Evaluation Dutch final nZEB requirements for University buildings

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Abstract. The need for (nearly) Zero Energy Buildings (nZEBs) in the Netherlands becomes increasingly important due to climate change, increasing energy prices, scarcity of fossil fuels and increasing geopolitical conflicts. In line with the EU EPBD, from January 2021 new buildings, including hospital and university buildings, have to fulfill more strict energy requirements. Besides that, also the energy requirements for existing buildings will become stricter to realize an energy neutral built environment by 2050. On request of the Dutch Universities (WO) and the Dutch Academic Medical Centre's (UMC), the Netherlands Enterprise Agency (RVO) assigned Royal HaskoningDHV to study the effect of the nZEB requirements on this real estate of the sector. The feasibility of the final nZEB requirements has been assessed for eight representative, recently designed and realized university buildings. The results show that:

- Compared to the provisional nZEB requirements it has become less difficult to fulfil the final nZEB requirements and sometimes even less difficult than using the former method (NEN 7120) and requirements (EPC);
- Five of eight university buildings comply with all nZEB requirements and three buildings do not comply with the nZEB requirement on primary energy (BENG 2);
- Effective and necessary measures in general are: good thermal isolation, energy efficient lighting with daylight and occupancy control, ventilation with heat recovery and CO2/occupancy control, Aquifer Thermal Energy Storage with Heat Pumps and local PV solar panels.

Although the nZEB requirements are feasible, organizations should keep in mind that fulfilling these requirements for only their new buildings is not enough to meet the 95% CO2 emission reduction target in line with the Paris Climate agreement in 2050. A roadmap with all measures to reach this target, including the existing buildings, should prevail when making design and energy transition decisions for the campus energy infrastructure and each building.

Keywords. nZEB Netherlands, Energy, University Buildings, Feasibility, Case Studies.
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1. Introduction

Finally, after some delay, the Dutch nZEB regulation is put into practice on January 1st 2021. Not only new requirements are introduced, but also the calculation method is altered. The provisional nZEB requirements were already proposed in 2015 and led to many questions regarding their feasibility, in particular regarding the demand for more than 50% renewable energy generation on site, see [5]. These provisional requirements from 2015 were updated in 2018. In 2019 the final nZEB requirements were introduced together with the calculation method NTA8800 that replaced the former calculation method NEN 7120.

Among most concerned organisations are universities and hospitals which own and use large multistorey buildings with high energy demand. The consequences of new regulations need to be known before renovations and new constructions can be planned. Therefore several nZEB feasibility studies have been performed [2-7]. In this paper the results of the last study are presented, answering the following questions:

- How do 8 selected recently realised and/or designed sustainable university buildings perform in regard to the set final nZEB requirements?
- How do the results of the new calculation method NTA8800 compare to the former method NEN 7120?
- Does complying with the new nZEB

requirements interfere with CO2 emission reduction target of -/- 95% in 2050 for the university building portfolio?

2. Approach

A straightforward approach is followed. Calculations with the new NTA8800 and old NEN 7120 method were made and analysed.

The following calculation methods are used as given in Table 1.

Tab. 1 – Calculation methods used to compare the case studies

	Quantity	*Calculation method*	*Case*
1	Ecalc/Eref	commercial program Enorm (version: 2009;2015)	all Buildings
2	BENG(2017)	with commercial program Enorm (version 2017)	all Buildings except EUT Flux Building
3	BENG (2019)	NTA8800-excel calculation	only for EUT Flux Building different variants were calculated
4	BENG(2020)	NTA8800 with commercial program VABI-program (version 2020)	all buildings

For the EUT Flux building different scenarios are compared. For seven other buildings, only the design as built is compared. It was checked if the buildings comply with the nZEB requirements and the differences between the calculations with different methods were analysed. Next looking at the results and the CO2 emission reduction target in 2050, it was analysed and explained if fulfilling the nZEB requirements automatically leads to the best solutions to achieve the CO2 emission reduction targets in 2030 and 2050. We developed and used a Five-step method that was also previously published [1]. The characteristics of each building or variant were analysed by using the so-called 'Five-Step Method'. This is an upgraded version of the 'Trias Energetica' with the explicitly separated steps: demand and behaviour (step 1) and energy exchange and storage systems (step 4) [2], see Figure 1.

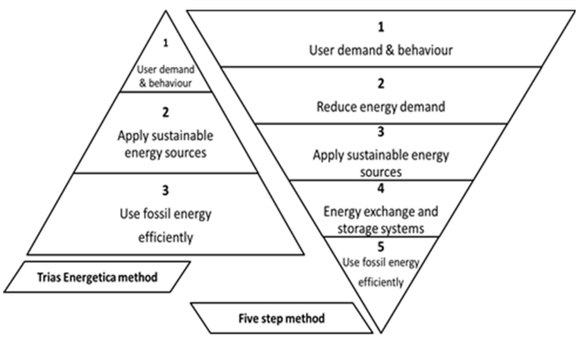

Fig. 1 - Building design approaches: 'Trias Energetica' versus the upgraded 'Five Step Method' [1].

3. Theory

The Dutch energy performance requirements for new buildings, which had to be met until 2021, are expressed in the dimensionless number E_{calc}/E_{ref}, which is the quotient of the calculated and the set admissible amount of primary Energy use and calculated according to the Dutch standard NEN 7120 [8]. Only the energy use of the Heating Ventilating and Air Conditioning (HVAC), lighting and sustainable energy are included and the energy use of appliances/equipment is excluded.

From January 1st 2021 the calculation method NTA 8800 is introduced. This is a new and more detailed calculation method, which is based on the developed EU EPBD CEN standards [11]. Together with the introduction of the new calculation method also the Primary Energy Factor for the electricity form the grid was changed from 2.56 to 1.45. This PEF is in line with the actual situation in the Netherlands and leads already to a significant reduction of the primary energy use related to the consumption of electricity from the grid.

In the Dutch nZEB method 3 energy performance indicators (EP 1, EP 2 and EP 3) are calculated which each need to fulfil for each type of building function a set requirement (BENG 1, BENG 2 and BENG 3):

- EP 1 with requirement BENG 1: Thermal Energy Demand consisting of heating and cooling. Influencing the geometry, insulation, infiltration, orientation, solar irradiance, internal heat production, thermal mass.

- EP 2 with requirement BENG 2: Total Primary Energy taking the different Primary Energy Factor of offsite energy into account. The same energy posts are considered as in the former NEN7120 calculation method: Heating, Cooling, Lighting, Fans, Domestic Hot Water, Humdification, (excl. Equipment) -/- Sustainable energy (PV, Wind, Aquifer Thermal Energy Storage (ATES) etc). The EP2 has the same meaning as E_{calc} in the EPC.

- EP 3 with requirement BENG 3: Fraction of locally generated sustainable energy, e.g. PV, Wind, ATES, Heating Source for Heat Pump.

For a whole building each BENG requirement is a weighted value based on the floor area of each available building function, e.g. an education building consists of an education function, but also an office function.

The nZEB requirements were adjusted several times in the years before they came into effect. The final nZEB requirements for some individual building functions are presented in Table 2.

Tab. 2 - Final (2019) nZEB requirements to be calculated with NTA8800 for some building functions.

Function	*BENG 1 – Energy demand [kWh/ (m²a)]*	*BENG 2 – Primary fossil energy consumption [kWh/ (m².a)]*	*BENG 3 – Percentage renewable energy [%]*
Office	$A_{ls}/A_g \leq 1{,}8$: 90 $A_{ls}/A_g > 1{,}8$: 90 + 30 x (A_{ls}/A_g - 1,8)	40	30%
Assembly function	$A_{ls}/A_g \leq 1{,}8$: 90 $A_{ls}/A_g > 1{,}8$: 90 + 30 x (A_{ls}/A_g - 1,8)	60	30%
Education	$A_{ls}/A_g \leq 1{,}8$: 190 $A_{ls}/A_g > 1{,}8$: 190 + 30 x (A_{ls}/A_g - 1,8)	70	40%
Healthcare without bed area	$A_{ls}/A_g \leq 1{,}8$: 90 $A_{ls}/A_g > 1{,}8$: 90 + 35 x (A_{ls}/A_g - 1,8)	50	40%
Healtcare with bed area	350	130	30%

A_{ls}: Building Shell Area including facade and roof.
A_g: Nett Floor Area

It should be noted that the nZEB requirements are design requirements that calculate a theoretical energy consumption based on a reference building usage and assuming an optimal condition of the building and the building services. Consequently, the measured energy consumption in operation can differ from the calculated value if the building usage and/or building and building services conditions differ. Furthermore, special attention should be paid to the indoor environment and requirements to avoid negative effects, e.g. (i) increasing indoor temperatures during summer that can lead to additional cooling and/or (ii) less ventilation that can lead to a loss of productivity or the application of additional ventilation systems when the building is in use, when applying measures to comply with nZEB requirements.

4. EUT Flux Building

The Eindhoven University of Technology Flux building was selected for a more in-depth analysis. It's a 26,200 m² facility, with around 9,852 m² offices, 5,945 m² education, 190 m² shops, 2,564 m² meeting spaces and shared corridors. Three different cases have been evaluated, trying to comply with the required energy use 53 kWh/(m².a), according to the nZEB requirements based on the combination of the building functions. Table 3 presents selected parameters of the reference scenario and changes that have been implemented in the three following cases. Building characteristics and changes are listed in order of the five step method.

Tab. 3 - Changes introduced in Cases Var 1, Var 2 and Var 3 compared to the reference case: REF.

	REF
1	Lighting control based on precense detection, sweep and daylight control
2	Rc= 3.5; 5.0 and 5.0 m²K/W (floor, facade, roof) HR++ glazing (U=1.6 W/m²K, g-value 0.35) Shades Infil.: 0.42 l/s.m², Heat recovery: 70% Lighting: 7 W/m²
3	Heatpump
4	Heat and cold storage
5	Electroboiler

	Changes REF ↔ Var. 1
1	
2	
3	2,250 m² PV (50% roof area)
4	
5	

	Changes REF ↔ Var. 2
1	
2	Rc= 3.5; 5.0 and 6.0 m²K/W (floor, facade, roof); Ventilation heat recovery 80% with bypass; Ventilation flow rate 140% requirements building code; Lighting : 4 W/m²
3	2,250 m² PV (50% roof area)
4	
5	

	Changes REF ↔ Var. 3
1	Mechanical ventilation with CO2 sensors controlled in different zones;
2	Rc= 3.5; 5.0 and 6.0 m²K/W (floor, facade, roof); Ventilation heat recovery 90% with bypass; Ventilation flow rate 140% requirements building code; Lighting : 4 W/m²
3	2,250 m² PV (50% roof area)
4	
5	

Various changes have been introduced to reduce the energy consumption. These three cases are presented on Figure 2, together with the reference case of the current situation.

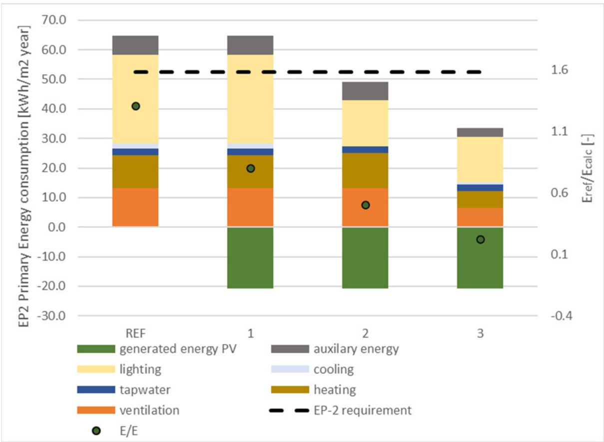

Fig. 2 - Results of the analysis of four cases, aiming to

reduce the energy usage and comply with nZEB regulations.

The results are summarised in Table 4.

Tab. 4 - Summarized results of the case study for the EUT Flux Building.

Variant	Energy demand [kWh/(m²․a)]	Energy use [kWh/(m²․a)]	Renewable energy [%]	E_{calc}/E_{ref} [-]
Requirement	< 122	< 53	> 33%	<1.0
Ref	95	65	43%	1.3
Var. 1	95	44	61%	0.8
Var. 2	95	28	65%	0.6
Var 3	85	13	75%	0.2

The BENG 1 requirement for the energy demand of the building is already fulfilled with the standard characteristics of the reference building. The same goes for the BENG 3 requirement for minimum use of renewable energy. The Flux building is connected to an aquifer thermal storage system (ATES).

Energy from this source is counted as renewable energy, together with air – water heat pumps, biomass, combined heat and power and energy generation by PV, wind and solar thermal collector.

The BENG 2 requirement is fulfilled, even without additional energy generation, if a highly efficient heat recovery system is used, the ventilation flow rate is lowered to a minimum required flow rate and lighting power is reduced. Furthermore, it is possible to fulfil the requirements if PV panels are introduced in the design.

From the case study can be concluded that for this building:

- The nZEB requirements are less strict than the former EPC requirement. After all, EP 2 is only 10% above BENG 2 for the REF variant, while the calculated primary energy with the EPC is 30% above the requirement (E_{calc}/E_{ref}=1.3)
- nZEB requirements are already feasible for the EUT Flux building with less than 50% PV on the roof.

5. Case studies

The energy performance of eight different recently realised and/or designed sustainable university buildings, see Figure 3, is investigated. The buildings are: (1) Eindhoven University of Technology Flux - EUT FLUX, (2) Faculty of Geological Sciences University Utrecht - UU GEO, (3) Education cluster University Utrecht - UU OWC, (4) Energy Academy Europe University of Groningen - RUG EAE, (5) Eindhoven University of Technology Atlas - EUT Atlas), (6) Delft University of Technology Pulse – TUD Pulse, (7) new Building Rotterdam University

Tab. 5 - Building characteristics of the case studies

Nr =>	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***
Building =>	***EUT Flux***	***UU GEO***	***UU OWC***	***RUG EAE***	***EUT Atlas***	***TUD Pulse***	***HR KZ***	***TiU N2***
NFA [m²]	21,561	14,095	10,440	9,363	33,204	4,542	12,404	2,847
Heating	HP	HP, CHP	HP	HP HE	HP	HP	HP	HP
Cooling	ATES	ATES	ATES	ATES	ATES	ATES	ATES	ATES
Ventilation	MB 60% red HR 70%	MB 20% red HR 70%	MB 20% red HR 60%	MB 40% red HR 70%	MB 40% red HR 70%	MB 20% red HR 76%	MB 60% red HR 75%	MB 20% red HR 75%
Windows	U=1.6 W/m²K SHF=0.35	U=1.6 W/m²K SHF=0.35		U=0.97 W/m²K SHF=0.15-0.5	U=0.8 W/m²K SHF=0.25	U=1.65 W/m²K SHF=0.4	U=0.9 W/m²K SHF=0.35	U=1.5 W/m²K SHF=0.6
Shades	S,W,E	S	Overhang	Solar panels	S,W,N,E	no	no	S
Lighting	9 W/m² dl and md	8 W/m²	8 or 13 W/m²	4.5 - 16 W/m²	7 W/m² dl and md	5 or 8.8 W/m² dl and md	5 W/m² on/off	8 W/m² dl and md
PV [m²]			500	3,030	4,300	948	2,250	
PV/NFA [-]	*0.00*	*0.00*	*0.05*	*0.32*	*0.13*	*0.21*	*0.18*	*0.00*

NFA	Net Floor Area	HR	Heat Recovery
HP	Heat Pump	U	Isolation [W/(m²․K)]
HP HE	Heat Pump High Efficiency	SHF	Solar Heating Factor [-]
ATES	Aquifer Thermal Energy Storage	dl	daylight control
CHP	Combined Heat and Power	md	motion detector
MB	Mechanical Balance	PV	Photovoltaic panels
red	% ventilation flow reduction	S,W,N,E	South, West, North, East

of Applied Sciences – HR KZ and (8) Tilburg University Building nr 2 – TiU N2.

Some characteristics of these buildings are described in Table 5 and more information can be found on the websites that are included in the Appendix.

In Table 6, the energy performance calculated with NEN 7120 and expressed in E_{calc}/E_{ref} are given.

Tab. 6 - The university buildings and the calculated E_{calc}/E_{ref} with NEN 7120.

Nr.	Building	Built [a]	A_g [m²]	EPC date	E_{calc}/E_{ref} [%]
1	EUT Flux	2014	21,561	1-jan-15	131%
2	UU GEO	2017	14,095	18-aug-15	84%
3	UU OWC	2015	10,440	6-nov-12	81%
4	RUG EAE	2016	9,363	8-dec-16	1%
5	EUT Atlas	2018	33,204	20-oct-20	47%
6	TUD Pulse	2018	4,542	20-jul-16	9%
7	HR KZ	2022	12,404	nvt	nvt
8	TiU N2	2021	2,847	29-mai-20	-15%

TU/e Flux is above 100% because the original calculation which had to fulfil the requirements of 2009 were recalculated with the more strict requirements from 2015. In Table 6 for every E_{calc}/E_{ref} calculation is indicated which requirements were used. The 2009 requirements for educational buildings became 45% more strict in 2015.

The energy performance expressed in the three EP indicators was first calculated in 2017 based on the old calculation method NEN 7120. Results from this study are given in Table 7. In 2020 the EP indicators were calculated again based on the new calculation method NTA8800. The results are given in Table 8.

Tab. 7 - Results comparison energy performance in BENG based on calculation method NEN 7120 and intended requirments in 2017.

Nr.	Building	BENG 1 [kWh/m².a]	EP 1 [kWh/m².a]	BENG 2 kWh/m².a]	EP2 [kWh/m².a]	BENG 3 [%]	EP 3 [%]
1	EUT Flux	124	93	61	105	34	32
2	UU GEO	50	41	60	91	50	10
3	UU OWC	50	74	60	127	50	27
4	RUG EAE	50	29	60	-11	50	132
5	EUT Atlas	50	61	60	39	50	49
6	TUD Pulse	50		60	_	50	
7	HR KZ	50		60	_	50	
8	TiU N2	50	59	60	-6	50	107

Tab. 8 - Results comparison energy performance in BENG based on final calculation method NTA 8800 and final requirements in 2020.

Nr.	Building	BENG 1 [kWh/m².a]	EP 1 [kWh/m².a]	BENG 2 kWh/m2.a]	EP2 [kWh/m².a]	BENG 3 [%]	EP 3 [%]
1	EUT Flux	122	95	53	65	33	43
2	UU GEO	97	63	47	76	31	32
3	UU OWC	164	141	67	94	37	59
4	RUG EAE	97	57	47	-35	31	170
5	EUT Atlas	164	122	64	28	37	70
6	TUD Pulse	171	137	68	43	38	77
7	HR KZ	134	86	62	0	34	101
8	TiU N2	171	154	68	3	38	98

Explanations by Table 7 and 8:

- *Results' type style means: does not meet the NZEB requirement and* ***does meet the NZEB requirement****;*
- *BENG are the requirements and EP are the calculated values;*
- *at TU/e Flux, the BENG score of 2019 with excel model NTA8800 has been entered in BENG Score 2017. This was available for TU/e Flux and not for the other buildings.*

Fig. 3 - The university buildings which have been considered in this study.

The results in Table 7 and 8 show:

- The RUG EAE, EUT Atlas, TUD Pulse, HR KZ and TiU N2 buildings comply with the nZEB requirements;
- The buildings EUT Flux, UU GEO and UU OWC UU do not comply with the BENG 2 requirement;

• Compared to the EP scores in 2017, it has become easier to fulfil the BENG 1, 2 and 3 requirements.

6. nZEB requirements versus former E_{calc}/E_{ref} requirement

Table 9 shows for each building the percentage wherein the E_{calc}/E_{ref} and EP2/BENG2 demand is exceeded. Besides, the table indicates whether the EPC requirement for 2009 or 2015 was applicable. The 2009 EPC requirements were less strict than the 2015 EPC requirements.

Tab. 9 - Results comparison energy performance in E_{calc}/E_{ref} and EP2/BENG based on final calculation method and final requirements in 2020.

	EPC	*BENG 2*	*EPC-eis in 2009*	*in 2015*
EUT Flux	31%	23%		yes
UU GEO	-17%	62%	yes	
UU OWC	-19%	39%	yes	
RUG EAE	-99%	-175%	yes	
EUT Atlas	-53%	-56%		yes
TUD Pulse	-91%	-37%		yes
HR KZ				
TiU N2	-115%	-96%		yes

Taking into account that the E_{calc}/E_{ref} requirements have become stricter by approximately 45% in 2015 than in 2009, it can be concluded the BENG 2 requirement has become stricter except for the EUT Flux, RUG EAE and EUT Atlas building.

Tab. 10 – The 7 Energy Performance Indicators

Name	*Goal*	*Energy performance indicator*	*Unit*	*Explenation*
Energy demand	Reduction building related energy demand	EP 1	[kWh demand/m^2 floor area]	Thermal energy demand without building services, not calculated to primary energy
Primary energy consumption	Reduction total (direct and indirect) CO2 emission	EP 2	[kWh primary/m^2 floor area]	Same as scope EPC with NEN 7120. Building related energy consumption taking into account efficiencies of the local systems and from energy generation on country level
Share renewable energy	Stimulating local renewable energy generation	EP 3	[%]	Excluding purchased energy, because allocated energy is in the Netherlands not allowed in EP 3, see also EP 7.
User energy	limit energy and internal heat load not related to building	EP 4	[kWh electric/m^2 floor area]	Outside scope EP 1 - 3.
Real energy consumption (on the meter)	Limit externally purchased energy that will eventually be fully renewable	EP 5/ Real energy consumption	[kWh/m^2 floor area]	Energy reduction for EP 1 has also effect on EP5
Direct CO2 emission	Reduce direct CO2 emissions (Goal of the climate agreement for buildings)	EP 6	[kWh CO2 direct/ m^2 floor area]	
Share purchased renewable energy	Stimulating energy transition energy sector	EP 7	[% kWh reality]	The share of renewable energy of all purchased energy

7. nZEB requirements versus 2050 Carbon emission reduction targets

In general, it can be stated that fulfilling the nZEB requirements does not automatically lead to the right steps towards the climate agreement goals of 2050. The nZEB requirements only set performance requirements for 1 new building and do not take other buildings, existing buildings and in future changes in buildings and energy infrastructure into account.

Furthermore, the BENG 2 requirements is currently (2021) focusing on reducing primary energy consumption and the associated direct and indirect CO2 emissions in a cost-effective way. It is a short-term goal/measure, based on current economic feasibility.

For the built environment, the Climate Agreement focuses on the reduction of direct CO2 emissions in the long term (2030, 2050), for which roadmaps are being developed. For a new gas-free/fossil-free building. The BENG 2 requirement will have no direct influence on the reduction of direct CO2 emissions.

Only designing according to the nZEB requirements can lead to sub-optimal solutions because it is not (explicitly) based on the long term and the roadmap for the buildings of the organization. Part of the roadmap can be a future transformation of the energy infrastructure near the building. This could be for example the development of sustainable central energy plant on the campus,

whereby requirements are also set for the buildings to be linked, e.g. a maximum connection capacity or energy demand. It includes a building that must comply with the nZEB requirements, which can also be seen as part of the roadmap for the buildings, including the future planning in energy infrastructure and the available capacity

To evaluate a building design against longer-term goals, it is recommended to add 4 energy performance indicators (User energy, Actual energy, direct CO2 emissions and share of renewable energy purchased) to the 3 BENG indicators for the building, see Table 10. In this way it is possible to monitor and manage the energy performance of buildings as part of the energy transition more effectively, in line with the corresponding goals of these additional energy performance indicators, see Table 10.

8. Conclusions

The nZEB requirements (BENG 1,2 and 3) can easily be fulfilled for university buildings with the new NTA8800 method. In some cases, the nZEB requirements are even less strict than the former EPC requirement E_{calc}/E_{ref} requirement with method NEN 7120.

The BENG 1 requirement appears to be most easy to be fulfilled. Although the insulation value of the investigated buildings is lower than the current building decree level. Consequently, it is concluded that BENG 1 is not a strict requirement for university buidings.

In addition to sustainability measures such as an air-water heat pump, PV panels are always required to meet the requirements in order to achieve BENG 2 and 3.

Fan energy and lighting are the largest energy posts for Flux and the Energy Academy Building. At the UU Geo building it is visible that heating has a large share in the primary energy caused by the use of natural gas for the CHP system.

9. Recommendations

The final nZEB requirements are further differentiated per building function, e.g. there are now requirements for a healthcare building function with beds and healthcare building function without beds. However, no distinction has been made for educational buildings, except for an indirect distinction within BENG 1 based on the ratio of the building shell (facade and roof) and nett floor area. However, it is also important to make a distinction in BENG 2 and BENG 3 based on the number of floors and the total nett floor area, e.g. educational buildings with only 1 floor can have much more advantage (in energy per m^2 nett floor surface) of PV-panels on the roof than larger educational buildings with more floors.

The BENG 1 requirement should be stricter and at least in line with the current building decree levels and also stimulate the optimization of the design and facade that will have a long lifetime with consequently long pay back times for adjustments when the building is in use.

Only complying with the nZEB requirements does not automatically lead to the best design choices to meet the energy and climate goals in the longer term. It is therefore important to always take into account the roadmap with which the buildings of an organization will contribute to the targets of the climate agreement.

To assess a building design against longer-term goals, it is recommended to add 4 energy performance indicators (User energy, Actual energy, direct CO2 emissions and share of renewable energy purchased) to the 3 BENG indicators for the building.

The datasets generated during and/or analysed during the current study are not publicly available because the datasets are the property of each building owner but will be made available after the permission of each building owner.

10. Acknowledgement

The evaluation studies were funded by the Netherlands Enterprise Agency (RVO).

11. Appendix

More information about the case studies can be found on the following websites:

1. TU/e Flux gebouw
   https://www.tue.nl/en/news-and-events/news-overview/28-08-2015-tue-halves-gas-consumption-with-the-official-opening-of-the-flux-building/
2. Faculteit Geowetenschappen Universiteit Utrecht (GEO UU)
   https://www.uu.nl/en/organisation/real-estate-and-campus/campus-utrecht-science-park/development/construction-projects-in-progress/new-office-building-for-geosciences
3. Onderwijscluster Universiteit Utrecht (OWC UU)
   https://www.ectorhoogstad.com/projects/owc-%E2%80%93-victor-j-koningsberger
4. Energy Academy Europe RUG (EAE RUG)
   https://www.rug.nl/groundbreakingwork/projects/eae/?lang=en
5. TU/e Atlas (TU/e Atlas)
   https://www.tue.nl/en/our-university/about-the-university/sustainability/atlas/the-

most-sustainable-building-of-education/

6. Pulse TUD https://campusdevelopment.tudelft.nl/en/project/pulse/
7. Hogeschool Rotterdam KZ Bouwdeel C (HR KZ) https://paulderuiter.nl/en/projects/hogeschool-rottterdam-bouwdeel-c/
8. Tilburg Universiteit Nieuwbouw 2 (TiU N2) https://www.tilburguniversity.edu/campus/developments/educational-building

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