

TAP2 - PAT2

PROGRAMME TO STIMULATE
KNOWLEDGE TRANSFER
IN AREAS OF STRATEGIC IMPORTANCE

Low energy housing retrofit

LEHR

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STANDARDISATION 

TELECOMMUNICATIONS 

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NEW MATERIALS 

**PROGRAMME TO STIMULATE KNOWLEDGE TRANSFER
IN AREAS OF STRATEGIC IMPORTANCE**

TAP2

FINAL REPORT

**LOW ENERGY HOUSING RETROFIT
LEHR**

P2/00/06

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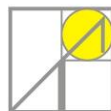
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TABLE OF CONTENTS

I. RESUME-SAMENVATTING-SUMMARY	5
Résumé.....	5
Samenvatting	7
Summary	9
II. TERMINOLOGY	11
Energy terms.....	11
Area definitions	12
Quality assurance expressions.....	13
Low energy building categories	13
III. INTRODUCTION	15
A. Context	15
B. Research goal	15
C. Low energy housing retrofit: a first definition	16
D. How to read this report.....	17
E. Annexes on the web.....	18
IV. POTENTIAL OF LOW ENERGY HOUSING RETROFIT.....	21
Abstract.....	21
A. Introduction.....	21
B. Research approach.....	22
C. Research results based on statistical data	23
1. General characteristics of the Belgian Building stock.....	23
2. Motivation for renovation.....	23
3. Energy characteristics of the building stock.....	27
4. Conclusion: proposed building typologies for further research.....	29
D. Potential of the existing housing stock to reduce energy	30
1. General considerations	30
2. A case study for the Brussels Region	32
E. Market segmentation for low energy housing retrofit.....	32
1. Segmentation based on ownership, private rent or social rent.....	32
2. Segmentation based on investment level	33
F. Conclusions.....	33
1. Policy should also address non-energy benefits.....	33
2. Different building types require different approaches	34
3. A target group oriented approach is required	34
4. Energy policy should reinforce best practice LEHR.....	35

V. TRANSITION TO LOW ENERGY HOUSING	37
Abstract	37
A. Context	38
1. Introduction	38
2. Research question	39
3. Research methodology	39
B. Technological innovation	40
1. Introduction	40
2. Thermal insulation and avoidance of thermal bridges	41
3. Indoor climate systems	51
4. Conclusion: a communication plan is needed	54
C. Economical and social challenges	55
1. Changing business motivation	55
2. The social challenge	57
3. The economical challenge	58
4. The quality challenge	64
5. From demonstration project to diffusion of innovation	66
D. Policy challenges	69
1. Introduction	69
2. Municipalities and regions as facilitator	70
3. The recast of the Energy Performance of Buildings Directive (EPBD)	71
4. The energy performance certification (EPC)	73
5. Policy border conditions for a transition to a low energy housing stock	74
6. European frontrunners being more ambitious	76
7. Recommendation: towards a SMART umbrella programme?	78
E. Conclusions	79
1. Sustainable (re)development can lead to technology clustering	79
2. Opportunities for technological innovation and quality assurance	81
3. Diffusion of innovation requires a balanced strategy	81
4. Government should develop a strategy for market development	83
VI. ANNEXES	85
A. Additional LEHR reports	85
B. Publications	87
1. Project files	87
2. Scientific publications (peer reviewed)	92
3. Other publications	92
4. LEHR working documents	92
C. Presentations	93
1. IEA Final Workshop, 14 October 2009, Antwerp	93
2. LEHR final workshop, 18 November 2009, Brussels	94
3. Other presentations (available on request)	94
D. Additional available tools	95
1. Media files	95
2. Additional tools	96
VII. REFERENCES	99
VIII. ACKNOWLEDGEMENTS	105

I. RESUME - SAMENVATTING - SUMMARY

RÉSUMÉ

Dans plusieurs pays européens, le secteur du bâtiment, et principalement du logement, est responsable de plus de 35% de la consommation d'énergie. La rénovation des logements existants constitue donc un énorme potentiel d'économie d'énergie. Actuellement, des projets exemplaires démontrent que la consommation d'énergie peut être réduite par cinq, tout en améliorant la qualité de vie.

L'objectif du projet LEHR (Low Energy Housing Retrofit) est de développer de l'information sous forme de divers documents publiés, de fichiers accessibles sur Internet et d'ateliers nationaux, destinés à différents groupes-cibles.

Le projet LEHR avait pour but :

- L'identification de rénovations très réussies, par un réseau d'experts nationaux et internationaux;
- La compilation systématique de données essentielles relevant du projet, de l'exécution et des performances énergétiques de ces rénovations;
- La publication de ces projets exemplaires de manière à toucher les maîtres d'ouvrage et les concepteurs.

Les aspects suivants ont été systématiquement examinés dans l'analyse des projets de rénovation réussis:

- (1) Stratégie énergétique: conservation, usage d'énergie renouvelable et stockage efficace;
- (2) Consommation d'énergie estimée: chauffage, eau chaude sanitaire et électricité pour la conception des systèmes techniques;
- (3) Confort: confort thermique hivernal et estival, qualité de l'air et éclairage naturel;
- (4) Intégration: solutions qui lient des mesures d'économie d'énergie à d'autres mesures stimulant la rénovation.

La première partie de ce rapport final est fondée sur la publication LEHR 'Potential of Low Energy Housing Retrofit' et fournit une analyse du parc immobilier belge afin d'identifier les typologies de bâtiments qui constituent le plus grand potentiel d'économie d'énergie et d'effet de multiplicateur. Une étude fouillée des analyses statistiques (recherche socio-économique), des résultats de recherches nationales (région Bruxelles-Capitale et région Wallonne) et des projets de coopération internationale (participation à l'IEA SCH Task 37 et observation du projet Européen E-RETROFIT-KIT) ont été examinés et intégrés afin d'identifier les typologies de bâtiments et les groupes-cibles pour la diffusion de la rénovation basse énergie des logements.

Les perspectives européennes et nationales pour les nouveaux bâtiments et pour les rénovations imposent des performances énergétiques de plus en plus élevées. On entend aussi de plus en plus parler du standard passif, des maisons zéro énergie ou neutres en CO₂. Cependant, il n'y a pas longtemps que l'information au sujet des premières réalisations exemplaires est disponible. Ce rapport analyse les données et les expériences de ces projets. Des projets de rénovation exemplaires belges présentant une économie d'énergie primaire considérable et une amélioration du confort de vie ont été analysés en prenant en considération la performance

énergétique du bâtiment et la motivation des propriétaires pour la rénovation. En partant de l'information des projets et des expériences acquises d'une part et des évolutions des recherches récentes de l'autre, des stratégies pour une future généralisation de la rénovation basse énergie en Belgique ont pu être déterminées. Cet aspect est étudié dans la partie suivante du rapport. Cette partie fournit des pistes pour des solutions novatrices au niveau technique, social, économique et politique offrant un haut potentiel d'économie d'énergie primaire.

Les rapports supplémentaires examinent les expériences des projets exemplaires belges présentant une amélioration de leur performance énergétique afin de diffuser ces informations et de toucher un marché plus large. Une typologie exemplaire a également été étudiée en détail en utilisant des méthodes d'analyse de cycle de vie et de coûts de cycle de vie. Cette analyse démontre que l'amélioration des performances énergétiques en rénovation peut être pertinente du point de vue économique et environnemental.

Des incitants économiques sont nécessaires pour passer du projet exemplaire à un marché croissant. De plus, certains aspects sociaux et le manque d'infrastructures de marché constituent une barrière importante pour atteindre un marché plus conséquent. Il faudrait notamment mettre en place des initiatives économiques, une réorientation de la politique et des stratégies de communication adaptées.

On peut conclure que cette recherche met en évidence de bonnes perspectives pour la mise en œuvre d'innovations groupées en rénovation, en particulier de mesures passives, pour plusieurs typologies de bâtiments. En vue d'une propagation croissante des rénovations basse énergie, il est important de répondre à la motivation des propriétaires et de mettre aussi en avant les aspects non-énergétiques, en plus des avantages énergétiques et économiques. En effet, chaque groupe-cible (acheteurs, loueurs sociaux ou privés) nécessite sa propre stratégie de marketing. Il faut répondre au manque de connaissances des professionnels de la construction, des responsables politiques, des propriétaires et des locataires de façon efficace, car une ou plusieurs de ces barrières peu(ven)t faire obstacle à la réalisation de rénovations basse énergie.

Parmi les publications du projet LEHR se trouvent entre autres:

- Une analyse du parc immobilier wallon;
- 'Potential of Low Energy Housing Retrofit' (détermination des typologies et groupes-cibles grâce à l'analyse du parc immobilier belge) ;
- Un guide destiné aux architectes/propriétaires (explication des principes à prendre en compte pour une rénovation basse énergie réussie) ;
- Des rapports destinés aux entrepreneurs expliquant les techniques de rénovation très basse énergie (fenêtres, rénovation de toit, isolation thermique des murs et planchers, chauffage, ventilation) ;
- Des brochures présentant aux concepteurs et propriétaires des analyses détaillées de projets exemplaires.

Les versions finales seront disponibles sur le site web: www.lehr.be

Les résultats de recherche du projet LEHR ont, outre ses propres publications, également contribué aux rapports finaux de l'IEA SHC Task 37 (participation belge).

Mots-clés : rénovation, efficacité énergétique, logement, diffusion d'innovation, analyse du parc immobilier

SAMENVATTING

In vele Europese landen beslaan gebouwen 35 % van het totale energieverbruik en de woningen nemen daarvan het grootste deel voor hun rekening. De renovatie van bestaande woningen houdt bijgevolg een enorm potentieel in voor energiebesparing. Heden tonen renovatieprojecten dat het energieverbruik met een factor 5 (en zelfs meer) verlaagd kan worden en dat tegelijkertijd de leefkwaliteit toeneemt.

Het project 'Low Energy Housing Retrofit' (LEHR) had als context de ontwikkeling van communicatiemateriaal over deze voorbeeldprojecten teneinde deze te kunnen verspreiden naar verschillende doelgroepen in de vorm van publicaties, internetbestanden en nationale workshops.

De doelstellingen van het LEHR-project waren:

- De identificatie van zeer succesvolle renovaties via een netwerk van nationale en internationale experts;
- De systematische verzameling van informatie m.b.t. het ontwerp, de bouw en de prestaties van deze renovatieprojecten;
- De communicatie van projectinformatie naar woningeigenaars en het documenteren van ontwerp-inzichten ten aanzien van ontwerpers.

Om deze succesvolle renovaties te analyseren werden de volgende aspecten systematisch bestudeerd:

- (1) Strategie voor energie: behoud, gebruik van hernieuwbare energie en efficiënte opslag;
- (2) Vooropgesteld energieverbruik: ruimteverwarming, warm tapwater en elektriciteit voor het ontwerp van technische systemen;
- (3) Comfort: thermisch winter- en zomercomfort, luchtkwaliteit en daglichttoetreding;
- (4) Integratie: oplossingen die energiebesparende maatregelen koppelen aan andere maatregelen die renovatie aanmoedigen.

Het eerste deel van dit eindrapport levert een analyse van het Belgische gebouwenpark om zodoende de gebouwsegmenten te onderscheiden met het grootst mogelijke multiplicatoreffect en potentieel voor energiebesparing. Een gedetailleerde studie van statistische analyses (socio-economisch onderzoek), resultaten van nationale onderzoeken (studie voor het Brussels Hoofdstedelijk Gewest en voor het Waals Gewest) en inzichten uit internationale samenwerking (deelname aan IEA SCH Task 37 en observatie van het Europees project E-RETROFIT-KIT) werden geanalyseerd en geïntegreerd ten einde de gebouwtypologieën en doelgroepen te definiëren voor de diffusie van lage-energie renovaties.

Europese en nationale ambities voor nieuwe gebouwen en renovaties leiden tot het voorschrijven van steeds betere energieprestaties, waaronder doelstellingen zoals het bereiken van de passiefhuis-standaard, nul-energiegebouwen of CO₂-neutraliteit. De projectinformatie van de eerst Belgische voorbeeldprojecten van zeer energiezuinige renovaties is echter nog maar pas beschikbaar. Dit rapport compileert de gegevens en ervaringen van deze projecten. Relevante Belgische voorbeeldprojecten voor renovaties met een aanzienlijke besparing aan primaire energie en een superieur wooncomfort werden geanalyseerd met betrekking tot hun energieprestatie en de beweegredenen van de eigenaars om te renoveren.

Op basis van projectinformatie en opgedane ervaringen enerzijds, en recente onderzoeksontwikkelingen anderzijds, kunnen strategieën bepaald worden voor de verdere verspreiding van lage-energie renovaties in België. Dit aspect wordt tevens bestudeerd in een volgend deel van het rapport. Dit deel biedt inzichten in innovatieve technologische, sociale, economische en politieke oplossingen met een hoog potentieel aan primaire energiebesparing.

In bijkomende rapporten worden de ervaringen van Belgische voorbeeldprojecten met een verbeterde energieprestatie onderzocht, met als doel deze ervaringen te verspreiden om een marktgroei te creëren. Een gebruikelijke gebouwtypologie werd tevens in detail bestudeerd met methodes voor levenscyclusanalyse en levenscycluskosten. De analyse geeft aan dat een uitstekende energieprestatie voor renovaties economisch en milieurelevant kan zijn.

Economische stimulansen zijn noodzakelijk om over te gaan van de voorbeeldprojecten naar een groeimarkt. Bovendien kunnen sociale aspecten en een gebrek aan marktinfrastuctuur belangrijke barrières vormen voor het bereiken van een meer substantieel marktaandeel. In het bijzonder is er nood aan economische initiatieven, beleidsveranderingen en aangepaste communicatiestrategieën.

We kunnen besluiten dat dit onderzoek goede vooruitzichten toont voor de toepassing van geclusterde innovaties bij renovatie, in het bijzonder passiefhuismaatregelen, voor diverse gebouwtypologieën. Met het oog op een toenemende verspreiding van lage-energie renovaties is het van belang om in te spelen op de motivatie van de eigenaar en om ook aspecten te beklemtonen die niet energiegerelateerd zijn, naast de energetische en economische efficiëntie. Verschillende doelgroepen (kopers, sociale huurders, private huurders) vereisen hierbij een eigen marktbenadering. Het gebrek aan kennis bij bouwprofessionals, besluitvormers, eigenaars en huurders moet doeltreffend worden aangepakt. Eén van deze barrières, of een combinatie van verscheidene, kan de realisatie van lage-energie renovatie immers in de weg staan.

Bijkomende publicaties van het LEHR-project zijn o.a.:

- Een analyse van het Waalse gebouwenpark;
- 'Potential of Low Energy Housing Retrofit' (bepalen van gebouwtypologieën en doelgroepen uit de analyse van het Belgische gebouwenpark);
- Een handleiding voor architecten/eigenaars (illustratie van de principes van geslaagde lage-energie renovaties voor woningeigenaars);
- Verslagen ter verkenning van de technologieën voor lage-energie renovaties, bestemd voor aannemers (beglazing, dakrenovatie, thermische isolatie van muren en vloeren, verwarming, ventilatie);
- Projectbrochures met inzichten van de voorbeeldprojecten bestemd voor ontwerpers en eigenaars.

De uiteindelijke versies worden beschikbaar gesteld op de website: www.lehr.be.

Bovenop eigen publicaties van de onderzoeksgroep hebben de onderzoeksresultaten van het LEHR-project ook bijgedragen aan de eindrapporten van IEA SHC Task 37 (Belgische deelname).

Kernbegrippen: renovatie, energie-efficiëntie, huisvesting, innovatiediffusie, analyse gebouwenpark

SUMMARY

Buildings account for up to 35 percent of the total energy consumption in many European countries and housing accounts for the greatest part of this. Accordingly, renovating existing housing offers an enormous energy saving potential. Nowadays, exemplary renovation projects demonstrate that renovation can achieve five-fold and more energy savings while improving living quality.

The context of the project Low Energy Housing Retrofit (LEHR) was to develop information destined for different target groups to diffuse information considering these demonstration projects in the form of published documents, files on the internet and national workshops.

The objectives of the project Low Energy Housing Retrofit were to:

- Identify highly successful renovations through a network of national and international experts;
- Systematically compile design, construction and performance information of these renovations;
- Publicize the projects to housing owners and design insights to planners

To analyze these successful renovation the following aspects were systematically studied:

- (1) Energy strategies: conservation, renewable energy use and efficient back-up;
- (2) Targeted energy uses: space heating, water heating and electricity for building technical systems;
- (3) Comfort: winter and summer thermal comfort, air quality and day lighting;
- (4) Integration: solutions that tie energy saving measures into other measures motivating renovations.

The first part of this final report is based on the LEHR publication 'Potential of Low Energy Housing Retrofit' and analyzes the Belgian building stock in order to identify building segments with the greatest multiplication and energy saving potential. A detailed examination of statistical analyses (social economic enquiries), results from national studies (study for the Brussels Capital Region and for the Walloon Region) and insights from international collaboration (participation in IEA SHC Task 37 and observing European project E-RETROFIT-KIT) have been researched and integrated in order to define building typologies and target groups for diffusion of low energy housing retrofit. For newly built houses and renovations European and national ambitions prescribe increasing levels of energy performances, even including achieving the passive house standard, net zero energy or carbon neutral houses. However, for very energy efficient renovation projects in Belgium, project information of first demonstration projects has only recently become available. This report compiles the information and experiences from these projects.

Relevant Belgian exemplary renovation projects achieving substantial primary energy savings while creating superior living quality have been analyzed considering energy performance and the owner's motivations behind the renovation. Drawing on project information and experiences, in combination with recent research developments, strategies can be defined for the further diffusion of low energy housing retrofit in Belgium. This issue is studied in a following part of the report. This part provides insights in innovative technological, social, economical and political solutions with great potential of primary energy reduction.

Additional reports examine the experiences of the Belgian demonstration projects with improved energy performance in order to diffuse them to reach a market increase. A common building typology has also been studied in detail using life cycle analysis and life cycle costing methods. The analysis shows that it can be economically and environmentally relevant to reach outstanding energy performance in renovation.

Economical incentives are necessary to go from demonstration project to a growing market. Also, social issues and a lack of market infrastructure can be important barriers to reach a more substantial market share. In particular, there is also a need for economical initiatives, policy changes and adapted communication strategies.

In conclusion, the research shows good prospects for the implementation of clustered innovations in retrofit, and passive house measures in particular, for different building typologies. For the increased diffusion of low energy housing retrofit it is very important to address owner's motivation and highlight also non-energetic aspects, besides energy and economical efficiency. Different target groups (buyers, social rent, private rent) will need an individual market approach. Lack of knowledge of building professionals, decision makers, owners and tenants has to be dealt with effectively. One of these barriers or a combination can prevent from carrying out low energy housing retrofit.

Publications of the LEHR project include:

- A building stock analysis for the Walloon Region;
- 'Potential of Low Energy Housing Retrofit' (defining building typologies and target groups from the Belgian building stock analysis);
- A guide for architects/ owners (showing housing owners the principles of successful low energy renovations);
- Reports explaining low energy renovation technologies to contractors (glazing; roof renovation; wall and floor thermal insulation; heating; ventilation);
- Project brochures informing planners and owners of insights from exemplary projects.

Final versions will be uploaded on the web site www.lehr.be.

Besides publications from the research group, the research findings of the LEHR project have contributed to the final reports of the IEA SHC Task 37 (Belgian participation).

Keywords: renovation, energy efficiency, housing, innovation diffusion, building stock analysis

II. TERMINOLOGY

ENERGY TERMS

The following glossary of terms was defined by the international experts within IEA SHC Task 37:

Auxiliary energy [kWh]:

The quantity of energy used by pumps, ventilators, controls, etc. to transform and transport the delivered energy into effective energy for lighting, heating, domestic hot water, etc.

Barrel of oil equivalent [boe]:

A term used to summarize the amount of energy that is equivalent to the amount of energy found in a barrel of crude oil. There are 42 gallons (approximately 159 liters) in one barrel of oil, which will contain approximately 5.8 million British Thermal Units (MBtus) or 1,700 kilowatt hours (kWh). Also known as crude oil equivalent (COE).

Coefficient of Performance COP [-]:

The ratio of the power output to the power input of a system.

Delivered energy / site energy [kWh]:

Energy supplied to the building through the system boundary from the last market agent to satisfy the energy requirements for heating, cooling, ventilation, domestic hot water and lighting. No adjustment is made in regard to energy losses occurring in the generation, transmission, and distribution of energy. Delivered energy is sometimes referred to as “site energy.”

Effective energy / useful energy [kWh]:

The energy for domestic hot water, heating, lighting, cooling etc.

Embodied energy [kWh]:

Embodied energy describes the energy required to manufacture a product. A product that requires large amounts of energy to obtain and process the necessary raw materials or a product that is transported long distances during processing or to market will have a high embodied energy level.

Energy consumption [kWh]:

The actual measured quantity of energy needed for heating, cooling, ventilation, hot water heating, lighting, appliances, etc. (metering).

Energy demand [kWh]:

Calculated quantity of energy for all applications and given end use. Energy to be delivered by an ideal energy system (no system losses are taken into account) to provide the required service to the end user (e.g. to maintain the required internal set-point temperature of a heated space).

Energy requirements [-]:

Energy supplied to the technical system (system losses are taken into account) to provide the required service. Energy requirements can be specified for each subsystem (e.g. distribution, storage) and express the energy supplied to the subsystem.

EPBD [-]:

European Energy Performance of Buildings Directive

Heat consumption [kWh]:

The measured quantity of energy for heating and domestic hot water.

Heat demand [kWh]:

The calculated quantity of energy for heating and domestic hot water.

Net energy [-]:

Energy supplied by the energy system to provide the required services, e.g. maintaining the building at the specified internal temperature, ventilating a space, lighting a space. Recovered losses and gains are taken into account.

Primary energy PE [kWh]:

Energy that has not been subjected to any conversion or transformation process. Primary energy may either be resource energy or renewable energy or a combination of both. For a building, it is the energy used to produce the energy delivered to the building. It is calculated from the delivered amounts of energy carriers, using conversion factors.

AREA DEFINITIONS

Form factor A / V [m^{-1}]:

The ratio between the building envelope area and the gross building volume.

Building envelope area A [m^2]:

Total external area of the building envelope enclosing the heated volume – façade (including doors and windows), roof and ground – and measured at the outer boundaries of the building.

Gross volume V [m^3]:

The heated building volume calculated on the basis of the outdoor dimensions.

Net heated volume V_N [m^3]:

The heated volume calculated on the basis of the indoor dimensions.

Net heated floor area A_N [m^2]:

The sum of the floor areas of all heated rooms including heated corridors and heated internal stairways but not unheated rooms.

QUALITY ASSURANCE EXPRESSIONS

The following quality assurance expressions are used:

Certificate [EIJL_08]:

A professional systematic judgement of conformity based on standardized methods, of a product, system, process or person. An assuring information tool provided by independent persons who work on the basis of requirements and research methods fixed with the input of several representatives of stakeholders.

Commissioning [IEA ECBCS Annex 40]:

Clarifying Owner's Project Requirements (OPR) from viewpoints of environment, energy and facility usage, and auditing and verifying different judgments, actions and documentations in the Commissioning Process in order to realize a performance of building system requested in the OPR through the life of the building.

LOW ENERGY BUILDING CATEGORIES

In literature many definitions occur for categorizing low energy buildings:

Low energy building:

Buildings with the explicit intension of using less energy than standard buildings. However, no specific requirements are defined.

Net zero energy building:

A building where the net energy consumed over a year is matched by an equal amount of energy produced on site.

Passive house:

According to the definition provided by the consortium Promotion of European Passive Houses, the following requirements have to be fulfilled:

- a maximum end-energy space heating demand of 15 kWh/m²a
- a primary energy demand for all end-uses including electricity for appliances is not higher than 120 kWh/m²a,

m² refers to the net heated floor area.

Plus energy building:

Building where more primary energy is produced annually than consumed. Typically net zero is reached by generating on-site electricity which has a high primary energy replacement value and can therefore be credited against thermal energy demand which has a lower PE factor.

Very low energy building:

Terminology introduced by the Flemish Region in Belgium. Buildings with the explicit intension of using less energy than low energy buildings. However, no specific requirements are defined.

Regional expressions with a vague definition are invented regularly like 'very low energy' buildings (Flemish Region), CO₂ neutral streets and cities (The Netherlands),...

III. INTRODUCTION

A. CONTEXT

Buildings account for up to 35 percent of the total energy consumption in many European countries and housing accounts for the greatest part of this. Recently, the McKinsey study for Belgium [MCKI_09] confirms that also in Belgium the highest potential for primary energy saving (48%) can be found in buildings. Accordingly, renovating existing housing can be expected to offer large energy saving potential.

For newly built houses and renovations European and national ambitions prescribe increasing levels of energy performances, even including achieving the passive house standard, net zero energy or carbon neutral houses. Nowadays, international exemplary renovation projects demonstrate that it is possible that renovation can achieve five-fold and more energy savings while improving living quality. However, for very energy efficient renovation projects in Belgium, project information of first demonstration projects has only recently become available. Therefore a need was felt to compile information from innovative projects and to learn-by-doing.

Relevant Belgian exemplary renovation projects achieving substantial primary energy savings while creating superior living quality would have to be analyzed considering energy performance and the owner's motivations behind the renovation. Drawing on project information and experience packages of measures in combination with the most updated research front, strategies could be defined for the further diffusion of low energy housing retrofit in the Belgian context.

Finally, the project 'Low Energy Housing Retrofit – LEHR' was set up to develop communications destined for different target groups to diffuse information considering these demonstration projects in the forms of published documents, files on the internet and national workshops. Example projects had to be chosen in function of common Belgian building typologies, and for this, it was decided that a statistical study of the Belgian building stock was necessary to be able to decide on representative cases. Also, the study of the examples would provide a golden opportunity to network internationally and to obtain information considering marketing of energy efficient renovations, innovative technologies and policy recommendations.

B. RESEARCH GOAL

The objectives of the project Low Energy Housing Retrofit were to:

- Identify highly successful renovations through a network of national and international experts;
- Systematically compile design, construction and performance information of these renovations;
- Publicize the projects to housing owners and design insights to planners.

To analyze these successful renovation the following aspects were studied:

- (1) Energy strategies: conservation, renewable energy use and efficient back-up;
- (2) Targeted energy uses: space heating, water heating and electricity for building technical systems;

- (3) Comfort: winter and summer thermal comfort, air quality and day lighting;
- (4) Integration: solutions that tie energy saving measures into other measures motivating renovations.

C. LOW ENERGY HOUSING RETROFIT: A FIRST DEFINITION

In the past few years, passive house principles and components have been successfully introduced in the retrofitting of existing buildings. Depending on the building type, energy savings vary between 80 to 95%. The specific heating demand is typically reduced from values between 150 and 280 kWh/m²a to less than 30 kWh/m²a. In some cases, the passive house standard of 15 kWh/m²a is reached. As pilot projects in different countries demonstrate, these passive house retrofit are economically feasible for a range of building types. [E-RE_08]

In general, the passive house standard of 15 kWh/m²a, although easily implemented in new constructions, is often difficult to achieve in a cost-efficient way for retrofit. Especially protected facades, existing thermal bridges and highly valued ornaments are difficult to tackle. On the other hand, from the technological point of view, a large group a building typologies from the sixties and seventies can relatively easy be transformed into passive houses. Providing that ownership and decision structures, inhabitants and their characteristics and actual groups of retrofit market players can be involved, renovations tend to be successful towards the passive house standard. A few exemplary renovation projects demonstrate that renovation can achieve five-fold and more energy savings while improving living quality. The success of these projects lies in their combination of conservation measures to reduce energy demand; using renewable energy to cover much of this reduced demand; and supplying the remaining heat by highly efficient, compact conventional systems.

For low energy housing retrofit the passive house principles tend to take a more important lead than the strict passive house definition. These retrofit principles include [E-RE_08]:

- Minimized transmission losses: The building envelope has a very high standard of insulation – typical thicknesses for wall and roof are around 20 to 40 cm. Typical windows will be triple-glazed or equivalent. Specific building details will reduce thermal bridges to practically zero.
- Minimized ventilation losses: Heat recovery in the ventilation system will reduce losses by about 80% while increasing both thermal comfort and air quality. A precondition for heat recovery is a high level of air tightness of the building envelope, minimizing losses from warm air leaking through cracks and crevices.
- Passive and active solar energy: internal heat gains (from people, lights, electrical equipment etc.) and solar radiation are typically taken into account in to the heating demand. In addition to passive solar gains, active systems like thermal collectors or PV-systems can be used.
- Efficient energy supply: Low energy retrofits have a very low heating demand but still need a heating system for the coldest winter days and a system providing domestic hot water. This remaining energy demand is typically supplied by very efficient systems like special heat pumps, high efficiency gas boilers or wood pellet burners.
- Overheating control: As a very high thermal comfort is one of the main marketing arguments in the development of low energy housing retrofits, overheating

control is an important issue. Mainly passive measures like overhangs, shading devices, (e.g. awnings) are used. Measurements in pilot projects have shown that with these measures, passive houses actually suffer less from overheating than regular houses because the thermal insulation keeps the summer heat out.

Low energy housing retrofitting implies a thorough retrofitting of the building including eliminating or heavily reducing thermal bridges from outside into the building, e.g. by replacing existing windows and in most cases making outside insulation of the walls. Another element will be to make the building air-tight and to install a central ventilation system with heat recovery.

In summary we define low energy housing retrofit (LEHR) as a thorough retrofit of a building towards a building with improved comfort, taking into account substantial thermal insulation, avoidance of thermal bridges, and provision of air tightness of the building and mechanical ventilation with heat recovery.

D. HOW TO READ THIS REPORT

Section IV of this final report summarizes the findings of the analyses of the Belgian building stock in order to identify building segments with the greatest multiplication and energy saving potential. A detailed examination of statistical analyses (social economic enquiries), results from national studies (study for the Brussels Capital Region and for the Walloon Region) and insights from international collaboration (participation in IEA SHC Task 37 'Advanced housing renovation with Solar and Conservation', and observing European project 'E-retrofit-kit') have been studied and integrated in order to define building typologies and target groups for diffusion of low energy housing retrofit. This part is interesting for regional policy makers and building stock managers, since it provides background information and decision criteria on which type of building stock to renovate. It also addresses business developers, who want to develop ideas for market segmentation.

Section V provides insights in innovative technological, social, economical and political solutions with great potential of primary energy reduction in existing housing. The technological and social part are very suitable for innovation managers and business/opinion leaders who are in charge of technological product and system research and development. The economical and political part provides ideas for national, regional and local policy developers.

The report's conclusion in both Section IV and Section V address a wide range of practitioners, policy makers, opinion leaders and business developers. The analysis shows good prospects for the implementation of clustered innovation in retrofit, especially passive house measures, according to defined building typologies. Besides energy and economical efficiency, the conclusion also comments on other advantages and non-energetic aspects. For example, different target groups (buyers, social rent, private rent) will need an individual marketing approach. Lack of knowledge of professionals, decision makers and tenants has to be dealt with effectively. One of these barriers or a combination can prevent from carrying out low energy housing retrofit.

E. ANNEXES ON THE WEB

The report has several annexes that are not included in this summarizing report but that are available from the web site www.lehr.be. All references on which this summarizing report is based (articles, main reports, workshop material, media material) are available on-line.

- Additional research reports

In addition to Section IV, a full report, entitled 'Potential of Low Energy Housing Retrofit', produced by PHP, is available on the web, as well as a report on the Walloon building stock (in French), produced by UCL. This report provides additional material for researchers, including all references used.

In Section V, summarized results are shown for the environmental impact of different types of renovation of an urban row house typology. In addition to this, a report on LCA/LCC analysis, produced by BBRI, is available on the web. This report provides additional material for researchers. Also, marketing managers with ideas concerning low energy housing retrofit, should read the report on environmental impact of low energy housing retrofit, since it provides a refreshing view on life cycle analysis, life cycle costing and strategies for market penetration of innovative technologies.

- Project files

The experiences of the Belgian demonstration projects with improved energy performance have been described in project files (See Annexes), in order to diffuse them to reach an innovation and early adoption market. These experiences were used throughout Section V.

All examined projects have been documented in information files per project. The project files cover projects in both the Flemish and the Walloon Region and are available in Dutch and in French. The files can be of particular interest for energy consultants, architects, owner and/or occupants who want to renovate, building companies, contractors, installers, and so on.

These project files document amongst others the situation of the renovation, the motivation of the user, the technical measures and data, the improvement of energy performance and/or comfort, aspects of sustainable housing and lessons learnt from the specific project. To document these project files questionnaires were used with both open and closed questions, and interviews were done with owner-occupants and architects regarding their motivation and their perception of low energy housing retrofit concepts and technologies. All owners-occupants (in some cases architects) of demonstration projects were interviewed using a questionnaire with both open and closed questions. The questionnaires and interviews addressed the following issues:

- Background variables of the interviewees
- General satisfaction: environment, living, construction, installations
- Perception of heating/ temperature, air humidity, ventilation/ air quality, health

In two projects also additional measurements were performed to verify temperatures in rooms.

- Technical manuals

An overview of technological solutions (manual) for the renovation of roofs, walls, floors, glazing, heating and ventilation is given in separate technical notes. These reports specifically address contractors and building professionals, and can be used as working documents for refinement in future working groups. After redrafting, these documents will be made available as an official web application from BBRI and via a link on www.lehr.be. On the web site the reader can also find an introductory document explaining the set-up of the web application.

For architects and owners a manual for sustainable renovation was also produced within the LEHR project by UCL. This manual is currently available in French, and will also be available in Dutch.

- Other material

In addition to the French and Dutch project files, English project files are also available. Those were produced in the joint framework of LEHR and IEA SHC Task 37. Also, film clips of international demonstration projects studied in the framework of IEA SHC Task 37 are available on the web site, and they provide a short introduction to the subject for opinion leaders by means of briefly reviewing specific international renovation projects and interviewing opinion leaders and innovators.

In October 2009, in the framework of LEHR, the joint IEA SHC Task 37/IEA ECBCS Annex 50 workshop, entitled 'Substantial Energy Saving in Existing Housing NOW', was organized in Antwerp. The presentations given by international energy experts are also available on the web. Also, the presentations from the final LEHR workshop (dissemination November 2009) in Brussels can be found. The presentations provide additional information to the subjects discussed in this report.

Also, published articles in the framework of LEHR and relevant links are shortlisted.

The web site www.lehr.be will also in future be maintained by PHP, and all LEHR deliverables will be provided through the web page to the general public.

In addition to Section V, a full report of the IEA SHC Task 37 Subtask A, entitled 'From demonstration to volume market', on which PHP collaborated within the framework of LEHR, will be made available, after its approval by the International Energy Agency Executive Committee in June 2010.

IV. POTENTIAL OF LOW ENERGY HOUSING RETROFIT

Summarizing lessons learnt from:

C. Kints (2008) La renovation énergétique et durable des logements wallons, LEHR report

W. Hilderson, E. Mlecnik, J. Cré (2009) Potential of Low Energy Housing Retrofit, LEHR report

'Substantial Energy Saving in Existing Housing Now', presentations and discussion IEA Final Workshop, 14 October 2009, Antwerp

Presentations and discussion LEHR final workshop, 18 November 2009, Brussels

All available on-line: www.lehr.be

ABSTRACT

Demonstration projects show that it is possible to drastically reduce energy demand for heating, and therefore primary energy demand in a whole region. Based on the analysis of the existing building stock in Belgium, this report examines for what type of residential building and for what target groups low energy housing retrofit demonstration projects should be initiated and stimulated.

The following research parameters were found to be crucial for analysis:

- Comfort, quality improvement and energy efficiency reduction potential, depending on building age and socio-economic status of the owner.
- The number of houses of in a certain building typology.

All parameters are linked with geography geographical location and building ownership characteristics. There appear to be more recently built houses in the north than in the south parts of the country. This has a great impact on the quality of the houses.

The analysis shows that energy and building policy decisions considering low energy housing retrofit should relate to the specificity of the municipality, province or region. The old industrial belt in the south part of the country, rental houses, and cities have a high retrofit potential.

Strategies for the promotion of low energy housing retrofit are needed and should be person-oriented, preferably related to ownership structure. Building owners should be reached at the stage when they intend to renovate. Urban areas need examples focusing on quality improvement of row houses or apartment buildings in the (private) rent sector. The social housing sector requires an approach focusing on cooperation between low-income target groups and their points of reference.

A. INTRODUCTION

In this section we elaborate amongst others on the background, the problem formulation and the approach we have chosen. The goal of this chapter is to describe and analyze the state of the art of the Belgian building stock. This will provide us with the knowledge to identify a focus on certain building typologies and target groups, in

order to define possible future instruments and incentives that are needed to overcome barriers to realize a more energy efficient building stock.

The first part of this final report is largely based on the LEHR publication 'Potential of Low Energy Housing Retrofit' and analyzes the Belgian building stock in order to identify building segments with the greatest multiplication and energy saving potential.

B. RESEARCH APPROACH

The two main questions we have asked ourselves at the start of this research were: Considering retrofit, what can we learn from the analysis of the existing building stock in Belgium? For what type of building should low energy housing retrofit demonstration projects be initiated and stimulated?

During this research several sub questions were studied:

1. What are the general characteristics of the Belgian building stock?
2. What are motivations for renovation?
3. What are the energy characteristics of the Belgian building stock?
4. What is the potential of the existing housing to reduce energy?
5. What can be a market segmentation for low energy housing retrofit?

To study the first three questions we have based ourselves on available statistical studies for the Belgian building stock and results from Belgian social economical enquiries (see the full report for detailed referencing). Statistical data have been used from the federal government (Belgium) and the Belgian regions (Flanders, Wallonia, Brussels capital region). The most important data in this study come from:

- Socio economical enquiry 2001, or SEE2001, a statistical sample of 2% of Belgian population and partially based on data of the whole population: [VANE_07];
- Flemish survey on dwellings 2005, a survey on 5216 families: [HEYL_07];
- A survey on residential energy consumption in Belgium with a representative sample of 1000 families in 2004: [BART_06];
- External study of housing quality by AROHM, 1995 with a representative sample of 8500 dwellings: [LROY_06];
- Surveys in 1961 (sample of 70000 dwellings), 1978 (300000 dwellings): [LROY_06] and others.

The sources can be considered as an important limitation since there is a lack of reliable data in function of building typology and degree of renovation. Nevertheless, we provided insights into the proposed questions, based on available data.

The last two questions are tackled by analysis of the previous data and also use findings from other research: insights from international collaboration (participation in IEA SHC Task 37 and observing European project E-RETROFIT-KIT) have been examined and integrated with national findings (study for the Brussels Capital Region and for the Walloon Region, social economic enquiries) and in order to define building typologies and target groups for diffusion of low energy housing retrofit.

C. RESEARCH RESULTS BASED ON STATISTICAL DATA

1. General characteristics of the Belgian Building stock

Belgium's buildings are relatively old because of a low demolition rate – at 0.075 percent a year one of the lowest in Europe – and growth in the building stock of only 1 percent, compared to a 1.5 percent average among Belgium's peers [MCKI_09]. The number of dwellings is still growing and the number of buildings, as well as the growth, is not homogeneously spread throughout the country. The biggest increase occurs in the suburbs.

If we look at the growth of the surface that is used by residential functions, we notice a large increase: in 1990, for Flanders, 227m² was used per inhabitant; in 2002, this has risen to 278m² per inhabitant.¹

If we look at the data collected in the period 2001-2005 we can see differences between single family houses and multifamily residences, for example in the Flemish Region 80% of all Flemish dwellings are single family houses, 20% of the Flemish residences are part of a multifamily housing stock.

As expected, there are some significant variations with dense building in the agglomerations of centre cities. In these urban areas the majority are apartment buildings, while semi-detached and detached housing are less common. On the other hand, there is a large percentage of detached housing in the small cities. In recent years, there is an increase in multifamily houses, which is more explicit in small towns and rural areas than in larger cities. Another trend is a slight increase of semi-detached housing.

Roughly speaking, between 1991 and 2000 almost three quarters of all newly built houses in Belgium were constructed in the Flanders Region. Further, as we compare the total building stock of the Flanders Region with Walloon and Brussels Capital Region, we see that the total building stock in Flanders is relatively young. This might be attributed to the lower impact of the Second World War in the southern part of the country. On the other hand, many renovations - alternation of the surface and/or the number of rooms of the house - have been done in the Walloon and Brussels region, especially in the period 1981-1990. The last two decades Flanders seems to catch up with houses being renovated.

There is no homogeneous spread of buildings areas with certain typologies, rather there is pattern following geographical and historical trends. This is illustrated with several maps in the report.

2. Motivation for renovation

If we take a closer look at the motivation why people renovate their building, we can see different reasons:

¹ For detailed referencing of all data, see the full LEHR report 'Potential of Low Energy Housing Retrofit'.

a) Rational use of living area

A most prominent reason is to extend or decrease the living area. While transition to owner-occupancy usually involves extension, project-based renewal tends towards decrease of living area. Often too small houses usually have been built after World War I. Motivation can mostly be found to renovate large density multifamily houses or small houses, for example in regions where for historical reasons a lot of terraced or semi-detached houses were built, often less than 4 metres wide, to house the workman's class. These regions are mostly situated in and around larger cities, the coastline, along the old Walloon industrial axis, and mainly in the West of Flanders. There is a recent increase in the renewal of too large houses towards residences with less than 3 living spaces and a decrease of the mean surface. However, the transition from rent to ownership usually involves the increase of the number of rooms per residence and vice versa.

b) Quality improvement

A second reason, for renovation, is to improve the quality of the residence. Houses of bad quality are geographically dispersed throughout communities. There is a large contrast between the Flanders and the Walloon Region. Municipalities with most real estate with basic quality appear in the Flemish Region. The most problematic areas are in the western province of Hainaut and the Brussels Region. Houses in very bad state do not regularly appear in Flanders, except in the cities (Antwerp, Ghent, Leuven, and so on).

According to data for the Flemish Region only 1%, or 30.000 houses, effectively needs serious retrofit or demolition. However, the scarcity on the real estate market still makes it easy to sell houses in a bad state. 11% of Flemish inhabitants judge that at least one major repair is needed in their house. Only 8% of all Flemish rental houses have no flaws and thus have basic quality conditions. These quality considerations do not include energy issues.

The quality of residences relates to several parameters, listed in order of importance:

- Ownership: Residences owned by inhabitants have a higher quality and comfort.
- Age of inhabitants: People living in older houses, tend to inhabit lower quality houses. 20% of inhabitants between 20 and 39 years old live in houses with poor or very poor quality. There are only few private owners amongst this group. For the group between 30 and 39, the number of private owners increases. Also the quality increases, but less rapidly than ownership, probably due to high cost of renovation leading to phased renovation.
- Income and ethnicity: Non EU-members have worse quality houses than EU members. This is correlated to ownership, because non EU members mostly live in rental houses. Families with two incomes tend to have a house of higher quality.
- Geography: In east Belgium and Flanders, quality of buildings is generally higher. There is no relation between location in urban or rural sites and façade quality.
- Building type: There is no significant relation between type and quality. Different studies give different correlations.

c) Comfort improvement

A third reason why people renovate is to improve the comfort of the residence. Housing associations define four indicators of comfort: high, average, low or no comfort, depending on the availability of heating, sanitary facilities, kitchen, electricity and newer indicators such as living surface and the condition of the facilities. Comfort of residences also includes satisfaction of the inhabitants and of the living environment. It's important to remark that in inquiries some correspondents deliberately underestimate the comfort of their residence, fearing fiscal repercussions.

In 2001 about 1.200.000 houses (31%) still have few or no comfort. Houses in Flanders have higher comfort than in the Walloon and Brussels region. Also there is a link between the age of the dwelling and the level of comfort: more recently built houses have a slightly higher comfort on average. Houses that are rented out by private persons also have lower comfort.

Compared to ten years before, in 2001 all comfort parameters increased. The use of coal heating decreased, but still exists in some parts of the country even for more than 30% of the residences.

There is a relation between location and comfort. Dwellings with a very good comfort level occur in rich, suburban municipalities with high average income.² The conclusion is that comfort, like quality, is higher in Flanders and in the eastern part of Belgium. The region along the French border is in particular bad shape. The lack of comfort is related to the pre-world war heritage of old industrial and rural areas.

Comfort in dwellings is correlated to the social status of the inhabitants:

- Family composition: single people or single parent's houses have worst comfort conditions compared to other family types.
- Income: The share of houses with high comfort is lower amongst families with only one part-time or full-time income.
- Age of inhabitants: Older inhabitants generally have less comfort. The share of high comfort houses is greatest for people between 35 and 64 years, because they are more likely to own their house. But also the share of houses with no comfort increases with age, because older people tend to inhabit older buildings.
- Ownership: Rental houses on the private market have less comfort than properties inhabited by the owner.
- Nationality: The share of houses with high comfort increases for EU citizens to almost 50%, but stagnates for non EU citizens living in Belgium around 25%.

It's important to remark that due to the high age of the Belgian population, the mortality is expected to have an influence on the real estate market. But only when real estate prices will drop, families with lower income will more easily become proprietors. The older the proprietor, the more houses have insufficient comfort.

² The dwellings are larger, often built after 1970 and thus still sufficient for contemporary necessities. Buildings with a good level of comfort appear in the eastern part of Belgium with more recent build buildings, while buildings with a basic level of comfort occupy the west of Flanders. Along the French border, in Brussels and around Liège, there is a more than average occurrence of buildings with an inadequate comfort level.

These houses are often retrofitted by new, younger owners who generally have higher comfort expectations.

d) Higher quality of life

A last important reason why people renovate, or purchase a house to renovate, is to have a higher quality of life, and better proximity to services. Satisfaction considering the direct house environment appears to be lowest in Brussels and highest in the Flanders Region. However, in the Flemish region, most buildings have a neglected building within 150 meters range. In the agglomeration of Brussels neatness, air quality and calmness are worse (typical for urban environments) than in the Flanders and Walloon Region. However, the appreciation of greenery is higher in urban environment, like Brussels, probably because of the lower expectations of green space. Inhabitants judge calmness and greenery to be the most important parameters. Calmness can be improved through renovation (for example acoustical measures).

The perception of the building context is evaluated on three aspects:

- Experience of the direct environment
This is an important comfort parameter because of the link between inconvenience and feeling of safety. The experience of the environment is correlated to both level of urbanisation and ownership. In agglomerations overall dissatisfaction is highest. For example, 30% of the correspondents report noise as a discomfort. The second most dissatisfied is the rich suburb around Brussels, probably because of (air) traffic. The satisfaction is still highest in rural areas³. The reports detect 5 relevant parameters concerning the environment: neatness, calmness, air quality, greenery and look of the buildings⁴. Satisfaction for these parameters are more or less geographically equally spread out. The dissatisfaction is nowhere extreme, probably because people appear to accept the consequences of their environment.
- Infrastructure
The quality of the infrastructure was evaluated once on a small scale in 2001, only looking at the direct environment of the building. The accessibility was studied on a larger scale in 1992, which also looked at the accessibility to important employment centres.
The first study asked the correspondents opinion of the accommodation of foot paths, cycle tracks, roads and public transport. The Walloon correspondents were worst satisfied. The people were most satisfied about the cycle tracks and roads in Flanders. While the experience of the environment is generally regarded as quite pleasant in most municipalities except cities, the satisfaction of infrastructure shows the opposite tendency. Public transport is generally

³ These factors make certain people like young families move from cities to suburban or per-urban municipalities. The disadvantages of lack of services and employment in these areas seem not to bother them.

⁴ Another strong correlation can be found between the environmental aspects and ownership: Inhabitants of rental houses are substantially less satisfied than proprietors. This can partly be explained by the better average comfort of a proprietor's house or their stronger involvement in the neighbourhood.

regarded as rather insufficient except for cities like Brussels, Antwerp, Ghent, Hasselt, Namur and Liège, and for the coastline.

The second study, derived the accessibility potential from railway and highway connections. Logically, agglomerations and suburbs have a high potential. The traces of some highways, like E411 and E19, often coupled with railways, is clearly visible. These traces form important axes of future suburban development.

- **Local Facilities**

Local facilities strongly depend on the level of urbanisation. City agglomerations, followed by the small towns, have the largest percentage of satisfied inhabitants, which is in accordance to the actual offer of facilities. Generally, the aspects “experience of the direct environment” and “local facilities” are opposed to each other. In contrast to the experience of the environment, there is no correlation between ownership and satisfaction of facilities. Furthermore, as opposed to infrastructure, there is a clear difference in satisfaction of facilities between south (Wallonia) and north (Flanders). For all examined facilities, the satisfaction is lowest in the Walloon and highest in Brussels Region and other large cities. The high number of small villages with only few facilities can explain the low level of satisfaction in the Walloon Region.

3. Energy characteristics of the building stock

a) Residential energy use and evolution

The EU aspires to reduce the greenhouse gasses with 20% in 2020 in comparison to the emission level of 1990. Therefore, special measures must be taken in all economic sectors. The European ODYSSEE database [ECON_07] shows a decrease in the fuel consumption between 1997 and 2000 of almost 10%, but after 2000 the fuel consumption remained more or less the same. Still primary energy consumption in Belgium – or gross inland energy consumption – amounted to 368 million barrel oil equivalent (boe) in 2005, of which 128 million boe derived from the sector Buildings [MCKI_09]. In 2005, residential buildings accounted for 73 percent of Buildings’ primary energy demand [MCKI_09]. The total energy use of the Belgian residences was almost 100 billion kWh.

As the average age of Belgium’s building stock is forecast to increase further than that of European counterparts in the next 25 years, the relative energy efficiency of the building stock is also likely to decrease [MCKI_09]. With an average energy usage of 348 kWh/m² per year, Belgium’s energy efficiency in residential buildings lags that of its neighbouring countries; also Belgian energy consumption per square meter in residential buildings is more than 70 percent higher than the EU average [MCKI_09]. Even it is still growing, while for example in Denmark, the consumption stabilised thanks to extensive energy saving policy.

In densely populated areas most of the primary energy goes to dwellings. For example in the Brussels Capital Region, 62% of the primary energy consumption goes to housing. The energy demand in older houses, built before 1945, is still on average double of recently built houses, period 2001-2005. 61% of all houses is built before 1980 and has been never seriously retrofitted. These houses represent almost

three quarters of the total energy consumption. Mostly they lack thermal insulation, improved glazing and a modern heating installation. Therefore, not only their energy efficiency but also their comfort is insufficient.

Recently, the McKinsey study for Belgium [MCKI_09] calculated the energy saving potential for Belgium, confirming that also in Belgium the highest potential for primary energy saving (48%) can be found in buildings. The study calculated a theoretical energy saving potential in Belgian buildings of 61.000.000.000 boe by 2030. Existing differences with surrounding countries can largely be attributed to thermal insulation of buildings.

b) Heating of dwellings and evolution

The energy consumption for heating of buildings in Belgium represents 21,8% of the distribution of greenhouse gasses compared with other sectors. Looking at the energy sources used for heating of dwellings, non-renewable energy is still the lion's share. Half of the Belgian dwellings use natural gas as energy source. 40% uses oil, but this number is still decreasing, and 8% uses electricity. Natural gas is used more over the last decades but also electricity (+8% in 2005). However, electricity is less often used in dwellings built after 2000. There are significant differences between the regions. In the Walloon region, oil is most popular (52%) while in Brussels 70% houses heat with gas. In the old industrial belt coal is still being used as an energy source.

The heating systems in the dwellings are mostly individual and on average 17 years old, suited with a programmable thermostat. In 2001, 71% of the dwellings in the Flanders and the Walloon Region had a central heating system, compared to 62.5% in 1991.

If we look at the age of the inhabitants and the use of a central heating system, we can conclude that 43% of people over 80 years have no central heating. These houses need to be retrofitted in the near future.

For the Brussels Region, energy audits performed by the ABEA confirm that basically all buildings built before 1970 show a very poor performance for energy consumption for heating, going from average consumptions before 1919 of 158 kWh/m²a, to 130 kWh/m²a in 1970.

Especially the Brussels Capital Region invested in increasing the energy performance of buildings by means of demonstration projects. For some building typologies possible energy consumption savings for heating of 86% were observed.

c) Thermal insulation of buildings

Thermal insulation of buildings is regarded as a low hanging fruit: in Europe alone, just by bridging buildings undergoing modernisation anyway up to contemporary (mediocre) energy standards, Rockwool estimates that 460 million tonnes of CO₂ per year can be saved and 500.000 jobs can be created [VHEE_09, p.5].

However, Belgian data on the thermal insulation of buildings are rather limited. Probably many buildings have some form of limited thermal insulation applied throughout the years, but this is never recorded in statistics. From limited data we can derive that, between 2001 and 2005, the use of thermal insulation increased, mainly because of the higher comfort expectations. Quality and comfort increase, coupled with fiscal advantages also make energy efficient measures more popular. The stronger socio-economic population, who have a house with high comfort and quality, mainly applies these measures. Again, older people, lower incomes and unemployed people, less educated people and singles are less prone to invest in energy efficiency. A lot of households don't know what the insulation level and thermal performance of their house is.

Rental houses on the private market on average have poorer thermal insulation than rental social housing. Owner-occupied houses have the most thermal insulation. This is in high contrast with the previous findings on quality and comfort: houses on the private market seem to have the greatest need and potential for improvement.

Currently, Belgium has a lower penetration of energy efficiency features, such as double glazing and insulation, than other European countries. In the absence of strict construction standards, only 41 percent of Belgian homes are estimated to have wall insulation and 36 percent to have full double-glazed windows [MCKI_09].

Of all thermal insulation measures, double glazing is applied most frequently (70%), followed by roof insulation (60%). Since double glazing is an indicator of comfort in most socio-economic surveys, and the large percentage of apply, it appears that comfort is an important parameter for thermal insulation choice. Considering air tightness and ventilation, still a lot of work has to be done. 6 out of 10 families do not use any form of ventilation, 16% has windows grills, 17% has extraction ventilation.

Compared to business-as-usual, improving the energy efficiency of the existing building stock, by renovating building envelopes is estimated to save 31 million boe of energy [MCKI_09]: this scenario assumes Belgium would move to a standard of 15-35 kWh/m².a for the existing building stock.

Such targets were set when defining the case studies in the LEHR project. As a result of the previous considerations and statistical analysis, building typologies were defined for further study. These are presented in the conclusion beneath. However, we should note that demolition and rebuilding may be preferable in cases where thorough renovations are only marginally cost-effective or not feasible for other reasons.

4. Conclusion: proposed building typologies for further research

For the Walloon and Brussels Region, the building stock analysis report defined typologies with the highest potential for retrofit. These typologies have been evaluated for use in the Flemish Region. Considering the analysis of the housing stock the following building typologies have been proposed as representative retrofit case studies for the Belgian situation:

- 1) The vernacular building: Built before the First World War (WWI) by the owner, usually in local material, detached, in rural areas or small city centres.
- 2) Rural house: Built during the inter-bellum, in towns all over Belgium. These houses can be detached, semi-detached or terraced.
- 3) Suburban villa: The houses form the bulk of the ever-growing suburbs around the cities, certainly since the seventies, and incorporate the dream of the villa.
- 4) Workman's class house: Very small houses in former flourishing industrial zones and in the far west of Flanders, quickly built in series in the inter-bellum.
- 5) The urban terraced house: Medium sized urban terraced house, built before WWI or during the inter-bellum, with architectural value, certainly on the level of the façade, often owned by the occupants.
- 6) The large urban terraced building: Located in the older urban zones, originally designed as single family houses for the rich and upper middle class, and later converted into apartments, or directly designed as an apartment building; built before WWI; often rented and in bad state, but with good intrinsic qualities and architectural value.
- 7) The suburban semi-detached house: Built after the Second World War, they are part of the suburbanisation, mainly built along main roads, creating long ribbons of habitation between cities.
- 8) Post war low rise apartment: Built in large numbers after the Second World War in the emerging suburbs, often built with low construction and architectural quality, often rented. Their relative closeness to the city centre makes them popular, so renovation can be an added value here.
- 9) The high-rise apartment building: Usually built after 1960, concrete slab construction and often prefabricated façades; low building and material quality, and small and outdated apartment units.
- 10) The social housing neighbourhood: Built mainly after the Second World War, as medium sized developments, mostly consisting of terraced houses or medium sized apartment buildings.
- 11) The conversion of an industrial building: Renovation of old industrial buildings into lofts has become trendy.

D. POTENTIAL OF THE EXISTING HOUSING STOCK TO REDUCE ENERGY

1. General considerations

The ERABUILD study [ITAR_08] shows that there is a great potential for sustainable renovation, in spite of the fact that a lot of modernisation activities are undertaken. Barriers to sustainable renovation are the low investment capacity and the lack of knowledge about technical solutions. Also, the complex decision-making process related to the co-ownership of building parts in multi-family dwellings, is an additional barrier. In theory, the social rented sector is easier to address because the investment capacity and organization structure are better.

The main barrier to sustainable renovation in both private and social rented sector seems to be the return on investment: the one who invests is not the one who profits. An opportunity for sustainable renovation could also be urban renewal, at least if

decisions on asset management were related to the technical quality of the buildings. For both aspects, specific financial and organisational solutions are needed.

Most renovation activities in the residential sector are maintenance, repair and modernisation activities aimed at increasing the service life of components, increasing comfort or replacing components. These activities are mostly decided by owner-occupants and small contractors. Especially considering small size firms and non-professional actors, there is a need for the dissemination of knowledge and decision tools and for specific organisations and processes.

One of the most significant barriers for achieving the goal of substantially improving energy efficiency of buildings is the lack of knowledge about the factors determining the energy use. Further international research for the definition of the total energy use is needed.

This discrepancy leads to misunderstanding and miscommunication between the parties involved in the topic of energy savings in buildings:

- Buildings and their systems improve, but building usage and activities in buildings can lead to increasing energy consumption.
- The implementation of energy saving measures is supported and enforced via standards and regulations, which define human behaviour and activities in buildings for the average situation and conditions and exclude non-building related issues. The instruments based on these standards lose some credibility of the public as they do not reflect the real energy consumption of a building.
- For investors in the field of energy, instruments are lacking that enable the assessment of the energy use of buildings and give information about real cost-benefit relationship between investments in energy saving measures and profits.

Building energy consumption is mainly influenced by six factors⁵: climate, building envelope, building services and energy systems, building operation and maintenance, occupant activities and behaviour, indoor environmental quality provided. There is lack of a scientific method to account for interactions between the six influence factors and energy use in a clear and thorough way, and to predict the expected energy use as well in the case of all the influence factor are taken into account.

On an international level there is an inconsequent use of terms related to building energy performance. This makes the analysis of the factors responsible for energy use impossible.

⁵ The last 3 factors, related to human behavior can have an influence as great as or even greater than the first 3 ones. Detailed comparative analysis on building energy data, concerning the six factors mentioned above, would provide essential guidance in identifying energy saving potentials and opportunities. A limitation of much current research is that it focuses only on the first three factors, whereas all the factors need to be analyzed using a combination of simulation and real measured energy consumption data. It is important to gather data on the real indoor climate conditions to understand and interpret measured data on building energy consumption.

2. A case study for the Brussels Region

CERAA [CERA_08] studied the potential for the existing housing stock in the Brussels Region to reduce energy consumption by means of the application of passive house principles. The study shows that an increase in building stock is still to be expected and that the current renovation rate (0,6%) will not be able to reach a very large part of the existing building stock. Due to this trend, it cannot be expected that the energy consumption for heating of buildings will reach the 1990 value, even if the passive house standard is introduced for new constructions.

Therefore, it is required that the energy saving efforts in the renovation sector should be increased, both in target as in volume. When the renovation rate increases, the energy consumption can be drastically reduced.

The case study shows that it is possible to reduce energy demand for heating of building, and therefore primary energy demand with stricter energy performance regulation: minimum passive house standard (15 kWh/m².a heating energy demand) for new built constructions, and minimum low energy standard (60 kWh/m².a) for renovations requiring a building permit. Also, a long-term continuous energy policy and stimulating context is recommended, even for renovations without a building permit. Building policy should also be prepared to increase the level of renovation activity from the current 1% to about 5%.

E. MARKET SEGMENTATION FOR LOW ENERGY HOUSING RETROFIT

Marketing and communication efforts address persons and not buildings. Therefore, for marketing purposes, it is important to define specific target groups, to be able to establish communication for the diffusion of low energy housing retrofit.

1. Segmentation based on ownership, private rent or social rent

The vast majority of inhabitants in Belgium are owners. Furthermore, half of all tenants wish to become owner. Ownership is thus very popular in Belgium, mainly because of the fiscal advantages.

The quality and comfort of private-rent houses is mostly poor. The Belgian renting market is difficult to target. Most people, who own a house to rent, only have one house to let. Only 15% has more than three houses to let. Most letting-owners are private persons who invest deliberately in real estate. Only a few rental houses are under the authority of professional real estate funds. This means that no large investments are made in residential renting real estate.

In Belgium there are three methods of addressing the social housing sector:

- Social housing associations own houses and rent them out.
- On municipality level, there are a small number of dwellings let by social welfare (OCMW), the municipality or intercommunal organisations.
- Social rent offices rent apartments in the private sector and sublet them as social housing with a lower price, thanks to subsidies.

Of all dwellings let as social housing, about 54% are single-family houses. Mainly in the city agglomerations, the majority of social housing dwellings are high apartment buildings with over 5 floors.

The quality of those houses is mostly good. These houses are built after World War II, with two thirds of these houses built after 1971.

2. Segmentation based on investment level

The evolution to more popularity of ownership is not entirely positive, because only the higher incomes are able to purchase one or more houses, since the pay off of the loan is higher than the average rental price. This makes the socio-economic gap between tenants and owners bigger. There is also a growing difference between the quality of rental houses and dwellings inhabited by the owners.

The choice of buying a newly built house or an existing house depends on the price. The average Belgian house costs 165263 euro.⁶ Price is somewhat related to quality and comfort, but more to location. The average difference between a dwelling of good quality and average quality is 24000 euro. Strangely there is no difference between houses of average and good comfort, but between good and very good there's a large gap of 46000 euro.

F. CONCLUSIONS

1. Policy should also address non-energy benefits

Our analysis shows that energy and building policy decisions considering low energy housing retrofit should relate to the specificity of the municipality, province or region.

From the research we conclude that the following research parameters are essential policy motivation parameters considering low energy housing retrofit:

- comfort and quality improvement,
- energy efficiency reduction potential,
- number of houses in a certain typology.

The first two parameters depend on building age and socio-economic status of the owner. The last one decides whether a certain typology is worth researching in detail. The three parameters are all linked with geography and ownership.

To increase low energy housing retrofit, the underlining motives can be:

- Resources & consumption of energy: to save energy, high energy efficiency is needed.
- Comfort & well-being: low energy housing retrofit can improve overall comfort & well-being.

⁶ The amount differs on the type of investment: purchase of a house: 122736 euro on average; purchase and retrofit: 148612 euro on average; newly built houses: 212163 euro on average.

- Construction protection: a better performance of the building can avoid many construction damages.
- Improvement of the construction value: more durable components and a better energy performance will lead to a better future value of the houses.
- Rentability and independency of energy costs: energy efficiency guarantees an assurance against increasing energy costs and due to the relatively stable energy expenses of low energy housing retrofits, tenants will be more able to pay the rent. The low energy expenses are also favourable to the payback time of the renovation investment.
- Urban development: retrofit of old buildings lead to a technical strengthening and a social, cultural an urban improvement.
- Employment creation: hundreds of thousands of regional jobs could be created and maintained through an aimed applied energy policy.
- Climate protection: It is possible to save 90% CO2 with cost-value relation with a broad effect. Insulation and energy efficiency must be made attractive, because they represent an environmentally and politically extreme thankful activity field.

2. Different building types require different approaches

Ideas have been elaborated of which types of dwellings need to be retrofitted. They are determined by following factors:

- North/South and New/ Old contrast: There are more newly recently built houses in the north of Belgium than the south. This has a great impact on the quality of the houses.
- City/ suburbs contrast: The vast majority of all dwellings are in cities and suburbs, because of their good accessibility. But the contrast of typology between the two is very large. Where the suburbs house is detached, recently built, large and has very good comfort, on the other hand, the city house is an apartment or an old row house which is often not very energy efficient. This is why the retrofit of urban dwellings will have a large impact. In further research, we will focus on this typology.

Roughly speaking, the most important share of the Belgian building stock can be divided in two classes: new-north or old-south on the one hand, and city or suburbs on the other. The old-south group and the city group have a high retrofit potential. These are mostly the Walloon houses of the working class in the industrial belt between Liège and Charleroi.

It's important to notice that houses with a high retrofit potential are mostly rental houses. Policy should be adapted to this type of ownership by making retrofit more attractive and giving advantages to owners. Due to increasing houses price, smaller houses and rental apartments are becoming more popular. This is also a reason why it is so important to focus on these smaller houses types.

3. A target group oriented approach is required

Strategies for the promotion of low energy housing retrofit should be person-oriented, preferably related to ownership structure:

- Building owners can be seen as easiest to reach for low housing retrofit, because of the large amount of privately owned buildings. However we notice that this group stays largely immobile between a first renovation and old age when other spatial or comfort requirements are needed. So, strategies should be developed to reach this group at the stage when they intend to renovate, usually because of non-energy related factors. Secondary, low energy housing retrofit should be stimulated, because energy policy objectives can never be reached with the current renovation rate.
- Urban areas need examples focussing on quality improvement of row houses or apartment buildings in the (private) rent sector. An urban area approach could highlight the extra difficulties to solve on the urban level.
- The social housing sector requires an approach focussing on cooperation between low-income target groups and their points of reference, municipalities and social housing associations.

4. Energy policy should reinforce best practice LEHR

The scenario analysis for, and demonstration projects in, the Brussels Capital Region show that it is possible to drastically reduce energy demand for heating of building, and therefore primary energy demand in a whole region. However, to obtain reduction in energy consumption compared to 1990 levels, stricter energy performance regulation is required: minimum passive house standard for all new built construction and minimum low energy standard for renovations with a building permit. A continuous energy policy and stimulating context during 25 years is also recommended, even for renovations without building permit. Also the amount of renovation activity should be increased by stimulating action from the current 1% to about 5%.

V. TRANSITION TO LOW ENERGY HOUSING

Summarizing lessons learnt from:

Participation of the authors in IEA SHC Task 37 and IEE-project E-retrofit-kit

A. De Herde, T. de Meester (2010) Guide for architects, LEHR report

J. Vrijders, L. Delem (2010) LCA/LCC analysis of LEHR, LEHR report

BBRI (2010) Technical guides, LEHR reports

PHP/UCL (2010) Project Files Low Energy Housing Retrofit, LEHR report

PHP (2010) Project Files IEA SHC Task 37 Belgium, LEHR report

'Substantial Energy Saving in Existing Housing Now', presentations and discussion

IEA Final Workshop, 14 October 2009, Antwerp

Presentations and discussion LEHR final workshop, 18 November 2009, Brussels

All available on-line: www.lehr.be

ABSTRACT

For very energy efficient renovation projects in Belgium, project information of first demonstration projects has only recently become available. This part of the report compiles the information and experiences from these projects considering technological innovation.

Drawing on project information and innovation potential, strategies can be defined for the further diffusion of low energy housing retrofit in Belgium. Social, economical and political barriers and solutions with great potential of primary energy reduction are defined.

A common building typology has also been studied in detail using life cycle analysis and life cycle costing methods. The analysis shows that it can be economically and environmentally relevant to reach outstanding energy performance in renovation.

The demonstration projects show the Belgian evidence to what extent energy efficiency and sustainability can be implemented in different building typologies. Now, systematic and successive learning and development is required on different levels. Economical incentives appear to be necessary to go from demonstration project to a growing market. Also, social issues and a lack of market infrastructure can be important barriers to reach a more substantial market share. In particular, there is also a need for ambitious policy and adapted communication strategies.

In conclusion, the research shows good prospects for the implementation of clustered innovations in retrofit, and passive house measures in particular. For the increased diffusion of low energy housing retrofit it is very important to address owner's motivation and highlight also non-energetic aspects, besides energy and economical efficiency. Different target groups (buyers, social rent, private rent) will need an individual market approach. Lack of knowledge of building professionals, decision makers, owners and tenants has to be dealt with effectively. One of these barriers or a combination can prevent from carrying out low energy housing retrofit.

A. CONTEXT

1. Introduction

Within the European Union the total building stock is responsible for about 40% of the total primary energy consumption. Housing accounts for the greatest part of the energy use in this sector. Space heating is responsible for 57% of the total energy use of households in the European Union, followed by sanitary hot water production (25%) and household equipment and lighting (11%) [ITAR_08].

A large number of research papers report on the success of implementing very energy efficient new built houses, for example passive houses ([MLEC_08a], [IEA28], [ELSW_08], [SCHN_03], [SCHN_06]). However, a decrease of greenhouse gas emissions will not occur if no energy is saved through retrofit of the present housing stock [HENS_01]. Several demonstration projects in Austria, Germany, Switzerland and Hungary have used the so called 'passive house technologies' in renovation to obtain substantial energy reduction ([E-RE_08], [MINE_08], [HERM_07], [PEP_08]). In some cases even the passive house standard is reached after modernization ([PEP_08], [PHP_09]). One of the prescribed actions on buildings in the EU Action Plan on Energy Efficiency COM(2006)545 is for the Commission to develop a strategy for very low-energy or passive houses towards a more widespread deployment of these building types by 2015 [THOM_08].

Some renovation projects are well documented, e.g. the city of Hanover offers a database of construction details for renovation of houses in Hanover towards the passive house standard. In some European countries, very energy efficient technologies are widely promoted for renovation and sometimes coupled with grants or green financing by private institutions. For example, in Alingsås near Göteborg, Sweden, a whole city quarter is being renovated using passive house technologies. Within the framework of this project the follow-up committee also had a chance to visit the neighbourhood renovation development De Kroeven in Roosendaal, which also targets the passive house standard after renovation. In Germany near Ludwigshafen, BASF has done efforts to renovate dozens of workman's houses towards a low energy or passive house standard (see project file in Annexes).

In this context, the impact of western building tradition and building type should not be underestimated. A study on cost-efficiency has demonstrated the economical relevance of thermal insulation before installing more energy efficient heating system and renewable energy systems in the Belgian context [VERB_05]. It therefore makes sense to develop strategies to accelerate the use of more thermal insulation and better glazing. In Belgium, the first low energy housing retrofit projects are now finished or under construction, as can be seen from the project files in the addendum. If these are to serve as regional demonstration projects, it is important to learn from successes and failures, and to detect opportunities and barriers considering broad market implementation.

Relevant Belgian exemplary renovation projects achieving substantial primary energy savings while creating superior living quality have been analysed considering energy performance and the owner's motivations behind the renovation. Drawing on project information and action-based experience, strategies can be defined for the further

diffusion of low energy housing retrofit in the Belgian context. This issue is studied in this second part of the report.

2. Research question

The main question we would like to address in the concluding chapter is:

What are lessons learnt from the national and international demonstration projects?

To examine this question we examine several questions in this chapter:

1. What are the technical and social challenges for innovation?

Literature research and interviews are combined with the experiences from industry and demonstration projects.

2. What are the political and economical challenges for energy policy?

A literature research is combined with LEHR research, the experiences from discussions in work groups, reflecting relevant international developments.

In conclusion, this information should allow us to define input for strategies that can be proposed to go from demonstration project to innovation and early adoption.

3. Research methodology

The research presented in this section is qualitative aiming at illustrating the problems occurring with low energy housing retrofit, when addressing different target groups, different building types and different scales of approach. Since 'low energy housing retrofit' is not well known as a research subject, driving forces for low energy housing retrofit are detected from advanced demonstration projects.

The work discusses specific cases for which in depth interviews and on site observations were used as means to collect information (see project files on www.lehr.be). To collect the necessary information on client motivation, building construction, energy use and user appreciation, specific interview sheets were developed and used. The interviewees were the owner-client and the architect, and in collective cases representatives of the occupants, social housing companies and controlling parties. Further, this section is based on literature review, findings from study trips in Germany and Austria, and work meetings and discussions (internet-meetings) during the work of the IEA Solar Heating Cooling Task 37 [IEA37] and the project 'Low Energy Housing Retrofit (LEHR), supported by the Belgian Federal Science Policy, assembling three research teams (PHP/PMP, Architecture et Climat – UCL, CSTC-WTCB-BBR!).

In our search for retrofit projects, we have defined a standard of an energy need for heating less than 30 kWh/m²a. Although it is twice the value for new built passive houses, reaching this goal appears quite a challenge in practice.

Understanding the context of the western European situation is a prerequisite for making the right decisions considering strategy development for broad market

implementation. Therefore in this section a lot of attention is given to two main levels of analysis:

- PEST analysis: Political, Economical, Social and Technological factors influence the marketplace and therefore indirectly each building actor and building project.
- Analysis of the competitive arena: Suppliers, competitors, substitutes, customers, and so on, have a strong and most direct impact on a project development.

The analyses performed use general knowledge about the market of very energy efficient renovations, passive and low energy houses (external factors), and experience with the promotion of new built passive houses, and the project range specifications (internal factors).

The authors use information from several sources:

- Low Energy Housing Retrofit (LEHR)
- IEA SHC Task 37 Advanced Housing Renovation with Solar and Conservation and related workshops and discussions
- The experiences of the Flanders' transition arena sustainable living and housing
- The experiences of the Flemish energy renovation programme 2020
- The experiences of the Brussels Capital Region demonstration programme for sustainable housing development
- The contributions to and discussion from the international passive house symposia, regional workshops, site visits and working groups under the auspices of the Belgian Passive House Platform (PHP)
- The results of workshops under the auspices of OTB TU Delft.

PEST factors and Competitive Arena issues of the demonstration projects are further reflected against the vision for the year 2020 of different European countries and from this chances, opportunities, barriers and possible solutions are derived to reach a specific energy goal in 2020. In the conclusion this will lead to us to understand the opportunities of broad market introduction for very energy efficient technologies for housing retrofit and to overcome threats.

B. TECHNOLOGICAL INNOVATION

1. Introduction

Low energy housing retrofit (LEHR) has been defined as a thorough retrofit of a building towards a building with improved comfort, taking into account substantial thermal insulation, avoidance of thermal bridges, and provision of air tightness of the building and mechanical ventilation with heat recovery. To update the discussion on energy saving technologies, we provide a review of the new development with these technologies, as detected during the follow-up of the national and international demonstration projects.

The following section is limited to the specific technologies as defined in the definition of low energy housing retrofit, and does not include innovative services. For a discussion on innovative services like project management, automation, software developments, quality assurance, energy consultancy, commissioning and testing

methods we refer to literature, for example [PFEI_08] and [SQUA_07], and to the further section on ‘the quality challenge’ (see also ‘links’).

The findings on technological innovation are particularly useful as knowledge transfer to researchers, educators, innovation managers and business R&D developers and opinion leaders.

2. Thermal insulation and avoidance of thermal bridges

Within the framework on low energy housing retrofit, updates on traditional construction methods have been found (for example cavity wall insulation with improved thermal insulation). However, with the choice for very energy saving construction and regarding the motivation of owners to increase or decrease space, alternatives have also found their way in demonstration projects (for example inside and outside façade thermal insulation, wood construction methods, and so on). In many retrofit cases of cavity walls the outside brick wall is removed or the backside extensions are replaced with a new construction with outside insulation. In the case of wall replacement different types of wall systems are used (see for example Figure 9).

A trend is visible in the bigger buildings to cover extra investment for the energy saving measures in the existing building, by adding one or 2 floors, an annexe building or transforming the attics into penthouses. Apart from the extra income, these new constructions often simplify thermal bridging or air tightness solutions necessary.

Also, new insulation materials are being used in Belgian practice of low energy housing retrofit, like improved carbon filled polystyrene, polyisocyanurate, wood fibre insulation and cellulose insulation. In neighbouring countries also vacuum insulation is used to reduce insulation thicknesses. This technology is more expensive but can offer suitable solutions when space is limited.

The BBRI reports (see www.lehr.be) provide a review of technological solutions for improved wall, floor or roof insulation solutions for retrofit, as well as options for the replacement of glazing or the retrofit of heating and ventilation. These issues are not described in detail here. In this report, we will highlight the most important developments considering innovation, and the experiences with novel technologies, in national and international demonstration projects.

a) Outside insulation of walls

Outside façade insulation systems have been used in several of the examined demonstration projects, especially for the insulation of the usually single brick back side façade (see for example Figure 1). Outside insulation with plaster covering or finishing (for example strips with brick appearance or wood panels) is a well known building method in other countries, but not very widespread in Belgium. In Germany this type of construction now implies a market of about 30.000.000 m² outside wall surface per year [KERS_07]. Although the insulation thickness of these systems was only 4 to 6 cm in the 70ies, regular thicknesses today are about 8 to 14 cm. For the examined demonstration projects thicknesses of 20 to 40 cm are used depending on the climate and the design of the building. Table 1 shows observations considering

façade thermal insulation from interviews with architects, clients and inhabitants in the examined demonstration projects.

Technology	Positive Experiences	Lessons from projects
Façade outside insulation	<ul style="list-style-type: none"> - Avoidance of condensation problems - Improved inside surface temperature - Increased indoor comfort - Easier to solve thermal bridges 	<ul style="list-style-type: none"> - Deep windows when windows are not replaced, less daylight⁷ - Special care for connection with windows (fire safety, structural stability, drip control, air tightness, replacement and cutting of window tablets) - Inside wall often needs a new layer after demolition of outside wall - Connection with roof insulation is best practice: if renovation of roofs takes place earlier, this requires extension of roof border - Prefabricated systems can reduce costs

Table 1: Lessons from demonstration projects considering outside façade insulation.



Figure 1: Outside insulation placement in Antwerp demonstration project: the roof has been insulated first, providing a roof extension for better connection with the outside insulation.⁸

A major benefit of increasing thicknesses of thermal insulation is the rise in inside surface temperature, also in critical areas like outside corners and connections with balconies. Figure 2 explains the problem when putting a cupboard in a room corner of a not well-insulated house (only 4 cm outside thermal insulation). The Figure shows a specific damage case in Germany, illustrating insulation thicknesses as they have been used for decades in standard construction in Belgium. The surface temperature behind a cupboard is too low, leading to surface condensation and mould growth⁹. Figure 3 shows the possible solution: increasing the thicknesses of insulation allows the surface temperature to be high enough to avoid condensation and mould growth.

⁷ In some cases the thermal insulation is cut to allow better daylight.

⁸ Photo: Erwin Mlechnik, PHP.

⁹ Also, the sensation of discomfort, due to radiation between the individual and the cold surfaces, increases when surface temperatures are low.

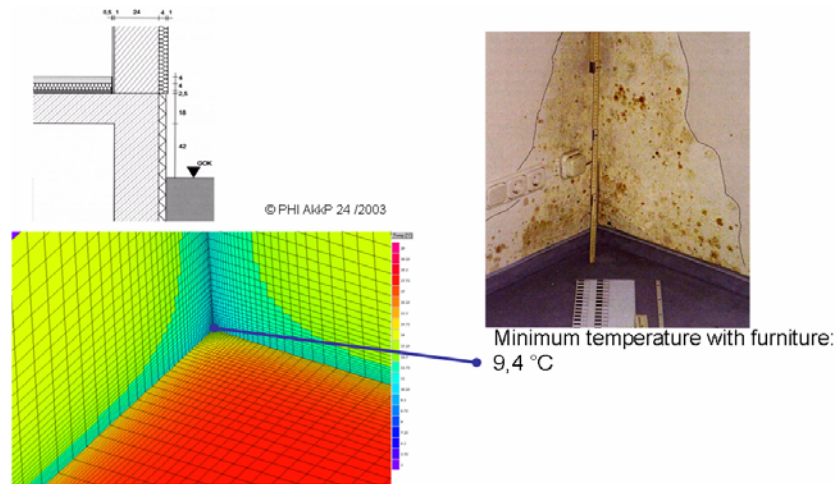


Figure 2: *Thermal simulation of low insulation thicknesses in a corner of a room in critical conditions (cupboard in corner): the simulation and pictures were derived from a specific damage case in Germany [FEIS_03].*

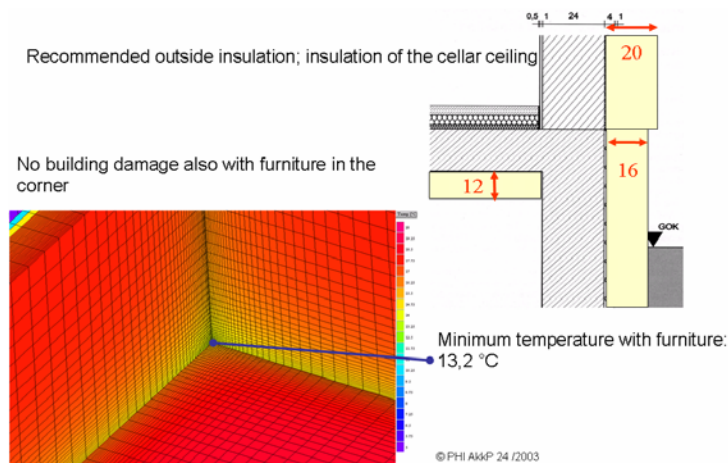


Figure 3: *Thermal simulation of different insulation thicknesses in a corner of a room in critical conditions (cupboard in corner): the solution recommended for the damage case: increased insulation thickness [FEIS_03].*

From an international example project of a renovation in Austria, it was noticed that renovation of the building façade towards the passive house standard lead to excellent acoustical performance and occupant appreciation concerning prevention of outdoor noise. However, because of lack of outdoor noise, noise from neighbours (unmodified partition walls in a 70ies construction) was perceived as more present and scored negatively. In such cases it is recommended to pay special attention to internal acoustics to avoid sound transmission between neighbours.

b) Outside insulation of walls (prefabrication)

Major breakthroughs in innovation development were observed in the field of prefabrication for large insulation thicknesses (see IEA ECBCS Annex 50). Figure 4 shows the façade prefabrication system that was developed and further optimised for the passive house demonstration renovation project in Alingsas, Sweden (IEA SHC Task 37 visit). In Germany demonstration projects have used prefabricated elements

with vacuum insulation for façade renovation: a 9 cm thick panel allowed to reach U-values of 0,15 W/m²K [BINE_08]. The prefabricated systems ensure quality of insulation placement and air tightness, since it is produced under controlled conditions. Its major benefit is the reduction of the construction time, and thus the annoyance to the inhabitants.

Also several developments have been introduced into the market as specific solutions for structural thermal bridges (see Figure 5), although these are not always easy to implement. In many demonstration projects structural thermal bridges, like for example balconies, have been thermally encapsulated, removed or replaced.

Hanging and aerated outside façades on a thermal insulation layer have also been used in the demonstration projects, in one case even a do-it-yourself case. Innovative developments in this area include thermal bridge free fixation materials.



Figure 4: Prefabricated wall retrofit system used in the renovation project Brogarden, Alingsås, Sweden¹⁰. The outside façade was removed and replaced with a fully prefabricated new façade. Optimization of the system after experimentation with a first demo project allowed for further cost reduction (IEA SHC Task 37).



Figure 5: Prefabricated connector system to allow thermally insulated connection with a balcony¹¹ (IEA SHC Task 37).

¹⁰ Photo: Erwin Mlecnik, PHP.

¹¹ Photo: Erwin Mlecnik, PHP.

c) Inside insulation of walls

Inside thermal insulation has also been used in several demonstration projects, even in protected monuments, mainly in those cases where the outside façade could not be touched due to city ordinance or monument protection, or because the client did prefer not to touch the outside façade because of its architectural quality. We note that very energy efficient housing retrofit examples with cavity wall filling, were not encountered in the practice of advanced Belgian demonstration projects, probably due to the limited thermal insulation properties of this solution.

Table 2 describes the project experiences with inside thermal insulation.

Technology	Positive Experiences	Lessons from projects
Façade inside insulation	<ul style="list-style-type: none"> - Also applicable when outside façades are protected or of significant architectural quality¹² - Increased indoor comfort - Instalment possible in less favourable outdoor conditions 	<ul style="list-style-type: none"> - Not much experience in Belgium, no specialized companies - Special care to avoid thermal bridges and structural damage, e.g. at the connection of carrier beams - Often complicated to implement the air tightness layer from the inside - Continuous insulation layer from the inside often leads to box-in-box solutions - Limited possibilities in small houses due to space loss¹³. - Clients often not prepared to put inside insulation because of inside ceiling ornaments or expected mess

Table 2: Lessons from demonstration projects considering inside insulation.

In some case inside thermal insulation was also applied behind protected façades, but this requires careful planning and investigation of possible risks (see for example Figure 12).

Innovations concerning inside insulation, encountered in Belgian demonstration projects, include the use of cladding systems with cellulose filling and vapour barrier with moisture control. In the research field hemp cement is being developed for thermal inside insulation.

In Germany also calcium silicate (CS) is regularly used as inside thermal insulation. To produce such plates, limestone, sand, cellulose and water are baked in autoclaves. In contrast to traditional insulation materials the calcium silicate plates allow smooth moisture control, while the glue behind the plates avoids the moisture to pass into the existing construction [KERS_07]. However, the thermal conductivity value is limited to 0,065 W/mK.

¹² E.g. applied in renovation towards passive house standard of a large residential complex (De Sleephelling) in Rotterdam with protected façade and protected roof structures, as well as in a registered monumental school transformation in Roosendaal.

¹³ The development of vacuum insulation might offer a solution.

Vacuum insulation plates (VIP) are known from industry (e.g. heat production systems and industrial fridges) and are now also finding its way into the (still only foreign) demonstration projects. VIP usually consists of plates of multiple barrier metalized plastic foil filled with a pressure resistant powder. Already with an evacuation of the air until 50 millibar a thermal conductivity value of 0,005 W/mK is reached. With loss of vacuum still a thermal heat conductivity of 0,02 W/mK is maintained [KERS_07]. In most cases, special considerations are taken to avoid decompression loss, e.g. by covering the plates with traditional insulation material to avoid perforation. The advantage in insulation thickness (1:10) is in those cases partially lost. The technology requires exact planning for perfect and thermal bridge free connection of plates. The innovation is still rather expensive, but in certain cases where space is limited, e.g. limited indoor surface or limited ceiling height, it can readily be used in renovation.

d) Thermal insulation of roofs and floors

For a further discussion on thermal insulation solutions of walls, roofs and floors, including target U values, we refer to the related BBRI reports (www.lehr.be).

In the demonstration projects, traditional insulation materials are usually used for roof insulation, as well as cellulose insulation. However, the practice of roof renovation with thermal insulation seems to be cumbersome for less experienced contractors: we remark that in one of the examined Belgian cases, the placement of additional roof insulation lead to building damage because of the lack of experience of the roof contractor.¹⁴ Clients noticed that many contractors are also not open to developing solutions to avoid thermal bridges in a later renovation stage. International innovative solutions for roofing materials include new roofing materials with integrated solar collectors.

Floor insulation is often perceived as cumbersome: especially when the users already inhabit the house, they are not too keen to do the effort to break up a floor. For houses without a cellar or crawl space, it is therefore recommended to insulate floors as a priority before moving into the house (for example demonstration projects show that roof and wall insulation can be tackled in a later stage with less intrusion). Cellar and crawl space insulation can sometimes offer a solution, but this practice is not common in Belgium. Even in many demonstration projects, floor, cellar or crawl space insulation was missing or limited. We also noticed that, compared to Belgium, in the Netherlands the market for crawl space insulation is better developed. Several small companies offer solutions with polystyrene, shells or foam material. Many clients opt for such solution to reduce odours and humidity from the basement and take the energy saving effect for granted.¹⁵

e) Retrofit of glazing

Demonstration projects show glazing with two or three glass plates with gas filling, air or mostly argon, and rarely krypton or xenon. Figure 6 provides a review of technical data of different solutions. Depending on the filling an optimal distance between the glass plates is maintained. Depending on consumer wished for noise reduction, different thicknesses of glass plates are used. All known technologies for

¹⁴ Boudewijnsstraat, Antwerpen: the roof started leaking after the works were finished.

¹⁵ Reference: Documentary Tros Radar 2009.

embellishment, solar protection and safety are also applicable on three- or four-pane windows (see Figure 7).

The next step in the evolution of glazing is expected to be quadruple glazing and/or vacuum glazing. Recently, also quadruple glazing has been introduced in Belgium for the market of inclined roof windows. Alternatively, two-pane glazing with one or two polyester foils spanned in the space in between the glass plates is also on the market. This gives U values comparable with triple or even quadruple glazing, but with a weight limited to the weight of double-glazing.

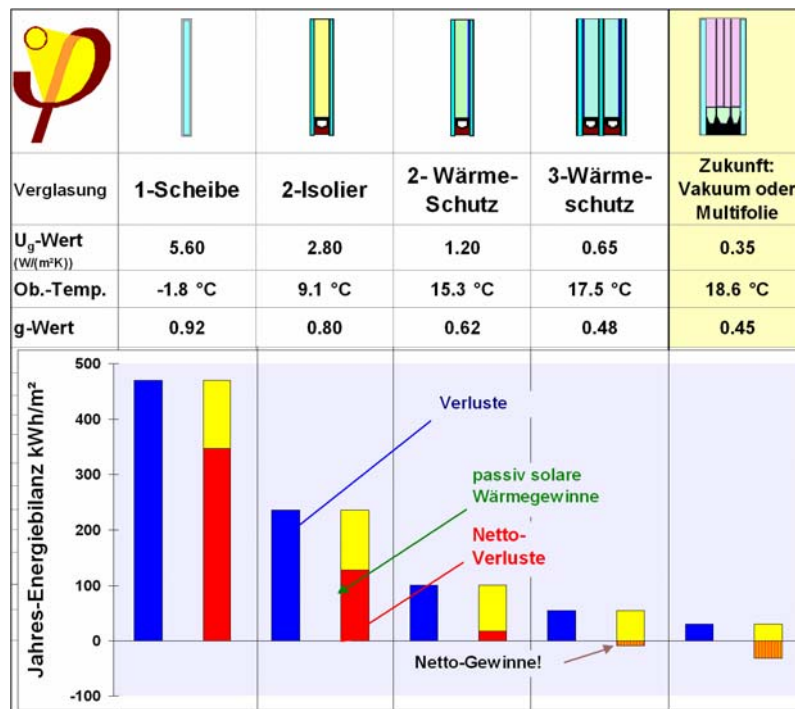


Figure 6: Comparison of technical data of different glazing solutions (Source: Passivhaus Institut Darmstadt). U-values decrease with increasing number of windowpanes, but so do values of solar transmittance (g values). However, from triple glazing onwards on a yearly basis there are more solar gains than heat losses.¹⁶ Notice also that the inside surface temperatures improve up to a level that a heating unit is no longer required next to the window.



Figure 7: Fancy triple glazing in a renovated harbour café near Gothenburg, Sweden.¹⁷

¹⁶ One could call a triple glazing thus a passive solar collector

¹⁷ Photo: Erwin Mlecnik

With energy efficient windows the spacer between the glass plates becomes a weak point in thermal efficiency. Stainless steel, aluminium, polycarbonate or glass fibre reinforced plastic spacers are being used to reduce the thermal bridge effect of the connecting point compared to usual metals. In the case of plastic spacers a metal foil is integrated to avoid gas diffusion. In other countries also thermoplastic spacers of modified butyl with integrated drying agent are being used: these are extruded directly on the glass plates in the factory before assembly. Innovative glass spacers can improve the U value of the standard norm window about 0,1 to 0,3 W/m²K. Depending on the covering of the glass plates with the window frame the glass border surface temperature can increase 2-4 K, leading to improved comfort and lowered risk of condensation water [KERS_07].

f) Retrofit of window frames

Although many clients opt to only change glazing because of pretended cumbersome intrusion, from the demonstration projects it was noticed that in practice replacement of full window frames can happen quite smoothly within the time frame of a few hours with only minor intrusion on the interior finishing (see Figure 8 left). Usually only a limited amount of finishing and painting has to be provided. However, intrusion in the habitat area is usually experienced on the fact that workers have to be able to reach the façades, usually through the building (see Figure 8 right). A real challenge therefore lies in providing fast solutions for inhabited buildings, based on minor outdoor intervention only.



Figure 8: *Left: Minor impact on interior finishing with the replacement of a window and window tablets. (Renovation project Antwerpen). Right: Putting windows and insulation into place usually implies scaffolding and workers carrying materials through the house: this has an important impact on the garden (Renovation project Deurne).*¹⁸

With improved thermal quality of glazing, the window frame becomes more and more a weak point. Already in 1996, when the first triple glazing with a U value of 0,7 W/m²K appeared on the European market, German industrial partners funded the development of window frames with better thermal performance.¹⁹ Such frames usually have an interior insulation material (see Figure 9). Compared to countries like Germany²⁰ and Austria the so called 'passive house' window frames with a U value

¹⁸ Photos: Erwin Mlechnik, PHP.

¹⁹ Through funding of the Arbeitskreis kostengünstige Passivhäuser: Superfenster im Passivhaus. Passivhaus Institut Darmstadt, 1996.

²⁰ In Germany such windows even can have a certificate as 'suitable for passive houses'.

below $0,8 \text{ W/m}^2\text{K}$ are still relatively rarely used in the Belgian retrofit market, although they are regularly encountered in new built constructions and they provide better thermal insulation properties.

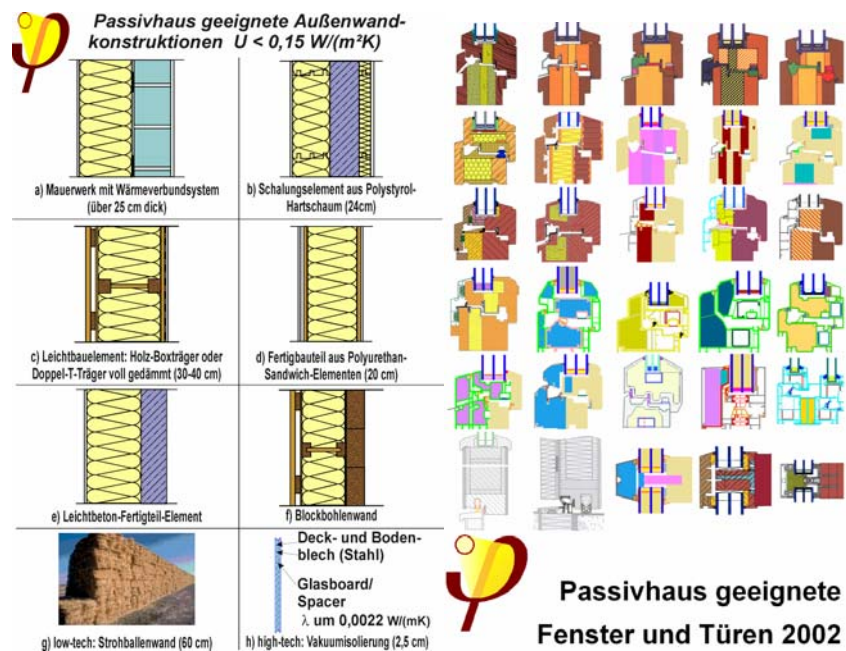


Figure 9: Some of the insulation systems and window frames already available on the German market in 2002 (source: IG Passivhaus Deutschland).

Considering window frame materials the classical distinction between wooden, PVC and aluminium frames makes no longer sense when choosing from the advanced window market. Virtually every combination is available according to consumer wishes: e.g. wooden frame with outside aluminium protection and inside PVC finishing. Such combinations are also seen in the demonstration projects. Major drivers for replacement of window frames in the demonstration projects have shown to be the decreased maintenance (no longer painting) and the improved comfort (avoidance of draft). Energy efficiency of window frames is currently only a minor consumer drive. Observed benefits usually also include better daylight when old wide wooden frames are replaced with slimmer versions and noise reduction because of the improved air tightness.

When windows are replaced it is advisable to choose for frames with better performance. When also the walls are being insulated, it is recommended to place the new windows in connection with the thermal insulation layer. To improve daylight intrusion with small windows and thick walls, wall sides can be cut in inclination (see Figure 10).



Figure 10: Inclined wall sidings after retrofit allow better daylight intrusion from small windows after retrofit (renovation project Brogarden, Alingsas, Sweden).²¹

In good practice the connection of the window with the wall requires an outside and an inside sealing layer and filling up of the cavity between the window and the wall. The outside sealing layer seals from the intrusion of rain in the construction, the inside sealing layer the intrusion of warm humid inside air. In some demonstration projects it was noticed that the windows were not properly placed. However, adequate sealing materials are available on the market in the form compressing bands and strips, profiles, foils and tapes or combinations of these. With increasing air tightness of the building the requirements for such placement become more stringent.

In one project also triple glazing with integrated solar shading was encountered (see Figure 11 left). The frames further offered the advantage of having two different tilt positions for winter and for summer ventilation.

In the Netherlands, several small companies also offer specific solutions for the renovation and thermal improvement of stained glass-in-lead windows (see Figure 11 right). The single pane is carefully removed and in the factory integrated in a new frame. Usually this implies that clients can now open their windows, an improvement in air quality compared to the situation before renovation. In the case of protected window frames, the architect usually prefers to place an extra window on the inside.²²

²¹ Photo: Erwin Mlecnik, PHP.

²² For example in the renovation project De Sleephelling in Rotterdam [IEA37].



Figure 11: Left: Triple glazing with integrated solar shading and winter/ summer ventilation mode. (Renovation project Victor Driessensstraat, Antwerpen); Right: Renovation of glass-in-lead windows in a protected housing area in Rijswijk, the Netherlands: the glass-in-lead is carefully removed by the specialized manufacturer and integrated in a new frame.²³

3. Indoor climate systems

The indoor climate systems in winter and in summer were illustrated for national and international example projects and the report by BBRI provide an overview of retrofit solutions for heating, and for ventilation (see the project files on the web).

According to the popular definition, passive houses have to reach a target energy demand for heating less than 15 kWh per square meter and per year. This definition makes sure that the heating demand can be provided by a small post-heater in the hygienic ventilation system, where as the ventilation system can be dimensioned purely for ventilation purposes. In theory thus the installed heating power should be less than 10 Watts per square meter. In practice it was noticed that a target demand of 30 kWh per square meter net surface and per year was already an important challenge for building teams to reach in retrofit projects, thus leading to alternative indoor climate systems, often using passive house related components.

Gain of space is an important issue in most renovation projects. Electric post-heating systems are sometimes chosen because they require no boiler and no chimney. Otherwise, if the client opts for solar renewable energy or biomass fired boilers for hot water production, it can be relatively easy to attach a water-based post-heating system.

A majority of low energy housing retrofit projects used mechanical ventilation with heat recovery, in some cases also coupled with ground-air heat exchanger to provide for some preheating in winter and cooling in summer. Observed renovation projects with only mechanical extraction usually revised the extractors to reduce noise or to

²³ Photos: Erwin Mlecnik, PHP.

increase or reduce ventilation capacity. In some cases, clients were very creative with integrating mechanical ventilation in existing shaft or chimneys (see for example Figure 12). In foreign demonstration projects, it was detected that new innovation were introduced specifically for the market of low energy housing retrofit, like room-based decentral ventilation with heat recovery (see for example Figure 13). Such systems can offer the advantage that large ductworks can be avoided and nuisance to inhabitants can be reduced. Solutions exist that can be placed only by drilling a hole in the wall, or by integration during window replacement.



Figure 12: Insulation planning behind a protected façade and integration of mechanical ventilation in existing neoclassical chimney infrastructure (project avenue Rubens, Brussels demonstration programme; source: C. Jadoul, IEA workshop, see also [IBGE_09])



Figure 13: Decentral room-based ventilation solution with heat recovery in a visited demonstration project in Gasen, Austria.

In IEA ECBCS Annex 50 it was observed that also solutions to integrate ventilation ductwork in the outside façade insulation were proposed as a means to have an integrated approach for low energy housing retrofit.

The analysis of demonstration projects shows that for low energy housing retrofits, clients tend to prefer new types of post-heating, adapted to the low power requirement. The retrofits towards passive house standard provided relatively simple space heating systems. Compared to traditional central heating systems, indoor climate systems often integrate space heating, hot water production, ventilation and heat recovery, and connection to renewable energy systems. Integrated units can be much more compact and require less space and maintenance.

Gas-fired post-heating tends to become an unpopular option in houses with very low energy demand. A marketing bottleneck for applying gas-fired boilers appears to be the over dimensioning of such systems. Modelling the intermittent operation of a gas boiler to provide small heat pulses into the building shell can be a challenge. In low energy housing retrofit projects with no ambition to reach the passive house standard, usually more backup heating was provided than necessary, or some of the original heating elements are recovered. In some cases of central heating, conversion to low temperature and deletion of a few radiators provided an option. Radiators were sometimes deleted where triple glazing and passive house level insulation was installed: the clients reasoned that surface temperatures would be high enough on those walls and windows.

Some form of renewable energy system has been implemented in most low energy housing retrofits. Apparently clients who opt for a low energy house are environmentally conscious and also want to show it by investing in renewable energy. In one Belgian case²⁴ it was observed that the roof was first insulated and renovated with expensive tiling and a few months later the owners decided to replace the tiling with a PV-system. Most low energy housing retrofit projects have considered placing thermal insulation before installing renewable energy.

The LEHR study included inspection of technical details, measurements of indoor comfort after occupation and interviews with occupants of several projects in Belgium. Concerning the performance of the indoor climate systems, occupants are mainly concerned with winter and summer comfort, air humidity, temperature differentiation, acoustics and psychological and social preferences. Some interviewees recommended improving the user friendliness of indoor climate systems. Also, a good realization of (passive) cooling is considered a very important issue in low energy housing retrofit, in most cases solar shading was or became an essential feature²⁵.

In most low energy housing retrofit cases the interviewed occupants/clients were not aware of the existence of detailed dimensioning documents of the indoor climate system. In most passive house retrofits the occupants/clients could provide a reference with a calculation with the passive house planning package PHPP²⁶. In

²⁴ Project Boudewijnsstraat, Antwerpen.

²⁵ E.g. renovation project in Oudenaarde: solar shading was installed later after occupation. The owners wanted to try first if overheating would be a problem. Measurements confirmed summer overheating without shading.

²⁶ The calculation is also obligatory to be able to get the certificate to apply for federal tax reduction for passive houses.

some cases regulation of air flows of the ventilation system was never done²⁷. This leads to questioning the quality of the work of the indoor climate system installer.

4. Conclusion: a communication plan is needed

Low energy housing retrofit goes far beyond the current practice of renovation of the dwelling stock. Whereas most renovation projects are dealing with extension, modernizing and reorganization of the dwelling according to the changing needs, low energy housing retrofit investigates the possibilities of advanced and ambitious energy renovation concepts, usually involving clustered solutions, for example:

- Thermal insulation of roofs + air tightness;
- Mechanical ventilation + heat recovery;
- Heat production + renewable energy;
- New glazing + new frames + airtight connection of frames;
- Thermal insulation of walls + window replacement;
- Prefabricated façade renewal;
- ...

In order to reach ambitious energy saving targets, a proper and sometimes innovative answer needs to be found for each project on the following issues:

- the bioclimatic conception, the solar supply and protection,
- the thermal insulation, air tightness and ventilation,
- the systems, techniques, and renewable energies,
- the problems of the building process and control.

Demonstration projects show the way how project developers, housing companies and private investors can take profit of innovations and advanced renovation concepts, resulting in a drastic reduction of the energy consumption while maintaining and even improving the comfort levels in their houses. Specialized companies, contractors, architects and engineers, developers and suppliers of construction materials and components for energy efficiency in existing buildings are opening a very promising and strongly growing market of energy related construction works, and this evolution can already be seen in other countries.

For low energy housing retrofit, like for most substantial retrofits, protection and renewal of construction is an important technological driving force. Thermal insulation and the implementation of ventilation measures can protect the construction from internal condensation and thus increase its life span. Minimization of thermal bridges and improved air tightness also reduces structural damages. Mechanical ventilation with heat recovery can contribute to a better air quality and reduction of moisture problems, while reducing ventilation losses. In fact, to cover all aspects, integrated solutions can be highly recommended.

Many innovations have been detected in demonstration projects. Many of them are still only used in foreign demonstration projects. The following issues were perceived as problematic by owner-occupants:

- Many traditional craftsmen are unfamiliar with the innovations;

²⁷ Case Herselt. The owner also complained about inadequate dimensioning of the solar system.

- Many craftsmen are not used to cluster their effort and work together on whole building solutions;
- Many craftsmen are involved, often resulting in problematic coordination;
- Poor coordination on site can result in lower quality;
- Renovation projects disturb the inhabitants for a long time.

These issues should be regarded in the development of new innovations. Whole building concepts, well coordinated modules and more rapid construction are needed, preferably with few companies involved, without technical compromises and with quality guarantee.

A bottleneck for further application of these innovations can be the lack of education or access to information. Therefore a communication action plan is needed to spread information, skills and competences. The existing demonstration projects can serve as a starting point of information to reach innovating businesses, opinion leaders and other motivated clients. The current information allows spreading the knowledge to reach other innovators. The BBRI reports can serve as guides for contractors and building businesses, the UCL/PHP guide can be used as a basis for communication towards architects, the PHP/UCL project files can serve as case specific best practice information, designed to provide information for building teams, according to specific building typologies or target groups.

The next chapter addresses some issues that are important in order to establish a communication plan for the diffusion of low energy housing retrofit and the associated innovative technologies.

C. ECONOMICAL AND SOCIAL CHALLENGES

1. Changing business motivation

Under the influence of global developments, public awareness, regional networks and policy decisions, the housing and construction industry are realizing that sustainability is an essential factor in future developments. More and more building professionals are recognizing that the provision of radical energy demand savings during design is an essential part of sustainable construction and renovation.²⁸

By anticipating regulation changes, companies have shown to be able to become market leaders [IEA28]. For companies to be recognized as market leaders (whether local, regional, national or international) the aim is to demonstrate that their products differ from those of their competitors. As sustainable housing now enters into its growth phase, it is the right time for companies to define their positions. Waiting on political decisions will make it more difficult to not be just another 'follower', whose competitive pool is limited to price. Brand building on sustainable values is a decisive opportunity for market leaders. There is a large latent market for a variety of businesses within the building industry for retrofit and rehabilitation. This latent market can be stimulated with public R&D initiatives, innovation funding and learning from successful and unsuccessful projects [IEA28].

²⁸ A recent confirmation was given in April 2009 by the Union of Belgian Enterprises (www.energyefficiency.be). See also [MCKI_09].

Very energy efficient technologies have also been promoted and developed by Belgian companies in the building industry, in order to gain a serious and innovative image. According to the results of more than 300 interviews performed by the Building Confederation²⁹ one out of five contractors in Belgium already believes that passive houses will be the solution for the future. Therefore large innovative Belgian companies like BASF, Renson, Wienerberger, Recticel, Isover, and so on, now offer specific passive house technologies. Belgian companies like FHW, Investsud, the Port of Ghent, Volvo Ghent, CIT Blaton, have even invested in building their own offices in the passive house standard. In 2007 Young Budget Homes was the first contractor in Flanders to present a passive house concept for the real estate market. Other real estate developers like Bostoan and Greenimmo soon followed this. Companies involved in very energy efficient technologies for housing have reported to be less affected by the economical crisis that hit during this research. However, none of these companies currently have a specific marketing strategy for the renovation market.

The market for new built constructions is currently decreasing. There are only a few companies that specifically address the low energy housing retrofit market. This is in large contrast with the findings from the previous chapters, where a huge potential and many technological innovation opportunities were detected.

Historically in Belgium, assembly and common identity construction of Belgian building and service companies within the framework of energy efficiency has led to the promotion of passive house technologies. For example, since 2002, companies have assembled their forces in organizations like the Flemish Passiefhuis-Platform (PHP), or later the Walloon Plate-forme Maison Passive (PMP). Thematic networking to stimulate innovation, in the Flemish Region funded by IWT³⁰, provided golden opportunities for these companies to reach new clients and expand business, but also media played an important role in the diffusion and popularisation of the first very energy efficient houses [MLEC_08a]. In the Flanders Region, PHP has grown to become a unique multidisciplinary organization for the promotion of energy conscious building, not only involving industry and professionals but also consumers and knowledge institutes. PHP has seen a large and steady increase in the number of its company members³¹. Company members offer products, services and technologies especially for the realization of passive houses.

In Belgium, mostly independent non-profit organizations take care of networking, contacts with companies, knowledge transfer and guidance of building teams in order to implement innovation into daily building practice. In Belgium, networks like PHP and PMP can be seen as a suitable multidisciplinary channel to distribute information regarding passive house technologies, which are often used in low energy housing retrofit. ODE-Vlaanderen distributes information considering renewable energy systems. VIBE reaches the business market of bio-ecological construction. Also specific centres exist that address the diffusion of information concerning sustainable

²⁹ Confederatie Bouw, Published in October 2007 in the magazine Bouwbedrijf.

³⁰ The Institute for the encouragement of innovation through science and technology in the Flanders Region.

³¹ Starting with 14 companies in December 2002, 75 companies were member in March 2007; this has increased in 2009 to more than 100 companies.

construction³². Also, some institutes address specific target groups³³ or regions³⁴. Specific industry networks were also created in the framework of the energy performance regulation development³⁵ and some efforts were undertaken to assemble companies in the renovation sector³⁶.

2. The social challenge

Although many networks exist, none of these have a sole mission or a substantial number of companies specifically addressing the low energy housing retrofit market, to be able to promote low energy housing retrofit from innovation to early adoption.

A Belgian research report [BART_06] stresses the necessity that citizens need to feel concerned by the problems that the policy tends to solve. Energy savings can be associated with improved comfort, citizen action, children's future,.. and should not always be reduced to money savings, as this can be counter-productive. On a federal and regional level the report recommended to talk about energy and experience from low-energy buildings, to provide positive feedbacks, and to support the social diffusion of technological progress, especially in the field of insulation and heating, substitution of primary energy sources and the promotion of existing low energy appliances.

The LEHR project identified many new Belgian demonstration projects, which can provide a starting point for further observation, comparison and research. They provide real-world data making energy-efficient and sustainable renovation a tangible and visible concept on the local level. They provide a means of learning-by-doing for the actors involved. We quote Feminias [FEMI_04, abstract]:

“Existing demonstration projects have the potential of becoming a strategy for systematic successive learning and development on the path to reaching long-term abstract objectives for sustainable development through realistic advancements and in accordance with conditions for learning and development in the building sector.”

Now, deficiencies have to be solved and new demonstration projects will have to be defined, since the projects found can be seen as far from representative for all types of ownership. The following deficiencies are often noted when using demonstration projects [FEMI_04] for further market creation:

- Lack of incentives and interest for learning
- Target group oriented reliable and useful information
- Lack of institutions for further dissemination

Bartiaux [BART_06] notes that Belgian authorities should promote and support the development of organizations, companies and services that have activities related to energy saving. These activities can include the information of the population and

³² For example Centrum Duurzaam Bouwen, Kamp C,...

³³ For example BBRI, NVA, VVF, Orde van Architecten, TCHN,...

³⁴ For example REGent, EHA!,...

³⁵ Privately funded by large companies.

³⁶ For example Renoforum.

companies. To rely on consortia of governments, non-governmental organizations, universities, companies and other institutions connected in energy-efficiency networks would also boost the sector and its potential (throughout media, exhibition, documentation, demonstration, training, networking, etc.) in order to develop this market while it is still time.

Business experts in energy efficiency indeed noticed that future builders are often convinced by previous builders, especially when they visit the house and talk with the owners about their experiences [MLEC_08a]. 'Peer-to-peer' information from a trusted source (previous builder/relative, non-profit organization, government, energy expert,..) is the most important driver to get innovative (energy efficient) technologies and concepts implemented. In this framework there might be a role for institutions (like the ones mentioned in the previous section) to provide further dissemination.

Observation from the research partners of client behavior on building fairs³⁷ showed that the initial choice for energy efficient materials can be driven by emotional choice or real concern for the environment. Usually only in a later stage, economical figures are compared of different options. Especially price is an important secondary driver to be able to reach an early adopter market. The way this price information is communicated should be considered. For example, from interviews of the demonstration projects, several architects stated that pay back times of energy saving measures can be presented as unconvincing and one can have long debates about them, but one can also present them to clients in comparison with other regular choices³⁸. In the following section we discuss some economical issues.

3. The economical challenge

a) Results from LEHR studies

Within the framework of LEHR, BBRI did an extensive study on the life cycle analysis (LCA) (environmental impact) and life cycle costing (LCC) (cost efficiency) of low energy housing retrofit. We hereby provide a summary. For further details, the full report can be consulted on www.lehr.be (see Annexes: Additional LEHR Reports).

Based on the literature review on cost efficiency of very energy efficient renovation, following conclusions can be drawn. A wide variety of methodological approaches exist when it comes to determining cost efficiency and environmental impacts of energetic retrofits of buildings. On the one hand, boundary conditions have to be chosen, on the other hand, data for evaluation is not always available, variable or is uncertain, especially when it comes to future forecasts.

Despite these varying methodological choices, some common conclusions can be drawn from the consulted research studies:

³⁷ LEHR exhibition on PassiveHouse 2008 and 2009.

³⁸ For example Flemish architect Bart Cobbaert stated that the extra cost of reaching a passive house standard can be financed by avoiding a second garage for a car (communication during visit). German architect Ingo Gabriel convinces clients by comparing one hour of insulation with one hour of sitting on a sofa, driving a car or using a gala dress (paper presented at the 2. internationale tagung Ökosan 07, 10-12 October 2007, Weiz, Austria).

- Energetic renovation insulation measures are usually cost efficient. Applied measures result in cost savings in a rather short period (small pay-back time, good return on investment, annual savings) ([ECOF_05], [VERB_05]).
- The cost efficiency rises when 'general renovation cost' is not considered, e.g. when renovation of the finishing layer had to be done anyway, or when windows or boilers had to be replaced at the end of their service life. This logic makes investing in very efficient windows and heating systems also cost efficient. ([ECOF_05], [PHI_05]).
- The optimal cost curve for individual insulation measures runs rather flat, which means that many solutions nearby the optimum have a similar cost efficiency, also going further than the optimum. The optimum U-value lies in many cases further than the legislative minimum requirement. ([ECOF_05], [ECOF_07], [PHI_05]).
- The cost efficiency becomes better when no insulation or other well performing component was present before. This means when a large difference between the old and the new situation can be realized. This implies that when doing a retrofit, one should go as far as possible, since e.g. adding insulation after 10 years will not result in the same efficiency.
- Depending on the methodology, data used and boundary conditions (costs included/excluded, e.g. tax deductions; energy price scenarios) the optimum solution in terms of cost efficiency in projects or case studies is a 'Low Energy' renovation or even a Passive house renovation.
- A recent Flemish study [3EHL_08] states that most insulation measures have very low payback times (couple of years, max. 12.5 years), except for window replacement. Optimal U-values for components are between 0.25 and 0.3 W/m²K for each opaque part of the envelope.

Additional conclusions from the literature review are:

- From an environmental point of view, energetic renovation measures are beneficial thanks to the resulting lower energy consumption during the use phase. However, this is not true for all environmental impacts considered, especially not for measures implying a greater use of electricity (e.g. installation of a heat pump).
- Renovation is considered to be more efficient (from an environmental & financial point of view) than demolition and reconstruction, on the condition that a thorough retrofit is technically possible (a good energy savings should be achievable).

The literature review served as basis for the LCC and LCA methodology used to investigate the cost effectiveness and environmental impact of the renovation of a Belgian row house to passive house standard. Ten alternative renovation scenarios were defined with varying heat demand levels (standard, low energy, very low energy and passive house standard) and installations for hot water production and heating (based on gas, electricity, pellets and solar energy). The environmental impact and cost efficiency of those alternatives were compared.

The LCA results for the specific case indicate that from an environmental point of view it is interesting to aim at the passive house standard and to use renewable energy sources. However, attention needs to be paid to the electrical consumption of

auxiliaries (e.g. pumps, ventilation system), as for some impact categories its negative effect can sometimes overrule the resulting benefits.

On the other hand, the LCC results for the specific case indicate that the renovation to passive house standard is interesting in the long run when taking into account financial incentives. Otherwise, a Low-Energy-solution using a solar boiler proves to be the most interesting.

Combining environmental impact and cost efficiency, no single optimum was found. However, since the more ambitious alternatives (Low Energy house, Passive House standard) have a similar total cost efficiency (over 30 years), it is beneficial for the environment to save as much primary energy as possible. However, reaching the PH-standard requires a serious extra initial investment, even when fiscal deductions and primes are taken into account.

In case more case studies would demonstrate the same results, then a recommendation towards policy could be to develop the necessary financial instruments. Stimulating energy efficient renovation by adapted primes or loans, to counter the elevated investment is also one of the recommendations stated in [3EHL_08].

We should remark that, when we look at the owner's motivation in the project files (see Annexes: Project files), for demonstration projects with motivated owner-occupants, cost-effectiveness showed not to be the main driver. Market prices of innovative technologies were usually more expensive; some even had to be imported from other countries. Contractors have been noticed that apply higher fees when working with unfamiliar solutions. Architects can charge higher consultancy fees due to complicated existing structures, lack of know-how and lack of ready solutions.

b) Competitiveness of houses also needs a broader vision

Discussions on cost and environmental efficiency should also be placed within a larger framework of the decision process of housing renovation (see Section IV: Motivation). For example, in some projects it was observed that renewal would have been a preferred option, but higher investment costs formed a bottleneck. Owners finally opted for renovation instead of renewal because of the lower associated VAT³⁹. This shows how policy can influence decision processes. Discussing surplus cost of low energy housing retrofit often leads to owner's relativity when seen within the framework of decision processes.

The real estate sector notes that the price development in the housing sector is determined by 4 factors: the evolution of the loan capacity, inflation, the development of buying power and tax incentives. But in the framework of sustainable development these factors are largely intertwined with the political, social, cultural and geographical side conditions.

Sales prices of houses are primarily defined by location. In the Brussels Region a house will roughly cost one third more than in the Flemish or Walloon Region. Averaged, in the Flanders Region a house is about one third more expensive than in

³⁹ During the economical crisis the VAT has also been lowered for new constructions. The start of the demonstration projects dates from before this period.

the Walloon Region. Also within the region large differences occur according to location⁴⁰. Currently the sales prices are not influenced by the energy performance of a house. This situation is expected to change in Belgium with the introduction of energy labels for houses and due to the effects of increasing energy prices.

Global events now have an increasing influence on the energy and house prices, reinforcing price fluctuations. Moreover increased energy prices also have led to increased prices for building materials and houses.

In Belgium, between 2000 and 2008, construction costs of houses have increased twice as fast as the prices of consumption goods⁴¹. The Flemish Confederation of the Building Industry (VCB) states that prices of construction costs will not decrease and that this evolution will not turn in the near future. VCB points to higher building costs caused by the introduction of the Energy Performance of Building Directive (EPBD), but notes also that this cost increase should reimburse itself to the owner. On the other hand the rise is due to the worldwide increase in cost of resources and building materials⁴².

The question of deciding between renovation and new construction has not been solved in this study. It can be seen from the demonstration projects that reducing energy use by renovation is challenging and that people's decision to renovate can sometimes be attributed to non-financial considerations, like location, environment or appearance of the existing building. For further economical study, it is recommended to study larger properties, since cost-effectiveness might be more a more important issue, especially when addressing mixed ownership, social housing or project developers.

c) Fighting (energy) poverty

The overall demand on energy is rising due to the growth of the world's economies. Unless the production of energy rises to meet this demand, energy scarcity will become a major social issue, especially affecting the low-income groups. Energy prices in Belgium have increased like in most countries. The reduction of buying

⁴⁰ For example, the average sales price of a single-family house can vary from less than 80.000 euro in the communities of Colfontaine and Quaregnon to more than 423.000 euro in the community of Sint-Pieters-Woluwe. See also: [BOUW_08] [VCB_08] [CCW_08] [STAD_08].

⁴¹ In comparison, from 1990 to 2000, both the construction cost index (the so-called ABEX index) and the consumption good index increased with about 20%. So for the same house and the same comfort level, the cost of a house was the same in 1990 as in 2000, when one does not take into account the inflation. From 2000 to 2008 the consumption index has risen 19%, but the building cost index with 37%.

⁴² The prices of building materials with high energy intensity (e.g. steel and non-ferro products) or based on oil resources (e.g. plastics, bitumen) clearly follow the trend of the oil price increase. E.g. the price of bitumen has doubled between 2005 and 2008. Compared to 2007, in 2008 the price of steel and concrete armour has almost doubled (90 cent per kilo instead of 30-50 cent per kilo). Between 2005 and 2008 the price of treated zinc has increased 83%, copper 114%, treated lead 167%. [VCB_08]. Construction costs also increase due to increasing transport costs. Renewable materials also tend to increase in cost because of their increased use as alternative fuel material and their dependency on energy and transport for production. E.g. the price of construction wood coming from Belgium has increased 42% between 2005 and 2008. The price of construction wood coming from Norway has increased 110% (Source: Federal Public Service Economy and VCB).

power due to rising energy prices is a very actual concern in the Flemish Region⁴³. Household energy is no longer solely an environmental consideration, but increasingly also a financial one⁴⁴. It is expected that the overall trend will be increasing energy prices.

The real estate sector in Belgium has been developing in an unsustainable way towards high cost (an increase of almost 11% per year, no matter what energy quality is obtained). For starting single persons the buying of a house has become less affordable. Also the increase of energy and rental prices leads to decreased buying power of consumers. Most affected are the vulnerable parts of society: young people starting with low wages, older people with small pensions, social housing with limited budget. The current situation makes it, even for a couple with two incomes, difficult to buy an affordable living unit. The lower side of the market has difficulties with the increasing mortgage. For social housing there are long waiting lists.

The increased cost of fuel, the liberalisation of energy markets and relatively decreased levels of welfare provision mean that an increasing number of low-income households cannot afford the costs of heating. For example, in the UK, this problem became known as the “choice between heating and eating”. Alternatively, it is known as “fuel poverty” or “energy poverty”. “Fuel poverty” is part of a complex picture, linked to multiple deprivation, unaffordable fuel prices and poor housing stock with inadequate insulation and inefficient heating systems. It is estimated that especially older people are in danger of not surviving the winter, because they often can't afford to heat or from ill health linked to cold, damp living conditions. Fuel poverty leads to energy conservation, but threatens health and welfare, and this is not sustainable.

Further we noted from our building stock analysis that the quality of the Belgian rental housing is poor. E.g. in a recent investigation the city of Gent counted 24.000 houses in bad condition. Although in the social housing in Gent, tenants spend 37% of their income on rent, 20% of the tenants still live in unsafe living units. The possibility of electrocution, fire or CO poisoning was noted in one third of the social houses.

A vision is necessary from social housing association, in order to be able to still manage their building stock when energy prices increase. With limited budget, social renters have proven to choose for paying energy instead of paying the rent on time. Scenarios indicate that for social housing the cost of energy will become similar to the rent per month, giving rise to cases of energy poverty. There is much to be gained in providing more energy efficient buildings. Investing in energy efficiency lowers the energy bills of households, thus providing more guarantees for housing owners to receive the rent, e.g. in social housing, and more financial reserve for owner-occupants.

The Walloon social housing society (SWL) wants to set an example and has declared a plan to provide ‘good housing’. In order to be good housing, today and for a long time, they intend to meet the definition of sustainable architecture⁴⁵.

⁴³ From 2004 to 2008 the health index, which determines the wages, has risen 8%, the general index 9%. While the food index has increased 12%, the gas index has increased 38% and the index for liquid fuels 83%.

⁴⁴ For example, the cost of fuel for heating in Belgium has almost doubled between 2004 and 2008.

⁴⁵ Communication by André De Herde as president of the Walloon social housing society.

d) What to do with a limited amount of money?

Since 2002, the Flemish renovation market has stagnated more or less at a figure of about 18.000 renovations with building permit per year. In the period before there was a continuous rise in renovation activity (e.g. 12.000-14.000 renovations ten years earlier). This can be a sign that due to the increasing prices there is not a lot of money left for renovations.

A market that is suspected to be increasingly important but that is not covered by any statistics is the field of minor renovation works not requiring a building permit⁴⁶. For electricity works, sanitary equipment, roof insulation, flooring and domotics the share of do-it-yourself (DIY) is estimated to be about 40 to 50%⁴⁷. Further, VEA and VCB state that only 13.000 of the 72.000 renovations a year is the Flanders Region specifically target energy saving [VEA_08] [VCB_08]. Considering the promotion of low energy housing retrofit it is therefore important to consider possible opportunities in the fields of education of occupants and repair workers, maintenance and/or DIY.

The questions of investment and affordability of a full low energy housing retrofit make some actors think that a focus should be set on simple sets of measures with best payback time. For example, the Flemish Renovation Programme 2020 only stimulates replacement of single glazing, roof insulation and old boilers⁴⁸: in this way investment costs can be reduced to less than 4000 euro with a payback time of 1 to 5 year. Nevertheless, it is obvious that if an owner performs these measures, he/she will not intend to do the same thing again after a few years. Such initiatives therefore might divert future investments from the real possibility of future-oriented innovations, clustered solutions and integrated low energy housing retrofit. Also, single measures might cause building physical problems. For example, it is known that replacement of glazing can divert surface condensation to the non insulated walls - with mould growth as a possible consequence⁴⁹ -, that roof insulation without wall insulation can lead to thermal bridges, and that condensation kettles might not condensate when the heating system is not adapted to low temperature heating. A 'low hanging fruit' approach therefore might turn into a problem⁵⁰. Also the life cycle of technical equipment is far below the life cycle of the building skin. In itself the pay back times of renewable energy systems are relatively high. Investment should therefore first be concentrated on the building skin (this confirms [VERB_07]), to improve energy efficiency with the best available technology. Renewable energy should be considered merely as the 'cherry on the pie', the last effort to show that a building is really energy efficient.⁵¹

⁴⁶ VCB interviewed about 1000 members and clients considering this aspect and can confirm this statement. The results of this study suggest that only about one fourth of all renovation works actually happening requires a building permit. In this manner VCB estimates the number of housing retrofits to be about 72.000 per year instead of about 18.000 requiring a building permit.

⁴⁷ Source: VCB.

⁴⁸ Presentation on the study day 'Energierenovatie 2020', Brussels, 2008.

⁴⁹ See also the chapter on Technological Innovation.

⁵⁰ On the other hand, also many initiatives are present to stimulate the use of renewable energy, like the placement of solar collectors and photovoltaic panels. These require relatively high investments. However, the use renewable energy makes more sense when the energy demand is low, so that a larger or even full portion of the energy demand can be covered. Also, the lower the amount of energy necessary and provided by renewable sources, the lower the energy mismatch between incoming and outgoing energy streams on the house level. This in turn might suit energy distribution providers. (Discussion during IEA Annex meeting 'Net Zero Energy Buildings', Wuppertal, October 2009).

⁵¹ Related to these considerations, the Brussels Capital Region already adapted its grant scheme for owner-occupants, to stimulate integrated energy efficiency solutions for low energy housing retrofit:

e) Conclusion

Technical feasible solutions to achieve a certain standard have been identified and analyzed in the previous chapter, based on the demonstration projects. If we want these innovations to enter the market, we should look for solutions to make them more cost-effective.

We recommend the development of appropriate financial instruments to reach an integrated and quality oriented low energy housing retrofit standard. These instruments can for example include the set up of beneficial grants⁵², green loans⁵³ and tax revisions (value added tax, property tax, income tax), as required by the recast of the EPBD. To control financial benefits, it might be appropriate to install an associated quality assurance scheme⁵⁴.

Policy should address the real financial drivers in the current real estate market. Prices should be in terms of quality. It is recommended to develop schemes to include energy performance in price setting. Owner-occupants should be convinced to target low energy housing retrofit when renovating. Owner-occupants with a limited budget should primarily be convinced to invest in substantial thermal insulation of the building skin. Social housing associations should define a strategic building stock management and energy plan in function of expected energy poverty.

4. The quality challenge

The previous section discussed financial benefits for low energy housing retrofit, but in the section on technological innovation we discovered several barriers that relate to the expected quality. Although technological innovations and demonstration projects are available, it is not obvious to implement a system that addresses the social barriers.

In Belgium, activity in the building sector is often organized around three loosely interacting actors: the client, the architect and the contractor. In practice, for small constructions, the client often takes the role of a not very well informed commissioning agent. The architect (when involved) tries to make the best choices from a budget imposed by the client, while his environmental knowledge is often limited. The contractor remains often the executor of a task that the design team has specified by means of plans and often-informal discussions. In practice, this situation often leads to conflicts in the definition of responsibilities.

<http://www.leefmilieubrussel.be/Templates/news.aspx?id=22868&langtype=2067&site=pa>, consulted 28 January 2010: grants for low energy housing retrofit are in the order of 125 EUR/m², for passive house renovation about 150 EUR/m². To apply for grants for renewable energy, building related energy efficiency measures already have to be done.

⁵² A challenge is to streamline all available national, regional and local grants so that the client has a one-stop shop.

⁵³ For example in Germany the KfW bank offers a very beneficial loan for low energy housing retrofit. We remark that for certain target groups, for example muslims, loans are often not acquired via regular banking systems.

⁵⁴ For example, for passive houses in Belgium, the 'passive house quality assurance' (passiefhuis-kwaliteitsverklaring) is used as a control instrument for income tax reduction. This certificate is currently issued by two organizations: PHP and PMP.

International research⁵⁵ confirms that there is a need for enhanced commissioning procedures and recommends special procedures for the realization of low energy buildings. The introduction of energy-related component, system and finished product performance requirements in building specifications is today still an issue in building research (see for example [SQUA_07]).

The owner-occupants in the demonstration projects required ambitious energy saving targets directly from the start of the building process⁵⁶, sometimes because of the associated financial benefits (tax reduction, grants, green loans). In general, for low energy housing retrofit, this is usually still not the case, often leading to lack of quality and complicated building processes involving many different and sometimes inexperienced actors⁵⁷. A more quality oriented building process therefore seems appropriate, and better collaboration within building teams to understand the potential and limitations of innovative energy saving technologies and clustering of renovation efforts.

For thorough retrofit of residential buildings (or even neighborhoods⁵⁸) examined demonstration projects⁵⁹ show that detailed commissioning processes are important:

- For complex ownership structures it is necessary to identify the owners and to convince owners concerning the responsibilities of the owner (maintenance of the product and the design conditions);
- Further a complete identification of the constructions must be made and the owners should be informed;
- The construction should be made fit to survive changes;
- The responsibility of designers and design teams is increased;
- The product is designed for an active, participating consumer.

These are important challenges considering participation processes. Only limited relevant experience could be detected in Belgium⁶⁰. Nevertheless, this also offers new opportunities for the development of technological innovations like specific social⁶¹ and engineering services.

From project observation we note that, considering the actual implementation of consumer wishes like increased energy performance, a more effective approach is needed in the building sector to transition towards contractual energy performance requirements and quality assurance. In some countries, certification of projects,

⁵⁵ IEA ECBCS Annex 40 and IEA ECBCS Annex 46.

⁵⁶ Compare: the project in Antwerpen (see Annexes: project files) did not require specific energy saving targets and this also lead to solutions of lower energy efficiency and an overall lower energy reduction.

⁵⁷ This was also experienced in the project in Antwerpen (see Annexes: project files).

⁵⁸ For example De Kroeven housing estate renovation, Roosendaal, the Netherlands or Brogarden, Alingsas, Sweden.

⁵⁹ For example Norwegian and Swedish demonstration projects IEA SHC Task 37.

⁶⁰ No demonstration project was found with mixed ownership or in the private rent sector.

⁶¹ For example in the Norwegian mixed ownership case study of IEA SHC Task 37 the company involved engaged a sociologist to determine the wishes of the owner-occupants and to convince them to renovate. The person in charge directed the real motivation of the consumer (see Section IV) and tried to integrate energy efficiency criteria.

technologies⁶² and/or actors is regarded as an essential component in order to introduce better energy efficiency.

For the do-it-yourself sector it is important to make the consumer aware of the opportunities and to make him/her recognize his/her responsibility towards the product and its life-cycle⁶³. For the social housing sector it is recommended to apply more strict commissioning procedures, and to develop specific participation processes and financing constructs.

5. From demonstration project to diffusion of innovation

The previous discussions highlight the following elements as essential features for the transition from demonstration project to diffusion of innovation.

a) Recognizing and spreading business opportunities

The demonstration projects have shown many opportunities to develop new products, systems and services for the low energy housing retrofit market. From a technological point of view, to avoid building damage, it can be recommended to cluster technological solutions in integrated products and systems. Clustering of technologies is also recommended to increase the possible market impact of technologies for low energy housing retrofit. The integrated concept of low energy housing retrofit provides golden opportunities to reduce energy costs and green house gas emissions, to fight energy poverty, to reduce energy dependency, while creating profit in a changing business environment.

The demonstration projects address the innovators. Market leaders in the field of energy efficiency can now seek contact with their more experienced peers to fill up their knowledge gaps.

For businesses intending to innovate for low energy housing retrofit, it is important to:

- identify technological innovation appropriate for business;
- identify the client and the border conditions of the client;
- give a complete identification of the product itself, inform the client;
- listen to customer wishes to adapt the product to survive the decision process and to design the product with respect for the customer;
- increase responsibility of own performance and of designers and design teams, contractors, project managers,...

These elements should be considered when developing own follow-up demonstration projects.

We note that an often perceived deficiency when finishing demonstration project is the lack of dissemination of information. For dissemination it is recommended to include regional networking of innovative companies, since this can lead to a

⁶² For example the Passive House Institute Darmstadt certifies passive house technologies concerning energy efficiency (glazing, doors, windows, building systems, heat recovery units, compact units). However, such certification does not include safety, quality, stability and other parameters.

⁶³ Solution discussed within IEA SHC Task 37 Sub Task A internet meetings.

diffusion of innovative technologies due to its social impact. Networking in itself can also create synergies to stimulate innovation.⁶⁴

b) Improve education

Demonstration projects are no end, but only a beginning to systematic successive learning. Incentives are needed to stimulate (interest for) learning and learning-by-doing. Building technologies (products, systems and services), especially to achieve low energy housing retrofit, are new to the Belgian market, and the associated processes to reach a high energy performance building are experienced as complex. Increased and adapted education of Bachelors and Masters in construction will be necessary. Especially regions with construction education on secondary school level, should be able to offer a higher level of training⁶⁵. This seems appropriate since there are important shortages on the job market, especially for construction specific functions like project manager or site leader, technician, calculator, designer and buyer, and to realize low energy housing retrofit⁶⁶.

Expect that engineers and architects will need to familiarize themselves with advanced energy analysis⁶⁷. Contractors will be more confronted with quality assurance and demanding customers⁶⁸. Participation processes in renovation projects will require special new abilities.

c) Professionalize product information

A qualitative implementation of innovative technologies for low energy housing retrofit, as suggested by interviewees of demonstration projects⁶⁹, needs professional, reliable and preferably independent information. With smaller renovation works concerning energy efficiency improvement, it is important to motivate the owners to choose for the products with the best energy efficiency and best comfort parameters. Also, it is essential to show the executors – in some cases the owners themselves - the way to install the product or system. Especially for placement of thermal insulation, air tightness and windows a careful placement is required, e.g. to avoid thermal bridges or air leakage, that can lead to structural damage. Installers should be able to deliver (flawless) mechanical ventilation with heat recovery and backup heating for low energy housing retrofit. Such information should be readily available from product and technology data sheets. One should consider to include systems to optimize products and systems to include consumer wishes, and learn from experiences.

d) One-stop shop for owner-clients

Although demonstration project show several acceptable innovations and technology clusters and concepts, increased quality of the final renovation is both an opportunity

⁶⁴ For example, this is acknowledged by IWT: special funds exist for thematic innovation stimulation with a focus on creating synergies. Recently a networking grant was attributed to PHP to stimulate low energy housing retrofit.

⁶⁵ For the moment such bachelor education only exists in Aalst, Brussels and Limburg and not in the provinces of Antwerpen and Western Flanders. In comparison, the Province of Antwerpen represents 30% of the Flemish building sector.

⁶⁶ Regarding the opening of the market for Eastern European building technician, there is a concern expressed that companies from other countries will invade the regional market.

⁶⁷ In many demonstration project PHPP was used as a calculation tool. For larger projects building simulation can be recommended.

⁶⁸ In the renovation market in Belgium, architects are still often not consulted. This means that contractors are expected to provide creative solutions themselves.

⁶⁹ IEA SHC Task 37 and LEHR demonstration projects.

to increase the market, as well as an item for further research. In the current situation, the owner-client is often expected to start a renovation project, although he/she often has no experience. Architects can provide information, but they are often still not consulted for renovations. Instead the owner-client often receives information and impulses directly from contractors, media or DIY shops. These actors are often still not well informed about energy efficiency and available innovations. Therefore it is important for the owner-client to be able to seek independent and trusted information sources. Most builders tend to get information from websites or on building fairs, for example on stands of the government or non-profit organizations. However, they are often left with a lot of questions concerning the execution of their own project. Some institutes provide first line consultancy based on plans⁷⁰. Some of these also provide introductory courses concerning energy efficiency measures for new built constructions. However, there are no specific courses for owner-clients concerning low energy housing retrofit.

Further, if the low energy housing retrofit market is to increase, owner-clients should be able to reduce the effort of coordinating craftsmen and the time necessary to get subsidies from different institutes and governments. It is recommended to do research to consider the development of a one-stop shop for owner-clients: for finding suitable quality oriented actors that can provide performance guarantees, for getting advice and for financial benefits for low energy housing retrofit. Such an agency should guard an associated quality assurance scheme⁷¹.

e) Develop policy and neighbourhood transition projects

Owner-occupants can be convinced to target low energy housing retrofit when renovating and this can be considered as 'low-hanging fruit'. What is still needed and expected is a well-defined Belgian policy vision for renovation of the building stock, as well as legal and financial instruments, in order to develop an integrated and quality oriented low energy housing retrofit scheme for the building stock. These instruments can for example include the set up of beneficial grants, green loans and tax revisions (value added tax, property tax, income tax) and should also specifically address target groups, vulnerable to energy poverty.

Meanwhile innovators should not wait to grab the opportunity to set higher standards. Demonstration projects show that municipalities and local networks can play an innovator role to stimulate regional development, business innovation, and to set quality standards. Lighthouse sustainable renovation projects should address fighting energy poverty and deterioration of neighbourhoods with decreasing property value. For the social housing sector and for the redevelopment of urban areas it is recommended to develop and apply more strict commissioning procedures, and to develop specific participation processes for mixed ownership and project developers. The possible use of energy performance contracting for low energy housing retrofit should be investigated in collaboration with third party financiers. Also, future local or national policy⁷² should be able to direct the real estate market, including the rental

⁷⁰ e.g. Bouwteams, PHP, VIBE, MAW, Cedubo,...

⁷¹ For example, in the region of Hanover a climate fund was set up with input from the local government and energy providers. An agency (proKlima Hanover) was created with the fund, where local citizens can get all the help, advice and extra financing, considering their own project.

⁷² Including the recast of the EPBD and the EPC, see next chapter.

market, in order to affect house prices in terms of good quality, including energy performance.

The following section discusses possible key entrances of low energy housing retrofit in national and local policy.

D. POLICY CHALLENGES

1. Introduction

Climate change and depletion of resources are some of the major global challenges of our time. It necessitates innovative national, European and global policy and closer international cooperation than before. Several reviews conclude that the risks and costs of 'doing nothing' are so high, at both national and international level, that it cannot be regarded as a serious option. Also in Belgium, action is necessary in the short term in order to avert potentially serious consequences in the longer term.

The United Nations Framework Convention on Climate Change (Rio de Janeiro, 1992) is one of the driving forces behind the national climate policies. The main objective of the convention is to stabilize atmospheric concentrations of greenhouse gases to a level where the climate system no longer suffers from any dangerous interference due to human activities.

The ratification of the Kyoto Protocol (1997) represent an important first step in combating climate change and stipulates that Belgium must reduce emissions of six greenhouse gases (CO₂, CH₄ and N₂O and the fluorine compounds HFK, PFK and SF₆) between 2008 and 2012 by an average of over 5% as compared to 1990 levels. Promoting energy efficiency is seen as an essential part of the implementation of the Kyoto Protocol.

In the spring of 2007, the European Council made a historic decision to cut greenhouse gas emissions in the EU by at least 20% by 2020 relative to 1990 levels. The Council also endorsed a commitment to reduce emissions by 30%, as part of a comprehensive, global climate agreement beyond 2012, provided other developed countries adopt comparable reductions and economically more advanced developing countries also contribute.

Some municipalities⁷³ are already highly active in the development of becoming fossil fuel free communities or regions. Less dependence on energy providers (uncertain future energy costs) and on resources from unstable regions is also reflected on the national, regional and municipal level in the framework of providing political stability.

As a result, also in Belgium, local and national authorities are increasingly putting environmental issues high on their agendas. Under the Kyoto protocol Belgium has to decrease emissions by 2008-2012 with 7,5% compared to 1990. According to

⁷³ For example Kristianstad (Sweden). Also many cities in the Netherlands have subscribed the ambition to become 'CO₂ neutral' within the next decade. In Belgium, only the city of Ghent has subscribed a clear vision.

recent data 1996 already provided a 7,25% increase compared to 1990, so reduction of 15% is now a target. In Belgium, about 21,8% of the greenhouse gas emissions is due to heating of buildings (see Figure 14). A reduction of the energy demand for heating by a factor 4 to 10 thus can contribute a lot to Kyoto targets.

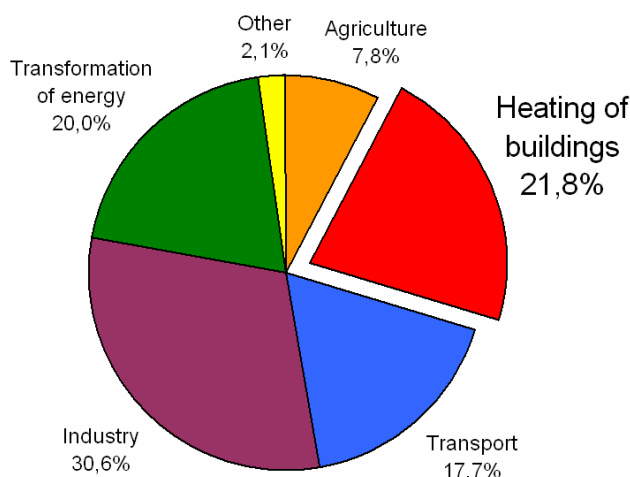


Figure 14: Distribution of the emission of greenhouse gases over the various industries in Belgium, according to [VYPE08].

The following table gives an overview of main energy sources for dwelling heating in Belgium: Belgium is still largely dependent on fuel for heating.

	Flanders	Wallonia	Brussels	Total (Belgium)
Gas	53,9	35,9	70,6	49,9
Fuel	34,8	52,4	(22,5)	39,2
Electricity	9,1	(6,8)	(3,9)	7,8
Other/unknown	(2,2)	(4,9)	(2,9)	(3,1)

Table 3: Percentages of main energy source used for dwelling heating in Belgium. Brackets mean that the statistical sample was too small to be completely reliable [BART05] pag 23.

Reality in Belgium is thus far behind the international targets, and the objectives of neighboring countries⁷⁴.

2. Municipalities and regions as facilitator

More regional and municipal authorities show a very high ecological and climate protection ambition level. This can be seen from the increasing number of members of European initiatives like the Climate Alliance of European Cities, Energie-cities, and so on, but also on the regional scale, for example Belgian municipalities are

⁷⁴ For example, the Netherlands target a 30% reduction in greenhouse gas emissions by 2020, relative to 1990, preferably as part of a European effort. How the Dutch government wants to reach its ambitious national goals can be read in the program: Clean and Efficient: New energy for climate policy [VROM_08].

engaging in local Kyoto targets and in the European Covenant of Majors. Some municipalities and provinces have taken the lead to provide examples for others.

In 2003 in the Flanders Region the assembly of environmental nonprofit organizations⁷⁵ started developing a Local Kyoto Agreement. This is a voluntary declaration of engagement whereby a municipality can engage to set up a local climate policy to reach the local Kyoto targets. How these targets are reached is left open to the municipalities. Three items are considered in this engagement:

- Internal policy: necessary steps will be undertaken to reduce the own CO₂ emissions due to energy use in buildings, vehicle stock, street lighting,... at least 7,5% to Kyoto targets by 2012, compared to current energy use.
- External policy: inhabitants and companies within the municipality are motivated to work together with (environmental) organizations, energy distribution net managers, schools, and so on.
- Reporting: the municipality provides a yearly report of the energy use of the own building stock, the own vehicle stock and the public lighting. The report is provided to the other communities that signed the Local Kyoto Agreement.

The content of regional action plans can therefore vary according to local situation and policy choice. Financial support can be provided by a collaboration agreement with the Flemish Government. Provincial authorities and non-profit networks provide information on good examples.

Also the Brussels Capital Region has set a leading example in providing funding for sustainable housing demonstration projects. The potential for low energy housing retrofit has been acknowledged by 20 renovation demonstration projects in the Brussels Capital Region.⁷⁶

Municipalities and region might thus be an interesting channel for facilitating the implementation of low energy housing retrofit. However, in order to spread the development in municipalities, financial support from the national government is recommended⁷⁷.

3. The recast of the Energy Performance of Buildings Directive (EPBD)

To reduce the total primary energy consumption in the building sector, the European Commission has put forward a directive on Energy Performance of Buildings, the EPBD (2002/91/EC), which came into force 2002 and should be implemented in the legislation of member states in 2006⁷⁸. In addition to the aim of improving the overall

⁷⁵ BBLV, Bond Beter Leefmilieu Vlaanderen

⁷⁶ These reach a target of 30 kWh/m².a as energy demand for heating, representing 25000 m² renovated surface, and a saving of 1 ton CO₂ per year (communication C. Jadoul, Leefmilieu Brussel).

⁷⁷ For example, in the Dutch Climate Agreements, the municipal and provincial authorities approve the climate objectives of the Dutch government and indicate what they will do to achieve these objectives. Minister Cramer of the Environment has provided €35 million to municipal and provincial authorities to support climate initiatives [VROM_08]. The allocation aims to encourage municipal and provincial authorities to minimize greenhouse gas emissions. The funds can be used for personnel, research, communication and education, but not for infrastructure investments and the like.

⁷⁸ The status of the EPBD implementation can be followed on the web, i.e. <http://www.epbd-ca.org/> or <http://www.buildingplatform.org/>.

energy efficiency of new buildings, large existing buildings are also a target for improvement, as soon as they undergo significant renovation. Further, the provision of a building energy label has become mandatory in Europe when selling or renting a house.

Recently the European Commission approved the European Parliament's amendments for strengthening the provisions of the European Performance of Buildings Directive (EPBD) 2002/91/EC, and for a 20% energy efficiency target in 2020 to be made binding for Member States. This will be translated in different supportive and obligatory measures within the recast of the EPBD. Member States will have to implement this recast. Also national, regional or local initiatives to support measures for the promotion of buildings with a very low energy use, such as fiscal incentives, financial instruments or reduced VAT, are expected from the Member States.

In Belgium the implementation of energy related policy is politically an issue to be addressed by regional policy making. Therefore implementation differs in the Flemish⁷⁹, Walloon⁸⁰ and Brussels Capital Region⁸¹: this is currently considered to be a bottleneck by businesses active in different regions.

Since January 2010, in the Flemish Region⁸², a calculated global 'E'-level (E-peil) has to be below or equal to 80. This is still a very high value compared to neighbouring countries⁸³ and merely represents current business practice⁸⁴. A progressive entrance of new requirements is considered but not yet officially declared. A good coupling of innovative technologies suitable for low energy housing retrofit is still to be obtained and requires a substantial research effort⁸⁵.

Recently, the European Parliament and Commission decided to have a recast of the EPBD to include 'near zero energy' housing and associated financial instruments. This means that also Belgium has to recast its energy policy to include obligatory measures, like the reporting of the development of very low energy housing to the European Commission. This recast now provides an opportunity to include the findings on low energy housing retrofit.

⁷⁹ Since 1st January 2006, as part of the process of demonstrating compliance with required energy performance, assessment of the energy performance of design of new dwellings is mandatory in the Flemish Region (EPB start declaration). For most buildings requiring a building permit, requirements are set not only for the energy performance but also for the indoor climate (EPB requirements). EPB reporters undertake the reporting of these requirements, using required EPB software.

⁸⁰ The Walloon 'Décret PEB' (performance énergétique des bâtiments) has been enforced from September 1, 2008.

⁸¹ Since July 2, 2008, every request for a building permit (also renovations) has to be accompanied with an 'energy' section in the framework of the Brussels EPB requirements. The Ordinance and Execution Decrees concerning these requirements can be downloaded from [IBGE_08].

⁸² In the Walloon Region, it is the intention to decrease the Ew value to 80 from September 1, 2011 (compare 130 kWh/m²a).

⁸³ For example, in the Netherlands, a strengthening of the EPC level for new buildings is proposed to 0,6 by 2011 and to 0,4 by 2015. The ultimate goal is for 'energy neutral' homes by 2020 [VR0M_08].

⁸⁴ From the analysis of the first load of start declarations the Flemish Energy Agency notes that, after one year of the introduction of the EPBD (E-level 100), most files already propose an E-level of 90 or less [VEA_08].

⁸⁵ For example PHPP is often used by passive house specialists and currently not accepted as an alternative to the obligatory EPB calculation.

4. The energy performance certification (EPC)

The Energy Performance Buildings Directive (EPBD) also requires that an energy performance certificate (EPC)⁸⁶ should be available when selling or renting a house and for display in public buildings. It can be recommended to integrate already existing voluntary labels⁸⁷ in the political scope of the further development of the EPBD. Also, this provides an opportunity to include labels or certificates for low energy housing retrofit, which can stimulate the market to reach a higher demand and a better quality.

Although an EPC does not include any obligation for the owner of a house, the buyer or renter should be informed in a transparent manner considering the energy use of the living unit. The EPC has to recommend cost effective improvements considering energy performance.

Project based certificates can provide a helpful tool for developing the emerging market of low energy housing retrofit. In a later stage certification of actors in the building process can become more important. A quality control process should link into new procedures for independent quality control during construction.

Since energy efficiency for low energy housing retrofit can be considered as a new type of certification, it can be interesting to have a look at already existing certification initiatives in the building industry to find out if a coupling is feasible. Far from being exhaustive, the following types of certification can possibly be improved to include specific energy efficiency on a project or installation level:

- Passive house certificates;
- Quality assurance of installations⁸⁸;
- Certification of building systems⁸⁹;
- Labels for sustainable construction⁹⁰.

The goal of such certificates should be security and responsibility considering conformity.

⁸⁶ The Flemish government voted positively on a step plan on July 22, 2005, for the obligation of the EPC (Energy Performance Certificate) for commercial transactions of housing by January 1, 2008. For sales transactions this has been postponed until autumn 2008, for rent transactions until January 2009.

⁸⁷ For example the already existing passive house certificate.

⁸⁸ For example, Sweden has already many years of experience with the control of ventilation systems: regular checks are obligatory for large buildings (see the so called 'Boverket' procedures).

⁸⁹ In the framework of the ATG-ButgB, certificates are also issued for building products and systems. Criteria for certification include a large range of criteria like building physics, fire safety, stability, construction details, and so on. This might offer an opportunity to include detailed energy efficiency requirements when accepting products like glazing, thermal insulation, mechanical ventilation, building systems, on the market.

⁹⁰ Other sustainable building labels exist in many forms. Also, several 'green building' ratings exist (LEED (USA), BREEAM (UK + global), HQE (France)) that assess the energy footprint of (mainly large commercial) buildings. These may provide owners and occupants with a solid yardstick of the energy efficiency and sustainability of properties. In Belgium the label Valideo has recently been introduced, mainly for large commercial buildings. However, the use of these ratings has so far been limited, and the global diffusion of rating systems is relatively slow. Since 2009, also the 'Referentiekader voor Duurzame Woningen' exists, which allows for a sustainability rating of newly built houses (as well individual houses as apartments). This framework will be further elaborated for renovation projects. It is reported that, a reduction in energy use is not necessarily the case for every 'green building'.

5. Policy border conditions for a transition to a low energy housing stock

In 2004 the Department of Environment, Nature and Energy⁹¹ of the Flemish Region started a project transition management sustainable housing⁹² following the Dutch example. During 2 years 80 participants established an agenda entitled 'Flanders under Construction'⁹³ including an analysis of the current system, targets for 2030 and strategies to evolve towards these targets. Also, about 10 transition 'projects' were defined in order to reach this transition. It is important to notice that the final text was prepared in consensus with various parties, involving the environmental movement, governmental bodies, research centers and industrial sectors like construction, building material producers and the real estate sector. A working group⁹⁴ on closed loops - energy⁹⁵ [DUWO_08] defined many barriers for the implementation of closed energy loops, like overconsumption and lack of a feeling of responsibility.

On an economic level, it was observed that the market is dominated by relatively low prices for energy and transport, and that often choices are made on the basis of cost instead of societal value, and maximum profitability. Lack of knowledge (considering alternatives) is put forward, also caused by a lack of attention for sustainability in regular education. Also, on a political level, barriers were defined like restrictions in urban legislations, deficient product normalization, quality assurance and the short-term governance in general.

In this research market broadening of passive houses and energy neutral houses was pinpointed as an important 'project' in order to reach the transition. Financing mechanism are recommended, as well as the design and setup of collaboration networks for the improvement of energy performances of buildings, focusing on reaching ambitious energy standard⁹⁶ and the creation of example projects for energy neutral buildings. Financial institutes and social housing are considered to be the most important pull factors.

⁹¹ Formerly known as AMINAL, now Departement Leefmilieu, Natuur en Energie (LNE).

⁹² In Dutch 'transitiemanagement duurzaam wonen en bouwen', in short DUWOBO: <http://www.duwobo.be>.

⁹³ Full title in Dutch: Vlaanderen in de steigers, Visie op duurzaam wonen en bouwen in 2030 en actie voor nu.

⁹⁴ Seven basic principles were defined to reach a sustainable transition of the urban environment [DUWO_08]:

- An integrated approach
- Shared responsibility and transparent decision making
- High quality of the building and the environment
- Accessibility and social justice
- A balance between private and collective housing
- Closed circuits for resources and materials
- An economically healthy and socially responsible building sector

⁹⁵ In Dutch the working group is named 'Sluit de kring – energie'.

⁹⁶ In the final document 'Flanders under Construction' the goal is stated to obtain a critical mass of buildings in the passive house standard by 2015, after which an obligation of the passive house standard can be considered.

The research project entitled ‘Ecopolis-Vlaanderen’⁹⁷ broadened sustainable development towards a higher urban level by stimulating also local governments and space planners and designers.

The Flanders Region now also developed a specific political programme entitled ‘Energierenovatie 2020’. In its first phase of execution it has the ambition to convince all people to insulate their roofs. In later stages, window and floor insulation will be addressed. However, this does not include specific target for integrated and quality oriented very low energy retrofits.

The Department for Environment, Nature and Energy of the Flemish Government (LNE) advised⁹⁸ to reinforce border conditions, positive market developments and energy neutral buildings and passive houses, the creation of positive market developments for renewable energy with optimized decentral production, and consumer awareness (Dries, 2007). Unfortunately, unlike the Netherlands, until now no action was undertaken by the government or housing associations to set up an action plan, to reach beyond the demonstration project, or to specify clear targets of reduction of greenhouse gas emissions and energy use in the existing building stock.

However, it is seen in 2008 [PHP_08] that some political initiatives in Belgium have already embraced very low energy targets in renovation, for example:

- a specific budget was allocated for the construction or renovation of demonstration projects of social housing in the passive house standard in the Flemish region;
- specific budgets were allocated for sustainable demonstrations projects in the Brussels Region, allowing grants of 100 euro per square meter for reaching the passive house standard;
- a Belgian federal tax reduction was introduced for passive houses (also renovation);
- municipal grants for reaching the passive house standard were introduced in 12 cities;
- renovation towards the passive house standard is rewarded by energy distribution providers.

In the Walloon Region, actors engage themselves to anticipate future PEB legislation and to create projects with better energy performance⁹⁹. This might also provide a vehicle to implement higher ambition levels for low energy housing retrofit. Enlisted projects in the Walloon Region are currently rewarded with a label and engaged professionals are publicly shown on listings through official web sites. The

⁹⁷ Information provided by VIBE.

⁹⁸ By handing over the results of the Flemish transition arena sustainable housing and living to the Flemish Minister-President. The arena stated that ‘in 2030 energy producing new built construction and energy neutral existing construction’ is the vision to strive for.

⁹⁹ To facilitate the implementation of the Walloon EPBD (Performance énergétique des bâtiments, PEB) in the construction sector the Walloon Region initiated in 2004 the action ‘Construire avec l’énergie’ (CALE), together with a consortium formed by the Belgian Building Research Institute (BBRI), the Walloon Construction Federation (CCW), the universities of Liège (ULg), Louvain-la-Neuve (UCL), Mons (FPMS) and the professional formation institute IFAPME. CALE is based on a charter signed by professionals in the building industry.

programme is very much appreciated by businesses¹⁰⁰ and can also set an example for other regions.

The Brussels Capital Region also offers inspiration for other regions. The Region has installed a network of independent energy experts to give free advice considering energy efficiency of buildings. Different energy facilitators are currently active:

- for service buildings,
- for combined heat-power generation,
- for large renewable energy systems,
- for collective housing,
- for passive houses.

The facilitators are not replacing architect or engineer, but they help to lead the work and they can evaluate proposals of third parties. E.g. for collective housing the facilitator offers:

- information about technologies and providers,
- information about financial aid and administrative procedures,
- information about energy efficiency tools,
- structural approach of energy efficiency,
- analysis of contracting documents for equipment and (central) installations,
- review of feasibility studies.

Also a facilitator considering passive houses is implemented and in addition there are initiatives in the Brussels Capital Region to provide technological guidance considering eco-construction.

The Brussels Capital Region further facilitated example projects considering high energy performance and ecological construction with a project call in 2007, providing:

- a total budget of 5 million euro financial support for the design and construction of example projects (also renovation),
- technological guidance to achieve quality targets,
- rewards for selected designers and buildings.

The call was a success and was followed by a second call in 2008.

6. European frontrunners being more ambitious

Hoffmann [HOFF_05] gives a review of standards that are currently being applied in Germany and in Switzerland. Standards for new built constructions like EnEV, Passivhaus, SIA 380/1:2000, Minergie and Minergie-P all show ambition levels that are currently much higher than in Belgium. These standards are currently also under discussion for renovations.

In the Netherlands, the Platform for the Built Environment was introduced to accelerate energy savings in houses and buildings. Working together with energy providers, housing corporations, the construction sector and recently also consumer

¹⁰⁰ The programme was until now highly successful. In May 2008, 453 architectural offices were listed, 20 engineering offices and more than 100 companies. The last sensibilisation colloquium in May 2008 was attended by more than 400 professionals.

organizations, the Energy Transition Platform for the Built Environment in the Netherlands initiated the 'More with Less' plan, which is now in its implementation phase.

This programme clearly states energy reduction targets for specific housing sectors. The plan specifies energy saving targets in existing buildings (residential as well as commercial and industrial)¹⁰¹. The national government will make a financial contribution to this plan. The Dutch coalition agreement of 2007 specifies that, by 2020, the Netherlands will have to reduce greenhouse gas emissions by 30% compared to 1990 levels and save 2% energy per annum. This statement itself has proven to be an important market driver.

Further, the Dutch governmental programme 'Schoon en Zuinig' clarifies a target of 11 Mton saving of CO₂ emissions in the built environment: 6 Mton should come from savings in existing constructions. Housing associations, the government, energy companies and building and installation companies have subscribed the goal to reduce energy use by 30% in 500000 existing buildings during the period 2008-2011. The Dutch social housing sector stated to deliver 24 PJ reduction of energy use by 2020. As a result, housing associations have made formal agreements in covenants and contracts. Aedes, the association of social housing associations, specified a goal to save 20% on the gas use in existing buildings in the coming 10 years. Some housing associations have increased this target.

Another result has been that many¹⁰² Dutch cities and regions claim the ambition to become 'climate neutral' or 'CO₂ neutral' on the long term.

Some European cities and regions are even further advanced. In the Austrian Vorarlberg region the passive house standard is already accepted as a standard for new construction of subsidized housing, and striving for the passive house standard and the use of passive house components (extensive thermal insulation, passive house windows, ventilation with more than 75% heat recovery) is encouraged in renovations. In April 2008, the municipality of Wels was the first Austrian city to sign a specific passive house declaration. This declaration states that the city should supervise all future new built constructions and renovations considering renewable energy sources and energy efficiency and that the city should strive for the passive house standard for the building stock of the City Wels and the Holding Wels GmbH.

The recently adopted Irish Building Regulations have placed Ireland among the best in Europe in terms of energy efficient new housing. In 2007, Building Regulations were amended to establish mandatory higher energy efficiency and emissions standards which are 40% better than the 2005 Building Regulations and it has been proposed that this will be increased to 60% in 2010. However, with the threat of climate change and the impacts of rising oil, gas and electricity prices, Irish Minister

¹⁰¹ A rate of energy efficiency improvement of 2% per year is a specific target of the new climate policy. Implementation of this plan should lead to an energy efficiency improvement in around 500000 buildings of 20 to 30% in the period up to 2011, and from 2012 onwards an additional 300000 buildings annually [VROM_08].

¹⁰² Apeldoorn, Heerhugowaard and Tilburg expressed their ambition to make their municipalities 'CO₂ neutral'. Borssele and Veere plan CO₂ neutral streets. The Province of Utrecht and the Utrecht Chamber of Commerce have expressed the ambition to become CO₂ neutral as an organization and encourage municipalities and companies to follow their example. The community Roosendaal renovates a housing lot towards the passive house standard.

Ryan aims for the very highest efficiency standards possible. Ireland decided August 2008 to schedule 9 million euro for developers of high energy efficient housing until the end of 2011. Homes built under the programme will be at least 70% more energy efficient and produce at least 70% less carbon dioxide than homes built to 2005 standards and will have a Building Energy Rating (BER) of at least A2. The scheme will seek to achieve zero or very low carbon emissions from supported homes by requiring a significant element of auto-generation of electricity from renewable technologies such as solar photovoltaic, micro-wind and micro combined heat and power (CHP). The programme will demonstrate the efficiencies that can be achieved with low carbon housing, and will also form an evidence-base for future policy decisions in the area.

Several parties show a political ambition level considering the improvement of energy efficiency in buildings. It remains to be seen if all these political initiatives will reach their goals. Nevertheless, political will is an essential element, in order to reach low energy housing retrofit, and to stimulate business towards innovation.

7. Recommendation: towards a SMART umbrella programme?

Since energy efficiency is a regional matter in Belgium, transition approaches are different in different regions, focusing on transition management involving large groups of stakeholders (Flanders Region), or pooling and facilitation through grants (Walloon Region, Brussels Region). There is currently no objective comparison method for the real energy saving obtained, so the success of these programmes cannot be compared.

Currently, an integrated national approach that defines Specific Measurable Ambitious Realistic Time constrained (SMART) targets for the existing building stock, and especially low energy housing retrofit, and that streamlines all the regional actions and ideas, is missing. Belgium can find inspiration in neighboring countries. From the international examples it is clear that Belgium is missing a national or regional framework, involving a higher vision and communication plan, and many lower implementation levels. Outside Belgium, it can be seen from many countries that high ambitions are formulated in official documents.

An appropriate national comprehensive framework should consist of the following building blocks:

- defining a shared vision¹⁰³ to reach the ultimate objective of specific short-term and medium-term target for energy efficiency, especially for existing housing;
- agreeing on deeper absolute emission reduction commitments;
- facilitating fair and effective contributions by municipalities;
- extending the low energy housing retrofit market beyond the demonstration project, including innovative and enhanced flexible mechanisms;
- increasing cooperation on technology, research, development, diffusion, deployment and transfer;
- enhancing efforts to address adaptation.

¹⁰³ The Flanders Region installed the Flemish Climate Conference, involving stakeholders from all sectors and ngo's. Focus was set on reduction of emissions to reduce greenhouse gases, but until now the Climate Conference did not produce any specific targets confirmed by the government.

The development of national and regional master plans, involving and coordinating public and private actors, is also a conclusion of the IEA SHC Task 37 research¹⁰⁴. In relation to this it is recommended to have an R&D policy focusing on international cross learning, demonstration projects and market development and adapted education policy, building codes and funding policies.¹⁰⁵

E. CONCLUSIONS

1. Sustainable (re)development can lead to technology clustering

The discussed barriers and opportunities considering the technological, economical, social and political transition to low energy housing retrofit suggest a new orientation to the issue of sustainable development in the building stock.

In this respect, the five following principles have to be remembered¹⁰⁶ as a guideline for decisions:

- the principle of integrating the dimensions,
- the principle of inter- and intragenerational equality,
- the principle of cautiousness,
- the principle of responsibility,
- the principle of participation.

Low energy housing retrofit has to be the pretext to a global and general improvement of the housing stock, including its surroundings, interactions with the neighbourhood, its functions and organizations. For reaching the goal of sustainable architecture, in symbiosis with the environment, it appears that low energy housing retrofit has to be placed in the larger context of neighbourhoods, towns and municipalities, stimulation of technological innovation and socio-economic development of regions. Municipalities and regions, as well as social housing, can play a role as facilitator and trendsetter to achieve ambitious goals.

In order to develop low energy housing retrofit from demonstration to volume market, also national and regional political will and action is required. While defining goals, a good coupling has to be found with regular motivation for renovation. Regarding climate protection and energy efficiency targets, as well as the need for quality improvement of the Belgian building stock, the Belgian renovation market will need to increase, both in volume as well as by going beyond low hanging fruit.

In order to achieve sustainable renovation and integrate innovative solutions, it is of importance to present a global reflection, which will be easily understood and integrated by the renovator so that he will be able to adapt it himself to his own situation. Within the framework of low energy housing retrofit development, also non-building related opportunities are provided to reconsider existing characteristics, in order either to lessen or reinforce the environmental and energy impact, for example:

¹⁰⁴ Rodsjo, A., et al., (forthcoming), From demonstration to volume market, IEA SHC Task 37 final report.

¹⁰⁵ Ibid.

¹⁰⁶ The statement of the Federal Plan Bureau (federal Plan for sustainable development).

- Clustering of innovative solutions to address practical problems with integrated solutions;
- Guiding the decision processes by using owner's motivation;
- Encouraging large-scale redevelopment and neighbourhood value increase by promoting the mix of functions, generations and social groups, common transportation and soft mobility and a minimized impact on the environment (energy saving, but also water use, choice of materials with LCA/LCC, waste processing).

Low energy housing retrofit allows to increase quality and comfort, to reduce the consumption of energy, and particularly non-renewable. In a specific case this report has even shown that at the same time costs can be reduced as well as environmental impact.

The main driving forces towards and opportunities of low energy housing retrofit can be seen as follows:

- When a renovation is necessary anyway, the investment of the low energy renovation is limited to the extra costs of the energy saving measures.
- Renovation towards low energy “standard” offers a considerable surplus compared to normal renovation, tackling draft problems, humidity and ambient temperatures inside the residences, and improving air quality.
- Reaching a low energy or even passive house standard sometimes results in avoiding investments in additional technical installations.
- Upgrading the façade of the building has a direct impact on the value of the property, and will radiate out towards the whole neighbourhood.
- Renovating the building can allow a redesign of the floor plan and an upgrade of the installations. This also will have an important impact on the value of the property, and will make houses easier to let or sell.

The research shows that a target space heating demand of 25-30 kWh/m² per year is achievable in demonstration projects, by means of¹⁰⁷:

- reduction of transmission losses,
- reduction of building air leakage,
- use of solar gains,
- introduction of mechanical ventilation with heat recovery,
- use of efficient household appliances,
- use of renewable energy.

It is recommended to promote these principles in an integrated way in order to assure quality. From these reflections, the demonstration projects show good opportunities to market clustered innovative solutions¹⁰⁸ in integrated concepts, for example the passive house concept.

¹⁰⁷ These principles can be translated into specific criteria, e.g. maximum thermal transmission values of walls, floors, roofs, windows, glazing; minimum g-values of glazing; leakage during a building pressurisation test below a certain level; minimum efficiency values for heat recovery;..

¹⁰⁸ Often related to passive house measures.

2. Opportunities for technological innovation and quality assurance

Demonstration projects show innovation opportunities in order to reach substantial energy savings. The example projects show a lot of possible hindrances of low energy renovations, as well as technological solutions to tackle the barriers detected. However, a holistic approach is much needed in order to assure quality and market penetration of low energy housing retrofit.

Low energy housing retrofit requires careful attention to floor, roof and wall insulation, the avoidance of thermal bridges and appropriate heating and ventilation. Products and systems from foreign countries show innovation opportunities, specifically for the renovation market.

As for protected and highly ornamented buildings, insulation of the façade can be difficult, on the outside as well as on the inside. This can limit the total ambition level, but still allows for a considerable reduction in total energy consumption, by consistently applying other ambitious retrofit measures. Also the adaptability of new energy supply systems, including renewable energy systems, as part of comprehensive renovation packages has to be assessed.

Apart from technical issues, an important question is the situation of the existing inhabitants. Can they stay in their flats during the renovation works, thus minimizing social and economical impact, or do they have to move (permanently or temporarily)? Also, to tackle this barrier, specific technological solutions have been used in international demonstration projects.

Many social challenges require innovation in the development of new services. For example, when the decision is made to renovate without moving the residents, the participation level of these residents in the project becomes very important. Reaching out to them, providing sufficient information, incorporating their own demands or wishes, can be a decisive factor towards success.

In general, most products, systems and services used in the demonstration projects are novel to the Belgian market. New products and concepts for advanced housing renovations still have to be assessed by individual companies. Manufacturers and contractors are in need of feedback to optimise products, systems and services. For contractors, building businesses, architects and owners the LEHR project allowed to develop and publicize adequate information based on Belgian and international demonstration projects. However, in order to diffuse this information, a communication plan is required.

3. Diffusion of innovation requires a balanced strategy

Currently renovations with improved energy performance only exist in a demonstration phase. To be able to have a diffusion of such projects and associated technologies it is important to first make them available in the market arena. Unless some government, entrepreneurial or non-profit organization makes the innovation available at or near the location of the potential adopter, that person or household will not have the option to adopt it in the first place.

We note that different types of people adopt innovations in different stages and can be pulled by different motives and/or actors¹⁰⁹. Diffusion of innovation can be driven by:

- Communication within a society, this means to increase the attractiveness of the innovation;
- Improvements made to the innovation itself over time, thus to increase the competitiveness of the innovation;
- Providing equal access to resources, affordability of the innovation should be increased;
- Providing the innovation near the location of the potential adopter, thus to increase the availability of the innovation.

For the analysis we note that the impact of commercial firms on technology diffusion is widely recognized to be an important one¹¹⁰. In terms of what empowers entrepreneurs to fulfil the role of innovator in demonstration projects and beyond, it is clear that a mix of entrepreneurial vision and will, managerial capacities, know-how and access to resources (capital) is needed to affect change¹¹¹. But entrepreneurs do not operate in a vacuum: policies that are put in place by government can strongly influence their business. A change in institutional conditions may be necessary for realizing the benefits of technological change, but at the same time the technological change, providing an opportunity to increase profits, may be the impetus to innovate a new institutional arrangement. In this framework it is important to develop methods in which government and industry will both be needed to contribute to speed up transition to a low energy built environment.

Collaboration with existing business networks will be essential in order to achieve ambitious goals. Technologies for low energy housing retrofit can be clustered in order to improve market impact. Also, education will have to be installed or improved. Businesses also need to engage in providing relevant product and system information, and should develop innovative services to motivate owners and proprietors. In order to reach consumers effectively, one-stop-shops on the local level have been recommended: this should allow the customer to obtain quality-oriented actors, advice and to reduce the burden of getting extra funding, while maintaining a quality oriented approach for integrated low energy housing retrofit. Meanwhile policy will have to deal with social and economical issues in an integrated way in order to promote options with best LCA/LCC, but also regarding competitiveness of houses in a broader scope, including the recast of the EPBD and EPC, the control of house prices in the real estate market, the provision of adequate quality, the reduction of risks associated to energy poverty and the transformation towards sustainable local development. An important challenge for both businesses and policy makers will be to develop quality assurance procedures for low energy housing retrofit (products, systems, services and concepts).

The current report merely represents emerging ideas and initiatives in Belgium and beyond. In order to obtain a transition to a low energy housing stock, transition projects are needed, addressing different target groups (owner-occupants, rent,

¹⁰⁹ See for example the books on the topic of diffusion of innovation by E.M. Rogers (Free Press, New York, various editions), and L. Brown (Methuen, New York, 1981).

¹¹⁰ See also : [WILK_70].

¹¹¹ [MILL_09], p. 48.

social rent). These projects should allow developing most suitable economical and social incentives, and should define the role of different actors (municipalities, energy providers, consumers, businesses, real estate developers) in the framework of a coherent vision.

4. Government should develop a strategy for market development

There are compelling reasons for policy makers to strive for lower energy use. First, the amount of fossil fuel in the world is limited, the demand is growing, and thus the price is rising. Second, burning of fossil fuels contributes to climate change. Last, but not least, the energy supply is not considered secure in many countries. Governments are likely to actively support or intervene in market development when the risks of not reaching national goals in these fields get too high.

Several nations and regions have established energy performance policies and regulations, also in the field of low energy housing retrofit. Technical solutions are currently available as demonstrated by the demonstration projects. Formulating ambition levels and sharpening regulations is both feasible and underway in many countries. However, regulations alone provide no guarantee for the associated market development that is needed.

Generally, renovation addressing energy saving is progressing, but at a much slower rate than that needed to reach national and international goals in time. There are many reasons for this. Integrated concepts (like low energy housing retrofit) that are made to substantially reduce CO₂ emissions have to compete with low investments where the long-term impact of CO₂ emissions reduction on the whole building stock is not taken into account. Work in LEHR and IEA SHC Task 37 shows that compared to ordinary renovation, low energy housing retrofit needs more holistic approaches, higher skill competence and stronger coordination in the planning and renovation process. However, the building sector, as a whole, is reported as diverse, complex, conservative and characterized by fragmentation. This represents barriers to change. Analyses carried out in LEHR and IEA SHC Task 37 also show barriers and opportunities according to different types of building segments, ownership and decision processes, and national, regional and local regulations and incentives. On the other hand better energy performance and increased renovation rate represent big business opportunities for proactive planners, consultants, building companies and suppliers of building components materials. So far only a few companies have seen and taken this opportunity.

Attractiveness and affordability of low energy housing retrofit should be proven to a broader customer segment in the introduction and growth phase. To cross the chasm to a growth phase is seen as a difficult and an important challenge. For a fast transition to take place it is important that the innovators both on the supply and demand side will function as guiding lights for the actors in the next phase. It can be noted that in each phase of the diffusion of low energy housing retrofit (introduction, growth, volume phase) different actors will have to be targeted. Important actors,

driving forces, barriers and measures to overcome the barriers in each phase are to be investigated¹¹².

¹¹² Initial work in this respect has been performed during IEA SHC Task 37 Sub task A. A first report on this subject is expected by the IEA in 2010:
Rodsjo, A., Haavik, T., Mlecnik, E., Prendergast, E., provisional title 'From demonstration to volume market', final report IEA SHC Task 37 Sub task A.

VI. ANNEXES

On the web site www.lehr.be the following additional reports and publications are provided as a reference to this report.

A. ADDITIONAL LEHR REPORTS

- Hilderson W., Mlecnik E., Cré J. (2010) *Potential of Low Energy Housing Retrofit*, PHP, Berchem, January 2010.

Demonstration projects show that it is possible to drastically reduce energy demand for heating, and therefore primary energy demand in a whole region. Based on the analysis of the existing building stock in Belgium, this report examines for what type of residential building and for what target groups low energy housing retrofit demonstration projects should be initiated and stimulated.

The following research parameters were found to be crucial for analysis:

- Comfort, quality improvement and energy efficiency reduction potential, depending on building age and socio-economic status of the owner.
- The number of houses of in a certain building typology is a decision factor.

All parameters are linked with geographical location and building ownership characteristics. There appear to be more recently built houses in the north than in the south parts of the country. This has a great impact on the quality of the houses.

The analysis shows that energy and building policy decisions considering low energy housing retrofit should relate to the specificity of the municipality, province or region. The old industrial belt in the south part of the country, rental houses, and cities have a high retrofit potential.

Strategies for the promotion of low energy housing retrofit are needed and should be person-oriented, preferably related to ownership structure. Building owners should be reached at the stage when they intend to renovate. Urban areas need examples focusing on quality improvement of row houses or apartment buildings in the (private) rent sector. The social housing sector requires an approach focusing on cooperation between low-income target groups and their points of reference.

- Vrijders J., Delem L. (2010) *Economical and environmental impact of low energy housing renovation*, BBRI, Limelette, January 2010, pp. 106.

Retrofitting the existing building stock is essential in order to achieve substantial energy savings in the building sector. However, renovation projects that achieve high levels of energy reduction, initially require more resources (e.g. insulation materials, equipments, labour). The question is to which extent this extra initial investment can be compensated in terms of costs and environmental impact by the resulting energy savings, and whether there is an optimal level of renovation.

Within the LEHR project, an extensive literature review has been executed considering cost efficiency of energy saving measures for houses, the environmental impact of retrofitting and comparing the economic and environmental impact of retrofit to demolition and new constructions. Some general conclusions are drawn, and insight is gained into methodological approaches and data sources for analysis.

Secondly, one Belgian case study has been analysed in detail. Ten alternative renovation scenarios were defined for a given rowhouse, with varying heat demand levels (standard, low energy, very low energy and passive house standard) and

installations for hot water production and heating (based on gas, electricity, pellets and solar energy). The environmental and financial impact of these alternatives were compared using LCA (Life cycle analysis) and LCC (life cycle costing) methodology, thus taking into account not only the initial impact (investment) but also the use and end-of-life phase of the building.

The LCA results for the specific case indicate that from an environmental point of view it is interesting to aim at the passive house standard and to use renewable energy sources. However, attention needs to be paid to the electrical consumption of auxiliaries (e.g. pumps, ventilation system), as for some impact categories its negative effect can sometimes overrule the resulting benefits.

On the other hand, the LCC results for the specific case indicate that the renovation to passive house standard is interesting in the long run when taking into account financial incentives. Otherwise, a Low-Energy-solution using a solar boiler proves to be the most interesting.

Combining environmental impact and cost efficiency, no single optimum was found. However, since the cost efficiency of solutions from Low Energy consumption to Passive House standard-alternatives is similar, it is beneficial to save as much primary energy as possible at a similar total cost (over 30 years). However, reaching the PH-standard requires a serious extra initial investment, even when fiscal deductions and primes are taken into account.

- Kints C. (2008) *La rénovation énergétique et durable des logements Wallons*, Architecture & Climat, UCL, September 2008.

This research examines the potential of energetic renovations and identifies preferential measures for the Walloon building stock. This stock is divided into approximately ten typologies, for which potential measures are explored.

Le parc de logement belge est relativement ancien et de nombreuses rénovations doivent être opérées. Il apparaît de façon claire que l'efficacité énergétique des bâtiments belges doit impérativement être améliorée. Ce n'est que de cette façon que la Belgique pourra rattraper le niveau moyen européen, atteindre les objectifs de Kyoto, réduire ses émissions de gaz polluants, ...

Une étude a été faite par Architecture et Climat afin d'analyser le bâti existant et de mettre en évidence les typologies de logements prioritaires à rénover (Kints Caroline, *La rénovation énergétique et durable des logements wallons*, Analyse du bâti existant et mise en évidence de typologies de logements prioritaires, Architecture et Climat, UCL, Louvain-la-Neuve, 2008). Cette recherche a été ciblée sur les logements wallons mais elle est assez représentative de la situation belge en général.

Architecture et Climat s'est chargé de sélectionner des exemples de rénovations basse énergie pour chaque typologie de logement identifiée dans cette étude en Wallonie et à Bruxelles.

- De Meester T., et al. (2010) *Guide sur la rénovation basse énergie des logements en Belgique*, UCL Architecture & Climat, 2010.

Rénover le parc résidentiel offre un potentiel énorme en terme d'économie énergétique et également en terme de confort. Déjà, des projets de rénovation exemplaires démontrent une réduction de consommation de 60 à 80 % en même

temps qu'une amélioration de la qualité de vie. Le succès de ces projets? Combiner et cibler les mesures les plus efficaces à réduire la consommation énergétique.

Ce guide développe une vision globale de la rénovation basse énergie. L'ensemble des thèmes abordés et leurs illustrations permettent de cibler les points clés de la rénovation et d'offrir un large panel des problèmes et solutions rencontrés. Ce guide reprend différentes techniques de rénovation et leurs étapes ; de nouveaux concepts et composants sont développés, illustrés et combinés aux développements techniques les plus récents.

Ce guide permet de mettre au point, de dégager et de définir les enjeux du développement durable dans la rénovation basse énergie à travers ses trois sphères : l'énergie, l'environnement et le développement durable. C'est en commençant par l'analyse du parc de logements belges qu'il sera possible de comprendre comment la rénovation basse énergie trouve sa place dans une politique de développement durable. Ce guide offre un large aperçu des différentes techniques et possibilités d'amélioration du bâtiment tant au niveau de la conception, que des systèmes le composant ou encore au niveau de l'environnement car la rénovation implique une stratégie globale et de ce fait, un regard sera porté sur l'environnement où a été implanté le bâtiment, le site,...

Ce guide permet d'informer et de trouver des conseils et surtout, une ligne de conduite pour la rénovation de bâtiments en bâtiments basse énergie. D'avance, il n'existe pas une manière type de rénover en basse énergie mais une multitude qui dépendent de nombreux paramètres: type de bâtiment, qualité du bâtiment existant, budget accordé à cette rénovation,...

Ce guide introduit les guides techniques et accompagne les fiches de projets exemplaires de rénovation basse énergie en mettant en évidence les points incontournables de ce type de rénovation. Il apporte les bases de la rénovation basse énergie aux architectes et entrepreneurs ainsi qu'un regard critique sur le comment intégrer cette rénovation au bâtiment existant tout en le respectant, lui et son site d'implantation.

B. PUBLICATIONS

1. Project files

a) LEHR project files

- Hilderson W. (PHP) & Branders A. (UCL) (2010) *Project files of exemplary sustainable and low energy renovations (in Dutch and in French)*

The LEHR project files described each Belgian demonstration project in detail. Below we provide a listing of all the available project files.

De nombreuses typologies étant présentées, les maîtres de l'ouvrage peuvent identifier des logements proches du leur et voir les différentes interventions adaptables à leur projet.

Les rénovations sont présentées de façon complète et détaillée de manière à être accessibles au tout public mais à apporter aussi des informations techniques permettant de réellement comprendre les travaux entrepris.

Toutes les publications suivent une structure identique afin que les lecteurs puissent soit faire une lecture complète du document, soit se diriger directement vers les aspects qui les intéressent.

Cette structure reprend de nombreux points touchant à l'énergie, comme l'isolation de l'enveloppe, les techniques spéciales, la performance énergétique du bâtiment, etc. Cependant, d'autres aspects ont été introduits afin d'avoir une vision plus globale de la rénovation durable. Aussi le coût des travaux, le choix des matériaux, la gestion de l'eau et de l'environnement, la mobilité, l'architecture, le vécu des habitants, etc. sont-ils également pris en considération dans ces publications.

Ces réalisations permettent aussi d'illustrer plusieurs techniques présentées de façon théorique dans le guide général sur la rénovation basse énergie des logements en Belgique et dans les guides techniques plus spécifiques.

Six projets ont été analysés par UCL. Quatre en Wallonie et deux à Bruxelles. Chacun projet représente une typologie de logement différente. Ceux-ci sont complétés par les exemples étudiés par la PHP en Flandre et à Bruxelles. L'ensemble des projets analysés donne un aperçu de techniques et d'équipements très variés. Face aux informations et aux atouts présentés, ces réalisations devraient inspirer et motiver les propriétaires de logements anciens à entreprendre des rénovations basse énergie.

Ces fiches de projets exemplaires apportent des illustrations concrètes et des informations pratiques, venant compléter et renforcer les guides réalisés. Elles s'adressent tant aux maîtres de l'ouvrage qu'aux professionnels de la construction. La distribution de ces fiches se fera sous forme de fichiers pdf téléchargeables sur le site du projet LEHR et sous forme de documents imprimés distribués dans différents salons ou conférences en rapport avec la rénovation durable.

Ci-dessous on peut retrouver une description des projets.

- Semi-detached house, De Pinte

For their home renovation, the owners bore in mind a healthy and energy efficient residence with lots of light and open spaces. Having conferred on this with their architect, they decided to renovate according to the passive house standard, which implied a rather complex renovation of the existing building. The main volume was stripped down entirely and equipped with a new insulation shell. The storey was raised and subsequently provided with a roof structure. The existing annexes were completely demolished and replaced by a well-insulated and highly compact annex building. During the renovation the owners decided to completely redesign the layout of the dwelling. The preference for renovation instead of the total demolition and reconstruction of the existing building is founded on three reasons: the favourable structure of the existing building, the economy of resources by preserving the existing structure and the reduced VAT rate of 6%.

- Terraced house, Eupen

This terraced house, located in the centre of Eupen, was bought by the current owners and intended to serve as a temporary home, in anticipation of finding an appropriate building plot. Since a number of construction works were inevitable as well as urgent measures with regard to the health of their asthmatic son, the step towards passive renovation was rather small and this terraced house would become their permanent home. The owners point out that opting for a passive renovation does not result from energetic, environmental or financial grounds, but from the consideration of their son's health condition.

- Apartment building, Wezembeek-Oppem

In the 90's the apartment complex, built in 1959, no longer satisfied the current comfort standards. A modernization was imperative. Both the apartment building and the two annexes (boiler room and store) were renovated and special attention was reserved for the improvement of energetic performance. The choice of an energy efficient renovation became increasingly self-evident because of the following reason: by simultaneously modernizing a second, identical apartment building and paying no special attention to its energetic performance, the pros and cons can be weighed up. Moreover, after the renovation the building could serve as an example project for sustainable social housing.

- Detached house, Herselt

This project concerns an independent house with garage in the annex building. When the owners purchased the building in 1996, a renovation was already being executed. Contrary to the previous owners, the new owners preferred a low energy renovation which started two years later in 1998. Due to urban development disputes the renovation was delayed, but around Christmas 2004 it was finally completed. Because of urban development stipulations the owners were constrained not to exceed the existing volume and to preserve the existing/original window openings. The owner observed that if he would redo the job now, it would be by using passive house technologies.

- Apartment building, Ludwigshaven

Before the renovation a considerable amount of apartments were vacant and the modernization of the roof, facades and balconies was imperative. The owner wanted to seize the opportunity to take several energy efficient measures in order to reach an economic optimum and to safeguard stable rent prices for tenants. In the past it was possible for the variable energy cost to exceed rent prices. LUWOGÉ consult has examined the optimal renovation strategy taking into account the existing parameters and comparing several technical variants. Only the economically most profitable option was accepted.

This project stands out because its economical and social components relate to the ecological components.

- Loft, Oudenaarde

This project deals with the renovation of a shed into a single-family home for a family with two children. Initially the building served as the current owners' workshop, which eventually turned out to be too small and therefore had to be relocated. As a result they decided to turn the building into their home. Different lectures on passive construction aroused the owners' interest and eventually brought about the outset of a passive renovation. The existing volume was almost entirely preserved, but the building arrangement was completely modified. Furthermore, a considerable number of window openings were provided, allowing the house to have the advantage of sufficient day light.

- Terraced House from the interbellum period, Deurne

Having purchased the building, the new owners initially intended a renovation for the sole purpose of meeting present comfort requirements and realising some energy efficient measures. Eventually they decided to raise the bar in order to reach the passive standard. This renovation will be accomplished in several stages.

- Terraced house, Antwerpen

This low-energy renovation project is realized in stages. The programme and building arrangement is to be modified. Several interventions were taken to lower the energy consumption of this row house. Insulation of the roofs and the rear and side exterior façade were the main interventions. The replacement of the single glazing by improved glazing was another measure that was taken to improve the indoor climate. Keeping the inner layout untouched, the owners looked for other measures to lower the energy consumption, such as energy efficient appliances and lighting. Renewable energy and insulating the front façade are kept in mind for a later stage.

- Farmhouse, Bousval

This project is the result of a passionate architect with experience in the sphere of durable architecture. The renovation demonstrates that complex technical systems are not imperative for energy savings. An intelligent design included a basic concept for this project: a greenhouse with roof and a central core assuring inertia and spreading heat. The result is fascinating, both from an energetic and an architectural point of view.

- Terraced house, Schaerbeek

This typical mansion situated in Brussels was bought in 2007. Because of the bad conditions, renovation was needed. The owners wanted to achieve a good insulated dwelling with the use of ecological materials. When the most important interventions were decided the owner heard about a low energy subsidy in the Brussels Capital region, so they checked if their renovation matched to the conditions of this subsidy. After a PHPP calculation, it was clear that this goal could be reached. The owners wanted to go further and tried to lower their heating demand as much as possible. On top of his subsidy the owners also received an award in the framework of a contest for best practice buildings in Brussels.

This project is especially interesting because the typology of this dwelling is widely spread throughout the Belgian cities, so the measures taken could easily be adapted to similar buildings.

- Farmhouse, Chaumont - Gistoux

This project demonstrates that it is possible to renovate and revalue the old rural patrimony which has lost its former agricultural functions, and at the same time achieve performance levels according to current demands. Architect Pierre Deru respects the character of the original building, but also manages to integrate an organic aspect in a highly personal and distinct manner. Moreover, this project indicates a considerable amount of respect for both the environment and the health of living creatures by the choice of construction materials. The apparent decrease in energy demand was realized without the employment of highly advanced technologies.

- Terraced House, Liège

This project demonstrates that an extensive energetic renovation is feasible, even for a building with a listed façade. This dwelling serves as Eco'Hom's showpiece and guided tours are organised regularly to inform the public tangibly on the concept of durable renovation. In this respect the owners' attempts to sensitize the tenants with regard to energy saving are also very interesting. It is apparent that these measures,

in case of rentals, are vital for optimal building usage and the subsequent decrease in energy consumption.

- Detached house, Sint-Lambrechts-Woluwe

The detached house is a very common building typology in Belgium. Unfortunately these dwellings display very high levels of energy consumption because of their large heat loss surfaces. This project shows that it is possible to obtain a relatively low level of heating consumption by properly insulating these dwellings. However, it should be noted that the corresponding costs are usually higher because both the insulation surface and the number of window replacements are larger. The owners had no notable knowledge with regard to durable construction and renovation, but succeeded in bringing the project to a favourable conclusion by their interest, perseverance and constant inquiries. One of the owners priorities was to provide a healthy indoor environment for their children and lead to the installation of a balanced ventilation system, bioruptors to minimise electromagnetic pollution and choosing healthy materials on the inside of the building. Although certain aspects might have been pushed further, the project constitutes a nice challenge.

- Working class house, Bousval

In spite of a very limited budget, the owners managed to consider a more ambitious project by dividing it into different stages, executing a large part of the works themselves, reusing certain materials and appealing to subsidies. The construction site presented several restrictions, such as the absence of connections to the gas mains, sewerage, etc. Nevertheless the owners managed to overcome these barriers by devising interesting solutions. The improvement to the energetic performance of the building is remarkable and appears to be very profitable in proportion to the renovation budget. On the other hand, the investment does not only relate to the dwelling's energetic aspects since the renovation also serves as an example project regarding the environment. This is shown by the choice of materials, the water use, the development of biodiversity, as well as the attention shown to mobility issues. This renovation constitutes a complete project integrating all aspects of sustainable development.

b) Belgian IEA SHC Task 37 project files

In the margin of the LEHR project, the three research teams also collaborated in IEA SHC Task 37 – Advanced housing renovation with solar and conservation - of the International Energy Agency (IEA) Solar Heating and Cooling (SHC) program. Within this task, the objective of subtask B, led by Robert Hastings, was to analyse advanced renovation projects. As a result of subtask B, several brochures with best practice low energy renovations of each participating country were formed. For Belgium, the following projects were described in a brochure:

- De Pinte: Retrofit of a semi-detached house from the 50's towards a passive house.
- Eupen: Transforming a 19th century row house into a state of the art passive house.
- Herselt: Retrofit of a century old land-house into a single family low energy house.

- Wezembeek-Oppem: Sustainable renovation of a social housing project towards current comfort standards.
- Brussels: Vertical extension: replacement of the sloping roof by three levels of apartments.

2. Scientific publications (peer reviewed)

- Rodsjo A., Haavik T., Mlecnik E., Prendergast E. (2010) From demonstration to volume market, final report IEA SHC Task 37 Sub Task A, submitted for review.
- Mlecnik E. (2010) Motivation for highly energy-efficient renovation, Open House International, expected June 2010, submitted for review.
- Hilderson W., Mlecnik E., Desmidt I., Van den Abeele S. (2009) Zeer energiezuinig renoveren, innoverende antwoorden op nieuwe uitdagingen, proceedings of Passive House 2009, PHP, Berchem, 30-39.
- Delem L., Vrijders J., Van Dessel J. (2009) Milieu-impact en kostenanalyse van een renovatie tot passiefhuisstandaard, proceedings of Passive House 2009, PHP, Berchem, 218-229.
- Mlecnik E. (2008) Ventilation in low energy housing retrofits, proceedings of Passive House 2008 PHP, Berchem, 131-139.
- Hilderson W., Mlecnik E. (2008) Lage energierenovaties van residentiële gebouwen, proceedings of Passive House 2008 PHP, Berchem, 283-290.

3. Other publications

- Mlecnik E. (2008) Ventilatie in energiebesparende renovaties, TVVL magazine, June 2008.
- Delem L., Vrijders J., Van Dessel J. (2009) Renoveren volgens de passiefhuisstandaard, WTCB-Dossier, 2009 no. 4.

4. LEHR working documents

- Van Den Bossche P. (2010) Technische praktijkgids:Laag energie renovatie van woningen Module 1: Plan van aanpak, BBRI, Limelette.

This report is the first part of the practical manual on low energy housing retrofit. In this module a flowchart for an action plan is described, analyzing all the construction elements of the building.

- Prius S., Vandaele L., Dobbels F. (2010) Energiezuinige renovatie van ramen en deuren, BBRI, Limelette.

Windows and doors can be seen as the communication parts of the building. They provide access to the outside world and they make it possible for daylight to enter the dwelling. Energetically and comfortably spoken, the demand for light and visibility is contradictory: to gain as much as possible free heating of the sun, large glass surface on the south are needed, but to prevent on heat losses at night, the glass surface is best limited and insulation values must be improved.

It is clear that renovations of the façade are the ideal moment to reconsider the existing windows and doors, with the necessary attention.

The report highlights the different specifications of glazing and profiles, the general characteristics of windows and doors and gives an insight on the renovation or energetic revaluation of windows and doors.

- Houvenaeghel G. et al. (2010) Na-isolatie van buitenwanden, BBRI, Limelette.
In this report the different aspects of post insulation of walls are discussed. After a general overview of the different techniques of post insulation the three ways of post insulation are discussed: insulation on the inside, insulation on the outside and post insulation of the cavity wall.
- BBRI (2010) Technische praktijkgids: isolatie van vloeren, BBRI, Limelette.
In this technical practical manual, the BBRI shows how floors can be insulated. The manual shortly reviews the general aspects of floor insulation and pays special attention to the points of interest of post-insulation. Different typologies are divided in function of their position and setup of the floor to renovate. Special attention is being given to avoiding thermal bridges.
- Dobbels F. (2010) Na-isolatie van daken, BBRI, Limelette.
This report covers the post-insulation of roofs. After an introduction, dealing with the general aspects of energy efficient renovations of roofs, and an analysis of the existing situation, a general overview of the different post-insulation techniques and systems for roofs is provided.
- Lesage O. (2010) Rénovation basse énergie chauffage, BBRI, Limelette.
With every renovation of a dwelling, it is relevant to consider a adaption or replacement of a part or even the whole heating system. This report pays attention to the impact of low energy renovations on the heating system and provides an analysis of the renovation project focused on the heating system. It also gives an preliminary draft of the heating system with some considerable systems.
- BBRI (2010) Rénovation basse énergie ventilation, BBRI, Limelette.
The ventilation system must be in conformity with the rules, commonly to each installation, regardless if it is in a new building or a renovation, low energy or not. This report gives some insights on the combination of low energy renovations and ventilation dealing with the different aspects such as air tightness of the building, ventilation and energy consumption, indoor comfort.

C. PRESENTATIONS

1. IEA Final Workshop, 14 October 2009, Antwerp¹¹³

- Environmental Impact Assessment of the building stock
Sophie Trachte (UCL, Architecture et Climat)

¹¹³ Discussions of the IEA and LEHR final workshops by E. Mlecnik, available on:
http://www.passiefhuisplatform.be/index.php?col=/nieuws/overzicht&doc=overzicht_603

- Scope and limitations of 'Energy Renovation 2020'
Luk Vandaele (Belgian Building Research Institute)

2. LEHR final workshop, 18 November 2009, Brussels

- Welcome and introduction
ir. Luk Vandaele, Departement of Acoustics, Energy en Climate, BBRI
- State of affairs on innovation, concepts and holistic approach
ir.-arch. Erwin Mlecnik, Passiefhuis-Platform vzw
- Building stock: solutions according to typology
prof. dr. ir.-arch. André De Herde, departement of Architecture UCL
- Heating and ventilation for low energy housing retrofit
ing. Paul Van den Bossche and ir.-arch. Olivier Lesage, Department of Climate, installations and energy savings, BBRI
- Case study for private housing: the l'Oréal project
arch. Sebastian Moreno Vacca, PMP
- Case study for social housing: the Sterrenveld project, part A
arch. Jo Quirynen, Quirynen-Jacobs architects
- Case study for social housing: the Sterrenveld project, part B
Rik Cornelissen, RCR
- Results of the LCC and LCA study for an ambitious retrofit
ir. Jeroen Vrijders and ir. Laetitia Delem, BBRI
- Suggestions for the policy level
ir. Luk Vandaele, Departement of Acoustics, Energy en Climate, BBRI

3. Other presentations (available on request)

- PHP:

Presentations at IEA SHC Task 37 meetings and workshops.

Presentation for general assembly PHP.

Presentation for Flanders' transition arena sustainable housing and living.

Presentation workshop social housing sector Delft University of Technology.

LEHR POSTER presented at Passive House 2008; VEA study day 'Energierenovatie 2020'; Passive House 2009, Brussels.

- BBRI:

Presentations at IEA SHC Task 37 meetings and workshops.

Presentations conference Energy Renovation Programme 2020 in cooperation with VEA.

Presentations at Technical Committees.

Delem, L., Impact environnemental d'une rénovation passive - différentes stratégies de rénovation, Journée d'Etudes ALLg-Eco-construction et développement durable, 15 mai 2009.

Delem, L., Exemple d'analyse du cycle de vie à l'échelle du bâtiment, Formation Conseillers Éco-Rénovation, Module 2 Matériaux & techniques, 26 Novembre 2009.

Vrijders, J., Delem, L., Economic and environmental impact of low energy renovation, POSTER presented at Passive House, 2009, Brussels & 4th Strategic Energy Forum, 2009, KVIV, Brussels.

- UCL:

Presentations at IEA Task 37 meetings and workshops.

D. ADDITIONAL AVAILABLE TOOLS

1. Media files

The following movie files were made available for consultation by the Norwegian companies Husbanken and Enova, in the framework of the IEA SHC Task 37 activities. They were originally produced for the Norwegian web site www.lavenergiboliger.no.

- Movie 1: Why low energy?

If we want to cut energy consumption and lower our carbon footprint, the building rate of low energy houses must increase. This movie shows some testimonies of architects and contractors saying that building a low energy house is not more complex than a standard house. Also some people who live in a low energy house, underlines the most important benefits: low energy costs and a better indoor climate.

- Movie 2: Low rise flats renovation in Nuremberg

This movie shows three examples projects of low energy renovations of low rise flats, all situated in Nuremberg, Germany. Different sorts of renovations strategies are discussed from completely renovating the building, with also a new layout, over adding an extra top floor in passive house standard, to a complete outside renovation with no modifications on the inside. This three projects shows that it's possible to reduce energy usage with a factor 10 in apartment buildings.

- Movie 3: Renovation of a housing cooperative in Brogarden

This movie introduced the renovation project of a housing cooperative in Brogarden, Sweden. With worn out apartment buildings from the '70ies, renovation was needed. After a study, the decision was made to renovate towards Passive House Standard. Before renovating different types of tenants were divided. The movie shows the importance of the forming of a building team in order to achieve the goal, the importance of knowledge, even for professionals, and what redesigning to passive house standard entails.

- **Movie 4: 15 innovative low energy projects spread throughout the area of Stavanger**

In Stavanger, Norway, the city council stimulated the building of low energy houses with a large scale operation called Norwegian Woods, focussing on eco friendly, innovative wooden architecture... This operation consists of the building of 15 innovative low energy projects, spread throughout the area of Stavanger. This movie gives a glimpse on the different projects and shows how municipalities and city councils can stimulate low energy houses.

2. Additional tools

During the research work, several tools were detected that might be of interest to boost or inspire low energy housing retrofit. For example, information considering relevant tools for low energy housing retrofit can be found on:

- <http://www.energiebesparingsverkenner.nl> (in Dutch)

The energy saving simulator shows you in some steps the energy saving possibilities of a house, and estimates the financial advantage. This can be interesting for individual house owners, but for example also for housing associations or an association of owners. For this reason the simulator is available in two versions. A version for private houses allows examining individual saving possibilities and allows choosing the energy saving ambition. Another version addresses maintenances and renovation projects.

- <http://www.hottgenroth.de/energieberater/index.php> (in German)

This link shows the possibilities of in Germany highly popular energy consultancy software of the company Hottgenroth. The applications are used for energy planning, energy consultancy, energy flow documenting for new buildings and existing buildings and it allows evaluation according to EnEV, DIN, VDI, IWU. The different software applications allow identifying cost-effective measures in renovation, also for apartment and non-residential buildings. Also, tools are available that allow to produce reporting during inspection.

- <http://www.modernus.de>

Modernus.de is a platform allowing you to find energy consultants in Germany. Interesting is the link allowing you to use the simulator “modernisation and savings”. This simulator makes it possible to choose for a budget that matches with your expectations and consequently several measures are projected for renovation. After your choices are made, the simulator will calculate for an optimum between your budget and the renovation measures you want to take.

Related research projects that have provided action based input:

- **IEA SHC Task 37**

Advanced Housing Renovation with Solar and Conservation

The objective of this Task force of the International Energy Agency is to develop a solid knowledge base how to renovate housing to a very high energy standard while providing superior comfort and sustainability, and to develop strategies which support

market penetration of such renovations explicitly directed towards market segments with high renovation and multipliable potentials.

Link: <http://www.iea-shc.org/task37/>

- IWT TIS ZenRen

PHP offers thematic innovation stimulation for low energy housing retrofit in the Flemish Region, with focus on creating synergies, funded by IWT.

Link: http://www.passiefhuisplatform.be/index.php?col=-diensten&lng=nl&doc=diensten_17

- TD DuBo (Duurzame Bouwschil)

Technological consultancy by PHP and BBRI for the development of sustainable building skins.

Link: http://www.passiefhuisplatform.be/index.php?col=-diensten&lng=nl&doc=diensten_16

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