL(s) framework[2]. Possible relationships with EU taxonomy have not yet been incorporated in this document.

1.1 Objective and target group

This report has been produced for the following target groups:
- Stichting NMD as manager of the National Environmental Database (NMD). This report acts as a supplement to the Assessment Method for operational energy use (B6).
- Organisations that aim to promote sustainability in the built environment through such things as certifications and use NMD data for this, including data on construction works' operational energy use.
- Market parties such as engineering and consultancy firms and contractors active in the infrastructure project and B&U sectors that use this as a source of information for applying NMD data via calculation tools.
- Compilers of LCAs to understand the principles of determining the operational energy use of construction works.

[1]European Commission (2021). COM(2021) 802 final, ANNEXES to the proposal for a European Parliament and Council Directive on the energy performance of buildings (recast). Consulted on 24-01-2023, from https://eur-lex.europa.eu/resource.html?uri=cellar:c51fe6d1-5da2-11ec-9c6c-01aa75ed71a1.0018.02/DOC_2&format=PDF

[2] European Commission (2022). Level(s) common framework. Consulted on 24-01-2023, from https://susproc.jrc.ec.europa.eu/product-bureau//product-groups/412/home[3]The final version is expected at some point in 2023.[4]'Regulated' means the energy demand of integrated systems (services) that fall under the EU Directive Energy performance of buildings (2018/844/EU) and the national implementations of this. The services that are included can be a national or regional choice.

2 Building-related energy use in the EPBD, NEN-EN 15978 and LEVEL(s) framework

EN 15978, the Level(s) Framework and NTA 8800 provide a well-founded framework for considering building-related energy use within environmental performance studies.

The WGBC and the DGBC Whole Life Carbon framework can be considered as a supplement to this framework. In this framework, the WGBC considers both operational energy use as well as material-related emissions. The Whole Life Carbon framework is based on the life cycle phases specified in EN15978. Unlike the Assessment Method, however, module D is declared separately and is not factored integrally. As the Whole Life Carbon framework is being developed in parallel to the Environmental/Energy Performance of Buildings system, further substantive comparison is limited.

2.1 EPBD (Energy Performance of Buildings Directive)

The EPBD is the European Parliament and Council Directive on the energy performance of buildings. Among other things, the EPBD sets requirements and a framework for calculating energy performance of buildings and minimum energy performance requirements for new buildings and renovations. Both indicator 1.1 and 1.2 of the LEVEL(s) framework and the requirements for BENG are based on the EPBD.

The EPBD recast proposal dated 15 December 2021, if passed, will be relevant for processing operational energy use[3]:

'Proposal for a EUROPEAN PARLIAMENT AND COUNCIL DIRECTIVE on the energy performance of buildings (EPBD recast 21 October 2022)

ANNEX III

REQUIREMENTS FOR CALCULATING THE GLOBAL WARMING POTENTIAL (GWP) DURING THE LIFE CYCLE (referred to in Article 7)
Calculating the global warming potential (GWP) over the life cycle of new buildings under Article 7(2).
In order to calculate the global warming potential (GWP) over the life cycle of new buildings under Article 7(2), the total GWP should be reported as a numerical indicator for each life cycle stage, expressed as **kg CO_2 eq/m² (of the usable area) averaged for one year of a reference study period of fifty years.** The data and scenario selections and calculations are carried out in accordance with **EN 15978 (EN 15978: 2011**. Sustainability of construction works. Assessing the environmental performance of buildings. Calculation method). The parts of the building and technical equipment to be assessed are defined in the joint EU **Level(s) framework for indicator 1.2**.
If a **national calculation instrument or method** exists or is prescribed for obtaining information or obtaining building permits, that instrument or method can be used to provide the required information.

[3]The final version is expected at some point in 2023.[4]'Regulated' means the energy demand of integrated systems (services) that fall under the EU Directive Energy performance of buildings (2018/844/EU) and the national implementations of this. The services that are included can be a national or regional choice.

Other calculation instruments or methods may be used if they meet the minimum criteria set in the joint EU Level(s) framework. Data on specific construction products calculated in accordance with [the revised Construction Products Regulation] should be used if available.'

2.2 NEN-EN 15978-1:2021, building-related energy use (B6)

The 'NEN-EN 15978-1:2021' standard has not yet been finalised. The formal vote takes place in May 2023. There are various changes for operational energy use in NEN-EN 15978-1:2021 compared with NEN-EN 15978:2011. The draft NEN-EN 15978-1:2021 standard is used in this analysis in order to incorporate these changes.

NEN-EN 15978 specifies that energy use must be split across the various energy carrier(s) and this should be reported.

With respect to energy use this NEN-EN standard makes a division between:
- B6.1 the energy use of regulated[4] building-related systems (services) (such as lighting, heating and ventilation)
- B6.2 the energy use of building-integrated systems (services) that are not regulated (such as lifts, security systems and communication systems)[5]
- B6.3 other energy use related to user activities in the building (such as plug-in appliances: computers, washing machines, fridges, audio-visual equipment, plug-in lighting and production or process-related equipment that is used in the building). B6.3 may be reported as additional information.

According to NEN-EN 15978, the construction work installations mentioned under B6.1 and B6.2 must also be taken into account in the material-related environmental impact. B6.1 and B6.2 can be considered as building-related impact and should therefore have a place in the assessment method. This division is necessary to stay in line with the energy performance requirements as set in EPBD, NTA 8800 and LEVEL(s).

The draft standard EN 15978-1:2021 provides the following guidelines:
- The energy performance of the structure being assessed should be quantified based on the calculated or measured annual energy that is used to meet the various demands associated with the defined use of the building, determined in accordance with the requirements stated in EN ISO 52000-1. The calculation interval <time> (e.g. every hour, monthly or annually in accordance with EN52000-1) used to estimate energy use, must be stated. The calculation interval set in BENG is an annual interval.
- Energy use is split according to energy carrier(s), (i.e. grid electricity, supplied gas, thermal energy, etc.) and this must be reported[6].

[4]'Regulated' means the energy demand of integrated systems (services) that fall under the EU Directive Energy performance of buildings (2018/844/EU) and the national implementations of this. The services that are included can be a national or regional choice.

[5] The NTA has made a reservation for this in the standard. As soon as this is available it will be added to the mandatory provision in B6.2[6] Contracted by Stichting NMD, LBP|SIGHT produced product cards for energy carriers. For this see: LBP|SIGHT (2022), LCA Report on Product Cards for Energy Carriers for National Environmental Database, https://milieudatabase.nl/rapport-over-het-opstellen-van-productkaarten-nmd-van-energiedragers/

[6] Contracted by Stichting NMD, LBP|SIGHT produced product cards for energy carriers. For this see: LBP|SIGHT (2022), LCA Report on Product Cards for Energy Carriers for National Environmental Database, https://milieudatabase.nl/rapport-over-het-opstellen-van-productkaarten-nmd-van-energiedragers/

- All impact and aspects relating to the use of operational energy are allocated entirely to the building.
- The energy demand of construction works must be calculated in accordance with EN52000-1 and ISO 52000-1, annex B.
- In a post-construction assessment, the impact of energy used for maintenance (Module B2), repair (Module B3) and replacement (B4) of the building and its components is unlikely to be distinguishable separately within the measured energy use (Module B6). This aspect must be taken into account when comparing the results of assessments prior to and after construction.

Module B6 also takes into account the energy generated within the building:

- The amount of building-generated energy and the exported amount is calculated in accordance with ISO 52000-1 (clauses 11, 11.6, 11.6.2). The amount of exported energy is presented in the 'Exported energy - [MJ]' indicator and is stated in Module B6.
- In accordance with FPr EN15643 requirements, the standard approach for assessing the upstream impact and aspects related to the on-site-generated and exported energy is Approach A, as shown below. The upstream impact comprises the embodied emissions of the energy-generation systems.
- Apart from the impact that is embodied (see Approach A and Approach B below), in the described energy-generation unit/systems, all impact and aspects related to the building's energy use must be assigned to Module B6. Substitution benefit impact arising from exported energy is reported in module D2. The exported energy declared in module D2 substitutes 'the most likely corresponding energy supply', such as the national or regional grid mix.

The Module B6 scenario defines per energy carrier the imported energy that is used to meet the specified demand and the energy exported per energy carrier. The scenario specifies how imported and exported energy streams are quantified (e.g. the specifications of solar panels, including quantifying the amount of energy that is produced on site and how much of this is exported).

NEN-EN 15978-1:2021, calculation method for energy use from on-site generation and exported energy

The calculation of used energy and exported energy from on-site generation must be in line with EN ISO 52000-1. Energy use from on-site generation, exported energy and imported energy differs over time. An annual calculation is standard. An hourly calculation may also be used within EN 15978. The method used must be harmonised with national regulations. An annual time interval is used within BENG and for Net Zero homes[7].

- **Annual basis**: this is a simplified representation of energy use (on-site generation, import and export) based on the annual statement of on-site generated energy and imported energy. This is the standard method.
- **Hourly basis**: this is a precise representation of energy use (on-site generation, import and export) based on hourly intervals (or shorter intervals).

Capital goods for on-site energy generation

[7] https://www.milieucentraal.nl/energie-besparen/aardgasvrij-wonen/energieneutrale-woning/#kenmerken-energieneutraal-huis[9] **Primary energy use** refers to the required energy before this is subject to conversion and transformation processes. Primary energy comprises both non-renewable as well as renewable energy. Together, this forms the total primary energy.

Within EN15978 (7.5.6.8.2. standard method, approach A) capital goods for energy generation starting from the delivery of the construction work fall into module A1-A3. Maintenance, repairs and replacements of these capital goods appear in modules B2-B4. No distinction is made here between capital goods for energy generation that form part of the building's structure (for example solar panels that also serve as roofing) and energy-generating capital goods that do not form part of the construction work (such as solar panels adjacent to the building).

When capital goods for energy generation are located within the construction work's plot, but are not connected to the construction work's energy supply and the energy output is supplied exclusively outside the boundaries of the construction work, the capital goods and generated energy are not allocated to the construction work. This method is in line with ISSO 75.1, as used for energy labels.

EN 15978 specifies a method B for processing capital goods: when an energy system has a dual function, for example solar panels that are also part of the roof system, 50% of the materialisation is allocated to the building (A1-A3) and 50% to energy generation (B6). Method A is used as standard.

NB. In the Dutch context, energy-generating objects installed in or on a construction work and where the energy generation is incorporated in the BENG calculation, the environmental impact is determined in accordance with the Assessment Method for environmental performance of construction works.

Exported energy
Benefits of exported energy are declared in module D2. As standard, these benefits are based on the substitution of today's annual average national energy mix. Alternative methods, such as benefits based on the anticipated energy mix until 2050, may be reported as an addition.

2.3 Level(s)

Level(s) is a European framework to investigate and report on the sustainability of construction works. Use of the Level(s) framework is voluntary. Building-related energy use appears in macro objective 1 of the Level(s) framework. Within objective 1, indicator 1.1 considers the operational energy use in **kWh/m^2/yr**. Indicator 1.2 considers the Global Warming Potential over the total life cycle in **kg CO_2-eq./m^2/yr**. Operational energy use (B6) is also part of indicator 1.2.

The Level(s) framework is used for evaluation during three project phases:

- Level 1: conceptual design
- Level 2: detailed design
- Level 3: 'As-built' and in use

The level of detail, available data and analysis requirements increase per level. As summary of the requirements for the Level(s) framework, this report assumes level 2, 'detailed design'. This is the phase in which EPB and BENG requirements are applicable when applying for an environmental permit within the Netherlands.

Level(s) uses the reference unit 'per m^2 of the total usable floor area'[8]. The reference standard 'IPMS Office 3' is used for this. Within Level(s) you can deviate from this standard as long as you indicate this clearly.

2.4 Levels indicator 1.1, 'Use stage energy performance'

Within indicator 1.1, Level(s) specifies that the energy performance calculation must be carried out in line with the national or regional calculation methods used at the construction work's location. It is possible to deviate from this under the condition that the calculation and assessment method used is in line with reported EN ISO 52000 standards and the EPB standards under 'mandate 480'.

Indicator 1.1. includes the energy performance in the use phase in kWh per year and in kilowatt hours per square metre per year (kWh/m^2/yr). This energy performance is measured in primary energy use[9].

System boundaries for energy use in Level(s)
Used electricity can be generated on site at the building, at nearby electricity generators and at more distant electricity sources (Figure 2.1). On-site generated electricity may also be exported.

The primary energy use originating from energy generated outside the system boundaries of the construction work are calculated by multiplying the energy use by a primary energy factor that compensates for conversion and transport losses. This includes the losses within the grid, as well as energy losses during primary energy production. The term primary energy use applies to both renewable as well as non-renewable energy. This energy factor differs per energy source and for the different distances at which the energy is generated. Electricity losses within the construction work's system boundaries are already incorporated in the construction work's energy use.

[9] **Primary energy use** refers to the required energy before this is subject to conversion and transformation processes. Primary energy comprises both non-renewable as well as renewable energy. Together, this forms the total primary energy.
[9] **Primary energy use** refers to the required energy before this is subject to conversion and transformation processes. Primary energy comprises both non-renewable as well as renewable energy. Together, this forms the total primary energy.

Within Level(s), the primary energy is calculated using the used energy and primary energy factors. The **primary energy factors** are calculated as: 'total used energy, including conversion and transformation losses' ÷ 'supplied energy'.

The primary energy factors may be based on national or regional average values, or on location-specific values. Within Level(s), determining and reporting on the primary energy factors must take place in accordance with EN 17423. Standard primary energy factors can be found in EN 52000-1 (Annex B.10) and in EN 15603 (Annex E).[1010] In option 1, a simplified approach may be adopted by focussing on the possible trade-off between the embodied impacts of construction materials and achieving a Net Zero Energy Building (NZEB) performance. This is particularly important because the impacts associated with the manufacture of construction materials will already have taken place upon completion of the building and, moreover, can be directly influenced by design decisions. 27 In addition to the embodied impacts associated with construction materials, the use stage modules relating to maintenance, repair, and replacement (B2, 3 and 4) shall be based on the clients required service life for the building as well as scheduled maintenance, repairs and replacements of construction products.

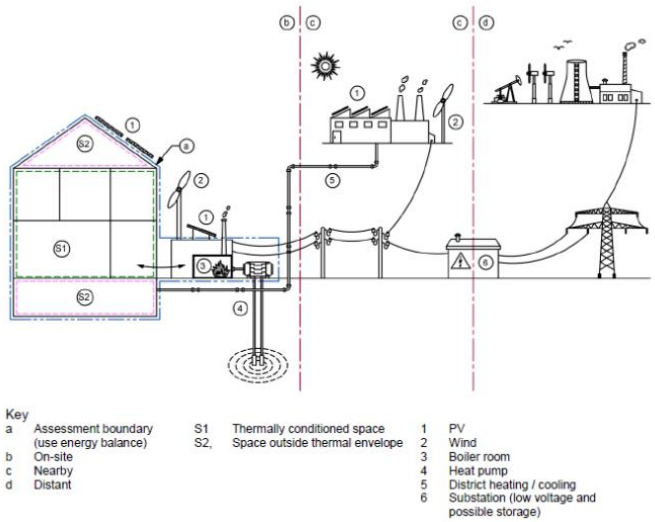

Figure 2.1
Building system boundaries, the blue line indicates the system boundaries of the construction work.

Level(s) indicator 1.1 report

Level(s) offers the table 2.1 report format for indicator 1.1 for level 2.

Table 2.1
Report format Level 2, indicator 1.1, Level(s)

Level 2 reporting item	**Information to provide (select/delete as appropriate)**
Type of assessment	Building permit, as built (calculated) EPC or tailored assessment
Calculation method	Specify the method and any software tools used
	The time interval for the data used by the method e.g. monthly, daily, hourly

Delivered energy use assessment for the building

Building service	**Energy need**	**System efficiency [1]**	**Energy carrier [2]**	**Delivered energy per energy carrier**	**Non renewable primary energy factor [3]**		**Renewable primary energy factor [3]**		**Total primary energy factor [3]**	
	kWh/yr	Decimal	Free text	kWh/yr	Decimal factor	kWh/yr	Decimal factor	kWh/yr	Decimal factor	kWh/yr
Heating										
Cooling										
Ventilation										
Hot water										
Lighting										
Other (please specify) 4										
Exported renewable energy 5	n/a	n/a								
Total										

1. The efficiency with which delivered energy is converted into needed energy. For example, if a boiler converts 85% of the calorific value of a fuel into heat in water coming out of the tap or shower, the system efficiency would be 0.85. Dividing the energy need by the system efficiency will produce the delivered energy result (delivered energy can never be lower than the energy needed).
2. For example, energy carriers from distant sources: solid, liquid or gaseous fossil fuels; solid, liquid or gaseous biofuels

or grid electricity. From nearby sources: district heating or district cooling. From onsite sources: electricity from PV panels, electricity from wind turbines, heat from solar thermal, geothermal or aerothermal. In cases where more than one energy carrier is used for the same building system (e.g. hot water from a gas boiler and from onsite solar thermal) two rows should be made for hot water, one for each energy carrier. There must always be a dedicated row for each energy carrier for any given service. 3. Any given energy carrier may have a non-renewable factor and a renewable factor, or just one of the two. These factors may be greater than, equal to, or less than 1, although the combined total of non-renewable and renewable primary energy factors for a given energy carrier cannot be less than 1. 4. If the methodology requires other energy needs to be accounted for, or the user simply wants to do this, then one row should be used for each "other" energy service. 5. When making the entry for delivered energy for any exported renewable energy from the building, a negative number should be used.

Table 2.2

Energy performance assessment, results

	kWh/m²/yr
2 L2.1 EPBD services [1] non-renewable primary energy self-used (mandatory)	
L2.2 EPBD services[1] renewable primary energy self-used[2] (optional)	
L2.3 EPBD services[1] total primary energy self-used[2] (optional)	L2.1 + L2.2
L2.4 Exported renewable primary energy (mandatory)	
3 L2.5 EPBD services[1] non-renewable primary energy balance (mandatory)	L2.1 – L2.4
L2.6 Non-EPBD services non-renewable primary energy self-used (optional)	
L2.7 Non-EPBD services renewable primary energy self-used[2] (optional)	
L2.8 Non-EPBD services[1] total primary energy self-used[2] (optional)	L2.6 + L2.7
L2.9 Total primary energy self-used[2] (optional)	L2.3 + L2.8
L2.10 Total primary energy balance[2] (optional)	L2.9 – L2.4
1. For the purposes of comparability, EPBD services in Level(s) reporting should be considered as: heating, cooling, ventilation (including any humidification and dehumidification), hot water and lighting. 2. Self-used means energy delivered to the building as part of the building operation. This includes all energy delivered from all sources, including onsite sources for EPBD services, such as PV panels and solar thermal installations and ignores any excess of renewable energy from onsite sources that is exported. 3. Primary energy "balance" means the subtracting any exported renewable primary energy from the total "self-used" energy.	

2.5 Levels indicator 1.2, Life cycle Global Warming Potential

Indicator 1.2 quantifies the global warming potential (GWP) in kilogram CO^2-equivalent over the total life cycle of a construction work. Indicator 1.2 is declared as kilogram CO_2-equivalent per square metre usable floor area over a reference period of 50 years (kg CO_2-eq/m^2).

In line with EN 15978, GWP is declared per life phase: production (A), use (B), end of life (C), additional benefits and costs (D). Within Level(s), the CO_2-eq is only mandatory for indicator 1.2. Level(s) does, however, offer the opportunity to supplement the results with the indicators as stated in EN 15804:A2.

Operational energy use is included in module B6. To calculate the operational energy use within Level(s) indicator 1.2, the energy use is applied as calculated for indicator 1.1. The imported energy must be recorded per energy carrier. The impact of exported energy must be recorded module D.

The energy scenario for the electrical grid must also be based on the country or EU-specific decarbonisation projections.

Level(s) indicator 1.2 report

For indicator 1.2. the GWP in kg CO_2-eq/m^2/year is declared per life phase for the reference building lifespan of 50 years within levels 2 and 3 (table 2.3). Dutch EPB calculation tools are suitable for the required calculations.

Table 2.3
Report indicators, Level(s) indicator 1.2, levels 2 and 3

Indicator	Unit	Product (A1-3)	Construction process (A4-5)	Use stage (B1-7)	End of life (C1-4)	Benefits and loads beyond the system boundary (D)
(1) GWP - fossil	kg CO_2 eq					
(2) GWP - biogenic	kg CO_2 eq					
GWP – GHGs (1+2)	kg CO_2 eq					
(3) GWP – land use and land use change	kg CO_2 eq					
GWP – overall (1+2+3)	kg CO_2 eq					
Notes: Impacts referred to the use of 1 m2 of useful internal floor per year for a default reference study period of 50 years.						

The standard assumption for indicator 1.2 is a building service life of 50 years. If a different lifespan applies, the above table should also be prepared for the modelled lifetime.

For indicator 1.2, two simplified scopes are permitted for declaring GWP. These are:
1: The production phase, replacements and operational energy use: A1-A3 and B4-B6[10]
2: The production phase, operational energy use and waste processing of materials, including module D. A1-A3, B6, C3-C4 and module D[11]

2.6 BENG & NTA 8800

BENG evolved from the Energy Agreement and the Energy Performance of Buildings Directive (EPBD). Since 1 January 2021, all new-builds must comply with the requirements for almost energy-neutral buildings (BENG). Three requirements apply here:

1. the maximum energy demand in kWh per m² usable area per year
    a. This is the sum of the energy demand of heating and cooling.
2. the maximum primary fossil energy use, also in kWh per m² usable area per year
    a. the sum of primary fossil energy use for heating, cooling, heating tap water and ventilators. For non-residential buildings, the energy use for lighting and humidification are also taken into account. If renewable energy sources are present on site, the avoided primary fossil energy use is deducted from the primary fossil energy use.
    b. 'Primary fossil energy use includes system losses (such as pipeline losses during heating), auxiliary energy (such as pumps) and efficiency of generators (such as the central heating boiler). This is not the case for energy demand.'[12]

[10][10] In option 1, a simplified approach may be adopted by focussing on the possible trade-off between the embodied impacts of construction materials and achieving a Net Zero Energy Building (NZEB) performance. This is particularly important because the impacts associated with the manufacture of construction materials will already have taken place upon completion of the building and, moreover, can be directly influenced by design decisions. 27 In addition to the embodied impacts associated with construction materials, the use stage modules relating to maintenance, repair, and replacement (B2, 3 and 4) shall be based on the clients required service life for the building as well as scheduled maintenance, repairs and replacements of construction products.

[11] In option 2, instead of looking at life cycle stages relating to repair and replacement, the focus is instead on the 'building material bank'. Stage D represents the net benefit of the materials used in the building if they were to be reused and/or recycled – sometimes referred to as the building material bank – and is also the starting point for considering whether a building is easy to deconstruct for reuse and recycling. The specific calculation rules stipulated in EN 15978 shall be followed.

[12] https://www.rvo.nl/onderwerpen/wetten-en-regels-gebouwen/beng/indicatoren

3. the minimum share of renewable energy in percentages
    a. Calculated as: renewable energy use ÷ total energy use.

The BENG requirements are based on the building-related energy use per m^2 usable area (UA). NTA 8800 is used as the Assessment Method for calculating the BENG values.

Within BENG, the fixed primary energy factor of 1.45 applies for electricity. Primary fossil energy is calculated within BENG 2. The primary energy as calculated for BENG is not suitable for the energy performance of operational energy use B6. Indeed, the pre-chain with associated losses is already included in the product cards. Using a primary energy factor would result in double counting. The primary energy factor is actually different per electricity generation source. Within the energy carriers' product cards, the used primary energy is included in parameter '101, Total use of renewable primary energy' and '102, Use of non-renewable primary energy'.
NTA 8800:2023 sets as system boundary the 'boundary within which all areas fall that are connected to a building (both inside and outside the building) where energy is used or produced'. In the Building Decree, the plot boundary forms the system boundary.

3 Suggested implementation of operational energy use (B6) within the Assessment Method

Definitions to be added, Annex I, Terms, definitions and abbreviations, Assessment Method.

Term (if applicable: translation from EN 15804) and explanation	Source	'Terms' (EN 15804)
Building-related regulated energy demand (B6.1) The sum of regulated energy demand for heating, cooling, humidification, dehumidification and lighting. The regulated energy demand is determined in accordance with NTA 8800.		
Building-related non-regulated energy demand (B6.2) The energy use of building-integrated systems (services) that are not regulated. This includes lifts, security systems and communication systems. 'Non-regulated' building-related systems are the systems that do not fall under the EPBD and NTA 8800.		
Primary energy Energy that is not subject to conversion or transformation processes.	NTA 8800	
Supplied energy Energy, indicated per energy carrier, supplied from across the system boundary to the building installations to enable the respective installation functions (heating, cooling, ventilation, heating tap water, lighting) or to produce electricity.	NTA 8800	
Usable area (UA) Area of a room or group of rooms, measured at floor level, between the partition walls enclosing the room or group of rooms in question, as detailed in 4.5 of NEN 2580:2007.	NTA 8800	
Exported energy Energy, expressed per energy carrier, supplied by the building installations within the system boundary and used outside the system boundary.	NTA 8800	
Building-related energy generation Energy produced by an on-site building-related installation.		

Operational energy for EPB (external supply) (suggestion for Chapter 3 of the Assessment Method)

The external supply environmental declarations must be used for EPB calculations. The external supply is declared in de production phase of the construction work (A1-A3). For supplied electricity, the environmental declaration 'Electricity, at consumer, materialisation external supply, average grid mix, per kWh' is used. For EPB, no distinction can be made in the type of electricity used. For energy produced from on-site generation, the environmental declaration 'Materialisation electrical grid, external supply, per kWh' must be used for construction works with a grid connection, where there is no or insufficient energy storage. This environmental declaration adds the electrical grid for building-related electricity generation. All product cards contain supply to the consumer at low voltage[13].

[13]The product cards for electricity assume supply to the consumer at low voltage. When electricity from the grid does not undergo conversion and is used at high voltage, this results in less conversion loss. Compared with low-voltage electricity from the grid, medium voltage saves 1.4% loss and high voltage 1.8% loss. The included product cards are also used for medium and high voltage applications.[14]'Regulated' means the energy demand of integrated systems (services) that fall under the EU Directive Energy performance of buildings (2018/844/EU) and the national implementations of this.

3 Environmental performance: operational energy use of buildings

To determine the integral environmental performance of a construction work, it is important to consider material-related emissions in the same units as emissions from operational energy use. EN 15978 presents the system for assessing the environmental performance of operational energy use of buildings (B&U). EN 15978 provides the basis for processing operational energy use within B&U for this Assessment Method.

Within EN 15978, operational energy use is declared in modules B6.1, B6.2 and B6.3. The substitution processes of exported energy are declared in module D2. Operational energy use is also declared in BENG based on the methods as set in NTA 8800. Within the European harmonised LEVEL(s) framework, operational energy use has a place within indicator 1.1 and 1.2.

This chapter contains the method for incorporating operational energy use in addition to the EPB calculation for the B&U.

3.1 Incorporating operational energy use within the Infrastructure project

The Infrastructure project client determines whether and how operational energy use is incorporated in ECI calculations. The Infrastructure project client determines the system boundaries and sets the requirements (for lighting, tunnel and other ventilation, movement of bridges or lock gates, etc.). The client can also use the life phases and calculation methods as recorded in this chapter for the B&U. The client determines the amount and type of energy carrier that must be used within the scope of the ECI calculation. For energy carriers, the client can rely on the available NMD category 3a energy carrier environmental declarations.

The rest of this chapter presents the calculation method for operational energy use within the B&U.

3.2 System boundaries for the energy performance of operational energy use B6

For buildings (B&U), the system boundary of the relevant materialisations and energy generation is in accordance with the system boundary as stated in the Building Decree: the plot boundary constitutes the system boundary. All energy generation resources at the system boundary that are connected to the building are taken into consideration, even if more energy generation resources than required for BENG are used.

3.3 Life phases operational energy use, B6

In line with EN 15978, the building-related regulated operational energy use is declared in the life cycle phase (module) B6.1. Module B6.1 is a mandatory component for the energy performance of operational energy use. For the B&U, B6.1 contains the sum of regulated energy demand for heating, cooling, humidification, dehumidification and lighting. The regulated energy demand is determined in accordance with NTA 8800.

In line with EN 15978, the building-related non-regulated energy use is declared in B6.2. The B6.3 module set within EN 15978 is not building related and therefore falls outside the scope of the Environmental Performance Assessment Method for Construction Works. In summary:

- **B6.1 Mandatory for the environmental performance of operational energy use.** The energy use of regulated[14] building-related systems (services) (such as lighting, heating and ventilation).
- **B6.2 Not part of the environmental performance of operational energy use.**[15] The energy use of building-integrated systems (services) that are not regulated (such as lifts, security systems and communication systems).
- **B6.3 Not part of the environmental performance of operational energy use.** Other energy use related to the building's user activities.

In line with EN 15978, exported energy is declared in module **D2**.

3.4 Environmental performance of supplied energy

Several category 3a environmental declarations are available for operational energy use from delivered/supplied energy[16]. These product cards were formulated based on the 'LCA Report on Product Cards for Energy Carriers for National Environmental Database' LBP|SIGHT (2023).

In calculating the environmental performance of operational energy use B6, the environmental declarations per energy carrier apply[17]. These environmental declarations contain the environmental impact of the energy carrier, including the materialisation of energy generation resources, environmental impact for conversion and transmission and declared benefits for substitution of capital goods through recycling. In calculations for operational energy use, the energy carriers must be included in module B6. The materialisation of the infrastructure for external energy supply is part of the energy carriers' environmental declarations. The materialisation of the infrastructure for external energy supply does not therefore need to be added separately in the production phase when operational energy use is part of the construction work calculation.

[14] 'Regulated' means the energy demand of integrated systems (services) that fall under the EU Directive Energy performance of buildings (2018/844/EU) and the national implementations of this.

[15] Non-regulated energy use does not form part of the EPBD and BENG. For consistent application and comparability, module B6.2 will not be included for the B&U until it is methodically added to NTA 8800. The use of lifts, escalators, and moving walkways are not regulated within the EPBD and NTA 8800. However, energy use can be determined in alignment with 'NEN-EN-ISO 25745-3:2015, Energy performance of lifts, escalators and moving walkways - Part 3: Energy calculation and classification for escalators and moving walkways'. If the NTA regulates and mandates to include the energy use of lifts, this should also take place in the calculation for operational energy use.

[16] Category 3 environmental profiles of energy carriers fall under category 3a, non-proprietary, non tested data, owned and managed by Stichting NMD based on generic data, without a 30% surcharge factor.

[17] The environmental declarations of electricity assume supply to the consumer at low voltage. When electricity from the grid does not undergo conversion and is used at high voltage, this results in less conversion loss. Compared with low-voltage electricity from the grid, medium voltage saves 1.4% loss and high voltage 1.8% loss. The included environmental declarations are also used for medium and high voltage applications.[18] Based on data quality, the environmental declarations of energy carriers are valid for five years. Annual reviews will take place to assess whether there are major changes in the energy mix production figures, which would result in an earlier review being required.

Within the calculations for the environmental performance of operational energy use B6, the environmental declaration of the Dutch average grid mix must be chosen for the electricity used[18]. The user of the building can choose their own energy supplier, therefore specific electricity sources cannot be selected when calculating the environmental performance of operational energy use (B6). The type of supplied heat is, however, building-related. For heat supply, the most representative type of heat supply must be used, such as high temperature heat supply or low temperature heat supply from grey or renewable resources.

The materialisation of external supply resources (electrical grid and power plants) should be declared within the environmental performance of operational energy use B6 in the phase in which the energy is used, which is B6.1. As stated in the Building Decree, inclusion of external supply is part of the EPB, with the aim of improving comparability between environmental interventions through local energy generation (e.g. material use of PV panels) and energy supply from an external grid (e.g. material use of power plants and distribution grid). For the environmental performance of operational energy use B6, the external supply of imported energy is not declared separately. The external supply from energy carriers is included in the energy carriers' product cards. The energy use and the external supply must be included in module B6.1. Benefits from substitution through recycling of capital goods from the external supply are included in the product cards for external supply, also incorporated in module B6.

3.5 Environmental performance of energy from on-site generation

The materialisation of energy generation resources within the system boundaries must be included in the production phase of construction work (A1-A3)[19]. In module B6, infrastructure of the electrical grid for energy from on-site generation must be included with the environmental declaration 'Materialisation electrical grid, external supply, per kWh'. For off-grid construction works, or construction works with sufficient energy storage capacity, no record of the materialisation of external supply from the electrical grid is required.

3.6 Energy balance

For the EPB, it is only necessary to declare the renewable energy generation systems that are needed to comply with the BENG requirements for licencing[20]. This means that a building can have more energy generation systems than declared within EPB. For the environmental performance of operational energy use B6 (as well as for BREEAM and the Municipal Practice Guideline for Buildings (GPR Gebouw)), the building-related energy generation systems and materialisations that are actually used and that fall within the system boundary must be declared.

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[18] Based on data quality, the environmental declarations of energy carriers are valid for five years. Annual reviews will take place to assess whether there are major changes in the energy mix production figures, which would result in an earlier review being required.

[19] For construction work-integrated energy generation resources, additional calculation methods may be developed. [20]NMD (2023). FAQ, How are PV panels included in the EPB calculation, consulted on 25-01-2023, via: https://milieudatabase.nl/faq/[21] Example: A construction work generates 1000 kWh in electricity from PV panels on the roof.

[20]NMD (2023). FAQ, How are PV panels included in the EPB calculation, consulted on 25-01-2023, via: https://milieudatabase.nl/faq/[21] Example: A construction work generates 1000 kWh in electricity from PV panels on the roof.

The applicable energy balance is also relevant for the net zero calculations.

The energy balance indicates the incoming and outgoing energy streams per energy carrier, and is calculated by subtracting all building-related renewable generated energy from the total final energy demand per energy carrier.

When more electricity is generated than used within the annual interval, we refer to this as net feed-in to the grid. The exported energy benefits are declared in module D2.

3.7 Energy storage

The following procedure should be used to position energy storage systems within environmental/energy performance:

- The materialisation of energy storage systems is part of the construction work and must be included in module A1-A3.
- If energy storage systems are used, module B6 does not need to include the electrical grid infrastructure (electrical grid materialisation, external supply) for electricity from on-site generation, although it must be plausible that the energy storage systems prevent feed-in for an average day. There are no standards for the required storage capacity. The required capacity depends on the installed capacity and energy use scenario. If no specific data are available, it must be demonstrated that the energy storage system can buffer on-site production. This is plausible for an installed storage capacity of 1.5 kWh per kWp of installed capacity.

3.8 Exported energy, D2

For exported energy, substitution benefits apply in module D2, equal to the exported energy equivalent. This means that when energy from PV is exported, this energy from PV is substituted in module D2. Energy carriers' technically most equivalent environmental declaration should be used for the substitution[21]. This is in line with the module D calculation for materials within the NMD Assessment Method. This prescribed method differs from EN 15978, where substitution of the average national energy mix is taken into account as standard.

It is possible that not all exported energy can be used by the energy supplier. In this case the energy will be 'lost'. For the time being, no correction is made for environmental/energy performance.

The timing of feed-in is becoming increasingly relevant. The electrical grid cannot always handle feed-in of solar or other energy and, in some areas, feed-in is already not permitted due to electrical grid overloads. In practice, this means that some electricity over-production is lost. However, an hourly calculation interval is required for correct modelling of the actual feed-in. Determining the energy generation and energy use per hourly interval is not realistic (administrative burden). To determine the actual net feed-in, non-regulated energy use must also be taken into account (B6.2 and B6.3). Again, this does not appear to be feasible as a standard (no uniform assessment method), which is why no correction is made for substitution benefits, although in practice a net loss does occur.

3.9 Use of environmental declarations for a building's energy demand

Within BENG 1, a construction work's energy demand is determined in accordance with NTA 8800 per square metre of usable area. BENG 1 does not yet take installation efficiency into account, which is why this energy demand is always lower than the construction work's energy use.

The primary fossil energy is calculated in BENG 2. This calculation is derived from such things as BENG 1 energy requirements, installation output factors, a deduction for building-related renewable energy generation and primary energy factors. The non-primary energy demand is relevant for the environmental performance of operational energy use B6, taking installation factors into account. This is the energy use as measured on the meter (supplied energy). For building-related renewable energy generation, the materialisation of the electrical grid without generation resources must be included (external supply) within the environmental performance of operational energy use B6. This is because the construction work has a grid connection. This does not apply to off-grid construction works nor for construction works with sufficient energy storage capacity. Energy carrier product cards for supplied energy include electricity generation, the grid, losses and conversion factors, which is why a primary energy factor is not applicable, as the addition of primary energy factors would result in double counting. The data required for operational energy use B6 is stated in table 3.1.

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[21] Example: A construction work generates 1000 kWh in electricity from PV panels on the roof.
The construction work itself consumes 800 kWh, the other 200 kWh is fed-in to the grid.

The PV panel is incorporated in the construction phase (A1-A5). For the 1000 kWh of electricity from on-site generation, the electrical grid's environmental declaration is added in module B6 under external supply.

200 kWh substitution of the energy carriers' most equivalent environmental declaration is available in module D2. In this case this is 'Electricity, Renewable, from PV, at consumer, per kWh'.[22]Develop Inc, 22 June 2022. Environmental performance energy and material use. [23]https://www.gww-bouw.nl/artikel/lantaarnpalen-geven-duur-licht/[24]Routekaart Energieopslag voorjaar 2023 (rvo.nl). 'Annex 4: Electricity storage, overview of technologies' offers an overview of the various storage technologies.

For the external heat supply calculated within BENG, conversion loss is incorporated in the output factor, as used within NTA 8800. One value for heat supply does appear in the BENG calculation program implementation results. A distinction is made here between low temperature heat supply and high temperature heat supply over the total annual use. The BENG calculation does take into account specified high-temperature and low-temperature systems. For the environmental performance of operational energy use B6, a division must be made between used high-temperature heat supply and low-temperature heat supply and the heat supply source, renewable or grey.

A building's regulated energy demand can be deduced from the BENG study results. The data required for operational energy use B6.1, feed-in (D2) and the data use is shown in table 4.1.

Table 4.1
Data required for the environmental performance of operational energy use B6 and environmental declarations to be used

Data required for the environmental performance of operational energy use B6 (available from data output for BENG)	**Unit**	**Calculating the energy performance of operational energy use B6**
Total non-primary energy demand natural gas (TEA)	nm^3/year	**Natural gas** Used for the natural gas environmental declaration: 'Natural gas, fired, at consumer'
Total non-primary heat supply, high temperature (TWHT)	MJ/year	**Heat supply, delivery, high temperature (WTHT)** WTHT = TWHT – WHTGHE For WTHT use environmental declaration: - 'Heat supply via heat network, High Temperature, Grey, at consumer, per MJ', or - 'Heat supply via heat network, High Temperature, Renewable, at consumer, per MJ'
Heat supply, non primary, high temperature, from building-related renewable energy generation (WHTGHE)	MJ/year	**Heat supply, high temperature, from building-related renewable energy generation (WHTGHE)** The installations used are included in modules A1-A3 and, if applicable, the environmental performance of the operational energy use in B6
Total non-primary heat supply low temperature (TWLT)	MJ/year	**Heat supply, delivery, low temperature (WTLT)** WTLT = TWLT - WLTGHE For this use environmental declaration: - 'Heat supply via heat network, Low Temperature, grey, at consumer, per MJ' - 'Heat supply via heat network, Low Temperature, Renewable, at consumer, per MJ'
Heat supply, non primary, low temperature, from building-related renewable energy generation (WLTGHE)	MJ/year	**Heat supply from building-related energy generation, low temperature (WLTGHE)** The installations used are included in modules A1-A3 and the environmental performance of operational energy use B6
Total electricity use from the supply, non-primary energy use. (Final supplied electricity use) (FTE)	kWh/year	**Final supplied electricity use** For this use: - Electricity, Dutch mix, at consumer, per kWh
Electricity from building-related renewable, non-primary energy generation (EGHE)	kWh/year	**Electricity from building-related energy generation** All installations used within the system boundaries must be included in modules A1-A3, even if more energy generation resources than required for BENG are used. Materialisation of the electrical grid infrastructure must be added in module B6 based on: - 'Materialisation electrical grid, external supply, per kWh'

		The materialisation of the electrical grid for building-related energy generation does not need to be declared when this concerns an off-grid construction work or if there is sufficient storage capacity.
Total non-primary electricity use of a construction work (TEB)	kWh/year	**Exported electricity (EE)** Used to calculate the energy balance. EE = EGHE - TEB When the calculated value for exported electricity is higher than 0, the electricity is exported. When the calculated value for exported electricity is lower than 0, electricity is supplied. Exported electricity is declared in module D2, with substitution benefits equal to the exported energy equivalent. For substitution, the following environmental declarations can be used as benefits: - Electricity, Grey, at consumer, per kWh - Electricity, Renewable mix, at consumer, per kWh - Electricity, Renewable, from biomass, at consumer, per kWh - Electricity, Renewable, from offshore wind, at consumer, per kWh - Electricity, Renewable, from onshore wind, at consumer, per kWh - Electricity, Renewable, from PV, at consumer, per kWh

3.10 Declared unit use function, m^2 GFA & m^2 UA

EN 15978 does not provide guidelines for the reference unit that should be used to assess the environmental performance of buildings. The EPB system is based on the reference unit GFA (Gross Floor Area). BENG and Level(s) are based on the reference unit UA (Usable Area) as referred to in NEN 2580.

The usable area is calculated by subtracting the following areas from the total floor area (GFA) within the walls of the home:

- Floor area of load-bearing walls.
- Area of voids and stairwells, if larger than 4 m².
- Area of rooms with headroom lower than 1.5 metres.
- Floor area of individual structures larger than 0.5 m².
- Floor area of piping shafts larger than 0.5 m².

The reference units for the environmental performance of operational energy use B6 and the EPB must be equivalent so these can be assessed in conjunction. A lifespan of 75 years and the GFA are used for this.
For uniformity with BENG and Level(s), the reference unit per m^2 UA is also used for the environmental performance of operational energy use. Compared with Level(s), the difference in building lifespan must be taken into account for the environmental performance of operational energy use B6. The EPB and the environmental performance of operational energy use B6 are based on 75 years for homes and 50 years for non-residential buildings. Level(s) uses 50 years as standard.

Overview of environmental declarations of energy carriers and applicability

The following overview is based on the environmental declarations of energy carriers from the 'LCA Report on Product Cards for Energy Carriers for National Environmental Database' LBP|SIGHT (2023). This overview is not exhaustive.

Environmental declaration	Applicability Environmental/energy performance	Applicability within EPB
Natural gas, fired, at consumer, per m3	B6	-
Electricity, Grey, at consumer, per kWh	B6* and D2 (substitution feed-in)	-
Electricity, Renewable, at consumer, per kWh	B6* and D2 (substitution feed-in)	-
Heat supply via heat network, High Temperature, Grey, at consumer, per MJ	B6	-
Heat supply via heat network, High Temperature, Renewable, at consumer, per MJ	B6	-
Heat supply via heat network, Low Temperature, Grey, at consumer, per MJ	B6	-
Heat supply via heat network, Low Temperature, Renewable, at consumer, per MJ	B6	-
Natural gas, fired, at consumer, materialisation external supply, per m3	-	A1-A3
Electricity, at consumer, materialisation external supply, average grid mix grey and renewable, per kWh	-	A1-A3
Heat supply via heat network, High Temperature, Grey, at consumer, materialisation external supply, per MJ	-	A1-A3
Heat supply via heat network, High Temperature, Renewable, at consumer, materialisation external supply, per MJ	-	A1-A3
Heat supply via heat network, Low Temperature, Grey, at consumer, materialisation external supply, per MJ	-	A1-A3
Heat supply via heat network, Low Temperature, Renewable, at consumer, materialisation external supply, per MJ	-	A1-A3
Electricity, Dutch mix, at consumer, per kWh	B6, all supplied electricity	-
Electricity, renewable, from biomass, at consumer, per kWh	B6*, D2 (substitution feed-in)	-
Materialisation electrical grid without generation resources, external supply, at consumer, per kWh	B6, for electricity from on-site generation resources, (except for off-grid construction works and if there is sufficient energy storage)	-
Electricity, renewable, from offshore wind, at consumer, per kWh	B6* and D2 (substitution feed-in)	-
Electricity, renewable, from onshore wind, at consumer, per kWh	B6* and D2 (substitution feed-in)	-
Electricity, renewable, from PV, at consumer, per kWh	B6* and D2 (substitution feed-in)	-

* Does not apply within the B&U in module B6. Within an Infrastructure project it is up to the client to prescribe the energy carriers to be used.

Applying energy use from the energy performance calculation

Installations for external energy supply (such as the connections for gas, electricity and/or heat as well as energy infrastructure and central systems for generation/conversion) must be included in the environmental performance calculation (EPB and the environmental performance of operational energy use B6). Such systems will need to be mentioned in the energy performance calculation and an equivalent in terms of material use will need to be included in the environmental performance calculation.

The Environmental Performance Calculation Input Guide has the following explanation for the amount of external supply that should be declared in an EPB calculation.

According to the Building Decree, for the energy-generating facilities taken into consideration in the environmental performance calculation, only the percentage share of environmental impact that is intended for the use functions' building-related energy use needs to be taken into account. In other words, the part specified in the permit application under energy performance (EPC) or BENG.

This means that, for energy supply via PV panels, a distinction can be made regarding the supply designated for domestic use and the supply for applications that are needed to comply with other regulations stated in the 2012 Building Decree. The environmental impact for domestic use does not need to be included for compliance with the Building Decree.

As a result, a negative final energy use is calculated for energy-efficient buildings up to net zero homes, so no external supply is calculated here. In fact, however, such concepts are not 'off grid' but use grid infrastructure for their energy balance. It is not practical to use an hourly balance method for this calculation. The external supply should be used for the final energy demand instead of use so that the energy balance can be calculated correctly.

Within **EPB**, the external supply card Electricity, Dutch mix, at consumer, external supply, per kWh must be used for all the imported final energy use. For all energy from on-site generation, the product card 'Materialisation electrical grid, external supply, per kWh' must be used.

The external supply of energy is included within the environmental performance of operational energy use B6 in energy carriers' product cards and does not need to be included separately within the EEPB (Environment and Energy Performance of Buildings). The external supply for on-site energy generation must be included within the EEPB in B6 with 'Materialisation electrical grid, external supply, per kWh'. When an energy storage system with sufficient capacity is used, no external supply needs to be taken into account for feed-in to the electrical grid.

4 Impact of the energy performance of operational energy use B6 on the value of reference buildings

The performance and applicability of the intended Assessment Method was investigated using various building calculations. Ideally, reference buildings for EPB and BENG would be used for this, but these are not currently available, which is why this study used recently modelled reference homes from Develop Inc[22] and reference buildings from the NMD from 2018/2019.

4.1 Reference homes

A corner house with glass wool insulation was used as reference home. This home has a Usable Area (UA) of 120 m^2, a Gross Floor Area (GFA) of 164 m^2 and a lifespan of 75 years. Develop Inc has two home variants. The first meets BENG requirements with the installation of three PV panels and the second is energy-neutral with 12 PV panels. The insulation values, installations and energy performance used are shown in table 4.1.

Table 4.1
Reference home, corner house. Develop Inc (2022), Corner house variant B.

Bouwkundig	Pakket B			
Rc-begane grondvloer	3,70 m²·K/W			
Rc-gevel	4,70 m²·K/W			
Rc-dak	6,30 m²·K/W			
U-ramen en deuren	HR++ (U_{gl} 1,0) | 1,3 tot 1,6 W/m²·K			
Infiltratie (qv10;spec)	0,50 dm³/s·m²			
Zonwering/ventilatieve koeling	-			
Installaties				
Verwarmingssysteem	Lucht/water warmtepomp 5 kW			
Koelingssysteem	Lucht/water warmtepomp 5 kW			
Afgifte verwarming en koeling	Vloerverwarming/-koeling | 35 °C			
Tapwatersysteem	Lucht/water warmtepomp 5 kW (180 l.)			
Ventilatiesysteem	D2 – zonder sturing, zonder zonering			
PV-panelen indien aanwezig	330 Wp per paneel			
Energieprestaties	**BENG 1**	**BENG 2**	**BENG 3**	**TO_{juli}**
BENG	61,44	29,18	61,9%	-
Energieneutraal	61,44	-0,52	100,6%	-
PV-panelen en fysische prestaties	**PV**	**EPV**	**Netto warm.**	**kWh meter**
BENG	3	34,57	2,94	2.416
Energieneutraal	12	34,57	2,94	-43

[22]Develop Inc, 22 June 2022. Environmental performance energy and material use. [23]https://www.gww-bouw.nl/artikel/lantaarnpalen-geven-duur-licht/[24]Routekaart Energieopslag voorjaar 2023 (rvo.nl). 'Annex 4: Electricity storage, overview of technologies' offers an overview of the various storage technologies.

Structural	Space for building installations
RC ground floor flooring	Vertical traffic area
RC facade	Parking area
RC roof	Outdoor bicycle storage
U windows and doors	Horizontal traffic area
Infiltration (qv10;spec)	Sanitary areas
Awning/ventilative cooling	Storage area
Installations	Layout loss
Heating system	Partition walls
Cooling system	Tare area
Heating and cooling output	Partition construction Inter-building functions
Tap water system	Non-accessible piping shafts
Ventilation system	Static building components
PV panels if present	Glazed area correction factor
Energy performance	Areas lower than 1.5 m
BENG	Space for building installations
Energy neutral	Vertical traffic area
PV panels and physical performance	Parking area
BENG	Outdoor bicycle storage
Energy neutral	Horizontal traffic area
Package B	Sanitary areas
Air/water heat pump 5 kW	Storage area
Air/water heat pump 5 kW	Layout loss
Underfloor heating/cooling | 35°C	Partition walls
Air/water heat pump 5 kW (180 l.)	Tare area
D2 - without control, without zoning	Partition construction Inter-building functions
330 Wp per panel	Non-accessible piping shafts
TA	Static building components
PV	Glazed area correction factor
EPC	Areas lower than 1.5 m
Net heat	Space for building installations
kWh metre	Vertical traffic area

In addition to the Develop Inc reference homes, in this study the same home without PV panels and with 18 PV panels was taken into account. For these two additional variants, the EPB and energy generation values were calculated using data available from
Develop Inc. An overview of relevant values per home type is shown in table 4.2.

Table 4.2
Energy production home variants

Corner house, type:	kWh on-site production from PV	energy demand (kWh/year)	kWh metre	GFA (m^2)	UA (m^2)
0 x PV. No. 8, B - BENG - VW	0	3227	3,227	164	120
3 x PV + inverter + cables. Reference No. 8, B - BENG - VW	820	3227	2407	164	120
12 x PV + inverter + cables. Reference No. 24, B - Neutral - VW	3279	3227	-52	164	120
18 x PV + inverter + cables, energy feed-in	4920	3227	-1693	164	120

The only difference between the four home variants is in the number of PV panels used with associated inverters and cables. For the associated EPB values, Develop Inc assumes the category 1 product card *'Exasun Xglass, one PV module 320 Wp per PV, monoSi; incl. support, excl. inverter + cables'* and the category 3 product card *'Inverter + cables, (excl. PV panel and support)'.*

4.2 Modelling

The NMD environmental values for operational energy use and external supply were used in the comparison. Table 4.3 shows an overview of the product cards used and the associated application.

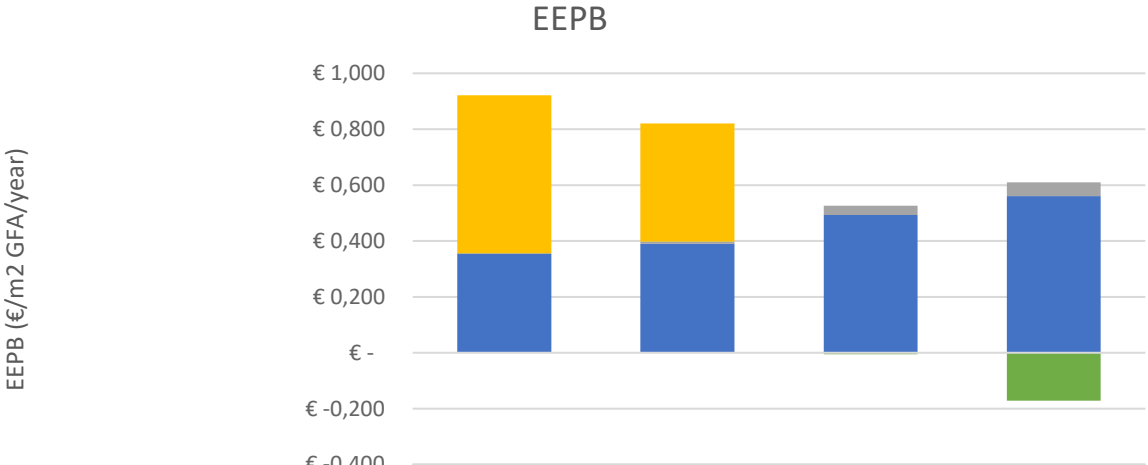
Table 4.3
ECI energy carriers

Product card	Total ECI/kWh	External supply ECI/kWh	Explanation of application.
Electricity - MIX NL (73% grey, 27% renewable)	€0.02873	€0.00366	The external supply is used for EPB. For the energy performance of operational energy use B6, the total is used (including external supply)
Electricity - Renewable, from PV	€0.01658	€0.01643	The total is used for substitution of exported energy from PV in module D2 for the environmental performance of operational energy use B6
External supply electrical grid		€0.00167	External supply used for both EPB as well as the environmental performance of operational energy use B6 for on-site generated electricity

Annex 3 includes the environmental performance of the scenario in which the MIX NL external supply card is also used for electricity generated within the system boundaries.

4.3 Results

For the four home variants, the EPB including the energy performance of operational energy use B6, reduces when the number of PV panels increases (figure 4.1). As electricity from on-site generation increases, less to no energy is supplied from the Dutch Mix. This decreases the EPB including the environmental performance of operational energy use B6 for supplied energy and associated external supply. When solar panels are used, the EPB increases including the environmental performance of operational energy use B6 on building-related materialisation and external supply from connection to the grid. For the energy-generating home, the EPB (including the environmental performance of operational energy use B6, benefits from feed-in and substitution) is greater than the costs from the additional used materialisation. This effect is explained in the sensitivity analysis in section 4.4.



	Hoekwoning 0x PV.	Hoekwoning 3x PV + inverter +kabels. Referentie Nr. 8, B - BENG - VW	Hoekwoning 12x PV + inverter + kabels. Referentie Nr. 24, B - Neutraal - VW	Hoekwoning 18x PV + inverter, energieleverend
MEPG teruglevering (substitutie van 'Elektriciteit -Hernieuwbaar, uit Solar')	€ -	€ -	€ -0,005	€ -0,171
MEPG toegeleverde energie (obv. 'Elektriciteit - MIX NL (73% grijs, 27% hernieuwbaar) (incl. externe levering)	€ 0,57	€ 0,42	€ 0,00	€ 0,00
MEPG externe levering eigen opwekking (obv. Externe levering elektriciteitsnet)	€ 0,000	€ 0,008	€ 0,033	€ 0,050
MEPG materialisatie	€ 0,356	€ 0,390	€ 0,493	€ 0,560

Figure 4.1
EPB results including the energy performance of operational energy use B6 for reference homes

4.4 Exported energy sensitivity analysis

According to the Assessment Method, substitution processes should relate to the representative resource equivalent, which is why, within this EPB, including environmental performance of

operational energy use B6 analysis, exported electricity from PV panels is substituted for the most representative NMD product card 'Electricity - renewable, from PV'.
In the EPB, including the energy performance of operational energy use B6 calculation, the PV panel used is based on cat. 1 data. Per PV panel, together with the required inverters and cables, the materialisation amounts to an environmental impact of €0.0085/kWh. Substitution with the category 3 product card *'Electricity - renewable, from PV'* that has an ECI of €0.017 provides substitution benefits that are a factor of 2 higher than the declared materialisation costs. This would mean that when introducing around 50 PV panels, the complete EPB including the energy performance of operational energy use B6 would amount to €0/m^2 GFA. Where more PV panels are used, the EPB including the energy performance of operational energy use B6 becomes negative.

The difference in the environmental impact of the materials used and benefits from substitution can be explained as follows. In the reference building cat. 1 data are used with a lower ECI. The substitution profile also assumes PV electricity from a ground-mounted installation with a considerably larger mounting system.

To avoid deviation relating to the used substitution processes, a choice can be made to declare substitution of exported energy in module D2 as substitution of the actual materials that provide the external supply. For the studied energy-generating building variant with 18 PV panels, this would mean that the materialisation of 6 PV panels with associated inverters, cables and external supply would appear as substitution processes in module D2. The first 12 panels are used for the required energy supply. The 6 additional panels provide net zero environmental benefits or costs over the entire life cycle.

4.5 EPB including the energy performance of operational energy use B6, GFA and UA

The reference homes have a GFA of 164 m^2 and a UA of 120 m^2. For the EPB including the energy performance of operational energy use B6, environmental performance must also be shown in UA to ensure connection with the Level(s) framework. In this case, the environmental impact for declaration in UA is a factor of 1.36 greater than for GFA (164/120).

The UA and GFA ratio can differ significantly for different types of homes.

4.6 White Paper 'Homes with heat pumps harmful for the environment?'

The White Paper 'Homes with heat pumps harmful for the environment?' presents a comparison of the environmental/energy performance of homes with a heat pump and solar panels, and homes with solar panels and a central heating boiler. This white paper shows the importance of integrated assessment of material-related environmental performance and operational energy use.

5 Case study: infrastructure project operational energy use

Lighting

This example is based on the LCA Report Category 3 data National Environmental Database, Chapter 34 Lighting (30 June 2020).

The lighting comprises the following product composition (table 5.1)

Table 5.1
Product composition lighting

	Sub-products with contribution to Main product Lighting		
Sub-products	Variant	Quantities	Unit
Lighting column	Lighting column 18 m (steel)	1.00	pc.
Light fitting	Light fitting with lamp (aluminium/glass)	2.00	pc.
Cabling	Cabling (installation)	18.00	m^1
Cabling	Cabling (earth cable)	90	m^1

The lighting column has a lifespan of 30 years.

Operational energy use (B6)
The underlying LCA report contains no information about energy use. Main roads are lit using lights with a capacity of 70 to 150 watt[23].

To make an estimate of the energy use in kilowatt hours (kWh) per year, we need to multiply the capacity of the streetlight by the number of hours that the lighting is lit per day and multiply this result by the number of days in a year.

In this example we assume that the lighting is on for 10 hours every night.

The energy use over 30 years for **70 watt** lighting would then be:
Energy use (in kilowatt hours) = 70 (capacity in watts) x 10 (number of hours lit per day) ÷1000 x 365 days x 30 years = 7,665 kWh

The energy use of 30 years for **150 watt** lighting would then be:
Energy use (in kilowatt hours) = 150 (capacity in watts) x 10 (number of hours lit per day) ÷1000 x 365 days x 30 years = 16,425 kWh

Figure 5.1 shows the impact of operational energy use for the lighting column. This figure presents two scenarios: use of the average Dutch grid mix and use of the average renewable Dutch grid mix. This comparison shows that the electricity choice has a major impact on the environmental performance of operational energy use.

[23]https://www.gww-bouw.nl/artikel/lantaarnpalen-geven-duur-licht/[24]Routekaart Energieopslag voorjaar 2023 (rvo.nl). 'Annex 4: Electricity storage, overview of technologies' offers an overview of the various storage technologies.

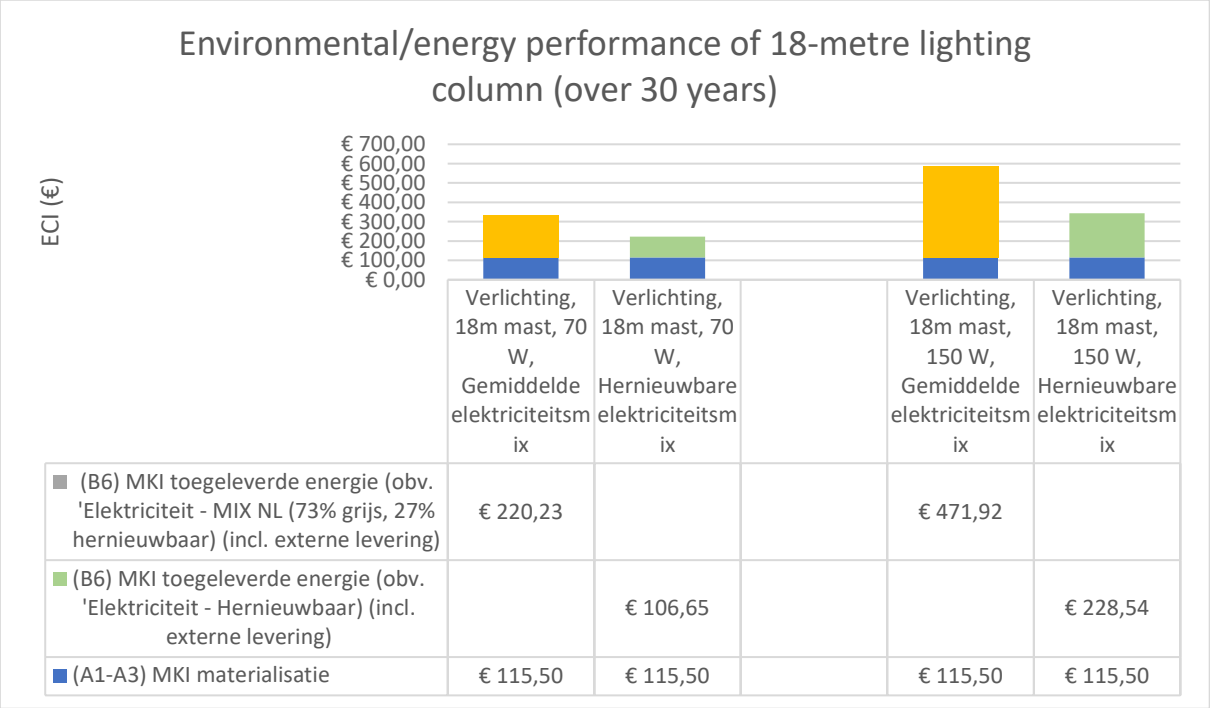


Figure 5.1
Environmental/energy performance lighting column

6 Comparison of NMD Assessment Method, Level(s) & EN15978

Operational energy	Level(s), 1.1	Level(s), 1.2	EN15978	NMD Assessment Method EPB	BENG, NTA 8800
Description	Use stage energy performance'	Life cycle Global Warming Potential	Sustainability of structures – Assessment of the environmental performance of buildings – Part 1: Environmental performance	Calculation rules and guidelines assessment of Environmental performance Construction works	Almost Energy-neutral Buildings, with assessment method NTA 8800
Applicable for	B&U	B&U	B&U & Infrastructure project	B&U & Infrastructure project	B&U
Scope (life phases), operational energy use	Heating, cooling, ventilation (incl. (de)humidification, hot water and lighting	B6	B6.1 energy use of regulated building integrated systems, B6.2 energy use of non-regulated building integrated systems, B6.3 other energy use user activity	B6	B6
System boundaries (on-site energy generation)	The system boundaries are set at the point where supplied and exported energy are calculated. Outside the system boundaries, primary energy factors apply to all forms of supplied and exported energy. This applies to both on-site, nearby, as well as distant energy sources.	The energy system is part of the building and must be taken into consideration.	Energy generation resources are resources that form part of the building shell or are connected directly to the construction work's energy supply.		Building-related energy generation Energy produced by a building-related installation.
Declared unit	kWh/m^2/yr (Usable area, UA)	kg CO_2-eq/m2/yr (Usable area, UA)	-	ECI/m2/yr (Gross Floor Area, GFA)	kWh/m^2/yr (Usable area, UA)
Indicators used	2 L2.1 EPBD services 1 non-renewable primary energy self-used (mandatory) L2.2 EPBD services1 renewable primary energy self-used2 (optional) L2.3 EPBD services1 total primary energy self-used2 (optional) L2.4 Exported renewable primary energy (mandatory) 3 L2.5 EPBD services1 non-renewable primary energy balance (mandatory) L2.6 Non-EPBD services non-renewable primary energy self-used (optional) L2.7 Non-EPBD	1) GWP - fossil kg CO_2 eq (2) GWP - biogenic kg CO_2 eq GWP – GHGs (1+2) kg CO_2 eq (3) GWP – land use and land use change kg CO_2 eq GWP – overall (1+2+3) kg CO_2 eq	environmental indicators and parameters from EN15804:A2 Parameter 'exported energy' in B6. This must be declared per energy carrier in MJ.	Environmental indicators and parameters from EN15804:A2	1. **the maximum energy demand in kWh per m² usable area per year** 2. **the maximum primary fossil energy use, also in kWh per m² usable area per year** 3. **the minimum share of renewable energy in percentages**

	services renewable primary energy self-used2 (optional) L2.8 Non-EPBD services1 total primary energy self-used2 (optional) L2.9 Total primary energy self-used2 (optional) L2.10 Total primary energy balance2 (optional)				
Environmental profile energy carriers	n/a	Split according to GWP per energy carrier	Split according to used energy carrier	-	-
Environmental profile energy-generating facilities	n/a	Based on validated software. Ecoinvent software is validated.	All energy-generating facilities that form part of the building or are connected directly to the building must be declared within the production phase (A1-A3).	Of the energy-generating facilities taken into consideration for the environmental performance calculation, only the percentage share of the environmental impact that is intended for the use functions' building-related energy use needs to be taken into account.	NTA 8800 assumes fixed CO_2 emission coefficients per energy carrier, except for heat supply
Declaration of exported energy	In the included indicators	In module D	Environmental impact of exported energy in module D2, based on the most relevant substitution, for example, the current national energy mix.	-	Calculation according to NTA 8800 assumes fixed CO_2 values.
Reference life cycle construction work	n/a	50 years	-	Homes: 75 years; non-residential; 50 years (including schools, shops, sports halls, etc.). Infrastructure project: 100 years	-

7 Recommendations

Study on the use of UA reference unit for EPB

For uniformity with BENG and Level(s), ideally the reference unit per m^2 UA should also be used in the Assessment Method for environmental performance of buildings. A more detailed study including calculations of a substantial number of buildings should indicate the impact that the transition from comparison unit GFA to UA would have on the 1-point score of the environmental performance of a building. Various building types would need to be included here as well as the policy objectives as set for the EPB.

Until decisions are taken based on a study, the EPB should be prepared in GFA and the EPB, including the environmental performance of operational energy use B6, should be prepared in both GFA and UA.

Draw up Witte Vlekken scheme for energy storage product cards and formulating cat. 3 product cards

Partly in the context of the Witte Vlekken Project, we recommend that NMD conducts research into possible product cards for energy storage. No product cards are available for energy storage systems at this time. Various forms of energy storage systems are available and are in development. The Energy Storage Roadmap (2023) provides information about the status quo of energy storage systems and the actions that are needed to promote energy storage[24]. The roadmap states that both electricity, molecule and heat storage are needed in the energy system.

Product cards must be produced for the current available energy storage systems (at construction work level). Various innovative energy storage systems are still in development and are still not suitable for the production of a product card. Separate product cards are also not needed for large storage systems at grid level.

Product cards are desirable for the following systems:

Electricity storage

- Home battery (2 - 10 kW), Lithium-ion battery
- Home battery (2 - 10 kW), Lithium-ion-phosphate battery
- Home battery, lead acid
- Home battery, salt water
- Large battery at generator/consumer (0.3 - 10 MW)

Using bi-directional charging, electric vehicles can also be used as an energy storage system. However, an electric vehicle is not building-related and the energy storage potential differs significantly

[24] Routekaart Energieopslag voorjaar 2023 (rvo.nl). 'Annex 4: Electricity storage, overview of technologies' offers an overview of the various storage technologies.

per situation. For these reasons, it does not seem feasible to process this form of home energy storage as a product card.

Heat storage

- Seasonal heat storage, Low-temperature ground thermal energy (open, closed), 50 kW - 1 MW
- Short-term storage heat, large hot water tank (short-term, large capacity) (TTES) 100 kW - 150 MW
- Short-term storage heat, small hot water tank (home) (TTES) 1 kW - 50 kW

8 Annex 1, other changes to Assessment Method for energy carriers

Replace: 2.6.3.7. Selection of data, Standard values, 3rd bullet

- *For energy from natural gas the following is used 'Heat, district or industrial, natural gas {Europe without Switzerland} heat production, natural gas, at industrial furnace >100kW | Cut-off, U' (process in MJ) [Ecoinvent 3.5]. An energy value of 31.65 MJ/Nm3 is used[4].*

+ footnote 4: *A conscious choice was made here not to use a 'market' process as that database process involves a combination of 'industrial furnace' and 'co-generation', and in principle co-generation does not play a role in industrial processes. The standard energy value is based on the 'Dutch list of energy carriers and standard CO2 emission factors, version January 2018' (Netherlands Enterprise Agency). This value may not be adjusted for the use of Dutch natural gas. In the case of foreign natural gas, an appropriate specific value should be sought from literature.*

Replace with:

- *The NMD 'Natural gas, fired, at consumer, per m3' process is used for energy from natural gas. If applicable an energy value of 31.65 MJ/Nm3 can be used here.*

+ footnote 4: *The standard energy value is based on the 'Dutch list of energy carriers and standard CO_2 emission factors, version January 2018' (Netherlands Enterprise Agency). This value may not be adjusted for the use of Dutch natural gas. In the case of foreign natural gas, an appropriate specific value should be sought from literature.*

5th bullet

- *Electricity, low voltage {NL}| market for | Cut-off, U [Ecoinvent 3.5] This process describes electrical energy use (230-400 V) including production from raw materials and distribution (grid and transformer losses).*

Replace with:

- *Electricity, Grey, at consumer, per kWh. This NMD process describes electrical energy use of non-renewable Dutch origin (230-400 V) including production from raw materials and distribution (grid and transformer losses).*

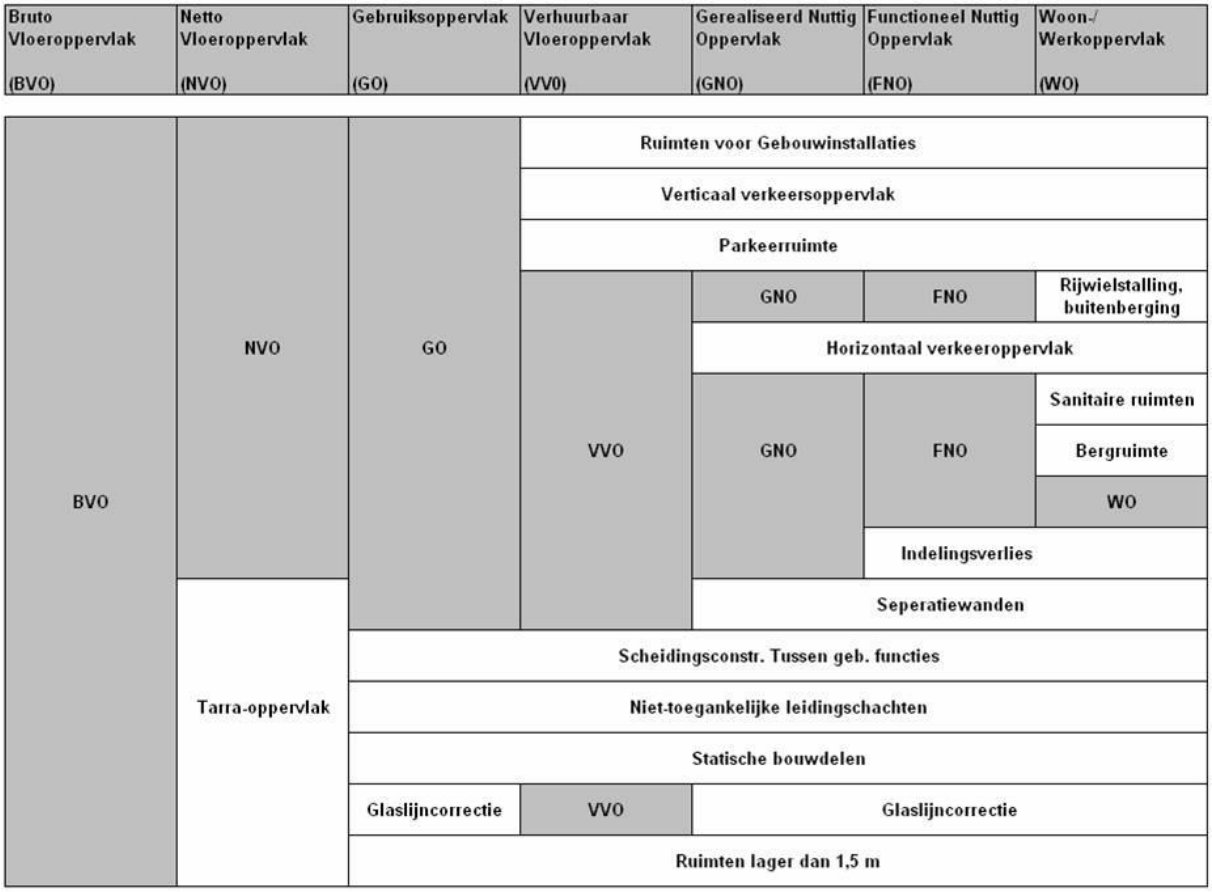
+ extra bullets:

- *Electricity, Renewable, from biomass, at consumer, per kWh This NMD process describes electrical energy use of renewable Dutch origin (230-400 V) including production from raw materials and distribution (grid and transformer losses). This card may only be used in calculations where Dutch Guarantees of Origin (GOs) apply. This must be supported by appropriate evidence. International GOs are excluded[5].*
- *Electricity, Renewable, from offshore wind, at consumer, per kWh. This NMD process describes electrical energy use of renewable Dutch origin (230-400 V) including production from raw materials and distribution (grid and transformer losses).*
  This card may only be used in calculations where Dutch Guarantees of Origin (GOs) apply. This must be supported by appropriate evidence. International GOs are excluded[5].
- *Electricity, Renewable, from onshore wind, at consumer, per kWh. This NMD process describes electrical energy use of renewable Dutch origin (230-400 V) including production from raw materials and distribution (grid and transformer losses). This card may only be used*

in calculations where Dutch Guarantees of Origin (GOs) apply. This must be supported by appropriate evidence. International GOs are excluded[5].

- *Electricity, Renewable, from PV, at consumer, per kWh. This NMD process describes electrical energy use of renewable Dutch origin (230-400 V) including production from raw materials and distribution (grid and transformer losses). This card may only be used in calculations where Dutch Guarantees of Origin (GOs) apply. This must be supported by appropriate evidence. International GOs are excluded[5].*
- *Electricity, Renewable, Dutch mix, at consumer, per kWh. This NMD process describes electrical energy use of renewable Dutch origin (230-400 V) including production from raw materials and distribution (grid and transformer losses). This card may only be used in calculations where Dutch Guarantees of Origin (GOs) apply. This must be supported by appropriate evidence. International GOs are excluded for operational energy use of construction works.*

9 Annex 2: summary table of areas of buildings to be taken into account according to NEN 2580



Space for building installations	Ruimten voor Gebouwinstallaties
Vertical traffic area	Verticaal verkeersoppervlak
Parking area	Parkeerruimte
Outdoor bicycle storage	Rijwielstalling buitenberging
Horizontal traffic area	Horizontaal verkeeroppervlak
Sanitary areas	Sanitaire ruimten
Storage area	Bergruimte
Layout loss	Indelingsverlies
Partition walls	Separatiewanden
Tare area	Tarra-oppervlak
Partition construction Inter-building functions	Scheidingsconstr. Tussen geb. functies
Non-accessible piping shafts	Niet-toegankelijke leidingschachten
Static building components	Statische bouwdelen
Glazed area correction factor	Glaslijncorrectie
Areas lower than 1.5 m	Ruimten lager dan 1,5 m

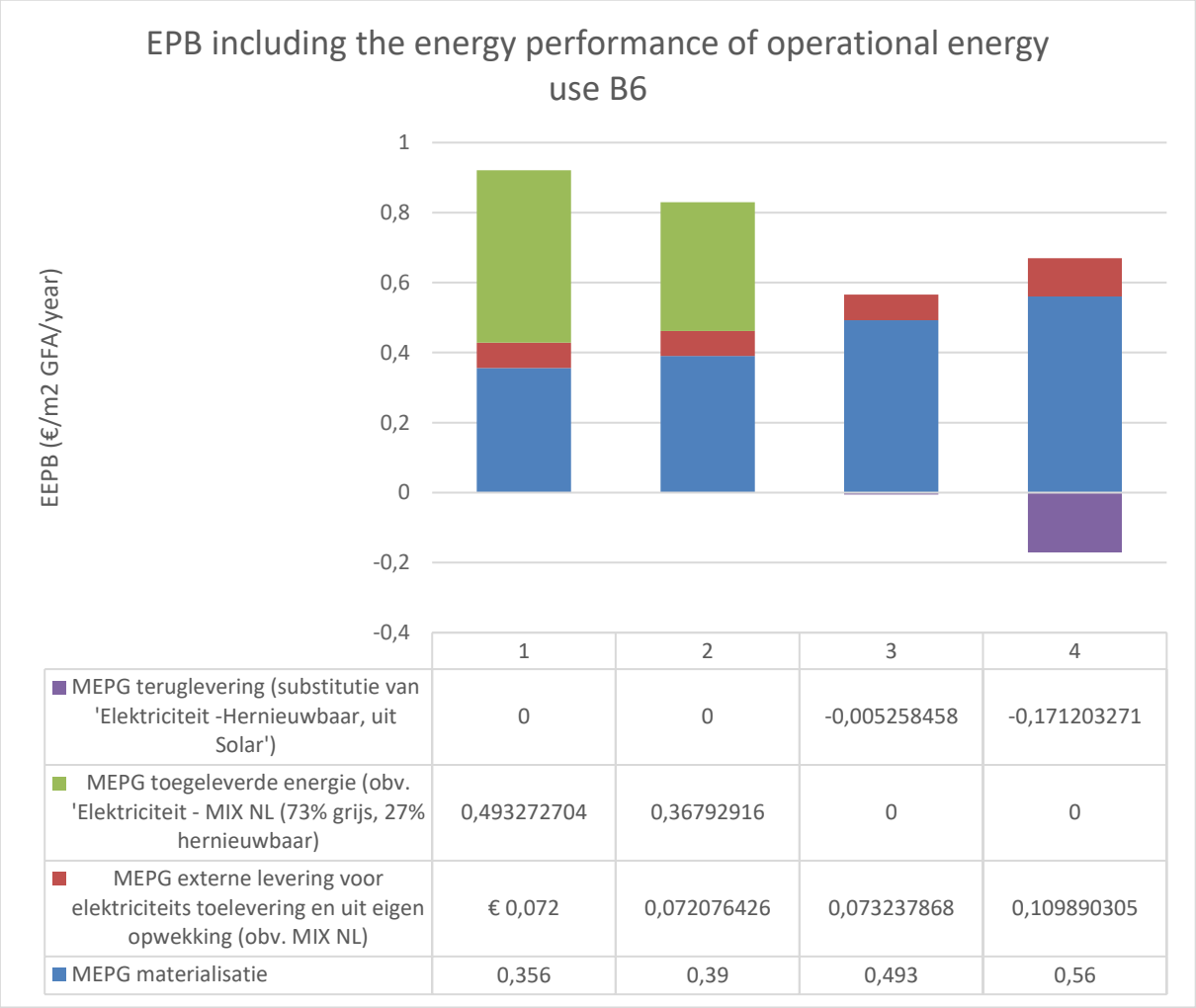
10 Annex 3, Effect of EPB including the energy performance of operational energy use B6 equivalent to external supply of imported and on-site generated energy.

This EEPB comparison is based on the same reference buildings as included in chapter 4. The only modification is the inclusion of external supply for energy from on-site generation. The NMD environmental values for operational energy use and external supply were used in the EEPB comparison. Table 1 shows an overview of the product cards used and the associated application.

Table III.1
ECI energy carriers

Product card	Total ECI/kWh	External supply ECI/kWh	Explanation of application.
Electricity - MIX NL (73% grey, 27% renewable)	€0.02873	€0.00366	The external supply is used for EPB. For the energy performance of operational energy use B6, the total is used (including external supply) The external supply is also included for energy produced within the system boundaries.
Electricity - Renewable, from PV	€0.01658	€0.01643	The total is used for substitution of exported energy from PV in module D2 for the environmental performance of operational energy use B6

The impact on the energy performance of operational energy use B6 is shown in figure 1. The environmental impact from the external supply has increased. In this scenario, the external supply contains both the electrical grid as well as generation resources from the Dutch electricity mix. The effect of this is that on-site generation of electricity within the system boundaries is less favourable. When a home is fitted with PV panels, the capital goods of the energy generation resources of the Dutch mix are also declared for this share of electricity for the external supply.



	1	2	3	4
MEPG teruglevering (substitutie van 'Elektriciteit -Hernieuwbaar, uit Solar')	0	0	-0,005258458	-0,171203271
MEPG toegeleverde energie (obv. 'Elektriciteit - MIX NL (73% grijs, 27% hernieuwbaar)	0,493272704	0,36792916	0	0
MEPG externe levering voor elektriciteits toelevering en uit eigen opwekking (obv. MIX NL)	€ 0,072	0,072076426	0,073237868	0,109890305
MEPG materialisatie	0,356	0,39	0,493	0,56

Figure III.1