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ORIGINAL RESEARCH

Defining nearly zero-energy housing in Belgium and the Netherlands

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Abstract Europe expects the housing sector to evolve towards ‘nearly zero-energy’ dwellings. Meanwhile, general terms and research, marketing and legal definitions considering such dwellings have already been introduced. Appraisal of existing definitions is now needed for further policy development. This paper examines what nearly zero-energy terms can be expected to be adopted in Belgium and the Netherlands. The research method uses an interview method based on innovation diffusion theory. The analysis traces the regional adoption trajectory of relevant definitions and examines the opportunities and barriers for the inclusion of existing definitions in regional energy policy. The analysis shows that—whilst international prominence of the terms ‘net zero energy’ and ‘net zero carbon’, in addition to ‘low energy’ and ‘passive house’, is observed—in Belgium and the Netherlands ‘passive house’ and ‘energy neutral’ are preferred. The research findings indicate that the adoption of already existing definitions for nearly zero-energy houses will depend on the region and can prove a very complex process with several conflicting issues. Terms should be clearly defined and used at all political and marketing levels. It is recommended to enhance the relative advantage, demonstrability, visibility and compatibility of favoured definitions by policy initiatives.

Keywords Buildings · Energy efficiency · Policy instruments · Passive house · Zero energy

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Introduction

In the European Union, the overall building stock is responsible for about 40% of the total consumption of primary energy. Housing, in turn, accounts for the bulk of the energy consumption in this domain (Itard et al. 2008). Though there is significant potential for realising cost-effective energy savings and reductions in CO_2 emissions in both new and existing buildings (McKinsey and Company 2009; Ürge-Vorsatz et al. 2007)—which would benefit society at large—certain market, technological and end-user characteristics are inhibiting rational, energy-saving choices in purchase and use (Koeppel and Ürge-Vorsatz 2007). This implies that marketing strategies and policies aimed at overcoming the barriers that are inhibiting the application of energy-efficient technologies and concepts[1] are crucially important in the efforts to lower greenhouse gas emissions from buildings.

More governments and companies are realising the energy-saving potential of dwellings and are pursuing the required strategies and policies. Researchers and networks have proposed different building codes and definitions to significantly reduce the energy consumed by housing. The first energy efficiency codes for dwellings were set in the 1970s in response to the oil crisis (Deringer et al. 2004). Since then, the range has expanded considerably, from regulatory and voluntary instruments in the initial phase to financial incentives and economic instruments (IEA 2005). These instruments regularly introduce definitions for highly energy-efficient housing concepts. 'Passive house',[2] for example, has recently been successfully defined and introduced in different countries and policies (Elswijk and Kaan 2008; Mlecnik et al. 2010).

One of the mandatory actions for buildings in the EU Action Plan on Energy Efficiency [COM(2006) 545] prompted the Commission to devise a strategy for the uptake of a definition of so-called 'nearly zero' energy buildings with a view to a more widespread deployment of such buildings by 2020.[3] The European Commission now expects Member States to introduce and register 'nearly zero-energy' buildings[4]: This is requested in the recast of the Directive of the European Parliament and of the Council on the energy performance of buildings (EPBD 2010). The European Parliament (2009) recommended a focus on buildings with CO_2 emissions and primary energy consumption which are low or equal to zero. National, regional or local tax incentives, financial instruments and lower rates of VAT (European Parliament 2009: Amendment 102) are expected to support the diffusion. Despite the numerous actions towards zero emission buildings and the excitement of the term 'zero', major challenges need to be met in the development of such regional definitions, in particular in relation to the lack of common understanding (Marszal et al. 2010). Defining nearly zero-energy buildings requires a prescriptive approach with stricter implementation of more ambitious strategies and targets and more policy commitment to market change (Atanasiu 2010). Member States can provide more clarity by defining their expectations in, for example, their building codes and tax legislation.

Meantime, the media coverage and the political attention paid to climate change and to lowering the primary energy demand appear to have sent the housing industry into a kind of 'carbon wild west'. Promoters, developers and communities bandy around words like 'passive' houses, 'climate neutral' living, 'carbon-neutral' streets and 'zero-energy' developments, sometimes without clear definitions, target values or (policy) evaluation procedures. Hence, one major obstacle for the implementation of the

[1] One consequence of pursuing the energy efficiency potential is the unavoidable transition to less energy- and resource-intensive building concepts. Von Weizacker et al. call for an integrated improvement in efficiency by, on average, a factor of 4 over 25 years (Von Weizäcker et al. 1998; Raad voor het Milieubeheer 1996; Reijnders 1998). Weterings and Opschoor, amongst others, state that eco-efficiency should be improved by a factor of 10 to 20 over 50 years (Weterings and Opschoor 1994; Jansen 1997).

[2] See for example (PEP 2008): The term 'passive house' refers to a specific construction standard for residential buildings with good comfort conditions during winter and summer and with no traditional heating systems or active cooling. This normally means excellent levels of insulation and air tightness and good indoor air quality guaranteed by a mechanical ventilation system with high-efficiency heat recovery. The heat load does not exceed the load that can be transported by the minimum required ventilation air. However, space heating does not have to be transported through the ventilation system. The following specifications apply for northern latitudes of 40–60° under the conditions in the PHPP calculation model:

- The total energy demand per year for space heating and cooling is limited to 15 kWh/m^2 of conditioned floor area.
- The total primary energy consumption per year for all appliances, domestic hot water and space heating and cooling is limited to 120 kWh/m^2.

A passive house has a high level of insulation with minimal thermal bridges and low infiltration. It utilises passive solar gains and heat recovery to achieve these specifications. The residual energy demand can be met by renewable sources.

[3] A time target for new building was set that as of 31 December 2020, new buildings in the EU must consume 'nearly zero' energy (ECEEE 2010). European industry advisory groups have identified research priorities as part of a longer road-mapping exercise for definitions, targeting the year 2050 and encompassing the vision that (EeB 2009): "By 2050, most buildings and districts could become 'energy-neutral', and have 'zero CO_2 emissions'."

[4] When the recast Directive was approved 19 May 2010, the meaning of 'very low-energy building' or 'nearly zero-energy building' was specified as 'a building that has a very high energy performance, determined in accordance with Annex I [of the Directive]. The nearly zero or very low amount of energy required should to a very significant level be covered by energy from renewable source, including renewable energy produced on-site or nearby.'

implementation of the recast of the energy performance of buildings Directive (EPBD 2010) seems to be the linguistic, cross-regional and legislative confusion caused by the number and variety of definitions and their historically determined meaning.

Outline of research

Research goal

To speed up the diffusion of the use of highly energy-efficient housing, it is necessary that policy provides visible and widely accepted definitions that help companies and other actors to distinguish themselves from the competition. It therefore makes sense to map out an overview of existing marketing and legal definitions for highly energy-efficient housing concepts, particularly with a view to policy adoption. The goal of this research is to identify openings and barriers for the adoption of existing definitions for highly energy-efficient housing concepts in Belgian and Dutch policy, which can also serve as an example for other European countries.

Research question

The main research question was: What definitions can be expected to be adopted for nearly zero-energy housing in Belgium and the Netherlands? This question was explored by asking the following subquestions:

1. What terms have been adopted in relation to highly energy-efficient housing concepts, especially in Belgium and the Netherlands, and by whom?
2. What definitions have been introduced in other countries?
3. What definitions show favourable innovation characteristics for further diffusion in Belgium and the Netherlands?

Research methodology

Diffusion of innovation can be driven by communication within a society, which increases the attractiveness of an innovation (Rogers 2003). In this perspective, it is relevant to frame the study within the innovation diffusion context, i.e. the communication of highly energy-efficient housing concepts.

Based on innovation diffusion theory (Rogers 2003), the study defined both open and closed questions to examine perceived attributes of existing highly energy-efficient housing concepts. How a relevant interview method can be derived from diffusion theory has been discussed in (Mlecnik et al. 2010). General questions in the interview used in this paper requested information about the existence of nearly zero-energy housing, their market penetration and national and legal recognition, including financial benefits, regional references, education and communication efforts and expert appreciation. Demonstrability questions were developed to document the degree to which nearly zero energy may be experimented with and is recognised by the state or region for incorporation in existing developments. Visibility questions asked about the degree to which low energy, passive house and nearly zero energy is visible to others. Further, compatibility was regarded as the degree to which nearly zero-energy definitions are consistent with the (recast of the) EPBD (2010).

After trial and regrouping, a final questionnaire contained three main groups of questions that addressed the relative advantage, complexity, demonstrability and visibility of highly energy-efficient housing as well as their compatibility with building code development:

1. Questions about low-carbon, low-energy, zero-energy or passive house development in Member States or region (directed at commercial actors and networks, change agents and knowledge institutes)
2. Questions about the compatibility of low-energy housing development with the development of building code (for experts only)
3. Questions about the latest development of relevant labels (for label developers only)

To reply to the questionnaire, experts from different countries were identified and addressed. Amongst other, a list of experts was provided by the European Council for an Energy Efficient Economy. Additionally, leading experts from national and regional passive house organisations and known label developers were consulted.

"Adoption of definitions for highly energy-efficient housing in Belgium and the Netherlands" section addresses the first question by combining research results with literature study on the emergence of highly energy-efficient housing concepts in Belgium and the Netherlands. The findings were reflected with interviews with regional key stakeholders (academic stakeholders, energy efficiency experts) and during discussions in working groups (working group 'close the circle—energy' of the Flemish transition arena sustainable living and construction: Duwobo 2010). Using the collected data, the adopted definitions were classified in five categories: general terms used, relevant definitions in research, definitions from demonstration projects, definitions introduced for market creation and legal definitions.

"Experiences in other countries" section deals with question 2 by examining interviewees' responses regarding existing legal definitions in the light of attaining the European goal of nearly zero-energy housing with a focus (detected from the research results) on zero-carbon and zero-energy definitions. It analyses the recent working definitions to trace if they can be translated into attainable criteria over time in the Netherlands and Belgium.

In "Definitions with favourable innovation characteristics" section, the diffusion characteristics related to several working definitions are discussed using the theory of innovation diffusion, and question 3 is answered by analysing the research results in terms of the possible adoption of definitions. This analysis unveils barriers that could potentially obstruct the adoption of some definitions and identifies cross-country opportunities for removing them.

Limitations of the research

This questionnaire was addressed to 188 Member State professionals involved in the development of labels for low-carbon, low-energy, zero-energy or passive houses. In total, 25 completed replies were received from 15 different countries. The limitations of the small interview sample need to be recognised.

Although the professionals were carefully selected, answers were diverse and reflected the expert's own experience and their view on the state of adoption of highly energy-efficient houses in the country. Some experts or regional representatives showed only limited experience with nearly zero-energy houses or even none.

This research method led to replies, detailed comments, additional references and empirical data from a small sample, but with a good international distribution. Possible knowledge gaps were tackled with further literature search and discussions with leading experts.

Since building traditions and practices can vary according to climate and country, the research focussed on western Europe, and Belgium and the Netherlands in particular. It addresses definitions used in countries that are dominated in particular by a heating demand and new housing. It does not specifically address definitions for energy-efficient or energy-positive non-residential buildings, nor districts or communities.

Experience in Belgium can be dissimilar from experience in the Netherlands, but differences in the adoption of highly energy-efficient housing concepts can generate added value when the findings are compared, also with other countries.

Adoption of definitions for highly energy-efficient housing in Belgium and the Netherlands

General terms used

Historically, energy efficiency has always figured as a theme in regional research and engineering, but most of the time it was confined to conversion processes involving large energy flows (Lysen 1996). Whereas the energy crises of the 1970s rekindled the interest in the field of energy-efficient housing, no statutory low-energy standards for new dwellings were implemented in Belgium and the Netherlands, like in, for example, Sweden and Denmark. This led to various general terms introduced in daily language for communication purposes.

In Belgium and the Netherlands, 'low-energy' buildings are usually defined as buildings, which have been designed with the explicit intention of using less energy than standard buildings. Sometimes specific energy requirements are set out by energy consultants, which then lead to performance-based strategies. For example, in the Netherlands and Belgium, the regional implementations of the European Energy Performance of Building Directive (EPBD 2002) have occasionally been used for project targets (e.g. an 'E-level' of 40 or 60 in Flanders and an 'EPC' of 0.4 or 0.6 in the Netherlands), but potential problems have also been reported on building controls and performance guarantees (Visscher et al. 2010).

Whilst in Belgium the term 'passive house' has seen a broad market introduction (Mlecnik 2008), in the Netherlands, the terms 'climate' or 'CO_2 neutral', or 'zero energy' are often used (PEGO 2009). 'Zero carbon' and 'carbon neutral' are used terms in Dutch marketing, but they can be understood in various ways, with no official definition. In the Netherlands, several authors have proposed local definitions for further use: CO_2-neutral homes or CO_2-emission-free houses (e.g. Van Hal 2007), zero-energy or energy-neutral houses (e.g. Rovers and Rovers 2008) or passive houses (e.g. Mlecnik 2009). CO_2 neutral is also applied for larger territories within communities (e.g. Roos and Straathof 2008).

The concept of 'zero-energy' is also subject to different interpretations and frequently occurs in Dutch and Belgian marketing jargon. 'Zero-energy' is generally interpreted as 'net zero energy', i.e. equilibrium between the used and produced energy.

Relevant definitions in research

Since the 1970s, different research models were proposed in different regions. In the Belgian Walloon region, the Passive and Low Energy Architecture movement (Cook 2002) received considerable interest, and terms such as 'passive solar architecture' emerged as the expression of a design philosophy for low-energy buildings that takes account of the natural environment. In architecture, the term 'climate-sympathetic architecture' subsequently appeared with regard to buildings which, because they are designed along the lines of 'passive solar' criteria, use the building envelope as the primary climate control and make mechanical installations supplementary. The term 'bioclimatic (or sustainable) architecture' was widely disseminated in the Walloon Region and refers to an alternative way of constructing buildings which takes account of local climatic conditions and which harnesses various passive solar technologies to improve energy efficiency; the term 'passive solar technologies' refers to heating or cooling technology that passively absorbs (or protects from, e.g. natural shading) the energy of the sun and has no moving components (Tzikopoulos et al. 2005). In view of its potential for generating significant energy savings and reducing greenhouse gas emissions (Tzikopoulos et al. 2005), bioclimatic architecture has continued to receive a fair amount of attention worldwide in recent years (e.g. Radovic 1996; Gallo et al. 1997; Zain-Ahmed et al. 2002; Nahar et al. 2003) and is regarded as an important parameter in contemporary architecture (Donald 1998), especially in Belgium (see, for example, UCL 2010).

Alternatively, the term 'integrated (energy) design' (IED) was more often mentioned in the Flemish Region, especially by energy consultants, which usually refers to a design process that is meant to lower the operational costs of the building, whilst striving for a comfortable indoor climate and lower emissions (see also: Syneffa 2008). In the Netherlands, Lysen (1996) initiated the 'Trias Energica'—now commonly coined the 'Trias Energetica' (VROM 2010)—as a research model to frame the merits of putting energy efficiency before using renewable energy. The Trias Energetica now represents an academically acknowledged three-step priority strategy: (1) reduce the demand, (2) use renewable energy sources and (3) solve the residual demand efficiently and cleanly. It is used in official communication, also for highly energy-efficient housing and construction (for example, VROM 2010).

International knowledge exchange had an impact on the further development of integrated concepts in all regions. For example, the work of experts from the International Energy Agency (IEA), within the Solar Heating Cooling (SHC) Programme, led to national guidelines in Belgium and the Netherlands on how to design, construct and evaluate cost-effective, energy-efficient 'passive' solar homes. The currently used research framework of the 'passive house' concept was developed in 1988 by Bo Adamson at the University of Lund, Sweden, from the basic IED strategy for lowering energy consumption by, for example, reducing transmission, ventilation and infiltration losses and optimising solar gains (Feist and Adamson 1989). 'Passive houses' were first defined as buildings which, in the central European climate, have a negligible heating energy requirement and therefore need no active heating.[5] Direct and indirect European funding (for example, PEP 2008) enabled the passive house concept also to be introduced to experts[6] and policymakers in Belgium and the Netherlands. The project-based stop-and-go efforts for the dissemination of the passive house concept have led to regional differences in the diffusion of the passive house concept (Elswijk and Kaan 2008; Mlecnik et al. 2010).

Belgian and Dutch researchers developed national guidelines on how to design, construct and evaluate such energy-efficient passive houses in the regional context. Researchers applied realistic technical solutions to translate some of the more general bioclimatic design criteria into specific recommendations for target values compatible with the local climate.[7]

[5] Theoretical proof of the feasibility of such houses was furnished by Wolfgang Feist (1993) and indicated that the use of thermal insulation, heat recovery, super-insulated windows and passive solar and other measures to reduce the heat demand could lead to a simplification of the heating system.

[6] The development of the passive house was picked up in the Netherlands by architect Erik Franke, who created a limited network of companies for this purpose in 1998 (Stichting Passiefhuis Holland). This resulted in the first Dutch project in 2000. By this time, the development of the passive house had come to the notice of a Belgian engineering firm that specialised in energy efficiency and developed Flemish demonstration projects. In Belgium, regional funding for the stimulation of thematic innovation combined with funding from a European Intelligent Energy Europe project led to extensive dissemination of the passive house concept and many follow-up projects, first in Flanders and later in the Brussels region, Wallonia and the Netherlands as well (Mlecnik et al. 2003; Mlecnik 2004; PHP 2010).

[7] These criteria are:

- Meet the low energy demand for heating: recommended values for thermal insulation of walls, floors, roofs, thermal bridges, glazing, frames
- Provide good thermal comfort conditions in both winter and summer with attention to the problem of overheating: recommended values for overheating
- Establish very good air tightness in the building: $n_{50} \leq 0.6\ \mathrm{h}^{-1}$

Meantime, 'cradle-to-cradle'[8] and 'sustainable' or 'green'[9] houses are attracting some interest in both the Netherlands and Belgium. As a whole, buildings are much more complex than materials or products alone, but this complexity enables them to close energy, water and material cycles through interconnected loops (van den Dobbelsteen 2008). Experience of buildings in this domain still has to be gained in projects, but it could breathe new life into a Trias Ecologica approach to sustainable building (van den Dobbelsteen 2008).

Definitions from demonstration projects

The late 1970s saw the emergence of rudimentary ideas for integrated concepts and experimental minimum-energy dwellings (see Table 1 for some experiences in Belgium and the Netherlands). As in many countries, several terms have been used by individual architects and companies in Belgium and

[8] The basic idea, proposed by McDonough and Braungart (2002), is to constantly upcycle materials and only when this is not possible materials can be downcycled to leave nothing but 'food' (in the form of organic waste) at the end of the lifecycle. The buildings that McDonough and Braungart (2002) cite as examples seem to be incorporations of cradle-to-cradle products.

[9] Different kinds of 'green' building labels are used—such as Leadership in Energy and Environmental Design (LEED) buildings, Green Buildings, Sustainable Buildings (Laustsen 2008a)—which define sustainable buildings by means of an integrated design strategy and a point scheme that awards credits for building-design features deemed to improve sustainability. These schemes have been explored in detail and compared (Cole 1998; Crawley and Aho 1999; Todd et al. 2001; Bosch and Pearce 2003; Fenner and Ryce 2008; Lee and Burnett 2008; Birt and Newsham 2009). Most rating schemes for 'green building' assess the energy footprint of large commercial properties in order to provide owners and occupants with a solid yardstick for the energy efficiency and sustainability of the building. Widely used labels include assessment in accordance with the UK's Building Research Establishment Environmental Assessment Method or the US Green Building Council or the LEED programme. However, the diffusion of green building ratings has been slow so far and application of rating systems in housing is very limited. It has also been reported that lower energy consumption does not apply in the case of every 'green building' (Birt and Newsham 2009).

Since the European Commission expects a focus on energy issues, 'green building' definitions were not withheld in this study.

the Netherlands by naming experiments and framing demonstration projects. Examples are the 'minimum-energy house' (Kristinsson 2007), 'energy-balance home' (Remu 2000), 'energy house' (Kristinsson 1999) and 'green house' (Groenwoning 2010).

Since these definitions were developed in only a few demonstration projects, until now these definitions did not find a strong enough response in the mainstream construction industry. However, some of these terms—and related positive and negative (!) experiences: see Table 1—still remain in the collective memory of interviewed experts.

In literature terms like 'EQuilibrium™ house' (CMHC 2010), 'active house' (Marszal et al. 2010), 'plus-energy house' (Activehouse 2010) and 'plushaus' (Wappler 2000) can also be found, but these terms have not been reported in interviews from Belgium and the Netherlands.

Definitions introduced for market creation

Due to the lack of policy definition for highly energy-efficient houses, different definitions were introduced by business networks and mixed business/policy networks. In the Netherlands, a general policy-related definition for highly energy-efficient houses is missing.[10] In the Belgian Walloon Region, low-energy houses were defined with more specific criteria by the regional government within the framework of a clustering initiative (CALE 2010). In the Brussels Capital Region, energy performance ambition levels were defined in a demonstration programme with associated grants (Leefmilieu Brussel 2010). The Flemish assembly of environmental non-profit organisations (BBLV 2010) introduced a charter for defining low-energy houses according to a German model and kilowatt-hour per square metre definition,[11] but it was not accepted in policy initiatives. Flemish architects recently received the proposal to become listed when working on low-energy houses (EA 2010). In parallel, business networks aiming for a higher ambition level introduced a passive house definition and labelling in the Flemish Region, the Brussels Capital Region, the Walloon Region and the Netherlands (PEP 2008; Mlecnik et al. 2010). Table 2 summarises the definitions introduced for market creation in Belgium and the Netherlands.

Legal definitions

Next to the previous definitions listed in Table 2, in Belgium definitions for the low-energy house, the passive house and the zero-energy house have recently been formalised in federal income tax[12] legislation (Belgisch Staatsblad—Moniteur Belge 2009, 2010) as shown in Table 3. A recent Royal Decree (Belgisch Staatsblad—Moniteur Belge 2010) reconfirms these definitions for 2011–2012 and defines that the 'renewable energy' in the 'zero-energy' house should be produced by:

1. A system of water heating using solar energy
2. Solar panels for the conversion of solar energy into electrical energy
3. Heat pumps that use energy stored in the form of heat:
   - In the surrounding air
   - Under the soil surface
   - In surface water

The number of kilowatt-hours generated renewable energy has to be calculated with the regional EPBD method provided by the Directive CE/2006/32 applicable on the house. An exception is made when this method does not provide an evaluation of the production of renewable energy. In that case, the conversion efficiency and the ratio between input and output of the systems and equipment for renewable

[10] One could argue that the 'A-label' according to the introduced energy performance certificate for existing housing shows high energy efficiency. However, the achieved energy performance in such cases is much higher than that expected of advanced concepts such as the 'passive house' or zero-energy houses.

[11] For example, in Germany, many projects have been developed and subsidised with the aim of reaching the criterion of 40–60 kWh/m^2, as the maximum total energy demand for space heating (Zick 2008).

[12] For 2011, the fiscal advantage during 10 years was 420 € for low-energy houses, 850 € for passive houses and 1,700 € for zero energy houses.

Table 1 Introduction of energy design concepts in experiments in the 1980s: example in the Netherlands (Kristinsson 2007) and in Belgium (Wouters et al. 1986; Vlaams Parlement 1998)

the Netherlands	Belgium
Housing demonstration project	
'Minimum-energy house' built in 1982–1983 by architect Jon Kristinsson	'IDEE-house' built in 1984 by the Belgian Building Research Institute
Resulted in	
Designing for investing an additional 4,500 €	Designing for technology demonstration in a research facility
Airtight house	Air tightness not considered
Insulated on all sides	Introduction of thermal insulation
Solar energy zoning	Heavily glazed south facades, no solar protection
Solar boiler	Solar collector for heating and hot water
Permanently balanced ventilation with heat recovery and heated by air	No controlled ventilation
Lessons learnt	
An integrated concept led to innovations (polystyrene foundation insulation, airtight walls, roofs and windows, balanced ventilation with heat recovery, electronically ignited gas heater with a modulation burner)	Hasty conceptual and construction decisions led to poor quality (ventilation, overheating, leaky points,…)
Initial problems with new technologies, but many of the companies that invested in the innovations are still in business	The demonstration programme for this building was abandoned and a follow-up project (PLEAIDE) was not realised until 1994 with predefined performance criteria[a]
The decline in the gas price prompted the authorities and banks to withdraw from follow-up projects, but the demonstration project is still used to promote the passive house concept in the Netherlands.	Until today, a strong emphasis exists in policy on providing a good indoor climate, ventilation and the avoidance of overheating. Indoor climate criteria have been integrated directly in Belgian energy performance legislation

[a] For example, the design criteria for the Belgian reference dwelling 'PLEIADE' were (Wouters et al. 1993): (1) meet low-energy demand for heating, (2) provide good thermal comfort conditions in both winter and summer with attention to the problem of overheating, (3) establish very good building air tightness ($n_{50} \leq 1\ h^{-1}$), (4) provide good conditions for indoor air quality, (5) establish an attractive design for the majority of potential clients and (6) use only realistic technical solutions

energy have to be valued by means of a European/ international procedure.

In the Netherlands, no definitions have been adopted so far in legal references. The Dutch agency for innovation and sustainability policy (Agentschap.nl) has tried to steer the definition process with a report (PEGO 2009) but without explicitly defining nearly zero-energy houses. Dutch experts argue if energy demand only needs to be lowered on the scale of a house, since energy can also be produced at a higher level such as the site, district or community (Ravesloot 2005). The term 'energy neutral' is being addressed in the Netherlands by a construction norm, defining the energy performance on location calculation method, which is applied to developments larger than 300 living units and by attributing a maximum score to energy-neutral neighbourhoods (Verlinden et al. 1999). Recently, a Dutch report (DHV 2010) also concluded that the term 'climate neutral' should no longer be used for utility buildings: The term 'energy neutral' is recommended when addressing buildings and 'CO_2 neutral' when addressing the organisational context.

Discussion: the policy challenge of introducing 'nearly zero energy' in Belgium and the Netherlands

The previous research data show that many definitions are already used. Definitions used in individual marketing efforts or demonstration projects are probably not widely diffused. Several experts stated that the knowledge of building experts, the collaborative interests of consultant engineers and research scien-

Table 2 Definitions from business networking initiatives in Belgium and the Netherlands

Category[a]	Energy criteria for homes	Reference
Low-energy house	Under no specified calculation model: The total energy demand for space heating should be limited to 60 kWh/m^2 gross floor area	Flemish charter 2003 (BBLV 2010)
(Low-energy house)	Under the conditions in the Flemish EPB calculation model: The E-level should be limited to 60	Label for Flemish architects (EA 2010)
(Low-energy house)	Under the conditions in the Flemish EPB calculation model: The E-level should be limited to 60	Flemish grants from energy providers (VEA 2010)
Low-energy house	Under the conditions in the Walloon EPB calculation model: $E_w \leq 80$	Baseline for subsidies[a] in the Walloon Region (Energie Wallonie 2011)
Low-energy house	Under the conditions in the Walloon EPB calculation model: $E_w \leq 70$; $E_{spec} \leq 120$ kWh/m^2/year	Label for construction companies and architects (CALE 2010)
Low-energy renovation	Under the conditions in the PHPP 2007 calculation model: The total energy demand for space heating is limited to 60 kWh/m^2 of conditioned floor area	Project listing for exemplary actors Brussels Capital Region (Leefmilieu Brussel 2010)
(Very-low-energy house)	Under the conditions in the Flemish EPB calculation model: The E-level should be limited to 40	Flemish grants from energy providers (VEA 2010)
Very-low-energy renovation	Under the conditions in the PHPP 2007 calculation model: The total energy demand for space heating is limited to 30 kWh/m^2 of conditioned floor area	Project listing for exemplary actors Brussels Capital Region (Leefmilieu Brussel 2010)
Passive house	Under the conditions in the PHPP 2007 calculation model: The total energy demand for space heating is limited to 15 kWh/m^2 of conditioned floor area The total primary energy use is limited to 45 kWh/m^2 year for heating, domestic hot water and auxiliary equipment (fans, pumps), excluding lighting and appliances	Exemplary projects Brussels Capital Region (Leefmilieu Brussel 2010; PMP 2011)
Passive house (including non-residential)	Under the conditions in the PHPP calculation model: The total energy demand for space heating and cooling is limited to 15 kWh/m^2 of conditioned floor area The total primary energy use for all appliances, domestic hot water and space heating and cooling is limited to 120 kWh/m^2 (the Netherlands) or to a compactness related formula[b] (Belgium)	Current definition promoted by Belgian and Dutch business networks: PHP, PMP, Passiefbouwen.nl and research centres in Belgium and the Netherlands: ECN, SBR, BBRI

[a] The brackets indicate that the term is not specifically used in reference documents

[b] {90 – 2 × Compactness kWh/m^2 } where the compactness [compactness=V/A] is a ratio between the building volume (V) and the envelope surface area (A)

Table 3 Definitions of highly energy-efficient houses in Belgium (Belgisch Staatsblad—Moniteur Belge 2009)

Category	Definition for homes situated in the European economic area according to Belgisch Staatsblad—Moniteur Belge (2009)
Low-energy house	The total energy demand for space heating and cooling should be limited to 30 kWh/m^2 conditioned floor area
Passive house	The total energy demand for space heating and cooling should be limited to 15 kWh/m^2 conditioned floor area
	During a pressurisation test (according to the NBN EN 13829 norm) with a pressure difference of 50 Pa between inside and outside, the air loss should not be more than 60% of the volume of the house per hour ($n_{50}\leq 0.6$/h)
Zero-energy house	Comply with the conditions for a passive house
	The residual energy demand for space heating and cooling can be fully compensated by renewable energy produced on site

tists and the lessons of nature and of indigenous architecture should not be ignored in housing. Researchers apparently developed their own research language throughout the years. The 'passive house', born from the research field and adopted by industry, can currently be considered as a state-of-the-art culmination of many of the research efforts in bioclimatic architecture and integrated energy design, whilst using the Trias Energetica.

The Belgian Regions and the Netherlands are (thinking about) tightening the energy performance levels (and the current implementation of the EPBD) towards 'low energy' or 'nearly zero energy', but definitions and level of implementation can vary in different regions. Tables 2 and 3 show that definitions vary, even for the passive house, and that earlier market definitions can conflict with legal definitions. Some interviewees mentioned that efforts in harmonization are wished for. The findings are in line with the study of Thomsen et al. (2008) for 22 European countries: In some countries, official definitions co-exist with unofficial definitions.

Compared to the Netherlands, in Belgium, the legal definition supports the 'passive house' as a political ambition to lower energy consumption in the building sector—see also Dyrbol et al. (2008) and Mlecnik et al. (2010) for a European comparison—and as a preferred model for business development—this model is also supported by EeB (2009). This has historical reasons: The introduction of previous grants and tax relief for passive houses in Belgium helped to create a niche market for similar demonstration projects (Mlecnik and Marrecau 2008; Mlecnik 2008). This niche market is currently supported by business networks, research centres and a few policy makers. 'Passive house' does not conflict with commonly regionally used research definitions, although researchers prefer to look beyond the energy scope or beyond the building.

The European Parliament recommended to introduce financial incentives and to express the energy performance of a building in a transparent manner and to include a numeric indicator of primary energy use expressed in kilowatt-hour per square metre per year (European Parliament 2009; Amendment 82). Table 4 lists how several definition initiatives are currently related to financial incentives and whether tools are recommended for an expression in kilowatt-hour per square metre per year. Table 4 shows that the relative advantage (financial incentives) and/or interregional compatibility with the EPBD recast (tool for calculation of primary energy use) of highly energy-efficient housing definitions can be improved.

The research further notes that the 'integrated energy design' and the 'cradle-to-cradle' discussion were also incorporated in the transition arena on sustainable housing in Belgium. This led, amongst others, to a recommendation to stimulate the further development of energy-neutral housing and to facilitate a positive market climate for passive houses (Dries 2007). When the definitions are reflected in relation to their historical background, e.g. the definition of criteria for bioclimatic architecture (Wouters et al. 1993), it is noted that in the case of 'zero-energy' and 'passive house', there are currently no legal specifications for good indoor climate conditions and an attractive design for a majority of potential clients. Since the recast of the EPBD (2010) offers opportunities to revise definitions, the next section puts a focus on comparing experiences with other countries.

Table 4 Possible barriers (relative advantage and compatibility) of definitions of highly energy-efficient houses in Belgium and in the Netherlands, in the framework of the EPBD recast

Definition initiative (reference)	Financial incentives for high energy efficiency?	Tool recommended to calculate primary energy use in kWh/m^2/year?
BBLV 2010	Not directly related to the initiative	No, Flemish EPB of PHPP can be used
EA 2010	Not directly related to the initiative	Flemish EPB software
CALE 2010	Not directly related to the initiative	Walloon PEB software
Leefmilieu Brussel 2010	Grants for (selected demonstration) projects	PHPP software[a]
Belgisch Staatsblad—Moniteur Belge 2009	Income tax relief	Not particularly mentioned, confirmation according to the definition should be proven by means of a certificate[b]
PEGO 2009	Not related to a definition of highly energy-efficient housing	No, several possible tools are presented
DHV 2010	No specific recommendations	Limits acknowledged of EPC calculations: defining the ambition level requires other tools

PHPP Passive House Planning Package

[a] The PHPP is a software tool designed by the Passive House Institute Darmstadt for the evaluation of passive houses. For Belgium and the Netherlands, it is available in a regional version

[b] A certificate issued by one of the following: (1) an institute recognised by the King, (2) a competent regional administration or similar administration and (3) a competent administration situated in another Member State of the European Economic Area. In practice, in 2008 and in 2009, the tax administration relied on PHP and PMP as 'institutes' and on the already developed passive house label

Experiences in other countries

UK

A 'true' zero-carbon home[13] is expected to emit no CO_2 and does not need to import grid electricity (RAB 2007). Heating loads are minimal and any remaining heating needs are met with renewable fuels and technologies. Similarly, electricity demand is reduced to a minimum and any remaining demand is met with renewable electricity. In reality, the achievement of 'true zero carbon' is a costly business as energy needs to be stored in order to overcome the mismatch between supply and demand in many renewable systems (RAB 2007). The alternative is the 'net-zero-carbon' home, which emits no net CO_2 on an annual basis, but could be either emitting or offsetting it at any given moment.

The term 'zero-carbon' homes appeared in official UK policy even though the technical aspects still had to be defined. The UK government has pledged to achieve zero-carbon standards for all new government-funded homes by 2016 (Jones et al. 2008). In February 2007, the Welsh Assembly announced that all new buildings funded by the Assembly must achieve zero carbon by 2011, but it was reported that it was still to provide a definition of zero carbon and explain how the targets are to be achieved (Jones et al. 2008).

In 2007, England adopted the BRE Code for Sustainable Homes (BRE 2006) as a reference framework. The government introduced the Code for Sustainable Homes (CSH) rating as a first major attempt to define 'sustainability in the built environment'. The CSH rates the sustainability of a development on the basis of nine key criteria, only one of which is energy and CO_2 emissions (Saunderson et al. 2008). This initial step also included a first definition of a zero-carbon home.

The latest version of the CLG guide (CLG 2009:46) defines a home as zero carbon when 'net CO_2 emissions resulting from ALL energy used in the dwelling are zero or better. This includes the energy consumed in the operation of the space heating/cooling and hot-water systems, ventilation, all internal lighting, cooking and all electrical appliances.'

[13] This definition of zero carbon is similar to the definition of 'autonomous' as in 'autonomous house': The evolution, significance and implications of the definition of 'autonomous' over the years has been reviewed by Brenda and Robert Vale (Vale and Vale 2002).

Dwellings must meet the minimum mandatory energy requirements for CSH Level 5—which means that that emissions must be zero or better. The definition (CLG 2009:46) further states that "A 'zero-carbon home' is also required to have a Heat Loss Parameter (covering walls, windows, air-tightness and other building-design issues) of 0.8 W/m^2 K or less, and net zero CO_2 emissions from the use of appliances and cooking in the home (i.e. on average over a year)." According to the UK definition, off-site renewables can only be used if they are directly supplied to the dwellings by private wire.

Further, a zero-carbon house is also defined in the Stamp Duty Land Tax SDLT (UK Government 2007) as a house that should meet the following criteria: fabric energy efficiency (minimum HLP of 0.8 W/m^2 K), space heating demand (up to 15 kWh/m^2/year) and carbon neutral over a year. SDLT and CSH version 2 definitions of zero carbon are similar, except for the unregulated energy[14] that is a fixed value for the SDLT (Poveda 2010).

'Zero-energy' definitions

The term 'net zero energy' first appeared in US law, but it was defined for commercial buildings. On 19 December 2007, the US Administration passed the Energy Security and Independence Act outlining plans for 'net-zero-energy commercial buildings' and stating that all new commercial buildings should attain net-zero-energy status by 2030 (USC 2007). In Section 422 (a) (3) (USC 2007:113), 'zero-net-energy commercial building' is defined as a high-performance commercial building that is designed, constructed and operated in such as way that:

– It has a much-reduced energy requirement.
– It meets the residual energy needs from sources that do not produce greenhouse gases.
– It produces no net emissions of greenhouse gases.
– It is economically viable.

In a number of publications (Torcellini and Crawley 2006; Laustsen 2008b; Crawley et al. 2009; Marszal and Heiselberg 2009), authors present the wide variety of zero-energy working definitions and highlight the significance of these definitions in the framework of final design and actual performance. Torcellini et al. (2006) have defined 'net zero site energy' and 'net zero source energy'.[15] 'Net zero site energy' means that a site produces at least the same amount energy that it uses in a year, regardless of energy type. 'Net zero source energy' refers to a system whereby imported and exported energy is multiplied by a primary energy converter, which allows for some degree of flexibility in the use of heating fuels. Hernandez and Kenny (2010) attempted to introduce a further element in the definition of zero-energy buildings, viz. the embodied energy[16] of the materials used for the construction of the building and its systems. 'Energy-positive' buildings are defined as buildings that are able to produce more energy than they use.

Discussions are still underway at international level (IEA SHC Task 40 2010) to determine whether these definitions should be evaluated on an annual or on a seasonal basis to reduce the energy mismatch. The 'Source' definition is difficult to interpret since there is no readily available data on the location, source and conversion (Torcellini and Crawley 2006). 'Site' can also be difficult to define, e.g. does it refer to the building site or the total ground surface? Building owners are primarily interested in obtaining verification that their building has

[14] Unregulated energy involves energy demand of electrical appliances that are not included in current SAP calculation such as fridge, microwave, TV, radio; both 'white' (kitchen) and 'brown' (entertainment) goods. The unregulated energy is estimated using a formula that accounts for total floor area and a factor for the number of occupants.

[15] Net-zero-energy definitions according to Torcellini et al. (2006):

- Net zero site energy: A (zero energy building) site produces at least as much energy as it uses in a year.
- Net zero source energy: A source (zero energy building) produces at least as much energy as it uses in a year. Source energy is the primary energy used to generate and deliver the energy to the site. A building's total source energy is calculated by multiplying the imported and exported energy by site-to-source converters.
- Net zero energy costs: The amount the utility pays the owner of the building for the energy exported to the grid is at least equal to the amount the owner pays the utility for the energy services and the energy used over the year.
- Net zero energy emissions: A net-zero-emission building produces at least as much emission-free renewable energy as it uses from emission-producing energy sources.

[16] Embodied and operational energy was also studied for solar houses and passive houses; see, for example, Sartori and Hestnes (2007).

'net-zero-energy-cost' status, but this is difficult to determine in practice because of the non-transparent structure of energy rates (Torcellini and Crawley 2006). Sartori et al. (2010) developed a series of criteria that need to be evaluated in order to achieve a sound zero-energy definition.

There are many unanswered questions. For instance, there is no standardised way of making zero-energy calculations (Voss 2008; PEGO 2009). The problem is not so much the lack of a definition but rather the need for appropriate analysis and representation methodologies to reveal differences and commonalities (Voss 2008). As evaluations of zero-energy projects are usually based on calculations, decisions need to be taken on which units to use (final energy, primary energy, non-renewable share of primary energy, CO_2, CO_2 equivalent etc.) (Voss 2008; PEGO 2009).

Discussion: relevance for Belgium and the Netherlands

The research detected only a few additional legal references considering the definition of zero-energy or zero-carbon buildings (see Table 5 for an overview). The starting point for all common definitions is a far lower level of energy consumption than standard. 'Zero carbon' or 'net zero energy' has not been defined in official Belgian or Dutch policy although the above-mentioned discussions have been acknowledged by the Dutch policy body responsible for the energy transition (PEGO 2009). Belgium opted for another legal approach to the 'zero-energy' house (see Tables 2 and 5).

The implementation of the UK 'zero-carbon' definition can be considered as a regional implementation. Regarding the specificity of the Belgian and Dutch context, it could inspire in particular the Netherlands, where the term 'carbon neutral' is often used in marketing. However, the use of an assessment method for zero-carbon homes, such as the Code for Sustainable Homes with its emphasis on point scoring, may cause people to see higher complexity and sustainability as add-ons, rather than integral elements in housing design (Jones et al. 2008). Also, many players in UK industry expressed concern at the inclusion of the private wire connection (Saunderson et al. 2008).

Terms like 'zero carbon' and 'zero net energy' were coined to simplify the issue and make it more 'accessible', but these simplifications may themselves be to blame for constraining debate and stifling innovation (Saunderson et al. 2008). It can therefore be questioned whether introducing such new definitions, next to the already existing research, marketing and legal definitions in Belgium and the Netherlands, will improve innovation diffusion.

Definitions with favourable innovation characteristics

Relating definitions to innovation diffusion

The goal in the Netherlands and Belgium is to increase the adoption of highly energy-efficient housing (PEGO 2009; Dries 2007). Within this framework, 'zero-energy' or 'zero-carbon' housing can be considered an innovation for Belgium and the Netherlands, in addition to the 'passive house'. Clear definitions of highly energy-efficient housing concepts geared to attaining 'nearly zero-energy' homes are expected to bring this goal closer and promote innovation in housing.

In this paper, definitions of such innovations are seen as a communication tool in a changing economic and legal landscape. Innovation diffusion theory examines the processes whereby an innovation is communicated through certain channels over time amongst the members of a social system (Rogers 2003). Mobilising resources and creating legitimacy are two basic functions that innovation systems need in order to develop (Alkemade and Hekkert 2009). Clear definitions can create legitimacy and associated resources can form a basis for the development of market infrastructure.

Rogers (2003) identifies five perceived attributes of an innovation that can help to explain the rate of adoption of an innovation: relative advantage, complexity, trialability (in this paper 'demonstrability' is used), observability (here 'visibility' is used) and compatibility. Table 6 gives examples how these attributes can be interpreted for our previous discussion.

Opportunities and barriers in the Netherlands

The energy transition platform for the built environment has put forward several definitions for use and evaluation in the Dutch market and wanted to define further requirements for energy-neutral and CO_2-

Table 5 Legal references and key requirements for 'nearly zero-energy' buildings (status December 2009)

Definition initiative (country)	Legal reference: key requirements
Zero-energy house (Belgium)	Belgisch Staatsblad—Moniteur Belge 2009:
	The total energy demand for space heating and cooling should be limited to 15 kWh/m^2 conditioned floor area
	During a pressurisation test (according to the NBN EN 13829 norm) with a pressure difference of 50 Pa between inside and outside, the air loss should not be more than 60% of the volume of the house per hour ($n_{50} \leq 0.6$/h)
	The residual energy demand for space heating and cooling can be fully compensated by renewable energy produced on site
Zero carbon home (UK)	Code for Sustainable Homes (Level 5):
	Energy-related net CO_2 emissions from a dwelling over a year (emissions from energy required for heating, hot water, lighting and ventilation as well as appliances and cooking)≤0
	Heat loss parameter ≤0.8 W/m^2 K
	Equivalent renewable energy generation capacity must be installed to reduce CO_2 emissions to zero. All installations for the generation of renewable energy must be located within the curtilage of the development or directly connected. In the case of electricity installations this means a private wire connection
Zero-net-energy commercial building (USA)	US Congress (USC 2007:113) Section 422 (a) (3):
	A high-performance commercial building that is designed, constructed and operated in such as way that:
	It has a much-reduced energy requirement
	It meets the residual energy needs from sources that do not produce greenhouse gases
	It produces no net emissions of greenhouse gases
	It is economically viable

neutral building projects relating to, for example, maximum energy use per square metre (PEGO 2009:43). Therefore a 'carbon-neutral' approach appears to be most compatible with the current market and policy situation. However, it should be noted that, when the term 'zero carbon' was first introduced in the UK and prototypes were developed, case studies within this framework showed that an integrated energy design can offer a total package of both passive and active measures to achieve zero carbon (Jones et al. 2008). In this perspective, defining more precisely the integrated energy design and the Trias Energetica approach can also result in zero carbon solutions for the Netherlands. Regarding the market support, this might also result in 'passive house' as a preferred term. A strategy for formulating any definition is still needed, as well as appropriate calculation tools and a study to determine compatibility with the new regulations on the energy performance of buildings.

The market appeal of terms for highly energy-efficient housing in the Netherlands is currently limited because no definitions have been adopted so far in legal references. However, demonstrability is high and the Dutch agency for innovation and sustainability policy (Agentschap.nl) has tried to steer the definition process and acknowledged the complexity of the transition process. Many definitions are currently in circulation, not least in the application files of the subsidy programme for demonstration projects (in Dutch: 'Unieke Kansen Regeling' or 'UKR').

At present, a definition of 'low energy' based on the Dutch energy performance legislation has the highest visibility in official websites, whilst 'zero carbon' is often used in projects. Both might have low compatibility with the desire of the European Parliament to express indicators of primary energy use in kilowatt-hour per square metre per year (see Table 4). In the meantime, 'passive house' is used by industry networks and a few communities and housing associations.

Table 6 Examples of how definitions used can have an impact on the adoption of highly energy-efficient housing concepts, using Rogers' innovation diffusion characteristics (2003)

Perceived attribute of an innovation and relation to rate of adoption	Example of interpretation for nearly 'zero-energy' houses
Relative advantage: The greater the perceived advantage, the more rapid the rate of adoption	When in Belgium a more important tax reduction is given for a 'zero-energy house' than for a 'passive house' and a 'low-energy house', the adoption of more energy-efficient housing concepts is expected to increase
Complexity: Simpler innovations are adopted more rapidly	A simple definition can be easily communicated. A complex evaluation procedure can evoke opposition
	Example: Initially, the idea of 'zero-carbon buildings' met with a favourable reception from UK industry, but when the detailed requirements were unveiled many businesses found them unrealistic and unnecessarily complicated and either downscaled their ambitions or abandoned projects altogether (Saunderson et al. 2008)
Demonstrability: Opportunities for education and hands-on learning and innovation trials on a partial basis could improve the rate of diffusion	The industry is concerned that, even under favourable conditions many homes may be unable to generate sufficient electricity on-site [to reach net zero energy] due to physical restrictions alone (RAB 2007). This can decrease the diffusion rate of 'zero-energy'
Visibility: The easier it is for individuals to see the innovation and its results, the greater the likelihood that they will adopt it	An independent institute (e.g. for grant control) can certify the definition of 'passive house'. The official certificate can serve as a marketing tool and certified projects can be made public in a database (Mlecnik 2008). This appeal is currently further enhanced by independent appraisal (Belgisch Staatsblad—Moniteur Belge 2009): confirmation according to the legal definition should be proven by means of a certificate issued by one of the following:
	An institute recognised by the monarch
	A competent regional or similar administration
	A competent administration situated in another Member State of the European Economic Area
Compatibility: Incompatibility will not lead to adoption unless a new value system is embraced. This is a relatively slow process	The research efforts relating to defining zero-energy buildings focus primarily on local energy generation (integrating for example massive PV, micro-generation…) without taking too much account of some integrated energy or bioclimatic design aspects (popular in Belgium) like lowering the operational costs of the building whilst striving for a comfortable indoor climate. In discussions on net-zero-energy buildings the first and third step of the Trias Energetica are often conflated

At present, no specific relative advantage has been attributed to certain definitions—for example, in the form of grants or tax benefits, or social prestige for the market players. This might lead to low visibility and market confusion. The Dutch 'Unieke Kansen Regeling' programme allows communities to apply for grants for demonstration projects for very-low-energy houses. A continuation of this programme potentially offers a trial of grants for certain (prescribed) definitions. Experiences from the previous call for projects can lead to defining favourable definitions for a next call. Also, other countries, like Belgium, might provide experiences from a more advanced policy situation.

Opportunities and barriers in Belgium

In Belgium, definitions for the low-energy house, the passive house and the zero-energy house have been formalised in tax legislation (Belgisch Staatsblad—Moniteur Belge 2009, 2010), which creates attractiveness to use these definitions and gives an opportunity to reduce complexity. The tax law provides a clear framework plus income tax relief

Table 7 Grants for new low-energy housing categories in the Flemish Region, according to E-level (building energy performance level) for building applications from 1 January 2010 (VEA 2010) and in the Brussels Capital Region (Leefmilieu Brussel 2010)

Housing category	Grant	Possible additional grant
E60 Dwelling (Flemish Region)	1,000 €	+ 40 € per E-level point below E60 + 300 € solar boiler
E40 Dwelling (Flemish Region)	1,800 €	+ 50 € per E-level point below E40 + 300 € solar boiler
E60 Apartment (Flemish Region)	400 €	+ 20 € per E-level point below E60 + 300 € solar boiler
E40 Apartment (Flemish Region)	800 €	+ 30 € per E-level point below E40 + 300 € solar boiler
Passive house (Brussels Capital Region)	100 €/m^2 floor area for houses up to 150 m^2 and 50 €/m^2 floor area for houses above 150 m^2	+ first blower-door test + €/m^2 for several 'sustainable' options (e.g. roof insulation, wall insulation, environmentally friendly insulation materials, Forest Stewardship Council labelled wood window frames)

incentives which enhance the market appeal by creating a clear relative advantage. The current tax benefits based on energy performance will make people perceive a higher energy performance as superior to other alternatives possibly leading to a faster rate of adoption.

The introduction of the low-energy and zero-energy category, in addition to the already existing passive house category, has been perceived as allowing demonstrability consistent with the existing regional value of the 'passive house'.[17] It would therefore be reasonable to expect that past experience and the needs of (potential) adopters will be more readily adopted.

In this context, the visibility of uniform definitions to potential adopters can be considered a key factor in diffusion. This visibility is built up by, amongst others, business networks, mixed policy/business networks and promotion by the federal government taxation services (for example, at building fairs).

However, the tax law and market definitions are currently not compatible with the regional EPBD (2002) implementation. The diffusion of these definitions might therefore be hindered by current regional initiatives promoting other or previous EPBD-related definitions. For example, Table 7 shows the additional grants available under the energy performance regulations in the Flemish Region and in the Brussels Capital Region.

The Brussels Capital Region offers a specific situation. The Flemish Region and the Brussels Capital Region are pursuing the same strategy to increase the relative advantage for a better energy performance by buildings. In the Brussels Capital Region—in contrast with the Flemish Region—the definitions of the passive house are maintained for grants, regardless of the legislation on the energy performance of buildings. This is largely due to the good visibility and compatibility that the definition provides within the framework of the policy programme for demonstration buildings in the Brussels Capital Region. Moreover, the calculation tools for passive houses must be used for evaluation, which is compatible with the design practice of passive houses. In the Brussels Capital Region, the passive house is the

[17] 'Net zero carbon' is relatively rarely used in Belgium. In contrast, the non-profit organisations Passiefhuis-Platform and Plate-forme Maison Passive in the Belgian market have counted more than 150 companies that use the term 'passive house' in their marketing. In contrast with the Netherlands, the definition for 'net-zero-energy' in Belgium has no significant basis as yet in market infrastructure or in regional policy. Compared with other definitions, the 'passive house' has an obvious advantage in that the related criteria and instruments are readily available. Since space heating accounts for the majority of the total energy consumption of households in the European Community, a policy focus on definitions that stand for a substantial reduction in the demand for space heating is compatible with the desire to reduce the primary energy demand and achieve political ambitions. Nevertheless, calculation procedures should be carefully revised when introducing any definition of nearly zero-energy housing, so that a reality-based estimate of energy consumption can be provided.

only category to be rewarded with grants for new houses. 'Very low energy' (≤30 kWh/m^2/year) and 'low energy' also receive grants, but only for renovation.

EPBD incompatibilities should be solved when introducing the EPBD recast (EPBD 2010). Previous research has shown that the current energy performance standard can lead to 'lock-in' effects by encouraging only incremental innovation and techniques that reflect the principles in the energy performance policy (Beerepoot 2007:204). It is recommended to avoid penalising techniques that break with convention and that are needed for the transition to nearly zero-energy housing, e.g. some experts noted that 'passive houses' are systematically penalised for fictitious overheating in Flemish EPBD implementation.[18]

Discussion

Table 8 presents a summarised interpretation of the discussion to show how definitions can influence the rate of adoption for nearly zero-energy housing in three regions. Table 8 shows that the policy interpretation of 'nearly zero-energy' into workable local definitions might differ from region to region, depending on the adoption history of highly energy-efficient housing concepts and the existence of specific policy programmes which have already introduced certain definitions. Where necessary, the relative advantage, demonstrability, visibility and compatibility of favoured definitions can be enhanced by energy policy initiatives to increase the rate of adoption.

Conclusion

Definitions for highly energy-efficient housing have been introduced through general terms and demonstration projects and have been adopted and refined by innovators, researchers, business networks, mixed business/policy networks and policy developers. In search of defining nearly zero-energy dwellings, international researchers are currently proposing prominence of the terms 'net zero energy' and 'net

[18] Due to historical reasons (compare with the negative experiences in Table 1), the regional EPBD expresses energy performance in a non-dimensional parameter and also includes an indoor climate appreciation. Fictitious overheating often appears and is penalised in calculations for passive houses.

Table 8 Innovation characteristics that can influence the rate of adoption of definitions of nearly zero-energy housing concepts in the Netherlands, the Flemish Region and the Brussels Capital Region

Attractiveness	Demonstrability	Visibility	Compatibility	Complexity
the Netherlands				
Lack of legal definition = lack of attractiveness	High but current (UKR) demonstration programme does not distinguish definitions	High for 'carbon neutral', emerging for 'passive house'	'Passive house' compatible with IED and Trias Energetica	Platform Energy Transition tries to reduce complexity
The Flanders Region				
Marketing makes 'passive house' solutions attractive	'Passive house' important trial area; 'zero-energy' new trial area	High for 'passive house', emerging for 'zero-energy house'	Federal Decree compatible with 'low energy', 'passive house' and 'zero energy', less compatible regional interpretations	Transition network reduces complexity with information and education
The Brussels Capital Region				
Policy and market embraces 'passive house'	Current demonstration programme allows trials for different building typologies	High for 'passive house', involved actors are listed by official demonstration programme	Compatible Federal (Royal) Decree	Company clustering and facilitators reduce complexity

zero carbon' in addition to 'low energy' and 'passive house', in order to enable compatible regional market infrastructure development and innovation diffusion. Although definitions can have a different meaning in different regions and are poorly integrated internationally, a few countries have already adopted definitions in their building or fiscal policies.

The analysis shows that in Belgium and the Netherlands, 'passive house' cannot be neglected as a useful term, offering market and some policy acceptance, for the realisation of net-zero-energy or zero-carbon definitions in the future implementation of national energy policies. A clear definition compatible with the regional context is necessary to increase attractiveness and demonstrability. Though the reduction or offsetting of energy and/or emissions in nearly zero-energy definitions seems fairly straightforward, the complexity when examined in detail and when integrated in building energy performance regulations can be reduced.

An important challenge to avoid market confusion is that targeted definitions are clearly formulated and used consistently at all political levels, national and regional. Whilst the research shows that new terms have been easily introduced, a huge effort lies in providing—and reducing the complexity of—associated evaluation procedures and in improving compatibility with local legislation and the recast of the energy performance of buildings directive. The Belgian situation provides an example of a legal framework, compatible with the required EPBD recast, in order to reward better energy performance for passive houses and zero-energy houses. It shows that early fiscal tools can be used to reduce market confusion and to try out or enforce definitions for highly energy-efficient houses.

A challenge now remains in providing a system of appraisal, especially with regard to compatibility with market initiatives and regional grant schemes, regional implementation of the recast of the EPBD, administrative control of tax relief and other energy-related issues (e.g. calculation of relevant energy indicators and tools, indoor climate appraisal and so on). These quality appraisal systems will be an important subject of future research.

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