Roadmap to nearly Zero Energy Buildings in 2020

In 2014 a roadmap study has been performed for nearly Zero Energy Buildings (nZEBs) in the Netherlands. Current situation on nZEBs in the Netherlands and Europe were discussed; EU countries are at various stages of development on their nZEB definition. Existing Dutch nZEB show good technical potential; most promising building energy saving measures are ground source heat exchangers and aquifers systems (including heat pumps). The Dutch energy infrastructure (gas and electricity) is discussed, focusing on future policies and implications for nZEBs. Smart grids including local energy exchange will play a major role for nZEBs. The financial feasibility of three nZEB scenarios is compared to a reference scenario for a middle sized office building in a case study. Energy saving measures in the nZEB scenarios lead to an average primary energy consumption of 20 kWh/m²a. LCC (Life Cycle Cost) calculations including additional gains (increased productivity, reduced sick-leave) are executed to determine the cost-optimality of three nZEB scenarios. Results show that nZEBs are financially feasible when benefits are included.

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This study was commissioned by Royal HaskoningDHV, TVVL and REHVA. The study was executed by Royal HaskoningDHV in cooperation with Eindhoven University of Technology. The aim of the study was to prepare a roadmap for nZEBs towards 2020 in the Netherlands. [1] TU/e student Kristian Gvozdenović contributed to this study with an internship at Royal HaskoningDHV. In April 2014 the nZEB project has been presented at the REHVA Technical Research Committee during the annual REHVA meeting. Kristian also competed with his work in the REHVA the Student Competition. [2] Master students from all over Europe presented their works, after which the students were assessed. The judge found the nZEB study very useful as it covered a wide range of topics. TVVL Magazine published a Dutch article on the nZEB Roadmap in September 2014.[3] On the 26th of January 2015 the study was also presented to the 63 state members of ASHREA Associate Society Alliances in Chicago. The full report is available at on TVVL website*.

Introduction

In 2010 the European Commission launched the EPBD-recast (Energy Performance on Building Directive) with the main targets to reduce CO_2 emissions with 90% by 2050 compared to CO_2 levels in 1990. The EPBD requires all newly built buildings to be nZEB in 2020 for different building functions. Existing buildings will also have to comply with this regulation towards 2050. [4]

* http://www.tvvl.nl/website/kennisnet/publicaties/technische-publicaties/i-06-roadmap-to-nearly-0-energy-buildings

In 2012 the Dutch government presented a plan to implement nZEB regulation for the coming years. [5] In the nearby future (2015/2017) building performance requirement will be stricter for residential buildings and non-residential buildings. In 2020 all newly build buildings have to comply to the nZEB regulation with an EPC close to zero.

To support future policy on energy performance, this study provides information which can be used to determine technical and financial feasibility of nZEBs in the Netherlands. The financial feasibility of building energy saving measures is the foundation to determine an nZEB definition in the Netherlands. Nowadays the main focus is on cost reduction; however when benefits of healthy buildings are incorporated in LCC calculations, it will stimulate innovations and make nZEBs far more attractive. In the study case on nZEB offices, LCC calculations are be performed to determine the cost-optimality for nZEB scenarios with benefits, concerning increased productivity and reduced sick leave.

nZEB definition

European Union member states have to define an nZEB definition for their country in the coming years. A preliminary definition on an nZEB is stated in the EPBD recast. [6] It is specified that by 31 December 2020 all new buildings shall be nZEB and governmental buildings, occupied and owned by public authorities, will have to be nZEB by 31 December 2018. The definition of nZEB is given in Article 9 of the EPBD:

> *"Nearly Zero Energy Building: Technical and reasonably achievable national energy use of > 0 kWh/(m²a) but no more than a national limit value of non-renewable primary energy, achieved with a combination of best practice energy efficiency measures and renewable energy technologies which may or may not be cost optimal."*

Currently no nZEB definition has been set by the Dutch government. The definition of 'nearby energy production' will be critical for buildings in urban areas, since high building density creates enormous challenges for on-site renewable energy production. In order to be able to contractually link a 'nearby' renewable energy production capacity to a building (site), it is a prerequisite to have fitting national legislation. This legislation should allow allocating new capacity to the building/development with a long term contract, assuring that investment on that new capacity will lead to a real addition to the grid or district heating or cooling mix. To ensure that future nZEB buildings and renovated buildings utilize as much on-site renewable energy as possible, instead of buying renewable energy from the grid, it is recommended to consider a legislative system were the amount of on-site sustainable energy yield is linked to the building density of the specific area. For example, a certain percentage of renewable energy may be contractually imported when a building is built in a dense area.

Current situation

In the Netherlands building energy performance is expressed in an EPC score, which includes energy performance of installations (heating, cooling, hot tap water, ventilation, and lighting) and levels of insulation (roof, walls, floor, and windows). The EPC for has been introduced in 1995 and been tightened onwards. Building companies have agreed with the Dutch government on further tightening of the requirements in the near future, in order to move towards nZEBs. The EPC requirement for the residential sector is scheduled to decrease to 0.4 in 2015. For the non-residential sector, EPC requirements are scheduled to be lessened by 50% in 2017 compared to the requirements of 2007. In addition to the EPC requirements, minimum requirements for building components (R_c-value and U-value) are in place.

Renovation of existing buildings plays an important role in obtaining an energy neutral building stock. The renovation depth and rate will have to be increased significantly to achieve the goals set in 2050 (all buildings nZEB) according to European studies. [7]

A "deep renovation track", focusing on energy efficiency with high use of renewable energy, is recommended because it can be considered as a financially viable route, meeting CO_2-targets. The renovation rate needs to be increased from the current rate of around 1% of total floor area renovated annually, to 2.5% – 3% annually from 2020 onwards. [8]

Examples of current nZEBs in the Netherlands show the technical feasibility of different buildings types. The nZEB designs are mainly based on the so called Trias Energetica approach: first reducing energy demand, than use renewable energy sources, and if necessary use fossil fuels as efficiently as possible. Example nZEB buildings have very good insulation (R_c-value up to 8 (m²K)/W), triple glass and are built extremely airtight. Common installations are ground source exchangers and aquifers (including heat pump), mechanical ventilation with heat recovery, and large scale solar systems (PV and solar collectors).

Energy infrastructure in the Netherlands

Energy infrastructure is of crucial importance for nZEBs because of the two-way supply/demand characteristic; this requires an advance network were energy exchange and storage is possible. The transition from a supply-demand system to smart grids is required; this is a major technical challenge that has to be overcome.

The Netherlands has an extensive gas infrastructure and the largest gas producer in the EU. The 'gas-roundabout' (the Netherlands as gas hub of Europe) and sustainable 'green gas' projects show a promising future for gas in the Dutch built environment.

The electricity grid in the Netherlands faces a major transition; from a supply-demand system (using mainly fossil fuels) towards a supply-dependent system (using fluctuating renewable energy sources). Electricity networks, 'smart grids' will play an important role in the future; the average energy consumer will also be an energy producer, storage systems and local energy exchange will be important for energy management systems.

Furthermore electrical vehicles and smart appliances will be implemented. Currently many smart grid projects are carried out; these projects range from local smart grids for residential areas and business parks, to initiatives to create an electrical storage system for electric taxi services.

nZEB potential in the Netherlands

The potential for nZEBs in the Netherlands is mainly determined by the availability of building energy saving measures. Currently, measures are applied according to the Trias Energetica method (**Figure 1**). An adapted version of the Trias Energetica method should be used in the future because of changing conditions for buildings. First of all, the focus should be on adapting the energy demand to the building user. Awareness should be raised and energy saving behaviour should be stimulated by the government. Another step that is added is the implementation of energy exchange and storage systems (smart grids): these become crucially important for nZEB because of the intermittent characteristics of most renewable energy sources.

Energy exchange has great potential for reducing energy demand, especially when buildings with a specific heat or cold demand are combined (e.g. nursing homes and ICT data centres). Currently a study is being performed, investigating the potential for direct (hourly) and indirect (seasonal) thermal energy exchange for buildings in urban areas. The calculation tool will allow to calculated energy performance of three buildings separate including a wide variability in energy exchange concepts including generation (centralized/decentralized), distribution (smart/ conventional thermal grid) and seasonal storage.

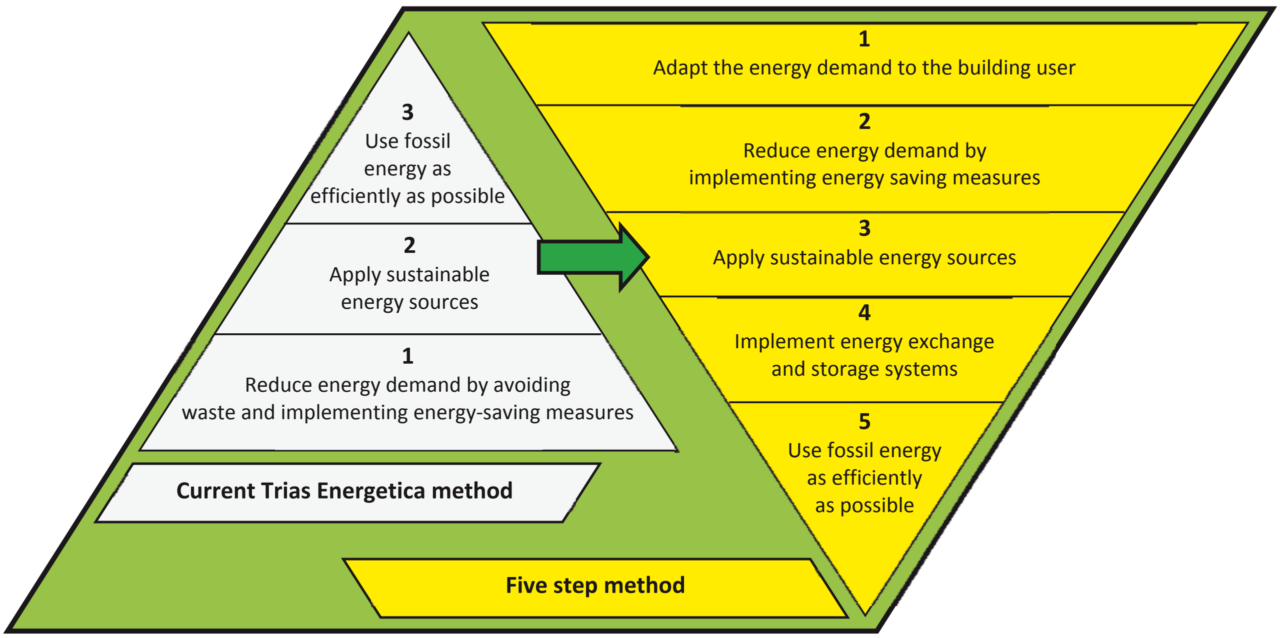

Figure 1. The Trias Energetica method and the Five step method.

Study case: cost optimality for Dutch nZEB scenarios

Financial feasibility of nZEBs in the Netherlands is demonstrated in a study case for a middle sized office building (3,000 m²). The goal is to show that energy saving measure can be cost effective when additional gains are included.

Figure 2 shows the Life Cycle Costs (LCC) versus the annual primary energy demand. Currently (2013) LLCs and primary energy demand are high. By applying building energy saving measures, buildings within the "cost optimal range" are already possible. By creating nZEBs (by applying more energy saving measures) LLCs rise. By including additional benefits of a healthy nZEBs (increased productivity, reduced sick leave) into the LCC calculation, LLCs of nZEBs are reduced.

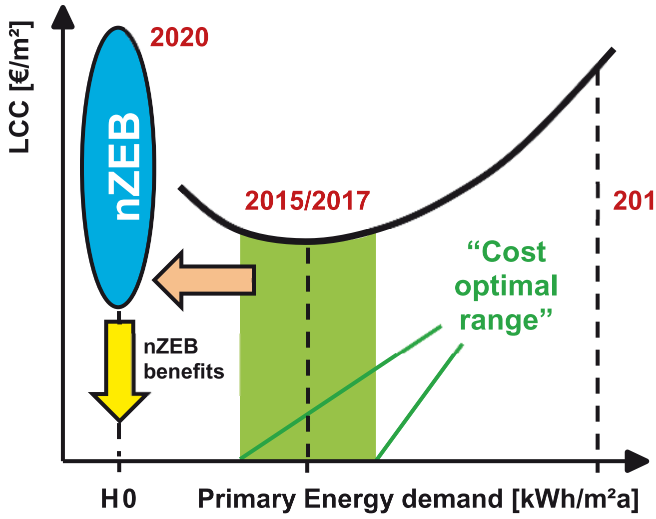

Figure 2. Schematic representation of LCC in current and future situation.

An LCC calculation with a period of 30 years is performed comparing three nZEB scenarios to a reference case. The calculation method is based on standard EU approach, using Dutch principles (from previous studies [9][10]) on cost optimality of energy saving measures.

The reference building has an energy performance that applies to coming EPC demands for office buildings (EPC = 0.7). The nZEB scenarios have been composed applying energy saving measures according the Five step method (**Figure 1**) and using solutions applied in existing nZEB projects. The nZEB scenarios are well insulated and built airtight reducing energy demand. Installations used are ground source heat exchanger heat pumps, aquifer heat pumps and large scale PV application. An average primary energy demand 18.5 kWh/m²a was obtained for the three scenarios.

Additional gains that have been included in the LCC calculation are increased productivity and reduced sick leave. Scientific research has proven that buildings with a healthy indoor climate (high ventilation rate) increase productivity and reduce sick leave. [11]

Results of the LCC calculation show that the nZEB scenarios are not cost effective yet without additional gains. Average additional costs for the energy saving measures are 15 to 50 €/m² higher (financial analysis) and 100 to 140 €/m² (macro-economic analysis) higher compared to the reference case. When additional gains are added, the total LCC cost drops significantly for both analysis (700 up to 1,100 €/m²). In the sensitivity analyses, the LCC gap between the reference building and the nZEB scenarios fluctuates for both analyses; however they do not influence the positive outcome of the LCCs for the nZEB scenarios.

Conclusion and recommendations

This study provides insight on current status, technical and financial feasibility of nZEB in the Netherlands.

Currently no nZEB definition is specified by the Dutch government; based on this study an nZEB definition is provided for middle sized office building. Requirements for such type of building should apply to a primary energy limit of 20 kWh/m²a. Energy saving measures that can be utilized to achieve this limit are: heat & cold storage systems (aquifer including heat pump) in combination with large scale PV cell application.

It is unattractive to become an energy producing building under current regulation, because of low energy tariffs for PV generation (if $E_{electricity\ production} > E_{electricity\ consumption}$). When current regulation on energy tariffs still applies in the future, it is recommended to define nZEB as buildings with a higher primary energy demand limit than EPC = 0: this can prevent energy efficient measures (e.g. PV panels) from becoming financially unattractive.

Energy infrastructure will play an important role to achieve nZEBs in the future. Smart grids will have to be adapted to on-site and nearby renewable energy production. Furthermore energy exchange and energy storage will be integrated in local networks.

Existing buildings will have to undergo a "deep renovation track" and the renovation rate has to be increased to 3% in order create a complete nZEB building stock in 2050.

For buildings in urban area (high building density), it is proposed to apply fitting legislation to stimulate on-site production and minimize the possibility to purchase nearby renewable energy (e.g. wind power) from distant locations. It is advised to consider a legislative system determining on-site sustainable energy yield depending on the building density.

Finally the Dutch EPC is a policy tool and does not represent the primary energy demand in a straightforward way. Energy saving measures, such as applying PV cells on large scale, can negatively influence the EPC score.

Future studies

Royal HaskoningDHV is currently working in cooperation with the Eindhoven University of Technology on a follow-up project on sustainable (re)development of urban districts with special focus on nZEBs. Kristian contributes to this project with his EUT graduation project on a Design methodology for energy positive buildings and communities. A method and a tool are being developed to assess and compare energy exchange, storage and generation concepts for several building functions in urban areas.

Furthermore the Eindhoven University of Technology is a partner in an EU wide consortium of Universities and Knowledge Institutes that submitted the EU Horizon 2020 research project proposal DeDeZEB (Development and Demonstration of ZEBs with reduced cost) in February 2015. The DeDeZEB project (proposal) is led by Prof Jarek Kurnitsky and focusses on solution development of large scale and beyond nearly zero buildings. This includes demonstration in districts and non-residential buildings showing cost reduction and realizing market uptake. ■

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