A GUIDE INTO RENOVATION PACKAGE CONCEPTS FOR MASS RETROFIT OF DIFFERENT TYPES OF BUILDINGS WITH PREFABRICATED ELEMENTS FOR (N)ZEB PERFORMANCE

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A GUIDE INTO RENOVATION PACKAGE CONCEPTS FOR MASS RETROFIT OF DIFFERENT TYPES OF BUILDINGS WITH PREFABRICATED ELEMENTS FOR (N)ZEB PERFORMANCE

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11-10-2018

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This project has received funding within the EU Framework Programme for Research and Innovation H2020 under grant agreement No 633477

ISBN 978-9934-22-209-2 (pdf)

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RETROFITTING EUROPE’S HOUSING STOCK

1

RETROFITTING EUROPE'S HOUSING STOCK

1.1 INTRODUCTION

It is a simple calculation, really: if we have to reduce energy consumption by 20 % overall in Europe, so has the housing sector. There are two ways to reach this target – either to apply measures to all houses to reduce their energy consumption by 20 %, or 20 % of all houses has to become 'zero energy'. This applies not only to Europe as a whole, but also to each country and region.

In Europe, there are about 255 million houses, and this implies that over 50 million houses should be retrofitted to provide for the zero option. It is interesting to note that the EU targets, adopted by the national governments, require this to be done before 2020. In other words, now we have 3 years left to deal with 50 million houses, that is, we have to retrofit around 8.5 million houses a year.

Realizing this, the only strategic option is to introduce immense retrofit and upgrade programs to be run for many years to keep these targets in sight. This could and will provide a huge amount of work and thus reduce unemployment. What remains is a focus on improving the built environment, which, combined with the rising energy prices, requires a large-scale retrofit program aimed at creating jobs and reducing energy impacts and costs of living.

The EU has already recognized this when it launched its strategy to reduce consumption and increase production of renewable energy. Already in 2011, the EPBD recast was introduced, requiring buildings to become (nearly) zero energy [1].

Since then things have changed in a way that it has become even more urgent to address energy consumption by housing (among other sectors) within the Paris Agreement, considering the published data about the remaining CO_2 emissions to stay below 2 degrees of global warming. The data show that we only have 800 Gt CO_2eq of emissions left to have a 66 % chance to stay below 2 degrees of global warming. At current emissions levels, which are even rising, this budget will be exceeded by 2035! That is, compared to the global level, the EU targets are even higher.

As a spin off from MORE-CONNECT project and in cooperation with iiSBE [3], the consequences have been investigated, especially by the author

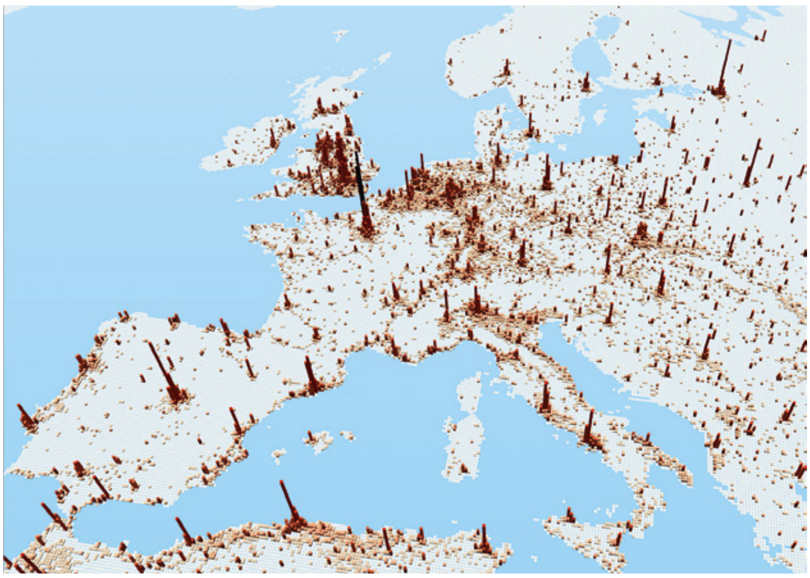

Figure 1.1. Cities and population density in Europe, PBL-NL, http://themasites.pbl.nl/cities-in-europe/

with regard to retrofitting housing towards zero energy. The figures show that we have to retrofit 6–10 % of housing stock yearly to have a chance to meet the overall emission targets [3]. This applies to retrofits with zero energy ambition, highly reduced demand and including the emissions from the energy embodied in the materials for retrofits. In MORE-DEL 3.2, the consequences of embodied energy are explored [4].

With this in mind, the MORE-CONNECT project is one of the solutions explored to create a mass approach and speed up the reduction of CO_2 emissions associated with the building-related energy demand.

[1] http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32010L0031:EN:NOT

[2] https://www.theguardian.com/environment/datablog/2017/jan/19/carbon-countdown-clock-how-much-of-the-worlds-carbon-budget-have-we-spent?CMP=twt_a-environment_b-gdneco

[3] Staying below 2 (1.5) degrees of Global warming : a (near) 0 – CO_2 built environment expert explorations of CO_2 consequences for the built environment , iiSBE report. Ronald Rovers, Thomas Lützkendorf, Guillaume Habert, Launched at : COP22 Marrakesh, November 2016
Version 1.0 April 2017 available at: www.buildingscarbonbudget.org

[4] MORE-CONNECT, deliverable 3.2: Tool to optimize the combined energy and materials performance of the alternative configurations in relation to local typologies, January 2017

1.2 LIMITING (FOSSIL) ENERGY DEMAND

Zero or nearly zero energy houses ((n)ZEB) are in fact houses that meet their energy demand by on-site production of (renewable) energy, that is, by limiting consumption of fossil fuels and replacing them with local, building-connected generation.

There is an ongoing discussion whether energy neutral buildings could sometimes be a better option, namely, the houses that use only renewable energy, which can be produced elsewhere, either in the direct vicinity, or by the classic grid. National power supply systems are also in transition in most countries, and they will also eventually shift towards renewable energy production. For the housing sector, however, it has been decided to start as locally as possible, and not to wait until the whole system has been transformed. In some countries, local district heating will still be the major option to explore.

This is the starting point in analyzing retrofitting concepts for housing. With this in mind, to create zero energy houses, or nearly zero energy houses 4 main areas can be targeted.

1. (Local) production of renewable energy.
2. Reduction of energy loss in buildings.
3. Adaptation of building use.
4. Changing inhabitant behavior.

Figure 1.2. On the Island of Eigg, Scotland, people have adapted their energy use to the amount of renewable energy generated. http://www.ronaldrovers.com/the-eigg-of-scotland-sharing-society-2-0/

The MORE-CONNECT approach focuses mainly on Steps 1 and 2, assuming the usual mode of operations for Steps 3 and 4. Although it might turn out that to reach real zero energy targets and possibly beyond – energy plus houses, which, for instance, include energy generation for electric driving, Steps 3 ad 4 might have to be addressed as well. Within Step 3, for instance, there is an option that the heated (or cooled) area should be reduced square wise. Within Step 4, there is an option that average temperature levels are reduced or differentiated among different rooms. In some retrofit concepts, Steps 3 and 4 are already addressed. We will also consider them within 'Concepts' section.

The MORE-CONNECT approach focuses mainly on heating and ventilation (cooling), since this energy demand is related to the building itself. Household-related energy use will not be influenced by retrofitting directly. Optimization in energy and materials input will mainly be ensured by optimization of heating/ventilation. If Steps 3 and 4 are left out, household energy is a set demand that can be supplied by the related given amount of extra energy generation. This will be shortly addressed in Chapters 2 and 3C.

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2

THE EU HOUSING STOCK

2.1. ROOF SHAPES

2

THE EU HOUSING STOCK

The EU housing stock consists of around 250 million dwellings, which all in some way "consume" energy, mostly fossil energy, for operational use. The EU has set a target to reduce this fossil energy and the related CO_2 emissions, issuing the directive known as the "EPBD recast", which states that all buildings/houses in some way should be transformed to operate with "nearly zero or very low amount of energy required".

This is no sinecure, since the housing stock in question is very diverse and is located in different climate zones with different heating and cooling demands. Besides, such factors as different ownership situations, different market organization and regulations should be accounted for.

Below there is a short introduction into this housing stock to have some insights into the task lying ahead of us.

Energy consumption in buildings accounts for roughly 40 % of Europe's total final energy consumption, the share of households being 27 % of the total [1-Eurostat 2015a]. Final energy from renewable sources in households in the EU 28 accounted for only 15 % [1-Eurostat 2015b]. In 2012, greenhouse gas emissions generated by households caused 19 % of Europe's total emissions [1-Eurostat 2015c].

From the total EU housing stock, around 66 % is built between 1945 and 2000, 22 % – before that and 10 % – after 2000.

Greece, Spain, Ireland, Portugal, Croatia and Bulgaria have the youngest housing stock, with the largest proportion added after 2000.

Regarding the oldest fraction, where the housing stock was mainly built before world War II, Finland, Slovakia, Greece and Cyprus have the least, less than 1 in 10 dwellings built before 1946. By contrast, more than one third of the housing stock in Denmark, Belgium and the United Kingdom was constructed prior to 1946 [2].

Another significant difference is the costs of housing: they may vary from 20 % to 40 % of income in the EU 28. This, in turn, means that on the one hand the interest in reducing these costs might be high, but at the same time the remaining budget to invest might be low for that same group and vice versa.

In the light of energy reduction, the type of dwellings and the distribution of population per dwelling (Fig. 2.1) are the factors to be considered [3].

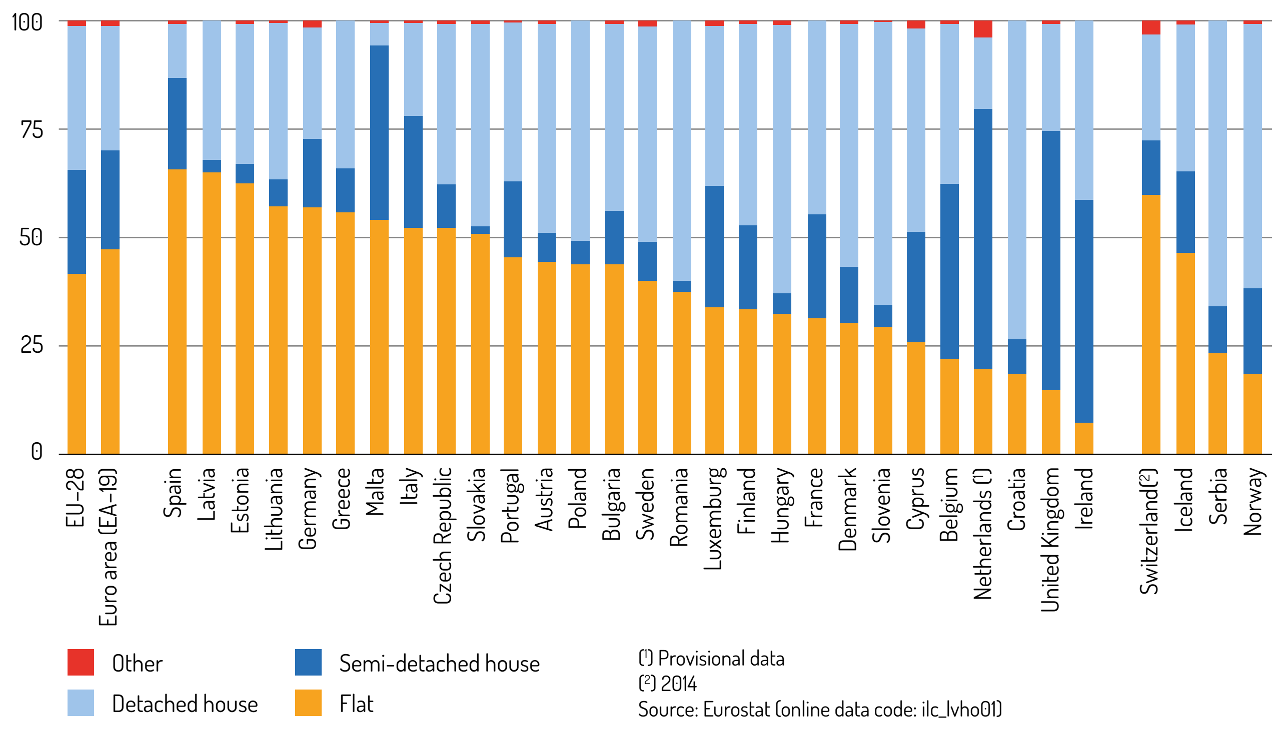
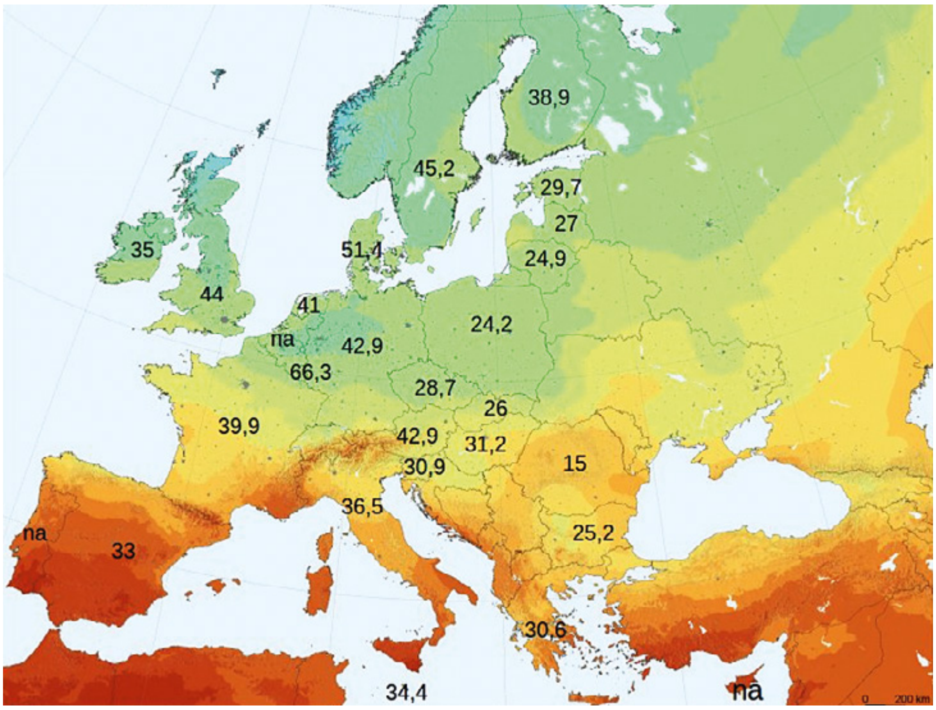


Figure 2.1.



Yearly sum of global irradiation incident on optimally-inclined south-oriented photovoltaic modules

Global irradiation [kWh/m^2]

<600 800 1000 1200 1400 1600 1800 2000 2200>

Yearly sum of solar electricity generated by 1 kWp system with optimally-inclined modules and performance ratio 0.75

<450 600 750 900 1050 1200 1350 1500 1650>

Solar electricity [kWh/kWp]

Figure 2.2. Solar energy potentials over Europe and average useful floor area of housing per capita.

The main difference may be observed between the people living in flats/apartment blocks, and the ones residing in individual houses (terraced, semi-detached and detached). This is a significant difference in the light of potential solar energy generation on or nearby the house: The average roof surface per house and per inhabitant differs greatly.

The average useful floor area occupied per person is a directly related factor [4], which has a direct impact on the energy demand: The housing statistics report shows that people in Luxembourg occupy the largest useful floor area, 66 m^2/cap, and in Romania this index is the lowest – 15 m^2/cap.

These are two exceptions, in the majority of countries this indicator is between 25–50 m^2. However, this already can imply the difference in the heated surface of a factor 2! It is interesting to analyze how these occupied square meters are distributed over different climate zones in the EU, which relates directly to the surface area of solar panels required in particular geo-clusters considering their solar electricity potential. If smaller useful floor area were occupied in the areas with low insolation, it could theoretically compensate for the lack of solar energy, and vice versa. Figure 2.2 shows this distribution.

The warmer areas have significantly lower average occupied useful floor area per capita than the colder North-Western areas, while having a much higher potential in solar electricity per m^2. On the other hand, the countries in the north and west have lower potential in solar electricity, while having much more area to be heated on average (and potentially larger roof surfaces to install more solar devices). Central and eastern European countries have lower solar potential but also lower demand with regard to useful floor area per capita.

Of course, it is only indicative, but it illustrates how diverse the challenges faced all over Europe can be. Other issues that will influence the potentials are the household size, and more specific housing typologies, of which one aspect is particularly important: the roof.

2.1 ROOF SHAPES

There is no doubt that roofs are crucial in a transition towards (nearly) zero energy buildings, if energy is to be generated on the building envelope. Roofs in Europe have always been the mirror of climatic conditions. First it is the shape of the roofs.

Figure 2.3. Some roofs in Europe: Italy (left), the Netherlands (center), and France (right).

In the cold areas, in the North and the Alps, one often sees slightly steep roofs to guide the rain downwards, which are nevertheless not too steep, because snow helps to insulate the building in cold periods, and it should not slide off. This, in its turn, hinders harvesting of active solar energy in colder periods.

In the central part of Europe one can spot many very steep roofs, mostly in densely populated areas. With not much space to build, or for financial reasons, people build on a limited land area and can use the space beneath the steep roof as an extra living space.

In the south, there are flatter roofs. There are no severe weather problems, and the roof is left unfinished, or used as a roof terrace (and sometimes for rainwater collection).

In the south, there are also other things to observe: The construction of *velo's* and *tolda's*, or big sheets covering the roof or parts of the (narrow) street to keep them cool. It is actually an easy, cheap, and effective way to cope with heat. On the one hand, it is easier to install solar panels as roof terrace covers, but at the same it limits the possibilities to use facades as solar panel surfaces.

These are of course some very generic observations. It is important to note that roofs have never been designed with the intention to harvest as much active solar energy as possible, and nowadays they are still not designed as such. This poses an interesting challenge to retrofitting concepts.

One more thing should be mentioned here, it is the height differences among the buildings: It may seriously affect the potential solar gains, if buildings cast shade over each other [5].

Figure 2.4. Roof shapes and climate.

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RETROFITTING CONCEPTS

3

RETROFITTING CONCEPTS

It is this diverse housing stock that has to be addressed to ensure nearly zero energy performance, and in the near future this concept will have to be developed to achieve zero energy performance, as already demonstrated in several countries. But it is not easy, and there are big differences regarding not only the housing types, but also energy challenges.

The per capita final energy consumption in the EU is around 2 tonnes of oil equivalent, or 23,269 kWh, with 27 % attributed to households, this is 6,280 kWh per capita. This figure does not include reduction measures and includes the household energy. As an illustration let us consider the following observation – ~45 m^2 of solar panels will be required to provide this amount of final energy in the southern regions and up to 90 m2 per capita of solar panels will be needed in the northern regions (on average), which is again a factor 2 difference. This in its turn influences the measures that have to be applied to reduce the demand before adding solar panels for production. The surface area occupied, the local climatic potential in solar energy, local housing styles, availability and shape of roof surfaces combined make a retrofit of each house a very delicate balancing act, not only with respect to energy consumption, but also to materials input with its rebound effects on the embodied energy [6].

Apart from these building typology observations, there is a whole range of other issues to address to make a large retrofit program work.

The social and environmental urgency of large-scale integrated retrofitting of the European building stock is widely acknowledged and supported by the EU Member States. However, the European building sector has not been able yet to devise a structural, large-scale retrofitting process and systematic approach.

The main reasons for this deadlock are:

- the European building sector is fragmented and not able to offer holistic, integral solutions for (n)ZEB deep renovation toward nearly Zero Energy Building ((n) ZEB) at reasonable costs and good quality;
- the European building process is typically based on a 'layered' structure, with many labor actions on the buildings site, with many sub-disciplines involved, leading to extra costs and failure risks;
- the European building market is typically top down and supply driven, with a mismatch between the offered products and the end-user needs and the end-user's affordability;
- due to the long-lasting renovation process and failure risks during that process, customers hesitate to renovate their property; sometimes high operating costs are more acceptable for owners-residences than deep renovation with low exploitation/energy costs; a faster and quality guaranteed renovation solution is needed.

Yet there is an opportunity to overcome these barriers by applying prefabricated multi-functional renovation elements which have the potential to reduce costs, reduce the renovation time and disturbance for occupants and, at the same time, enhance quality and performances (both in terms of energy efficiency as indoor climate). As the larger building companies are usually very traditional and have no specific economic interest in this transition, it is most likely that this transformation in building practices will be initiated by motivated innovative SMEs, combined with production line design specific experience.

The challenge is to make this major step forwards using a combination of product innovation, process innovation and innovative marketing approach, in a process of cost and quality optimization driven by motivated and innovation-driven SMEs.

There are 250 million houses to address, which makes such projects as MORE-CONNECT very valuable to explore how mass retrofit methods can be developed and applied.

[1] http://episcope.eu/fileadmin/episcope/public/docs/reports/EPISCOPE_FinalReport.pdf

[2] http://ec.europa.eu/eurostat/statistics-explained/index.php/People_in_the_EU_%E2%80%93_statistics_on_housing_conditions

[3] http://ec.europa.eu/eurostat/statistics-explained/index.php/Housing_statistics

[4] https://www.rijksoverheid.nl/documenten/rapporten/2010/12/17/housing-statistics

[5] Urban and building dynamics: a 3D (exergy) approach required, R. Rovers, 3rd International Exergy, Life Cycle Assessment, and Sustainability Conference (ELCAS3), 07-09 July, 2013, NISYROS - GREECE

[6] MORE-CONNECT, deliverable 3.2: Tool to optimize the combined energy and materials performance of the alternative configurations in relation to local typologies, January 2017

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4

GENERIC CONCEPTS OF RETROFIT / THE OPTIONS TO RETROFIT HOUSES

4

GENERIC CONCEPTS OF RETROFIT / THE OPTIONS TO RETROFIT HOUSES

There are in effect several options to renovate/retrofit houses with regard to limiting CO_2 emissions. Here the focus is mainly made on heating (cooling) and ventilation, since this is the factor that requires building and construction measures. All other energy demand will not have direct consequences for the building/house performance.

For all options, the targets are much easier to be reached when energy demand is reduced beforehand, demand in the sense of changing the inhabitants' habits and behavior of the house (Steps 3 and 4 discussed in the introduction), for instance, limiting heated floor area, accepting a reduced temperature level, etc. This will reduce the actual need for energy generation and reduce the amount of materials used, as well as reduce possible materials needs, for instance, for insulation, avoiding rebound effects in materials-related CO_2 emissions. In general, here the focus is made on Steps 1 and 2, unless otherwise indicated.

4.1 NEARLY ZERO OR ZERO ENERGY?

Within the MORE-CONNECT project, the concept of zero energy is the starting point for analysis: it is chosen to analyze all options assuming retrofits with the ambition to design zero energy or energy productive buildings. It is done for several reasons. In due time, all houses will become zero energy. Even if today an (n)ZEB retrofit option is chosen, to meet climate targets it will be required to make an additional step to zero energy at some point in the coming years. Attempts to perform a *nearly* zero energy retrofit might lead to a suboptimal result (see Del 3.2). Even if the actual retrofit is nearly zero energy, for economic reasons, for instance, it is better to make a plan for a zero energy retrofit and have only proportional measures executed, delaying others for the future. This guarantees that an optimal solution is chosen for the future, a no-regret concept that allows avoiding disinvestments and non-optimal CO_2 reductions. Besides, as Del 3.2 showed, in practice a zero energy retrofit may in fact yield only an 80 % energy reduction result, when (fossil) energy embodied in the materials (life cycle energy) is included.

The options to perform zero energy retrofits can be roughly characterized by the following list:

4.2 ENERGY NEUTRAL (OPERATIONAL)

All operational energy is directly obtained from renewable energy sources outside the building boundaries: as a co-owner in wind turbine cooperation, as a partner in a joint Solar PV cooperation, etc. Most likely, the house will need to be all electric. There are some options for non-electric heating, but these are not widespread (ground source aquifer system, district heating). These options are analyzed in Del 3.2. The house will need minor adaptations, mainly installation all-electric equipment.

4.3 ZERO ENERGY (OPERATIONAL)

All energy is obtained on site, within the legal boundaries of the building. It is commonly accepted that the existing electricity grid is used to counter average seasonal demands imbalances. Most likely the house will be all electric, there are hardly any options for heating sources within a buildings plot. Some heat might be supplied by solar collectors into the overall electricity driven system.

In both above-mentioned cases, the energy embodied in the materials is normally not included (for generation and/or reduction), with a resulting rebound effect in CO_2 emissions. This can be significant and decisive for the ultimate retrofit plan. To optimize *CO_2 emissions reduction*, the materials impacts have to be included, and below some options with increasing ambition are described.

4.4 ZERO ENERGY AND LOW EMBODIED ENERGY (BIO-BASED)

The operational target is similar to the one described above, using the materials of bio-based origin to the extent possible. In general, bio-based materials have a much lower embodied energy/ CO_2 effect per unit of service than non-bio-based materials. The reduced embodied energy is mainly to be obtained with reduction measures, e.g. insulation. It is more difficult to change energy generation and heating equipment for bio-based material use, although there are promising developments, like organic solar cells and bio-based plastics used as a material for equipment parts, as well as a low-tech approach to installations.

4.5 'CLIMATE NEUTRAL' (IN YEAR X)

A building retrofit that eliminates CO_2 emissions from both operational and materials embodied energy can be classified as a 'climate neutral building' since all CO_2 or greenhouse gas emissions are addressed in combination and reduced to zero. In case of a house, it could also be named a zero CO_2 house/building, since other greenhouse gases hardly play a role in an average housing situation.

However, this requires a target year to be introduced, since materials with embodied CO_2 emissions will have to be used anyway. The zero target can only be achieved after a certain period, when the reduced CO_2 emissions from the operational energy have compensated the invested CO_2 emissions from materials. For example, for a retrofit to be zero CO_2 in 2030, the maximum CO_2 investments via materials (for zero energy retrofit) cannot exceed the avoided CO_2 emissions from the operational energy between present and 2030. This puts a limit on the materials embodied energy to be invested. If more materials (and embodied energy) are invested, the year in which a building can be claimed to become zero CO_2 will move further away.

4.6 CLIMATE NEUTRAL (IMMEDIATELY, NOW)

The next level would be a house retrofit which is directly 'climate neutral', or has a zero CO_2 performance immediately. It is obvious that in this case all materials invested (to become a zero operational energy house) should be zero embodied energy materials from the start, which is only possible when all materials are obtained from industries that work using zero energy production facilities, in similar terms as a zero energy house described above. In other words, materials come from the companies that have already established production running 100 % on on-site produced renewable energy. It is theoretically possible, there are a few companies that have already made this transition, but such options are very limited. It has been mentioned here, if all materials were zero embodied energy produced, there would be no rebound effect in the zero energy housing retrofit sector. This is an important issue to address in new policy programs. In fact, since industry will have to make a transition to zero energy performance, it will be more efficient to start with the industry.

4.7 SYSTEM-NEUTRAL (YEAR X)

This category has been added to make this overview comprehensive. CO_2 emissions have become our main concern nowadays, as they pose a direct threat to society. However, they are actually a side effect of an even larger problem – resource depletion. To maintain a sustainable level of resource stocks these will have to be restored, regenerated or exploited at a natural replenishment level. This could imply that energy has to be invested to restore or re-concentrate stocks or to regenerate land. It is beyond the scope of this project, but it was mentioned to provide a comprehensive picture since ultimately this may also become a serious threat.

The aim of the MORE-CONNECT project is to conduct zero energy retrofits with low embodied energy rebound effect. The zero energy target is a hard target, the 'low embodied energy' is a soft target, which provides initial experience in this field. A hard target for embodied energy should be included in the future projects to avoid a too significant rebound effect (See also IEA EBC Annex 56 and 72).

Before we describe the MORE-CONNECT project more in detail, we should analyze the current state of affairs concerning housing retrofits and the road gone so far.

4.8 INTERMEZZO: THE DUTCH EXPERIENCE

Case Study

The Netherlands: Mass retrofit for zero energy

INTRODUCTION

A few years ago, the Netherlands started zero energy housing renovation schemes. The main program was initiated by a government supported program office to support social housing corporations in their community tasks. The program called "Stroomversnelling" (literally – "river rapids" actually meaning "flow acceleration") started when 6 housing corporations and 4 building consortia agreed in a green deal to start piloting house retrofitting. It was planned to expand the project to batches of a hundred houses and then to move to the next level of neighborhoods with 1000 houses. All houses were set to be retrofitted for NillOntheMeter (http://energiesprong.nl/transitionzero/)[1].

The program has set ambitious goals, aiming at what is now called NulOpdeMeter: NOM (in English, Nill(zero) On the Meter). The difference between this approach and a general zero energy approach is that the latter addresses only building related (operational) energy, whereas NillOntheMeter addresses all (operational) energy demand, including building services, household appliances and total plug load (to be specified below). The project includes joint concept development, research, as well as building process and market process evaluation and improvement. The pilot projects are financed by the project partners (social housing corporations and construction consortia, the research and management is performed by the program office, while the government has committed itself to adapt regulations and tear down regulative barriers if required (for instance, the way how social housing corporations are financed by the government). Apart from this major program, several other concepts have been developed by other parties, also offering zero energy retrofits.

The way for this NOM program was paved a few years ago. Several projects experimented with an ambitious retrofit approach (see Del 3.1 for some detailed description of pilot projects). One of the milestone projects is known under the name of "Kerkrade West" (KW) (see Del 3.1 for a technical description of these projects). KW covered about 150 (row) houses with each house retrofitted in only 10 days to create a (nearly) zero-energy building, whilst the residents remained in their home. The process entailed installing prefab panels on the facade and roof, which were mounted in a process that I called "mass renovation trains" (Rovers 2014): the construction work was organized using a continuous flow approach, moving one house every day repeating the same actions. The project was a huge success, technically and organizationally, as well as from inhabitants' point of view. It showed that high ambitions were possible with a new on site approach, without having to move inhabitants. Given the scale and the number of homes that need to be retrofitted in the Netherlands and other countries, a questions may be raised whether this retrofitting process could be even more ambitious. Can it be scaled up, made faster, more efficient and less costly? (see Table 4.1)

Although really ambitious, these questions became the basis to start the NillOntheMeter housing program now aiming for zero energy houses. It is also known under the name "Energiesprong" or the name of a new foundation established – "Stroomversnelling". Mr. den Harder, director at Volker Wessels and one of the new program construction partners, stated at the start of the program, "If we take our climate targets seriously, this is the only possible answer".

The idea is simple: If the house does not consume net-energy anymore, the amount of money that had previously been spent on energy bills can be invested in renovation, and the cost for the inhabitant (as a yearly redemption and interest) in the end could be the same. Besides, the lifetime of the (old) housing stock would be prolonged by 40 years and investments would be spread accordingly, leveling the energy bills for the same 40 years. Energy is saved, inhabitants are happy, housing corporation is happy as well.

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[1] Information videos and pictures in English: https://www.youtube.com/watch?v=6b22xNw_fFU&list=PLxqrMoxgE53ndDAFqpEb9h9tbLuB3MD7c&index=

Time	Can retrofit time be reduced from 10 days to 3? Or less?
Cost	Can the cost be reduced from €100 000 to €60 000 or even €45 000?
Performance	Can performance be guaranteed for 40 years?
Design	Can the installation of services be made more compact?
Disruption	Can the presence of workers inside the house be minimized? Can the turmoil to inhabitants be reduced?
Energy	Can energy generation match total energy demand? Can energy demand be managed?
Construction	Can the construction be done without the need for scaffolding?

Table 4.1. Some key project-related challenges for the Stroomversnelling and the next generation of retrofits.

Retrofitting 100 000 houses a year with nil-on-the-meter ambition cannot be done the way the industry is organized now, and it was the basic assumption of the program. A project by project approach, going through all the hassle of implementing several one of a kind projects, was not considered efficient. Mass retrofit requires a process-oriented focus in which a continuous flow of retrofits is established, employing highly standardized procedures and mass produced materials. It is also necessary to develop an interesting offer for the tenants and house owners. There are different ways to do this, but the continuous process is basic. This prerequisite was recognized at the start of the program; it even became the main reason for it. The main focus of the construction and principal partners is to develop retrofitting concepts implementing pilots, organizing the suppliers and reducing cost, the main focus of the program management is to eliminate institutional barriers, such as financing, licensing, performance guarantee mechanisms and so forth. This is the main focus of the program to investigate and develop. The project has been running for 3 years and after some delays is now being accelerated, with many barriers already removed and solutions developed.

Besides this formal and national 'Stroomversnelling Program', other initiatives have emerged in the periphery. Many stakeholders in the construction sector have partnered and grouped to come up with their own concepts. The social housing sector is no longer the only sector targeted: The first NOM-retrofit projects with private home owners have been completed, and now many consortia offer new housing based on NOM-nillonthemeter concept. This chapter starts with the analysis of the social housing renovation sector aiming for NOM concept; in the end, other initiatives will be shortly described.

In summary, the main issues to deal with include technical concepts, organizing a different supply chain, reducing retrofit cost, removing institutional barriers, and having inhabitants convinced and on board. Of course, many of these issues are interrelated and influence each other.

TECHNICAL CONCEPT

The first project in KW still required some significant work on location. The first main target of the new program is to avoid work on location as much as possible, to reduce costs and nuisance for inhabitants. The most successful pilot required five people on location for one day to install four facade panels and two roof elements. Although this is still not an established practice in all pilots, experience suggests there are no major barriers for this to become a standard in future. This is less important for social housing, since rows of houses can be

Figure 4.1.

Figure 4.2.

Figure 4.3.

retrofitted simultaneously. Addressing home owners in the private market, from the contractor's point of view it is important to make offers for individual houses and still have a business case[2].

The panels are completely prefabricated in the factory and transported to the site in one piece (see videos)[3]. There are in general two main ways in which the new prefab-panels can be installed: directly against the old facade (sometimes stripped from balconies and small cantilevers, old window and door frames removed), or with the old facade removed completely (Fig. 4.1).

This depends on the design and the technical state of the old facade. In some cases, houses have some kind of wooden curtain wall infill facade, which is of no use afterwards. Besides, architects prefer the full removal of facades, creating opportunities for a new design not limited by the fixed facade openings.

The prefab elements are either directly "mounted" on the old vertical structure (horizontal elements), or can be supported on the original, sometimes extended, foundation (with vertical elements, in case the main structure is weak) (Fig. 4.2).

The roof elements are usually placed on top of the old roof, with the roof tiles removed first. This way the inhabitants do not need to redecorate their attic. So far, the only part that is not directly included in the one-day makeover is the PV panels. They are too vulnerable to damage during transportation. Although this problem may also be solved, since there are first manufacturers on the market that produce and transport prefab elements including the PV panels (Unidek Kingspan, Fig. 4.3). Nearly all wall panels are made of a wooden structure filled with insulation material, with a vapor barrier integrated foils for airtight connections and optional finishes both inside and outside. They are fully prefabricated in the factory.

After a few first pilots employing different energy concepts, now it seems that the 'all electric' concept will become the standard approach, since energy generation on location is done by PV mainly. Sometimes solar collectors or combined PV and collector units are introduced, with ground source heat not really considered as an option in individual existing house retrofits, mainly for economic reasons (although there are other ways, to be discussed below).

Advantages
• inhabitants are satisfied;
• comfort raised, housing cost fixed;
• house lifespan is significantly prolonged;
• new business model for construction sector;
• CO_2 emissions avoided;
• cost reduced by scaling;
• stimulating innovation;
• cost neutral;
• no direct subsidies needed.

Table 4.2. Advantages.

2 Of course, in general it could be more efficient to undertake complete neighborhood retrofits, which may also include urban solutions. This would require owners to organize themselves in a neighborhood trust, and possibly involve more stakeholders at the municipal level. Again, this would pose an extra organizational challenge.

3 An example of Day 1 of NillOntheMeter – NOM- retrofit in Nieuw Buinen, NL (equipment in white extension on the facade): https://www.youtube.com/watch?v=I3WBT2eAArI

Figure 4.4.

Figure 4.5.

Since these are 'NOM' houses, the energy generation includes the production of electricity for household use, not only to meet building-related energy demand. This makes the roof surface a decisive parameter, since it should produce all the household energy on a yearly basis. As a consequence, the heat demand has to be brought to very low levels to preserve roof space for PV panels for the household energy consumption. The main equipment for heating is a heat pump, air to air or air to water.

After the first few pilot projects, it has become more or less standard to have heating and ventilation installations brought together in a building extension placed outside the dwelling (the "engine room" or sometimes called the "outboard motor", Fig. 4.4, 4.5). This had a large effect on reducing the need to enter the (inhabited) house. Now there is hardly any need for real construction work inside, only some finishing work around windows and doors should be performed, some fittings/connections to the inside equipment should be made as well.

Technically, construction wise on site, pilot experience shows that there are no real difficulties in doing a NOM renovation on site: the main problems are to make the whole process before actual implementation more efficient, to reduce costs and to develop new installation devices, that is, to compact the whole installation into one small unit, which seems as a matter of time and upscaling. The main barriers, however, lie in in the process itself: both in the organization of a different construction supply chain and in re-organizing the market. As one of the stakeholders puts it, "It requires a process-oriented approach, no longer a project approach." Since the projects are similar, a facade is a facade, it is the process that is turned upside down. This was recognized from the start, and small working groups addressed these issues from the very beginning.

INHABITANTS

Some 1000 NOM renovations are now completed and the response from inhabitants has been favorable. Jan Postema, one of the social housing corporation directors and partner in Stroomversnelling, states,

"We ask the tenants what they want, and they are immediately enthusiastic. Every time we complete a project, the neighbors come and ask when we start with their houses."

Except for an occasional problem, the program is performing beyond expectation regarding the inhabitants. However, it must be said that the main success is that people feel as if they live in a new house, have much more comfort, the neighborhood is upgraded as well. One of the inhabitants notes, "The whole operation was less stressful than we thought. In a few days everything was fixed, and we felt we had moved into a new house."

Financially, it hardly makes a difference for the tenants, as for them the costs before or after the renovations are equal, or even somewhat less. After renovation, the energy counter reads zero each year. The money that normally went to the energy supply company is now transferred to repay a long term loan in equal monthly costs for private home owners. As regards social housing tenants, a new law has been passed recently that allows the social housing corporation to charge tenants an 'Energy Performance Fee' (EPV) that will cover the investment cost made by the corporation. The fee that can be charged by the social housing corporation is based on the level of heating demand per m^2 of floor area in kWh. In practice this means that the tenant pays the same amount as the former energy bill, only now directly to the social housing corporation, who made the investments. This is one of the main issues already solved to make the whole program work, since before that scheme was not authorized, it could be used only after all tenants had signed to agree, which was a very time-consuming and uncertain process.

ON COSTS

The financial concept is simple. The sum that went to pay a former monthly energy bill can be considered as the capital and interest for a 25 or 40-year loan of the same amount. This provides investment budget for the retrofit. In the Netherlands, this is based on an average of €175 per month, resulting in a loan/investment budget of around €47 500 for the retrofit (on a 30-year loan pay off basis). The cost of the initial project in Kerkrade West was €100 000 per house, but the cost has been reduced with subsequent pilots to €80 000 and now is around €60 000–65 000. This amount could be acceptable in social housing sector because the calculations can be based on a longer period of return on investments, up to 50 years extended life time of the house. However, 50 years and €60 000 is too high for the private sector (housing loans are granted for maximum of 30 years). Prices need to be further reduced to be viable for the private sector.

A further radical reduction in the price of retrofitting is feasible. When considered pragmatically, the exercise consists of the production of six elementary prefab boxes (wooden frames fitted with insulation, windows, doors and finishes), the provision of an external, compact service units and their fixing by a few people and a crane in one day. Why should this cost the equivalent to the cost of 6 small cars? One of the program partners (a social housing corporation representative) regretfully noticed, “The biggest problem (and cost) is that there is still a traditional construction firm in between the factory and mounting....”

SUPPLY SIDE PROCESS

Most important conclusion so far is that the step from a project to a process approach has not yet been made. This conclusion was made by the project team after analyzing the latest group of pilots. As Jan Willem van de Groep, one of the driving forces behind the program, puts it, “The project-oriented builders hardly contact with the component manufacturers and suppliers, who are by definition process-oriented, and these do not easily contact with the (building) project industry.”

It is two different worlds so far, while for upscaling and industrialization (and cost reduction) the two should co-operate. Builders are not yet fully convinced of the importance of industrialization. In his recent evaluation (van de Groep 2016), van de Groep concludes that there are only two consortia really developing a process approach, say “NOM 2.0”, which will include completely industrialized production lines delivering on command, with built-in design flexibility. The question is whether traditional builders will be able to develop and adopt this new process, or whether it will be the existing component industry that will develop the new market, and building and construction industries will follow, or not.

However, van de Groep mentions, “Going through this Generation 1 process is unavoidable on the way to Generation 2 development. But Generation 2 is essential to really promote transition, upscaling and bringing costs down.”

An important role could be played by the supply industry producing components like window frames and classic facade panels. They are equipped for prefab panel production; they should only consider producing elements of larger size. They can be the natural new market leaders, and they should learn fast how to extend their business to include installing and mounting the panels. At the same time, large construction companies from the first hour are also looking at building new production lines. The market is in motion and future will tell where that leads us.

MARKET ORGANIZATION

As mentioned, the main issues pertain to the institutional and regulative sphere. This has been acknowledged, and as a result a new association has been established involving stakeholders in order to develop a clear supportive framework dealing with the issues listed in Table 4.3. The organization is set up as a foundation named “Stroomversnelling”, and companies and principals can join subscribing to the goals of the program. Even a police-related organization dealing with burglar safety has joined to help integrate the issues of their concern in the prefab concept. A fire safety organization and many commercial industries keep joining, afraid to miss the train. From the start, this program was nationally oriented, but more and more provincial governments are coming into the scene: It is seen as a powerful instrument to implement regional policies and meet targets, and support local organizations and roll out of retrofits. It even goes down to municipal level initiatives. A recent independent survey showed that 42 % of people see NOM retrofits as attractive to very attractive, and

Non-technical issues to solve
Energy performance overall and PV output
"Energy-bundle" to balance
Clear agreements with tenants
Monitoring performance
Maintenance and exploitation contract over 40 years
Financial agreements
Reducing electricity for household consumption
Licenses in 1 day
Thermostat level for the base case
Acceptable temperature level in summer
Quality surveying
Guarantee scheme
Dispute settlement
Label /certification / NOM standard
Cost reduction
For private home owners: how to deal with contracts
and guarantees when selling a house
Front facade extension over public land/sidewalk

Table 4.3. Non-technical issues to solve.

after they were showed the pictures of pilot results this figure increased to 53 %. People interviewed mentioned their municipalities as stakeholder to actively promote the scheme. The survey was initiated by a large energy company Eneco as a move to becoming a partner in the new foundation.

TRANSITION

The whole initiative has become a huge crowbar in promoting transition, not only in reorganizing the process and market, but also as 'a national movement'. The initiative created substantial pressure on the 'old fashioned industry', as well as on the politicians to develop new innovative market approaches. Here the new social media come in becoming a game changer in this new era: Most people involved in the program are very active on Twitter, LinkedIn and the like, and push the new approach. Every quote from a politician, which seems to be in favor of 'the old school', is heavily reacted upon. Everything is included: closing coal mines, changing subsidy schemes, criticizing lobbying statements, etc. Every report, publication or news item is directly responded to in the social media, either in positive or critical line. The overall publicity is making hard pressure on the 'old economy sector' to make a real shift.

THE PRIVATE SECTOR

Now the first projects have been piloted selling zero energy 'make overs' in the private sector. This entails a different set of financial parameters, as there is a different financial regime and ownership pattern as compared to the social housing approach. The financing scheme for private houses entails the valuation before and after a retrofit, since this is a deal directly between the market party and the owner/inhabitant. One of the things already in place is that the government has allowed for an extra loan-space when people retrofit to NOM standards. Normally when buying a house, the buyer is only allowed to have a banking loan not larger than the value of the transaction. This is a government regulation to create a healthy housing market without too much risk caused by over-financing. Now the government has adapted the rules to allow the amount of the loan to be extended if there is an energy efficient retrofit. A maximum of €27 000 extra is allowed for a mortgage to cover this cost. Banks are interested as the living costs afterwards are fixed and there are no energy bills for the inhabitants.

However, other issues for private house owners have not been resolved yet. For example, what happens when the house is decreasing in value? Or what happens when the house is resold? If the loan is person related and the house has increased in value then no problems are expected, although taxation experts will have to learn how to value the property for NOM. How should the NOM value be reflected when the house is sold? The now prevailing idea is that loans, at least for the retrofit part, could be building related instead of person related. So when buying a NOM house, it comes inclusive of the loan for the previous NOM retrofit by the previous owner. This makes sense since the loan comes in place of the energy bill that new owners normally also have to adopt. Some financing oriented pilots are running, and within one of them the NOM investments are seen as part of service costs of the house (as it is frequently done in privately owned apartments being part of a multifamily building). The recently established new government (October 2017) has announced that it is going to make provisions for the development of a legal framework for building related loans.

Figure 4.6.

RELATED INITIATIVES

Considering the issues to overcome discussed above, it is obvious that there are other concepts developed by ‘non’-NOM partners looking for other solutions, especially since certainly not all houses are fit for the standard NOM approach.

MODULAR

The NOM approach is an all-in-one concept: The whole house is refurbished, financed and as a result it demonstrates zero energy performance. Since the retrofit costs are still high, there is an option to do this process step by step: the retrofit is done in phases, and some organizations and industries have joined to offer a modular concept (Alliantie+): the engine, the facades or the roof can be retrofitted separately. Of course, the elements combined deliver a similar performance as the NOM concept. It is a way to spread investments.

Examples of retrofits with modular components: facades and roof (NOM-ready), only facades (NOM-ready), only roof (NOM ready), facades and roof (‘no regret’), and full NOM retrofit (‘NOM ready’ includes HH energy, ‘No regret’ is optimized for building energy coverage). Source: Bouwhulp, the consultancy partner, most examples retrofitted in cooperation with Eindhoven Social Housing Corporation ‘Woonbedrijf’.

PURE ‘PV’

This is the most basic approach: All operational energy (building related and/or household energy) is supplied by renewable energy sources, which may be building connected (zero energy), or supplied distantly, relying on a full transition of the national renewable energy supply (energy neutral). In fact, a lot of people already buy the so called “green electricity” from a grid based supplier, and formally are zero energy in terms of their electricity use. However, nearly all houses in the Netherlands use gas for heating, which therefore requires an additional and separate strategy to make heating zero energy or energy neutral (see below). It is possible to change the heating system to all electric option as well, and produce or buy more renewable energy. Usually this is combined with basic reduction measures, like cavity wall insulation, roof /floor insulation and double or triple glazing.

URGENDA / THUISBAAS

One of the alternative approaches has been developed by the NGO Urgenda.[4] Two years ago they launched a plan to have the housing sector energy neutral in 25 years, and started piloting zero energy housing retrofits. Their approach is more case by case, and it takes inhabitant behavior into consideration.

Their first pilots aimed at the private sector helping people to create a NOM-similar situation. Energy reduction by behavior is the start, people themselves decide what can be reduced in demand before planning the retrofit. It must be noted that the first pilots took place with families that already held a more sustainable attitude and thus were prepared to accept adapted behavior and in some cases were ready to put up with a somewhat lower level of comfort (like putting on a sweater when needed). This makes it possible to do a retrofit without a full facade makeover, and, for instance, to have the former architectural solutions

4 Urgenda is the organization that successfully sued the Dutch government in 2015, which by the court ruling was obliged to increase CO_2 emission reduction to 25 % by 2020. They not only claim that more should be done, but are also active in demonstrating how it can be done.

preserved. That factor has certain implications for the inside climate and comfort. The remaining demand is addressed in a more technical way, by installing efficient equipment, like heating with infrared panels, and mounting a larger number of PV panels, sometimes not only on the house roofs, but also in the direct neighborhood, for instance installing some extra panels on garage boxes. The result is NillOntheMeter as well, at a lesser extreme – zero balance level, that is, less extremely insulated house with a lower overall energy demand considering also the household energy. The rebound effect by the embodied energy also seems lower, although it still has to be calculated in detail. Urgenda has succeeded in doing this for much smaller money, pilots range between 20 000 and 35 000 Euro per house. One of the prerequisites, however, is that inhabitants should have positive attitude to the process, since it requires adaptation to a new way of living in the house, whereas NOM renovations in the social housing sector are very vulnerable to inhabitants that do not want to have their way of living radically changed.

RETROFIT OR DEMOLISH AND ERECT A NEW CONSTRUCTION?

There are many other options under development that are not going to be considered here, however, there is another approach that should be mentioned. It is lobbied by some stakeholders who claim that demolition and new construction is by far better than renovation of old houses to NOM level. There are many reasons why a new house could be preferred to a NOM retrofit, but cutting the CO_2 emissions is not one of them. In the end, both retrofitted and new houses will be NOM houses, zero energy houses, so both will have no emissions from operational energy anymore. However, as argued before, the remaining CO_2 emissions come from materials invested, their production requires the use of fossil energy and thus is responsible for the related CO_2 emissions. It is quite obvious that the new house will require around twice as much resources. Both a retrofitted and new construction have no emissions from operational energy, but a new house is responsible for roughly double CO_2 emissions from materials.

More detailed calculations are presented in other papers, e.g. in the IEA annex 57 (embodied energy, www.annex57.org) and DEL 3.2 of the MORE-CONNECT project (http://www.more-connect.eu/).

(It should be noted that although it has not been discussed in this chapter, the NOM approach has now also been adopted by the construction of new houses as well.[5])

MATERIAL BURDEN

As illustrated by the example considered above, materials are becoming an ever more important factor, also comparing different renovation concepts in terms of their resource use and CO_2 emissions. In fact, a paradigm shift is taking place in the process of creating zero energy houses: At the moment of reaching zero, operational energy demand becomes obsolete from an environmental impact perspective. The use of solar radiation (or sometimes heat from sub-soil) is completely impact free, it has no side effects. What creates impact is embodied energy; conversion devices are used for capturing and converting renewable energy and facade and roof panels are installed to reduce demand. The balance level at which zero energy is established (more/less insulation, less/more generation equipment) can vary, but zero remains zero, and the optimal level is set at the least impact from all materials invested (As I sometimes put it, a solar panel is a building material, and has impact, the energy is a free bonus with the panels) (Rovers 2015).

There might be other reasons to change a particular retrofit concept, like facade renewal due to bad technical conditions, but from a resource and CO_2 impact point of view, there is no need to extremely insulate, for instance (See Del 3.2 of this project).

Seen from this perspective, the Urgenda case is extremely interesting, since it operates at a higher zero balance level, with reduced consumption relying more on new low impact technology like, for instance, infrared heating panels. The first rough calculation shows that in terms of the embodied energy in all the measures to create a NOM house, the Urgenda approach might have even lower indicators. That is, the burden from

5 The NOM retrofit approach has ignited new initiatives in the new housing market as well, and different comparable concepts are now on offer and realized in practice. One of the best scoring examples is by Volker Wessels Construction Company that built around 500 new NOM houses last year, completely prefabricated in a new factory. The concept is concrete-based, and the house is built in one day. Onno Dwars, innovation officer at VW, notes, "On the construction day, at half past one the ground floor connections are installed and you can already go to the toilet."

operational energy impacts shifted to materials related impacts, which are lower, making it overall a better solution from the environmental point of view. It is, however, a completely different business case, which requires inhabitants to cooperate. As such, it implies different operation of the building chain and calls for individualized and case by case solutions, in contrast to the industrialized targeted approach of the Stroomversnelling. Both research and adoption of good practice should show which option is more feasible for each kind of projects.

BEHAVIOR AND GUARANTEES

Despite four decades of efforts to calculate and predict energy demand, in practice it appears to be a complex task: such factors as maintaining comfort levels, inhabitant behavior and construction interaction with heat and ventilation should be accounted for. Nevertheless, zero energy performance is possible, it has been proven by many (it is clearly measurable, since the meter should be zero at the end of the year), but it usually requires some calibrating by the inhabitant or owner. They should know how to manage installations, either reducing temperature at night or not, when and how to use ventilation, drying the laundry inside or outside, opening windows at night in the bedroom, etc. Many things are interrelated, and after a few years, the front-runners have these factors under control. In fact, zero energy performance is possible, it is not a big deal if people are really concerned.

However, with mass renovations of houses inhabited by people that have no clue about the issues discussed in this chapter, who still want to guarantee zero energy performance for over 25 years or more, it is a different thing. In that case everything on the back end must be solidly boarded up to avoid disappointments and even claims. And this still is a lot of work...

Besides, research shows that most of the time people in their old houses live more energy efficiently than calculations predict (Itard 2012, Sunnika 2012). One of the reasons is they behave more economically, and have years of experience of how their house interacts with their heating device. With a completely new installation, they cannot ensure fine-tuning of the heating-building interaction. On the other hand, with the very low heating demand, things get less critical. But here, in the background, there is still a lot of work to do.

If the renovation includes energy supply for household use, it is important to agree on the delineation regarding what part of energy is supplied for what use, and what the maximum use is for either building related or household related energy demand.

The NOM retrofit program contracts come with household energy use included. The regular basic standard set for household energy use is 2 700 kWh (see Fig. 4.7), it is determined in the contracts and is made part of the Blue Table performance agreements. The list includes showering, cooking, lighting, etc. at the basic comfort level. 2 700 kWh to be generated by PV on the roof requires a retrofit that is fully based

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NOM houses last year, completely prefabricated in a new factory. The concept is concrete-based, and the house is built in one day. Onno Dwars, innovation officer at VW, notes, "On the construction day, at half past one the ground floor connections are installed and you can already go to the toilet."

VW plans another 1,000 retrofits for this year; it is already moving to the German market, where they hope to contract a few hundred houses this year (an example of a one day construction of a nillonthemeter – NOM – new constructed house : https://www.youtube.com/watch?v=G0nyZFYCF-I)

The current concept is just clumsy concrete poured elements based system, but they are aware of the materials impacts and will pilot the first bio-based new NOM housing concept somewhere this year.

Figure 4.7.

Blauwe tabel Prestatiespecificatie

	De minimale haalbare temperatuur in woonkamer en keuken	[Y] °C			De minimale haalbare temperatuur in woonkamer en keuken bedraagt 21 °C
	De minimale haalbare temperatuur in slaapkamers	[Z] °C			De minimale haalbare temperatuur in slaapkamers bedraagt 18 °C
	In de woonkamer en slaapkamers bedraagt de maximale luchtsnelheid (tocht)	[V] m/s			De maximale luchtsnelheid bedraagt 0,15 m/s conform NEN 1087.
	Het maximaal onderling temperatuurverschil tussen ruimteluchttemperatuur, stralingstemperatuur en temperatuur van de ventilatiestroom bedraagt	[T] °C			Het maximaal onderling temperatuurverschil tussen ruimteluchttemperatuur, stralingstemperatuur en temperatuur van de ventilatiestroom bedraagt volgens NEN 1087 5°C
	Maximaal aantal uren boven de 26 °C in de zomer in verblijfsruimten en slaapkamers	[H] uur/jr			150 uur wordt beschreven als maximum in ISSO 74, thermische behaaglijkheid.
	Beoogde beoordeling (rapportcijfer tussen 1 en 10) van de bewoner				Dit wordt middels enquête vastgesteld
Binnenmilieu	Ventilatie conform bouwbesluit nieuwbouw of bestaande bouw?	nieuw / bestaand			Het verdient de voorkeur de Nieuwbouweisen voor ventilatie te volgen.
	Indien de woning wordt voorzien van mechanische luchttoevoer en -afvoer	Ja/nee			Het verdient de voorkeur dergelijke ventilatiesystemen uit te voeren met 100% bypass en conform ISSO 62

Figure 4.8.

on extreme levels of insulation and airtightness to have enough roof surface available for this household demand in addition to the building related demand. It can be noted that a pure building related energy and material optimization might have led to a different concept.

Energy saving by inhabitants in the Stroomversnelling/NOM approach is not actively stimulated beforehand, although information is provided. It must be mentioned that the NOM principle implies that in case people reduce demand below the set standards afterwards and as a result have a positive energy balance at the end of the year, they will be refunded for the delivered energy in the current business case. This is done according to the current feed in the tariff structure in the Netherlands. There is much discussion about this scheme considering whether the consecutive governments will maintain it. Although it is not directly intended, in fact, the 2 700k Wh scheme puts a cap on the household energy demand. It is open to question whether this 'accepted level of consumption' can be sustained in future with tougher CO_2 targets in place.

DELIVERY AGREEMENT – BLUE TABLE

Now what if inhabitants leave the windows open in winter (i.e. willfully disregard the intended operation)? These kinds of questions are the main regulatory problems to tackle, not the technical ones.

With regard to opening windows, the chosen approach is aimed to guarantee a fixed-energy bundle for operational energy with a set standard of comfort and performance. This poses another question: How to monitor the fact that energy increase is not related to malfunctioning of the equipment? This requires a monitor protocol, which is now being developed. Based mainly on the long distance data gathering from the outdoor engine it is easy to check equipment without disturbing inhabitants. It is intended to help guide the inhabitants, when a strange data series pops up: The inhabitant can receive an e-mail informing that his/her energy consumption is unusually high.

But to monitor and evaluate, you need to know not only how much energy is involved, but what in fact is delivered and guaranteed as 'performance'. Part of all this is of course a clear understanding and agreement with the inhabitants on what should be guaranteed: A so-called Blue Table[6] is in place, listing all terms and conditions that are legally binding for the performance contract. It contains a number of indicators, for example:

- minimal available renewable energy for household use;
- maximum required energy for building related demand;
- amount of hot water at *x* degrees at tap points;
- the minimal indoor temperature which the system guarantees;
- maximum difference between air temperature and radiant temperature;

6 Link to the Dutch version of the Blue Table: http://www.svbrabant.itscreative.nl/downloads/index.php?file=20150217%20Blauwe%20tabel%20prestaties%20uit%20Afnameovereenkomst-16-2-2015.docx

- maximum number of hours of temperature above *x* degrees in summer;
- maximum CO_2 levels for certain % amount of time.

In fact, this also includes minimal PV panel output throughout the years. This is the reason why most systems are somewhat overpowered. It has already been experienced in the first pilots that a certain margin in performance should be allowed, so that inhabitants occasionally can heat above the agreed levels.

DISPUTES

Regardless of how well you arrange things, there will be disputes. One of the measures to tackle this challenge is to have a certification and labeling scheme installed, an independent evaluation of what is delivered by the market parties. In March 2017, the first 'NOM labels' were issued for different concepts used by the parties involved in the program. In fact, there were three labels, one for NOM products design, one for NOM product application, and one for NOM product maintenance. This is also done to safeguard the approach, since others outside the formal program are also developing market offers for NOM houses, sometimes employing different approaches. This is done to protect the entire program scheme. Certainly, a dispute settling protocol is needed, which is still under development.

The first results are encouraging; a survey of the inhabitants of the pilots showed that the average score awarded to the retrofit was 9 out of 10, the lowest scores were obtained in the category "honoring agreed commitments", 3 out of 10. This, in its turn, has already led to using an adapted approach on site: The workers won't leave until complaints are addressed!

'ENERGY NEUTRAL' APPROACHES: HEATING

So far this article addressed mainly zero energy approaches. But there are other ways, such as the energy neutral approach: the total is zero, but it can also be derived from (controlled) local solutions, outside the buildings boundaries. This approach makes a less rigid focus on the individual house, it rather introduces more neighborhood or district oriented solutions. These could be interesting from a materials perspective helping avoid the rebound effect from energy impacts to materials impacts. The main issue here is the heat supply. One of the options could be district heating, however, it often depends on unreliable heat sources. For instance, it may be waste heat from industries, which is only available as long as the industry has a very inefficient organization of its production process. If the industry invests in energy efficiency measures, the waste heat source will eventually run dry. Or in case of long-term heat supply contracts, the industry is impeded in becoming more efficient (lock in).

Biomass as a fuel for heat-plants is popular in some countries. It depends of course on the availability of biomass not compromising agricultural land use, or resulting in deforestation. Currently there is also much debate about the CO_2 effect: indeed, using wood could be carbon neutral, the tree is replaced, but only after 40 or 50 year. This implies that at least the first 40 years the trees cut and burned will add to the CO_2 emissions.

Another promising way is to use shallow or deep soil heat. Deep soil heat generated using aquifer technology is an interesting option, which becomes feasible when applied on street or neighborhood level. An even simpler approach is shallow soil heat: a basic piping grid (potentially made of small tubes from bio-based plastics) applied at minus two meters (depending on the local situation), which can provide basic heat at 7–12 degrees all year round. It is of course difficult to have such a grid placed under an existing building, but in the period ahead of, say, 35 years, all roads at some point will be replaced or re-paved. That could be a natural moment to install such heating grid and connect the houses to the grid sections in front of them. It requires a multi-stakeholder approach, but it could be very effective. The retrofit project would become a two-phase process: During the first step, only roofs would be retrofitted, insulated and covered with PV on the top, which would directly reduce CO_2 emissions by the household without changing or interfering with their housing habits. During the second stage, heating is addressed at any moment, since the grid is in place and could be connected when new inhabitants move in. This has not been piloted yet, but it demonstrates that a business case is one thing but optimizing should be considered not only from the operational point of view (and from one building perspective), but also from an effective materials investment point of view. New business cases and cooperation partnerships would be needed.

Another interesting development is that poly-crystalline PV panels may become obsolete and be replaced by thin film technologies, which by now already are stable in producing 12–14 % efficiency [Jager 2016]. There will be many more efficient materials that more flexible in applying to roofs, as well as on facades. Again, a detailed study should compare all these concepts in development.

RECENT DEVELOPMENTS

INFRARED PANELS

There is one technical option that is hardly used, addressed or researched: heating with infrared radiation panels (used in the Urgenda retrofit approach). These fit in an all-electric concept and can have interesting features, like only heating when people are around, and requiring reduced air temperature levels since heat radiation levels are higher than normal. There are some promising pilots carried out, but it requires a solid and robust research program to have all the ins and outs documented.

HOUSE EXTENSIONS

The retrofit options that include household energy reduction and little behavior change sometimes face the problem of the lack of surface to install PV panels. This situation is similar to multifamily houses that have less surface per household available and have limited options for installing enough PV elements. However, smaller outside facade surface per living unit is of course a positive aspect, related to less heat loss through walls.

In case of single-family houses, we see some first initiatives to offer house extensions as a carrier for additional PV, like green houses, pergolas and the like. This is a doubtful trend, since it is necessary to supply the original house, while at the same enlarging the useful surface and (potentially) energy demand for lighting and in some cases heating. It also intensifies the rebound effect of the embodied energy, since more construction work is performed. It might seem a better solution to find nearby locations for PV panels, or have joint solutions at the neighborhood level for these cases (and/or have demand reduced beforehand).

RESEARCH

The research on large-scale prefab solutions has intensified. In preparation for a MORE-CONNECT contribution to the International Conference Transition 0 in Utrecht in 2016, (a MORE-CONNECT

MORE-CONNECT	Prefab retrofit in 5 climate zones: techn. dev. & EU Guidelines	http://www.more-connect.eu/
Refurb	Refurb gives an overview in a one-stop-shop model	http://go-refurb.eu/
BERTIM	Building energy renovation through timber prefab models	http://www.bertim.eu/
Breasar	Cost-effective, adaptable and industrialized "envelope system"	http://www.bresaer.eu/
NewTREND	Design methodology to improve the existing European building stock	http://newtrend-project.eu/
OptEEmAL	Optimized Energy Efficient Design Platform for refurbishment	http://www.opteemal-project.eu/
INSITER	Self-inspection techniques and quality check for efficient constr. processes	http://www.insiter-project.eu/
E2VENT	Integration of an innovative adaptive ventilated façade system	http://www.e2vent.eu/
HOMESKIN	Advanced Aerogel-Based Composite material insula for insulation materials	http://homeskin.net/
MODER	Business models for efficient refurbishment	http://www.vtt.fi/sites/moder/
CREATE	Developing a compact heat storage	no website
BUILD UPON	Design and implement strong, long-term national strategies	http://buildupon.eu/
Europhit	EnerPHit Standard as the goal and Passive House principles as the basis	http://www.europhit.eu/
REVALUE	Develop a set of norms, standards and policies for the valuation of EE property	http://revalue-project.eu/
Rennovates	Systemic deep renovation concept using smart services	http://rennovates.eu/
Energiesprong UK	Mass housing retrofit removing institutional barriers	http://www.energiesprong.eu/
EU-Gugle	(FP7) Nearly-zero energy building renovation models in 6 pilots	http://eu-gugle.eu/
Cohereno	(FP7) Develop high efficiency refurbishment of single-family houses	http://www.cohereno.eu/about.html

Table 4.4. 2016 EU H2020 projects related to large scale prefab retrofits.

session on retrofitting the EU), an inventory was made on how many EU funded projects were related to large scale and prefab oriented retrofit for zero and nearly zero houses. Already 17 major H2020 projects were identified (in early 2016), all long-term four-year multimillion projects (Table 4.4). The body of knowledge is growing as well as the urgency to act in this field, recognized by the EU. It will still require serious research into the environmental impact consequences of all options, since we want to avoid ending up solving the energy issue, when we find out that the materials impacts is greater than energy saving. In my view, this is the most important task to address in future.

CONCLUSIONS

Building for ages has been a 'one-time investment' market, with longevities beyond someone's lifetime. That is changing. Just like other sectors are forced to develop new business models, so has the building sector. And now we are witnessing the moment when walls, roofs and a complete building become a commodity, just as other building and housing elements before [Rovers 2015]. As described in this paper, market organization and business models will be turned upside down.

Delivering panels and doing retrofit on site do not pose considerable difficulties, this area is developing fast and is getting actively improved. The real innovations come from two other areas: re-inventing the regulatory and institutional framework around housing, and secondly, innovating the supply chain. In order to speed up production and reduce costs of prefab retrofits, it is necessary to change from a (single) project orientation to a (continuous) production process organization (at least part of the market).

The structure of the construction industry is changing. There are efficiencies to be gained by moving more production away from the site to larger organizations with a minimum amount of time spent on site to fix the new panels and new 'service boxes'. In other words, the construction industry might move away from a craft-based industry to a service based industry with the products made off-site and just bolted into place.

In the field of regulative framework and financial arrangements, the development is fast, procedures are adopted, financing schemes are designed, and formats are developed. The supply side development is going slower than expected, mainly due to the fact that construction firms still have difficulties in connecting to the component industry, and vice versa. Jan Kamphuis from BJW, one of the consortia performing NOM retrofits (a MORE-CONNECT partner), shares his experience in this area, "Suppliers of components also have to learn how to produce for a process market: As prefab element builders we want different specs than those they used to deliver to the construction site."

After having optimized the work on site, the next step is to optimize the production of the prefab elements. Supplier cooperation is required to minimize costs in the factory. First talks between suppliers and panel builders are now ongoing.

The concept of NOM retrofits as in "Stroomversnelling" is gaining interest, and in 2016 a UK-France proposal led by Energiesprong received funding from the EU for building a similar organization as in the Netherlands to introduce Energiesprong /Stroomversnelling approach in England and France. A consortium has already been formed in England to have a quick start.

In cooperation with RiBuilT/SBS center I am involved in developing a similar initiative for Ireland, as well as for Scotland. However, it must be pointed out that apart from retrofit, Ireland is in urgent need for new houses. There is a big shortage at the moment, and it could be even more interesting to introduce NOM concepts right from the beginning.

We are only at the beginning of this major change. We are still to see how, for instance, 3D printing will fit in this new market as an alternative approach; there are interesting pilots running at the moment. All those changes will be accelerated by the increasing pressure from such global challenges as climate change and scarcity of resources. A drastic reduction of CO_2 emissions of 255 million houses in the EU is at stake, and the time is running out: Climate change will not wait for us to act, and it is going even faster than expected. It was stressed in March 2017 in the paper by 19 scientists headed by James Hanssen, who made the following conclusion, "We have a global emergency. Fossil fuel CO_2 emissions should be reduced as rapidly as practical." [Hansen 2016] The old model will not work anymore.

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Additional material (videos and websites)

2012–2013

First project – Retrofit in 10 days, in inhabited situation, near-0: https://www.youtube.com/watch?v=mvEOQTxFRYE

This was the inspiration to move to faster retrofit and real net zero retrofit. The program started under the name ("green deal"): Stroomversnelling,

2014

First pilot net-0: Jan 2014: https://www.youtube.com/watch?v=BvXVVQZ_hso

The first pilot, English version: https://www.youtube.com/watch?v=6b22xNw_fFU

Short lecture in English from 2014: https://www.youtube.com/watch?v=IYIa_JlcR3o

This was the basis for an international EU proposal: Transitiom-0, now granted: see below "English"

One of the first pilot houses, showing the labor intensive prefabrication: (Arnhem): https://www.youtube.com/watch?v=qRCGZ6Y0ooc

Another 1st series pilot, (Nieuw Buinen): https://www.youtube.com/watch?v=UyEKBVEdgpM

1st multi-family house: https://www.youtube.com/watch?v=nHu52TMuGXo

The step to new housing construction: Building netZEB houses in one day: https://www.youtube.com/watch?v=G0nyZFYCF-I

2015

Renovation in one day, by Volker Wessels Building Company: https://www.youtube.com/watch?v=I3WBT2eAArI
Pilot in Tilburg: https://www.youtube.com/watch?v=B_vLFZImCDw

2016

Second generation pilots: (Roden) https://www.youtube.com/watch?v=cBDuBjZt9gU

General

Website for the partners in the Stroomversnelling program: http://stroomversnelling.nl/
Website with photo documentation on all projects: https://www.flickr.com/photos/140019931@N07/albums
Website as knowledge base for the projects (standard contracts, performance statements, financing, etc.):
http://www.energielinq.nl/
In English: http://stroomversnelling.nl/initiatief/internationaal/,
http://transition-zero.eu/,
http://www.energiesprong.eu/

MORE—
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5

SPECIFIC RETROFITTING CONCEPTS COMPARED

5

SPECIFIC RETROFITTING CONCEPTS COMPARED

Project Results: Deliverables 2.1 and 3.2
Lead author: TARGO KALAMEES
Co-author(s): JOHN VAN OORSCHOT

5.1 INITIAL PERFORMANCE CRITERIA AND REQUIREMENTS FOR HOUSING RETROFITS (DEL 2.1)

5.1.1 INDOOR CLIMATE

Calculating energy performance of buildings, outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness should be taken into account. The requirements with regard to general indoor climate conditions state that such possible negative effects as thermal discomfort, inadequate ventilation, moisture damages, overheating, loud noise from traffic and building service systems, inadequate natural light, etc. should be avoided.

There are national and international standards and technical reports, which specify criteria for thermal comfort and indoor air quality (CR 1752, 1998; EN ISO 7730, 2005), where the thermal comfort criteria for the heating season (cold/winter) and cooling season (warm/summer) are listed. Criteria for local thermal discomfort such as draught, radiant temperature asymmetry, vertical air temperature differences and floor surface temperatures should also be taken into account in building design; these criteria can be found in EN ISO 7730.

Indoor air quality in residential buildings depends on many parameters and factors, e.g. the number of persons (time of occupation), emissions from activities (smoking, humidity, intensive cooking), emissions from furnishing, flooring materials and cleaning products, hobbies, etc. Table 5.1 presents the national design values for the indoor air quality for residential buildings in the MORE-CONNECT countries. For extra levels, see (EN-15251, 2007).

5.2 ENERGY PERFORMANCE OF BUILDINGS

The Energy Performance of Buildings Directive recast (EPBD recast, 2010) sets ambitious goals for the building sector to reduce energy use and greenhouse gas emissions. According to the Directive, the Member States shall ensure that by 31 December 2020, all new buildings are nearly Zero-Energy Buildings ((n)ZEB); and after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings. The revised EPBD strengthens long-term national renovation strategies to reach a “highly energy efficient and decarbonized building stock” by 2050 and requires Member States to specify how renovation strategies “contribute to achieving the Union’s energy efficiency target”.

Energy need represents the energy needed in a building for heating, cooling, ventilation, domestic hot water, lighting and appliances, Figure 5.1. Energy need for heating is caused by heat losses and is reduced by solar and internal heat gains. Net energy need is the energy need minus heat gains, i.e. thermal energy without any system losses needed to maintain indoor climate conditions. Electrical energy is needed for the lighting and appliances.

5.2.1 ZEB, ZERO ENERGY BUILDING

This section presents analysis of the requirements set for modular elements to meet the following targets: ZEB i.e. Zero Energy Building = the primary energy use = 0 kWh/(m^2 a) (on the annual basis) for:

- space heating (+ pumps);
- space cooling;
- ventilation (heating, cooling, fans);

Indoor air quality criteria	Geo-cluster and country						
	GC 1	GC 2		GC 3	GC 5	GC 6	Switzerland
	Denmark	Estonia	Latvia	Czechia	Portugal	Netherlands	
Heating season (cold/winter)							
General air change rate h^{-1} $l/(s\ m^2)$ $m^3/(h\ pers)$	0.5 0.3	0.6 0.5, 0.42 (detached house)	0.6	0.5 25	Winter: 0.40 h^{-1} Summer: 0.60 h^{-1}	0.7	0.19
Supply air to living room and bedrooms l/s, pers	7.0	6.0	4.2	6.9	7[2]	7	
$l/(s\ m^2)$	1	1.0	3	-	1[2]	0.7	
Exhaust air flow, l/s a) kitchen b) bathrooms c) toilets	20 15 10	20 15 10	17-25 14 7	[1] 27.8/41.7 13.9/25 6.9/13.9	20[2] 15[2] 10[2]	21 14 7	11-167 <8-11
Corresponding CO_2 above outdoors (400 ppm), ppm	N/A	800	Not defined directly	1100	Maximum concentration [3] 984 ppm	800	600-1000
Recommended ventilation during unoccupied hours, $l/(s\ m^2)$	N/A	0.05-0.1	N/A	0.1 h^{-1}	N/A	0.1 h^{-1}	0.14

Table 5.1. National design values for the indoor air quality for residential buildings in MORE-CONNECT geo-clusters and countries.

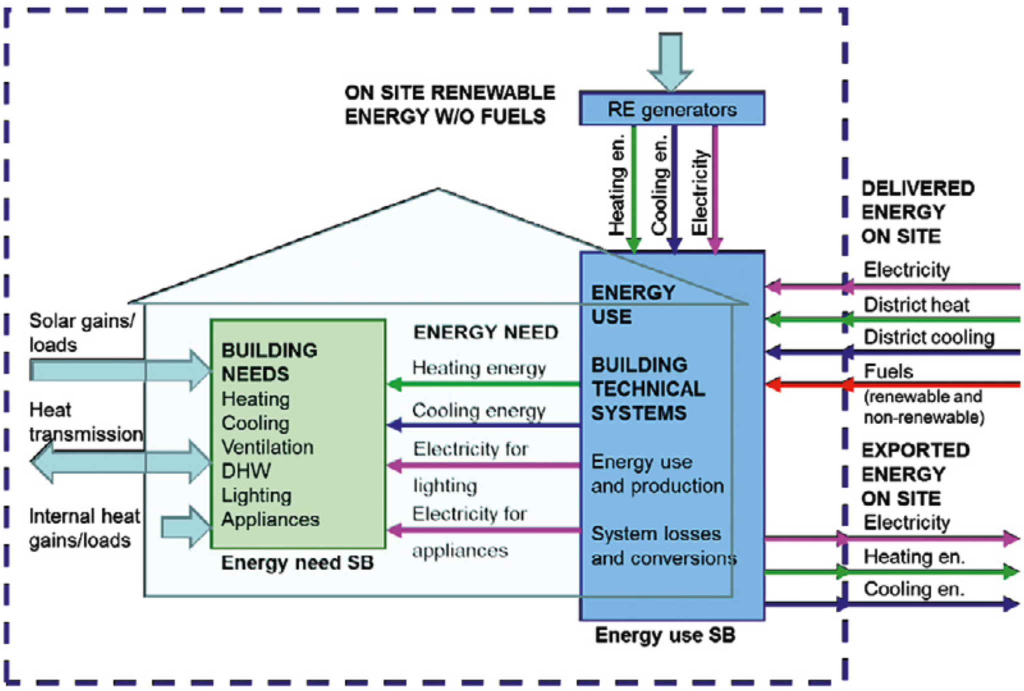

Figure 5.1. Energy boundary of net delivered energy and how it is formed from energy need, energy use of technical building systems, on site renewable energy production, delivered energy and exported energy. The box of "Energy need" refers to rooms in a building and both system boundary lines may be interpreted as the building site boundary (Kurnitski et al., 2011).

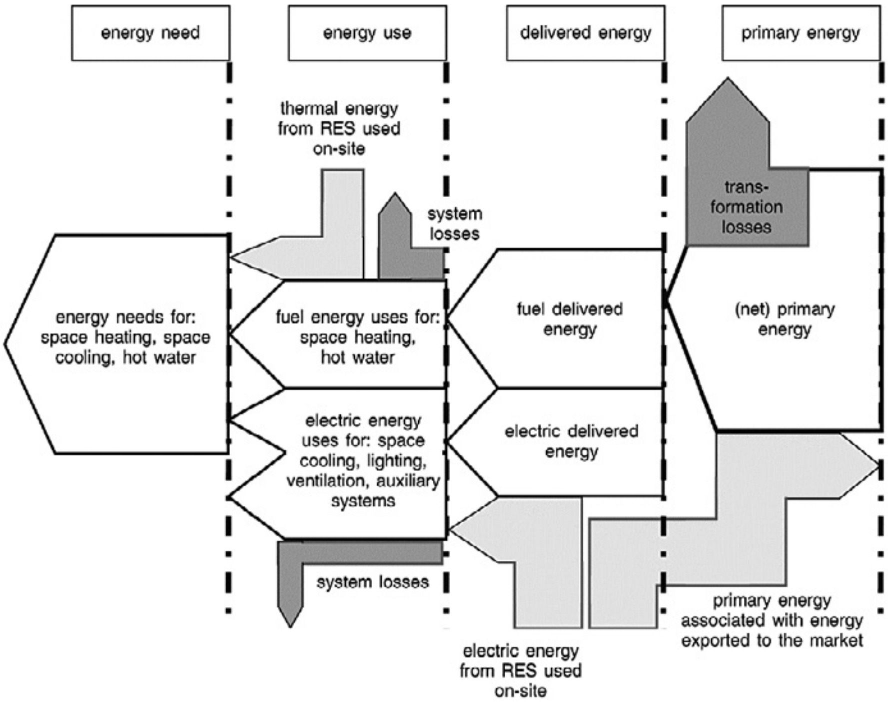

Figure 5.2. Schematic illustration of the calculation scheme (EC 2012/C 115/01, 2012).

- domestic hot water.

The indoor climate and energy simulations were conducted for six reference buildings applying the corresponding national energy simulation methodologies and requirements. All input data used in energy calculations represent the typical case of that GC and specific country and is defined by the partner:

- The heat source for room heating and DHW (from 5 °C to 55 °C) (Table 5.1);
- Information about outdoor climate (Table 5.1);
- Primary energy factors (Table 5.1);

ZEB (Zero Energy Building = the net use of primary energy on the annual basis = 0 kWh/(m^2 a)) requirements (Table 5.2, Table 5.3) for space heating and cooling, ventilation, and domestic hot water.

Requirements to building envelope vary depending on the requirements with regard to indoor climate and energy performance in a specific country, outdoor climate, availability of renewable energy, and building typology.

Thermal transmittance of modular wall panels for nZEB was ≈5 % from the pre-renovation thermal transmittance in Latvia (U_{EW}.ZEB ≤ 0.19 W/(m^2 K)), ≤10 % in Estonia (U_{EW}.ZEB ≤ 0.11 W/(m^2 K)) and up to 50 % in Portugal (U_{EW}.ZEB ≤ 0.47 W/(m^2 K)). This shows that panel manufacturers may face difficulties trying to develop a single product for the whole Europe. Differences in climates and national regulations are the reason why different requirements are put forward thermal transmittance of the building envelope. The strictest requirements regarding thermal transmittance of the building envelope are effective in Denmark and Portugal, whereas these requirements are the lowest for nZEB. As regards the roof, the decrease of thermal transmittance was smaller mainly due to smaller thermal transmittance before renovation.

Results point at the difficulties in reaching ZEB performance in multistory apartment buildings in cold climate, as there is no enough space to install equipment for energy production on site.

This chapter provides a general insight into the ambitions for *'zero-energy housing retrofits with low embodied energy"*, and how these ambitions could be translated into different actual and practical building retrofit approaches. Below there is a short list of approaches compiled based on the experience of the Netherlands. It is in a way limited since many more approaches are possible.

1. 'pure supply';
2. entire makeover ('Energiesprong/'NOM');
3. 'modular';
4. individual case optimization ('Urgenda');
5. 'summer/winter house';
6. hybrid/'gas phase out';
7. passive-unheated.

1. **Pure Supply:** Nothing is essentially changed at the house/construction level, energy requirements are fully met by extensive

Properties of the building	Geo-cluster and countries whose national energy calculation methods were used					
	GC 1	**GC 2**		**GC 3**	**GC 5**	**GC 6**
	Denmark	**Estonia**	**Latvia**	**Czechia**	**Portugal**	**Netherlands**
After renovation, ZEB						
Buildings need (net energy), kWh/(m^2·a)						
Space heating	2.2-7	2.9	4.0	6.1	16.1	36.6
Space cooling			---	-	3.2	-
Ventilation	incl. above	4.3	5.3	incl. above	15.0	6.8
Domestic hot water	14	30	56	25.7	29.3	24.9
Appliances, lighting	-	29.5	3.6	6.4 lighting	-	12.8
Fans, pumps	1.59	6.5	9	-	-	9.7
Delivered energy (energy use by technical systems with systems losses) net energy, kWh/(m^2·a)						
Heating	7.2-12	3.0	4.3	10.5	3.9	9.2
Space cooling				–	0.9	-
Ventilation	Incl. above	4.4	5.3	1.3	3.7	1.8
Domestic hot water	14	30	56	34.7	33.7	6.2
Appliances, lighting	-	29.5	3.6 lighting	6.4 lighting	-	3.2
Fans, pumps	1.59	6.5	9	0.2	-	0.2
Produced energy on site, kWh/(m^2·a)						
Solar collectors (heat)	9.5	21	29.3	0	10.4	
PV panels (electricity)	7.14	55.4	39.5	10.9	14.3	114
Heat pump		12.1		0	0	
Primary energy use, kWh/(m^2·a)						
Energy performance value, kWh/(m^2·a)	0	0	0	0	0	-82

Table 5.2. Results of indoor climate and energy simulations for ZEB.

renewable energy production and, if required, installation of additional equipment. Supply can be met on location (zero energy) or off location (energy neutral). Basic reduction measures could be included, like double glazing and cavity wall insulation.

PROS: the approach does not change inhabitants' use of the house, there are no disruptions; no change of architecture, if combined with basic reduction measures; zero operational fossil energy (building related); behavior adaptation is not required (but possible).

CONS: requires change for all electric equipment; possibly not enough roof surface for all PV (especially when household demand is addressed); no incentive for behavior adaptation (reduced demand).

2. Entire 'makeover'/Energiesprong/NOM

The house is completely renovated, new facades and roof are installed. Meeting the passive house level standard, all electric outfit is ensured. All roof surface is used for solar panels. Building as well as household energy consumption is covered. No change in lifestyle is required. Prefabricated elements are installed and retrofit is carried out in a few days.

PROS: Creates more or less a 'new house'; up to 50 year extension of useful life; zero operational fossil energy (building and household related); all measures in one phase; inhabitants do not need to move; covers near-future maintenance.

CONS: change for all-electric; whole house comforted: lock in inhabitant behavior; large EE-rebound effect; (still) too expensive; no option for heritage buildings or special "architecture".

Properties of the building	Geo-cluster and countries whose national energy calculation methods were used					
	GC 1	**GC 2**		**GC 3**	**GC 5**	**GC 6**
	Denmark	**Estonia**	**Latvia**	**Czechia**	**Portugal**	**Netherlands**
Thermal transmittance before renovation, W/(m² K)						
U_{wall}	0.14	0.08	0.08	0.21	0.47	0.18
U_{roof}	0.11	0.06	0.08	0.15	0.32	0.15
U_{floor}	0.34	0.15	0.11	0.27	0.86	0.29
$U_{window\ (glass/\ frame)}$	0.7	0.6	0.81	1.0	2.40	1.6
U_{door}	0.7	0.8	0.81	1.0	2.40	2.0
Linear thermal transmittance, before renovation W/(m K)						
$\Psi_{wall/wall}$		0.08	0.08	total influence of thermal bridges / couplings ΔU = 0.02 W/(m² K)	0.50	0.10
$\Psi_{roof/wall}$			0		1.00	0.10
$\Psi_{floor/wall}$	0.3	0.17	0.10		0.50	0.24
$\Psi_{window/wall}$	0.1	0.02	0.05		0.25	0.06
$\Psi_{door/wall}$	0.1	0.02	0.05		0.25	0.24
$\Psi_{balcony/wall}$		0.02	0.10			
Airtightness of building envelope before renovation q_{50}, m³(h m²)	2.4	1.5		1.5		
Ventilation						
Heat/cool recovery, %	90	85	85	80	-	95
Ventilation airflow, l/(s m²) Renovated case represents indoor climate category II	0.34 0.5 ach	0.42 0.6 ach	0.82 1 ach	0.21 0.3 ach	0.55 ach in winter 0.6 ach in summer	0.47
Specific fan power, W/(l/s)		1.5	1.25	1.5		Peripheral ventilation
Heating syst. with its efficiency	D.H 100%	0.97	0.97	biomass boiler 0.76	HVAC 4.1	Radiator 1.0
Renewable energy sources				FV		
Solar collectors for DHW, m²	2	180	285	0		0
Solar panels for electricity, m²	4	1500	1200	257		39
Coefficient of performance of heat pump if it is used	-		-	-	4.1	
Indoor temperature						
During heating period	20	21	21	20	18	20
During cooling period	23	<27	no control	no control	25	n/a

Table 5.3. Requirements to building envelope and ventilation for ZEB.

3. **Modular:** Comparable with Energiesprong/ NOM, only performed in phases and with modular components. Investments can be spread over many years.
   PROS: same as in 2;
   CONS: same as in 2.

4. **Individual case optimization / 'Urgenda'**: a personalized approach with any mix of measures aiming for zero energy: inhabitants can choose to adapt behavior, or limit energy demand beforehand, accept a somewhat different comfort experience, apply a basic set of reduction measures (cavity wall insulation, double glazing) plus the mix of installation measures: all-electric, usually a heat pump combined with infrared heating.

PROS: "personalized"; less expensive as "an entire makeover" (2, 3); including potential demand reduction beforehand (behavior, use of the house); flexible (demand reduction afterwards is possible by adapted behavior),

CONS: mainly all-electric; normal maintenance remains.

5. **Summer/winter house**

Summer/winter house concept: compartmentalization of the house, only the core of the house is kept at comfort levels during the coldest periods, or cooled during the hottest periods, only the core is retrofitted for zero energy performance. Outside the core, basic on demand heating can be available (infrared panels for instance) (in fact, it is an extreme version of 4).

PROS: less expensive; large demand reduction; low materials rebound effect; low impact on grid use; flexible, see also 4.

CONS: requires adaptation of inhabitant habits to adopt new use and comfort levels; still some issues to be solved (cold bridges); normal maintenance remains.

6. **Hybrid** / (Gas Phase Out concept):

Only basic measures (cavity wall insulation, double glazing) are implemented and a small heat pump is added in hybrid operation with the existing heating system. PV are installed on the roof, or the remaining need is covered by buy-in of a renewable energy as in case of the "energy neutral concept".

PROS: this solution can create a noticeable effect in the short term: millions of houses can be adapted this way in just a few years, making a significant contribution to CO_2 targets in the short term. Only limited rebound effect (EE), no comfort or behavior adaptation is required. Can be applied at any moment.

CONS: not directly zero energy, requires additional measures to be implemented to ensure zero energy performance in future, no reduction from inhabitant behavior.

7. **Passive -'unheated'**

A passive level house retrofit combined with large investment in installations is not an optimal approach from the embodied energy point of view. The optimum solution is lower insulation levels with some more PV panels added. However, with passive house concepts in moderate climates, there is hardly any heating required. The most likely situation that is often observed in practice occurs when inhabitants refrain from heating accepting an indoor temperature of 18 degrees in the coldest yearly period, and ventilate by opening the windows. This would make any investment in installations/ equipment obsolete and justify considerable (embodied energy) investments in insulation measures. It also prevents PV panels to be installed (for building related energy). 18 degrees so far are generally perceived as uncomfortable temperature, but comfort boundaries might need adaptation considering the latest research results.

This option is mentioned to make this overview comprehensive; it has not been calculated or researched. The option should be investigated for some climatic regions considering inhabitants/ clients that have an open mind for progressive climate adaptation behavior as the target audience.

PROS: no operational energy demand, no impact on grid, no requirement for solar panels, less expensive, whole house comforted (within the wider comfort boundaries), naturally ventilated.

CONS: no back-up heating, strong inhabitant adaptation required, ventilation by inhabitants.

Relation to MORE-CONNECT

The main focus of the MORE-CONNECT project is made on providing prefab panels for mass construction for several housing types in six geo-clusters. As such, it is related and supportive of several of the above-mentioned concepts, mainly the ones that involve facade and roof makeovers: 2, 3, 5 and 7. All these concepts make use of prefab components for the whole house or its part.

However, MORE-CONNECT relates mostly to the "entire house makeover" – NOM Energiesprong – and aims to generalize the approach and standardize the elements for use in more than one climate zone. As such, it tries to address such disadvantages as cost and embodied energy rebound effects.

5.3 CRITICAL (NON-TECHNICAL) ISSUES

Within all retrofit approaches there are critical issues to be addressed at the housing level, at stock level or at grid level. Some of the most important are listed below.

The Cost: Costs or investments are of course a critical issue, especially since the focus is ultimately to retrofit the whole European housing stock. Without providing or searching for the solution within the scope of this projects, there are several ways to bring the cost down (in the random order):

1) change tax system; 2) reduce amount of work; 3) reduce material investments; 4) reduce comfort levels; 5) reduce living space to be retrofitted (is also related to comfort); 6) upscaling of production.

There are also many differences among the countries with respect to tax measures, energy feed-in tariffs, and pay-back periods for loans, which together create differences in the ways retrofits are financed.

Speed: To have the whole housing stock retrofitted and performing at zero or nearly zero energy levels (operational fossil fuel related energy) requires a sufficient speed. With around 250 million houses in Europe, that means 10 million a year have to be CO_2 tackled by around 2045. It is open to question if we have enough workforce available in the construction sector to manage that task, especially if we employ labor or production time intensive concepts and want to avoid creating too big rebound effects in materials and production energy. This is critical, since fast and large (total stock) CO_2 reduction is the ultimate goal of this work. Ways to address this include 1) reducing work; 2) reducing retrofitted space; 3) introducing no regret phasing with easy and noticeable effect measures first.

HOUSEHOLD DEMAND

Most concepts address the building related energy, which is logical since there is a direct relation between building related measures and building related operational energy demand. However, when it comes to a household, there is also non-building related energy demand, which somehow should also be covered to limit households CO_2 impacts. This is outside the scope of the MORE-CONNECT project, but this issue still should be addressed to create a future proof housing situation.

ROOF SURFACE

Roof is a critical issue in creating zero or nearly zero energy houses, which all have renewable energy generation provided on site. Roof surface is limited, especially in multifamily buildings, and in most cases it is not enough to cover building related energy demands. It becomes even more critical when household energy demand is included. This can have unexpected side effects, like creating more roof surface with new building extensions. These in fact enlarge the living area, and as such increase the rebound effect in materials demand (and pose the risk of being added to the *heated* living area in future). Apart from options reducing demand, there are some other ways to address this issue, for example, to add facade energy generation or create and facilitate neighborhood solutions.

MORE—
CONNECT

6

THE MORE-CONNECT APPROACH

6

THE MORE-CONNECT APPROACH

Project Results: Deliverable 3.2
Lead author: JOHN VAN OORSCHOT
Co-author(s): All co-authors

The MORE-CONNECT approach focuses on refurbishment with prefab facade and roof panels and standard procedures applicable for full house or partial house retrofit. The focus is mainly made on the technical aspects, considering how several solutions can be introduced staying insightful of the client needs. The approach aims to develop a set of solutions for several housing types in several climate zones.

The work is carried out in three main areas: technical, energy supply and economic.

- Technically, it should be feasible and work for different housing types and different combinations of heating and ventilation technologies.
- In terms of energy supply, it should aim for zero energy in the design phase, although in execution it might be nearly zero energy with low embodied energy: solutions should be optimized to prevent a large rebound effect in materials related (fossil) energy consumption.
- Economically, it should be viable.

THE CONCEPT

The MORE-CONNECT project follows Concept 2 discussed in the previous chapter, the NOM/Energiesprong approach, although without the standard inclusion of the household energy. However, it is an option making choices for a geo-cluster on whether to include or exclude it.

In practice, the HH issue comes down to a basic set of PV surface area to be added on a set level of household energy demand in an all-electric approach.

As a result, the focus in MORE-CONNECT is also made on Steps 1 and 2 in creating (nearly) zero energy concepts: energy production and building related reduction. Steps 3 and 4, as well as the change of use and behavior, are not included.

In this chapter, the first (technical) results and choices are described, followed by the summary of experience and recommendations as guidelines for others to follow up presented in the next chapter. This deliverable will be the core document to produce a more elaborated book presenting all technical details and results at the end of the MORE-CONNECT project.

6.1 THE MORE-CONNECT: CONCEPTS OF RENOVATION PACKAGES

This chapter contains a description of five concepts for five different geo-clusters, based on the developments so far within the MORE-CONNECT project. The five geo-clusters are represented by **Denmark / Estonia / Latvia / Portugal / the Netherlands / Czechia.**

6.1.1 DENMARK

Lead author: Ove Mørck

1. The chosen housing type and the underlying rationale

In Denmark, housing generally consists of single-family houses and apartment blocks. Either the use of prefabricated elements or robots for facade and gable wall insulation and finishing would generally not be cost-effective for individual single-family houses. Therefore, apartment blocks are most suited for energy renovation using the technologies developed within the MORE-CONNECT project. The majority of apartment blocks are owned and administered by social housing companies. Many of these apartment blocks were constructed in the 1950-ies to 1970-ies in 3–5 stories. This is the background for choosing one of such buildings as the Danish pilot project, which is one out of seven blocks of a department called "Korsløkkeparken afd. 34" administered by Fyens Almennyttige Boligselskab – FAB. The block selected as the pilot building is referred to as building 34.6. It has 170 apartments, which after the renovation will be turned to 166 apartments. The building is 205 m long and 13.6 m wide and has 5 stories. The total living area is 13 685 m^2 and the basement area is 2737 m^2. The photos below show the Danish pilot building before and during renovation.

2. General strategy chosen to renovate the housing type

Generally, this type of buildings is energy renovated as part of the total renovation plan for the area under consideration, which means all the blocks of the department and the outdoor areas around the blocks are retrofitted. The energy renovation part of this total makeover typically includes the following activities:

- replacement of windows;
- installation of a mechanical ventilation system with heat recovery;
- additional roof insulation;
- insulation of facades and gable walls. Depending on the current conditions of the existing external walls, this additional insulation will be partial or complete.

The replacement of windows and insulation of the facade typically require the use of scaffolding.

Considerations

External insulation of facades and gable walls is costly and is normally only carried out when the condition of the existing walls is rather poor and the walls are in need for repair, for example, with a new external climate protection layer. In this situation, adding a layer of insulation becomes a marginal cost and the costs will be managed by the housing association.

3. Technical concept chosen for renovation

The energy renovation technologies developed as part of the Danish participation in the MORE-CONNECT project include:

- Photovoltaic (PV) roofing elements;
- Robot finishing of an insulated gable walls.

These two technologies are therefore chosen to be part of the total energy renovation concept for the building in Korsløkkeparken, which also comprises:

- replacement of windows;
- installation of mechanical ventilation systems with heat recovery;
- additional roof insulation.

Considerations

The overall energy renovation concept is well known in Denmark, so no special considerations were made.

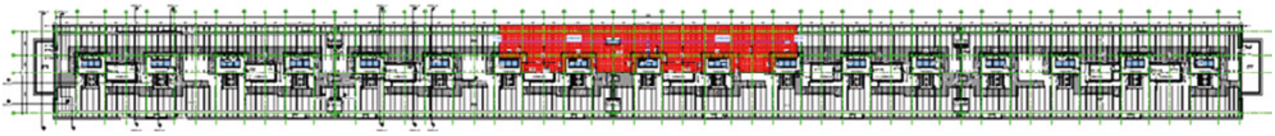

Figure 6.1.

4. Prefab panels

The figure 6.1 shows the placement of the solar photovoltaic panels on a very long building.

The figure 6.2 shows a prototype production of the robot gable wall decoration. The aesthetics will be different within the pilot project.

Figure 6.2.

Considerations

The size and architectural integration are important issues that have been considered in the installation of the PV-roof panels. The size is important because of the Danish legislation with respect to the use of the electrical output of the PV system. In the situations where the produced electricity cannot be used for the operation of the building (pumps, fans, elevators and lighting in the stairwells) it has to be delivered to the grid without any payment. Therefore, the size of the PV system has to match the running operational load of the building. For the insulation of the gable walls and robot finishing, the main considerations included the timing of the general renovation process and the integration with the other wall finishing.

As the implementation of the technologies was carried out in the period from October 2017 to May 2018, it is still too early to make conclusions and reflect on any experience.

This part will be reflected upon in 2018 and added to the final publication.

6.1.2 ESTONIA

Lead author: TARGO KALAMEES
Co-author(s): PEEP PIHELO, KALLE KUUSK

1. The chosen housing type and the underlying rationale

Building type chosen represents a typical multi-storey apartment building made of prefabricated large concrete panels and constructed during the 1960–90-ies period in Estonia, where about 65 % of people live in this type of apartment buildings. The design service life of these buildings was 50 years, which is almost over for the formerly constructed buildings, therefore, these buildings need current renovation. As it is typical of many older buildings, there are several topical problems, such as serious thermal bridges, mold growth at the external intersections of roof-wall, high energy consumption, insufficient ventilation, overheating during winter, unsatisfactory thermal comfort. Fresh air inlet was initially designed through the slits around untightened wooden window frames and natural exhaust via kitchen and sanitary rooms to the central shaft. The building had a one-pipe radiator heating system without thermostats and the room temperature for the whole building was regulated by a heat substation depending on the outdoor temperature.

The pilot building is a 5-storey TUT dormitory building with the total area 4318 m^2, constructed in 1986. The existing 250 mm concrete panel exterior wall consists of two concrete sections and insulation layers: 60 mm external reinforced concrete slab + 70 mm wood-chip insulation layer + 50 mm phenolic foam insulation layer + 70 mm internal reinforced concrete slab. The existing flat roof with parapet is covered with bitumen felt and insulated with wood-chip boards. The thermal transmittance of the existing envelope is $U = 0.9–1.1$ W/(m^2 K).

Therefore, the results of the pilot renovation within the framework of MORE-CONNECT project at Tallinn University of Technology campus in the student dormitory building conducted in 2017 give opportunities to very easily disseminate the results to the existing (and quite large) similar building stock

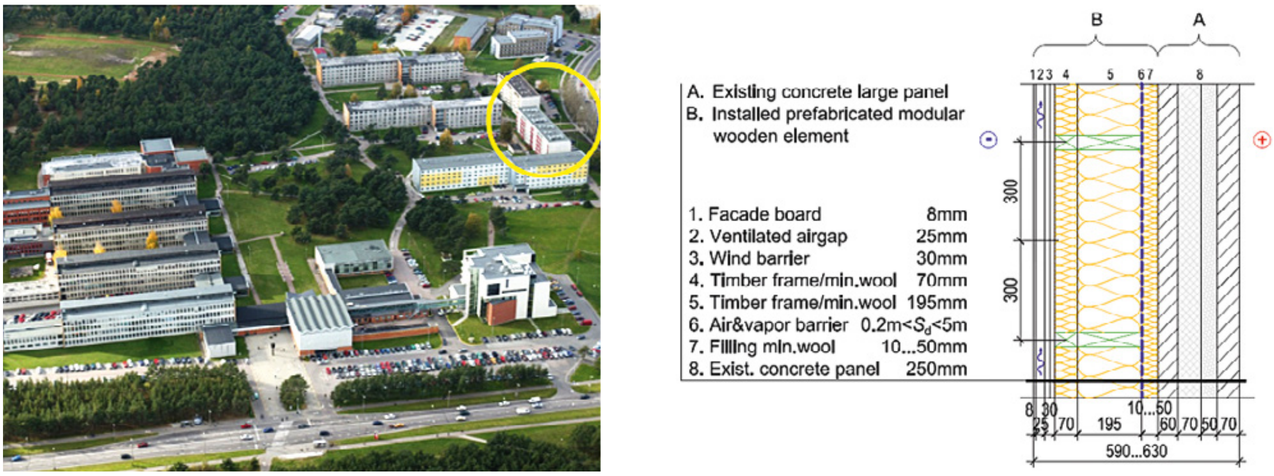

Figure 6.3. Location of the pilot building at TUT campus in Tallinn, Estonia (left) and basic design of wall insulation modules, placed onto the existing concrete wall (right).

and give an input to further development of (n)ZEB design of the integrated and multipurpose renovation of living houses with modular external envelope panels.

2. General strategy chosen to renovate the housing type

The general renovation solution implied that lightweight modular prefabricated panels were installed onto the existing envelope (roof and walls), without demolishing the existing loadbearing structures. The living spaces of flats would be enlarged with the help of closing open balconies with the same modular panels and would be closed with glazing, and thus would become an additional living space. The basement walls were insulated in-situ with an external thermal insulation composite system.

The current aesthetic state is not very demanding as it represents widely used soviet-time concrete multi-storey house building traditions from the 1960–90-ies. The value of a property could be raised via renovation according to the MORE-CONNECT principles (placing a prefabricated facade and roof panels). The quality and time schedule could be optimized thanks to the controlled preliminary installations made at the insulation modules factory (preinstalled windows, facade boards, mold drips, flashings, etc.) and shortened installation period at the building site. It was intended to realize the installation of the modules with help of pulleys (for workers) and with crane (panels lifted directly from the transport vehicle to the installation place).

3. Technical concepts chosen for renovation

In the pilot project, the building envelope was supposed to be insulated and rendered with the help of prefabricated modular renovation elements. To get accurate information about the unevenness and roughness of the existing surfaces of external envelope and inhomogeneity of windows location, 3D laser scanning of the envelope was conducted

Figure 6.4. Pilot building at the renovation stage in summer 2017 (left) and the final overview after the renovation in autumn 2017 (right).

Figure 6.5. Installation of the module panels on the walls (left) and onto the roof (right) in the pilot building in Tallinn, Estonia, in summer 2017.

before the design. Self-supporting modules were hanged onto the existing wall surface with the help of designed fixings, allowing adjustment of the modules in all three directions. Therefore, there was no need for additional foundation for the wall module panels.

The total thickness of a modular element in the current project was 340–380 mm, depending on the surface flatness of the existing wall. To fill the unevenness and roughness of the existing surface, it was planned to add 10–50 mm light mineral wool as a filling layer onto the inner side of the modular element. The timber-frame structure was filled with 265 mm mineral wool in two layers and covered with 30 mm dense mineral wool wind barrier. The 25 mm ventilated air gap was covered with 8 mm finishing hardboard, which also provides a firm rain screen to the structure beneath. For protection from weather impacts during the construction process and from constructional moisture, the inner side of the module is designed to be protected with air and vapor barrier layer.

The designed thermal transmittance of the external wall is U_{wall} = 0.11 W/ (m^2 K) and the airtightness of the entire building envelope is q_{50} < 2 m^3/(h m^2). To avoid thermal bridges and minimize the impact of air leakages, smart connectors and innovative fixings, as well as sealants and polyurethane (PUR) foam will be used at critical joints.

Designed roof elements were installed on the custom built timber structure because the original roof has an inward slope and a parapet. Therefore, technical appliances (e.g. heat exchangers, duct dispensers, automatics etc.) were placed under the formed slope roof in 0.6–1.2 m high attic between the old and new roof. The total thickness of the thermal insulation in the roof modules is 340 mm, U_{roof} = 0.10 W/(m^2 K).

Solution with highly insulated modular panels installed onto the existing concrete wall may prevent moisture dry-out and could pose a higher risk of mold growth. One of the most critical hygrothermal design tasks was the selection of a vapor barrier for the wall module. The most

Figure 6.6. Steel corner brackets for mounting wall modules.

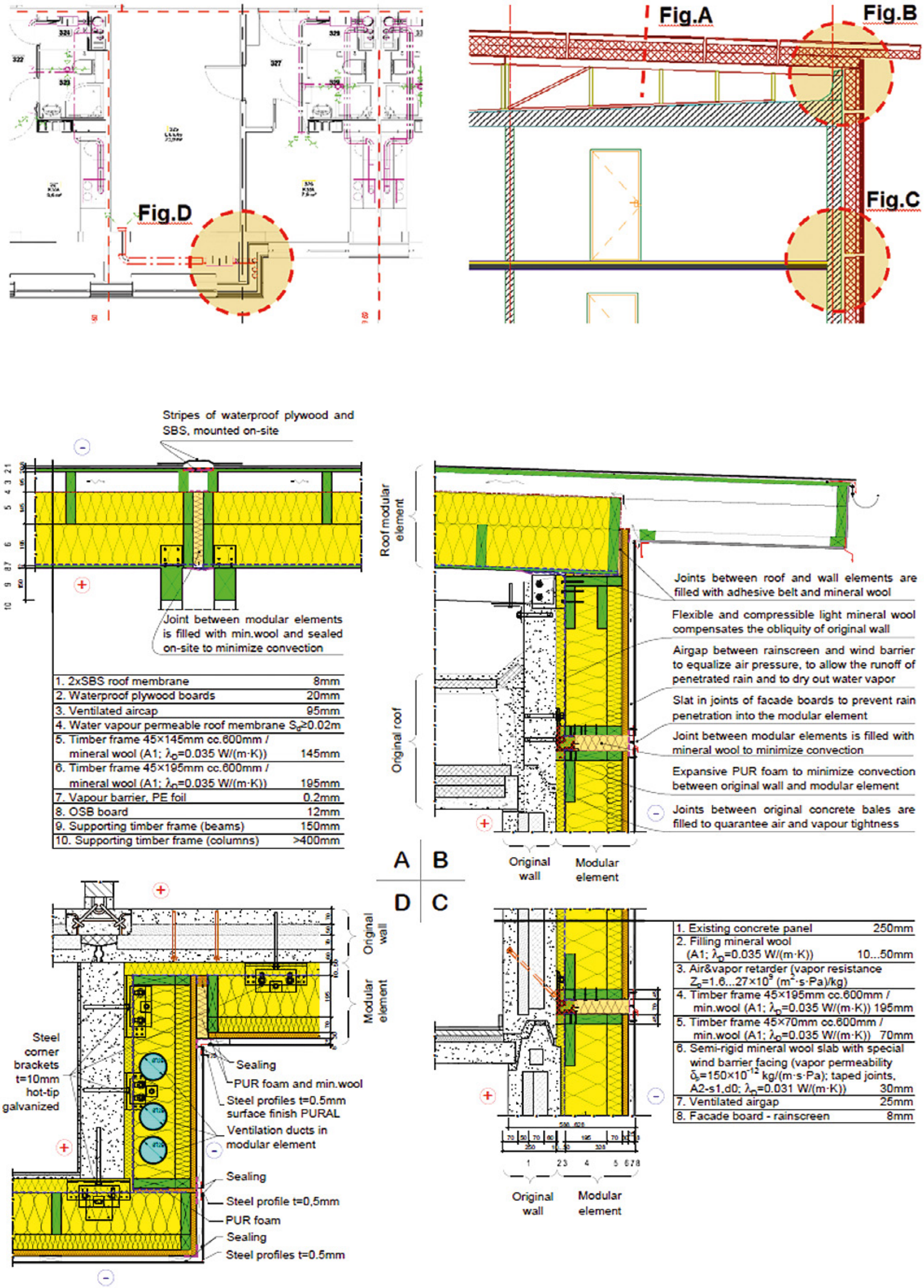

Figure 6.7. Design solutions at different structural points of the (n)ZEB pilot.

Figure 6.8. Well-insulated building envelope with onsite energy production is needed for nZEB.

influential parameters here are a built-in moisture dry-out after the installation of the insulation modules (requires a relatively permeable vapor barrier) and the long-term performance where a vapor-tightening barrier is required because the joints of the original wall would not be air and vapor tight. Cracks and openings in the walls contribute to the uncontrolled moisture flux into the structure. With hygrothermal analysis, it was found that in our region the south-west oriented wall has about 20 % higher moisture content than other sides of the building envelope and considering the impact of the wind-driven rain, the wall has almost 50 % higher moisture content. Analysis showed that the moisture content in the whole external concrete slab is about w = 110 kg/m^3 in the most critical periods, in the last quarter and the first months of the year. The required hygrothermal performance of the studied solutions was ascertained with a smart vapor retarder with changing vapor tightness 0.2 m < S_d < 5 m, when the initial moisture content of the existing large concrete panel was $w \leq$ 110 kg/m^3, or with 22 mm OSB as a vapor control layer, when the initial moisture content of the existing large concrete panel was $w \leq$ 75 kg/m^3, or with PE-foil as an air and vapor barrier, when the initial moisture content of the existing large concrete panel was $w \leq$ 55 kg/m^3.

4. Conclusions

A pilot (n)ZEB renovation of a typical large-panel concrete apartment building was conducted in Estonia. This is one of the first deep energy renovations that has been designed to correspond to the (n)ZEB target for new buildings. In addition to the use of prefabricated modular panels for building envelope insulation, the design solution includes many other tasks to be addressed, including parallel comparison of two different ventilation solutions: apartment based balanced VHR and centralized balanced VHR; parallel comparison of heating of DHW by solar collectors and sewage heat recovery.

The analysis and the whole process of design itself showed that it is essential to consider the initial state of the building when highly insulated module panels are intended to be used for an (n)ZEB renovation. The installation of the wooden modular elements indicated that a substantial thorough initial work (“measure twice and cut once”) and concentration on moisture safety issues are needed. Roof elements must be installed before the wall elements to prevent the wetting of the original external wall due to wind-driven rain and rain from the temporary roof.

The interaction between the design process and the construction work at the building site is of decisive importance and poses a major challenge. Engineers and designers should include hygrothermal modelling into design practices to assure moisture safety of the structures and their sustainability in the long term. The analysis, design and other preparation activities associated with the integrated (n)ZEB design process gave us a unique experience, showing weak links in the chain and helping to prevent major faults in the construction of the pilot and in the further design processes.

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6.1.3 LATVIA

Lead author: ANATOLIJS BORODINECS

1. The chosen housing type and the underlying rationale

The Latvian pilot building is a typical brick multi apartment building built in 1967. The pilot building is a silicate brick residential house with a lateral bearing system. The house has a wooden roof structure with slate covering. The building has simple, rectangular floor plan. It has two floors with similarly designed flats. The house has a hip roof with a number of chimneys. All old wooden windows were replaced by PVC windows 7–10 year ago.

The building represents typical buildings constructed in the 1950–60-ies. This type of building is very common in the rural areas and small cities. The selected building type has a high replication potential. Design and construction of buildings in the rural areas are usually associated with higher costs in comparison with the buildings located in cities.

Figure 6.9. Demo Building before renovation.

Figure 6.10. Technical conditions of the Demo Building.

2. General strategy chosen to renovate the housing type

All initial data for technical project development were gathered during the first part of the work package. In the very beginning, the agreement between homeowners, the housing company and Riga Technical University was signed. Before developing the technical project, the IAQ measurements, thermography and blower door tests were performed. According to the measurements, air tightness of the building envelope was 4.5 $m^3/m^2 h$. U-values of external building envelopes were around 0.3 W/(m^2 K) for ceiling, 0.95 W/(m^2 K) for walls and 1.9 W/(m^2 K) for windows. Quality of the construction work is very poor. The extra thermal insulation of the ceiling has many air gaps between mineral wool mats. Window/wall connections are not insulated and sealed properly.

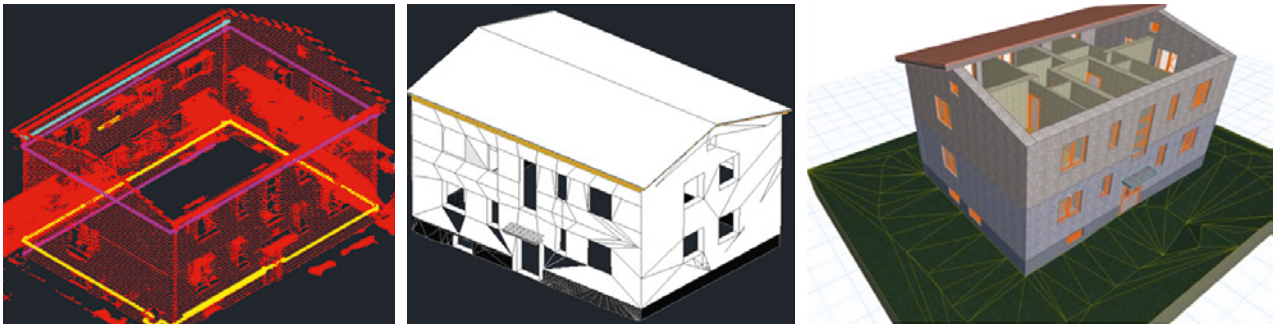
3. Technical concept chosen for renovation

Taking into account poor technical condition of the building it was decided to focus modular retrofitting on improvement of external building envelope. The general strategy included development and installation of prefabricated modular thermal insulation panels. Modular solution is based on the wooden frame. Extra attention is paid to air tightness of panel joints.

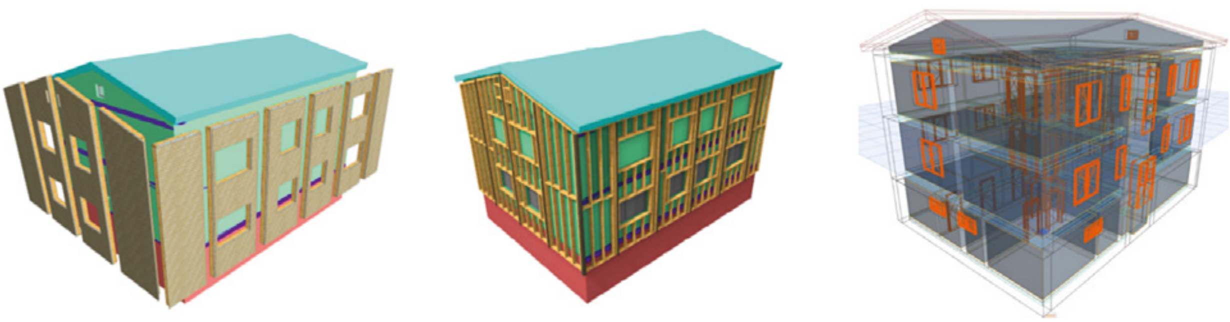
The main target was to get walls below 0.18 W/(m^2 K), windows below 1.1 W/(m^2 K) and ceilings below 0.11 W/(m^2 K).

4. Prefab panels

The moveable scaffolding was used to prepare the building for panel installation and crane lifting was used for panel mounting (Figure 6.13).

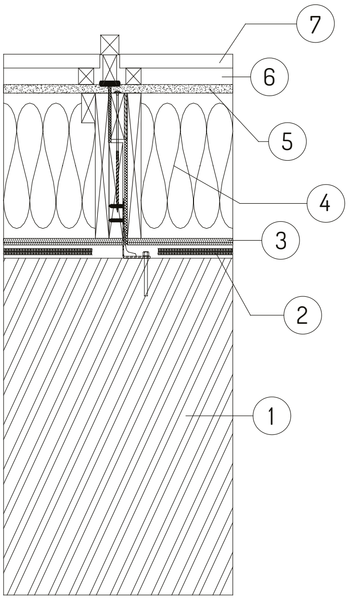


a) 3D point cloud **b)** intermediate 3D building model **c)** final building model



d) development of panel layout **e)** Thermal blocks for energy simulation

Figure 6.11. Retrofitting process of the Demo Building.



1 – Existing wall;
2 – Connection layer between the existing wall and modular panel – low-density mineral wool;
3 – OSB;
4 – Thermal insulation, λ – 0.033W/(m K);
5 – Wind protection, plasterboard;
6 – Ventilated air cavity;
7 – External finishing – wood planks;

Figure 6.12. Final layout of modular prefabricated thermal insulation panel.

In total, panel mounting took five working days and required six workers on site. Five days included also time to deal with problems with replacement of some panels. Taking into account experience gained, panel mounting time can be reduced up to three working days for similar buildings.

5. Conclusions

Installation of renewables was not taken into consideration due to bad condition of roof supporting structure and absence of central hot water supply system. Installation of PV was also limited due to home ownership specifics. There are four owners, thus, the calculation of the electricity supplied to the grid and received back would require extra effort to run a complicated metering system.

The proposed modular retrofitting allowed significant reduction of on-site construction work.

Figure 6.13. Use of scaffolding or crane lifting for retrofitting.

6.1.4 PORTUGAL

Lead author: MANUELA ALMEIDA
Co-author(s): RICARDO BARBOSA

1. The chosen housing type and the underlying rationale

The Portuguese pilot building is a building located in Vila Nova de Gaia, Porto Metropolitan Area, in the northern region of Portugal. It is a social housing neighbourhood, built in 1997, and managed by Gaiurb (a municipal company). It is a multifamily building with three separate blocks, each with three floors, corresponding to six apartments (a two-bedroom apartment and a three-bedroom apartment per floor). In total, eighteen apartments constitute the building (Figure 6.14), which has a gross heated floor area of 1265 m^2.

In terms of typology and construction characteristics, the building is representative of about 40 % of the Portuguese multifamily buildings, which justified its selection as a pilot in this study. It also presents additional common characteristics typical of this significant parcel of the Portuguese built environment. For example, as the majority of the Portuguese residential building stock, the building is not equipped with a central heating system. Some of the apartments have portable electric heaters, although the majority does not have any heating system installed. Additionally, building envelope presents some signs of deterioration,

Figure 6.14. General view of the Portuguese pilot building.

although on a small scale. The common parts of the building (stairs, halls and walls) show signs of mould and are in a higher state of deterioration. Inside the apartments, thermal discomfort has been reported – both in winter and summer – and mould is clearly visible in the corners of the walls and near the windows. Extensive mould areas can also be found on some of the ceilings of the rooms and bathrooms. All these issues highlight the need for renovation.

2. General strategy chosen to renovate the housing type

The general strategy is based on a modular approach to improve the overall performance of the facade. In that way, prefabricated modules will be added to the existing facade, using crane lifting as a working method. Calculations indicate that an estimated 25 % reduction in primary energy use is possible just with the application of the prefabricated modules alone. However, as the project has set the reduction of at least 80 % of the primary energy use as its main objective, other measures had to be considered in addition to the application of the prefabricated modules. In this context, it was planned to place additional layers of insulation on the roof and in the cellar. Existing windows are already double-glazed and therefore their replacement was not considered at this stage. Additionally, the building manager chose not to use solar panels for domestic hot water (DHW), but after the renovation, as part of the second phase, it was planned to install a biomass boiler, improving significantly the building systems performance for both heating and DHW preparation.

Considerations

Adding modular, prefabricated elements to the existing facade will allow faster interventions, as well as will help avoid disturbing the occupants.

3. Technical concept chosen for renovation

The prefabricated module to be implemented on the facade of the building was designed to reduce operational energy demand and increase hygrothermal comfort inside the apartments. Additionally, there was a concern about the choice of materials that constitute the facade panel, which includes a wood frame and a cladding based on

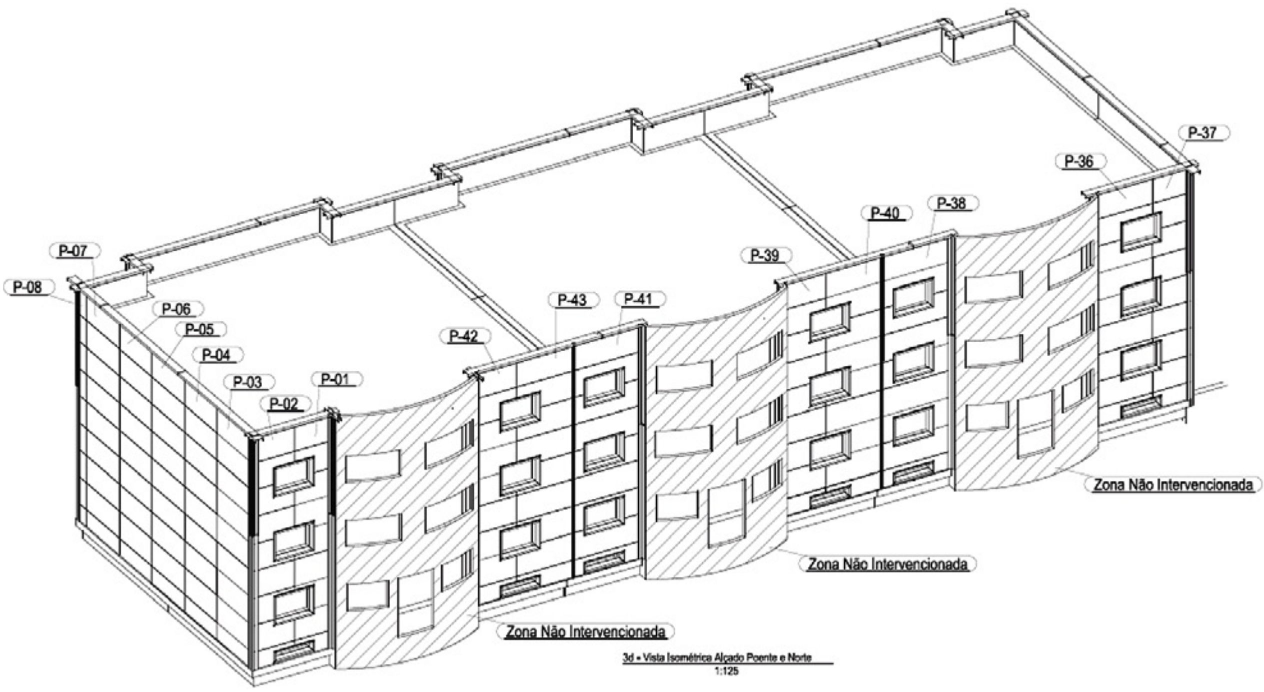


Figure 6.15. Planning of prefabricated facade module installation.

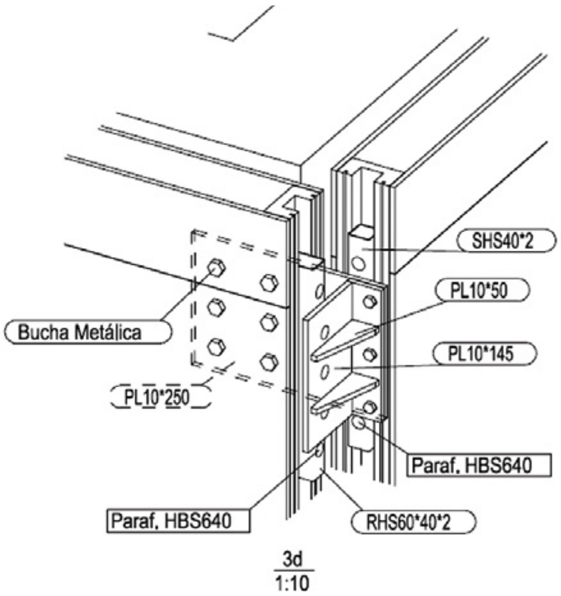


Figure 6.16. Elements of panel fixation.

a recycled material in order to reduce embodied energy and carbon emissions.

The modules will be vertically oriented (10 m height) and will use standard metal connectors assembled on the exterior wall. The renovation solution includes the application of an additional insulation layer of mineral wool put between the existing facade and the prefabricated modular system.

4. Prefab panels

The developed MORE-CONNECT prefabricated modular solution comprises a wood frame, an internal/external cladding made of Coretech® sheets and a filling material of polyurethane foam.

During the development process, both aluminium and wood were considered for the module structure (frame). The initial structure was considered to be in aluminium because it is a widely used material in Portugal in this type of prefabricated structures and in the construction sector in general. Nevertheless, wood is characterized by a higher thermal performance than aluminium, allowing reducing thermal bridges, particularly in the connection between modules.

Coretech® is a recycled material made from waste components of the car industry such as kraft and cellulose paper, polyurethane foam, fabrics and fiberglass. It offers such attractive characteristics as high durability, water and fire resistance and a very good thermal performance. Although it is not widely applied in the Portuguese construction sector, there are already several applications of Coretech®, both in building envelope insulation and external cladding of buildings. Other advantage of this material is the possibility of applying any material as external coating/cladding (paint, ceramic, plaster, etc.).

Polyurethane foam was chosen as a filling material of the prefabricated elements given its high thermal performance and high durability.

The Coretech® panel is 10 mm thick, the wood frame 100 mm and polyurethane foam 100 mm. In total, the prefabricated module has a thickness of 120 mm. The connection between the modules is a male-female connection in the wood frame.

In order to be tested in the laboratory facilities, 2.55 m long and 1.00 m wide prefabricated modules were produced. Nevertheless, the solution can be applied in different sizes, depending on the characteristics of the building. In the Portuguese pilot building, the dimensions of the panels are 10.0 m long and 2.4 m wide.

Due to the stiffness of the prefabricated element, there was a need to create an interface between the existing building wall and the prefabricated element, capable of absorbing the irregularities of the surface, guaranteeing a continuous insulation. This interface would efficiently prevent formation of thermal bridges and improve the energy performance of the solution. The chosen material to act as interface was mineral wool (MW) with a density of 25 kg/ m^3.

Considerations

Planned optimization of the industrial production line and mass production of the prefabricated panels are expected to significantly reduce the final costs of the modules and make them more cost-effective.

5. Preliminary conclusions

So far, the process has faced several challenges. Consideration of the life cycle and embodied energy in the choice of materials led to frequently non-

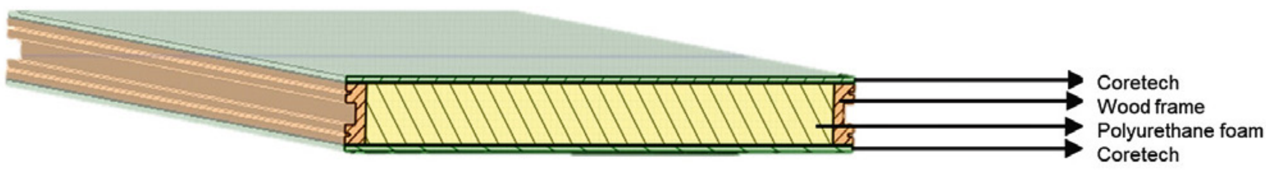


Figure 6.17. Illustration of the prefabricated module.

consensual discussions regarding the need for balance between technical and structural features and sustainability concerns, which calls for a more integrated perspective from all stakeholders in the process.

In addition, planned (and functionally adequate) dimensions for the prefabricated modules are not usual for Portugal, which is likely to cause difficulties regarding both transportation and installation.

6.1.5 THE NETHERLANDS

Lead author: JOHN VAN OORSCHOT

1. The chosen housing type and the underlying rationale

In the Netherlands, row houses with tilted or flat roof are the dominant housing type. There are more than 4 million homes that were built between 1950 and 1985, which are in need for renovation in order to be suitable for the next 40 to 50 years.

The repetitive aspect of building construction makes these buildings very suitable for an industrialized renovation approach.

2. General strategy chosen to renovate the housing type

We have chosen to remove front and back walls and replace those with prefabricated wall elements that close the opening at a high level of airtightness. Fixing the elements from the inside makes it possible to place the elements without scaffolding.

The elements are completely finished in and outside so no manual labor on the building spot is needed apart from fixation to the existing concrete walls.

Elements also contain ventilation ducts; replacing the old walls makes it easy to reach all rooms without the need to work inside the building. Good ventilation is essential since good isolation and good airtightness bring the need for good ventilation.

In order to reach very low level of energy use the ventilation is also combined with a heat-exchange installation.

Hot water for household use and for heating is generated using a water/water heat pump.

Electricity is generated by PV panels. Around 28 panels generate enough kW over year to supply all electricity needs.

3. Technical concept chosen for renovation

Wooden skeleton is the basic element of the buildup. Rockwool insulation is added to the panels, which are closed by OSB and gypsum plates. On top of the OSB, an EPS insulation layer is added in order to reach R-6.5 or better. The same procedure is used for the roof.

The outer side is finished with either putz or StoThermBrick. The inner side is covered with wallpaper.

In order to reach low energy use level, the windows are triple glazed HR++.

This measure also brings more comfort in the rooms since cold-fall does not happen with the use of HR++.

The elements are horizontal and element bearing is done at the foundation level. Elements are stacked on top of each other. The connection with the existing walls is only for wind draw.

For airtight connections, foil flaps are combined with Compri tape. This tape closes gaps of up to 2 centimeters.

4. Installation strategy

All installations are combined in a skid. When placed in the attic the installation is placed in one run when the roof is open. Prefabrication leads to smaller risk of failure and less labor time especially when produced in larger series.

The design implies that there is only one way to fix different installation parts.

Installation engine contains a heat pump with vessel, ventilation, heat-exchange, converter and monitoring hard and software. It is connected to two thermostats – in the living room and master bedroom. The house will have a very steady temperature of 21 in the living room and 19 in the bedrooms.

Ventilation ducts coming from the attic reach all rooms. Moisture sensors are placed in the kitchen and the bathroom, they regulate the need for extra ventilation in case of use.

Conclusions and guidelines

Monitoring data are used to manage the systems as well as to attest the correct working of the combination of renovation elements and installations.

Monitoring proves that calculations were correct for energy use as well as comfort and healthy indoor climate.

6.1.6 CZECHIA

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Co-author(s): MARTIN VOLF, PETR HEJTMÁNEK, KATEŘINA SOJKOVÁ, RADEK BRANDEJS

1. The chosen housing type and the underlying rationale

Based on the statistical research, a 3-story building built in the period from 1946 to 1960 is the most widespread multi-family residential building in Czechia. About 5 % of the complete Czech multifamily housing stock belongs to this type. A post-war residential block in Milevsko was chosen as a reference building, by its typology and materials the building is representative of a significant part of the residential housing stock of Czechia due for retrofitting.

This particular building, used as social housing, has 24 studios (room, kitchen, bathroom, hall), 31 m^2 each, in three stories (see Figure 6.18). Technical or housing facilities and cellars were put in the basement, which is partially situated under ground. Entrance to the building is located on the northern facade, leading to a wide central hall with north-south orientation. On the southern facade, central hall ends with a loggia. Each flat has two windows oriented either to the east or to the west. The building has a gable roof (33°); the attic space is currently unused. Building has longitudinal wall structural system made of bricks (450 mm), ceilings are made of reinforced concrete. Facades are plastered, windows and exterior doors are partly original, partly (3 out of 24 studios) replaced with insulating double-glazing, all with wooden frame.

In the time the reference building was build, usual U-values varied (there were no standards then): 0.76–1.72 W/(m^2 K) for the roof, 1.07– 1.70 W/(m^2 K) for the walls, 0.76–1.22 W/(m^2 K) for the floor and 2.18–3.44 W/(m^2 K) for windows and doors. The total heat loss of the building is 2037 W/K from which ventilation is responsible for 12 % and the remaining 88 % is accounted to heat flow by transmission. The annual energy consumed by one reference building is around 1,050 GJ.

Figure 6.18. Typical building representative of the typology in question in Czechia.

2. General strategy chosen to renovate the housing type

The general strategy was developed based on the analysis of the typical representatives of the selected typology, their technical shape and needs, and on the SWOT analysis of typical common retrofitting interventions that are offered in the market nowadays.

The limitations imposed by the building typology are conditioned by the fact that the major part of the building envelope is at the same moment the load bearing structure – typically the masonry walls of 450–600 mm form the supporting structure for the concrete floor structures. Therefore, there is no option for replacements, the only way is to make an addition to the existing walls.

Czech industrial partner of the project is company RD Rýmařov, the largest national producer of prefabricated family houses made from panels with a timber structural system. Therefore, technology development started from the company’s existing portfolio of panels and installation practices (direct installation of the elements by mobile crane from trucks that come just in time).

3. Technical concept chosen for renovation

A new system of anchors was developed that enable fixing of the panels on the existing facade (panels are hanged – no new foundation is needed). On the long facades with windows, the standard panels will be installed in horizontal position at the height of one floor. Their length will be up to 8 m for ease of manipulation by the crane. On gable walls, some panels might be installed also in the vertical position.

At the plinth, there will be a set of special panels that provide connection from the horizontal air ducts (installed under the ceiling in the basement) to the vertical air ducts in the standard wall panels. Thus, the fresh air is distributed from the central HVAC unit in the basement through the wall panels to the air inlets that are placed just between the new windows in panel cores and the existing walls.

At the roof, the old layers of ceramic tiles on lathes are removed and new roof panels ready for the integrated PV system are attached onto the existing rafters, the system comes separately

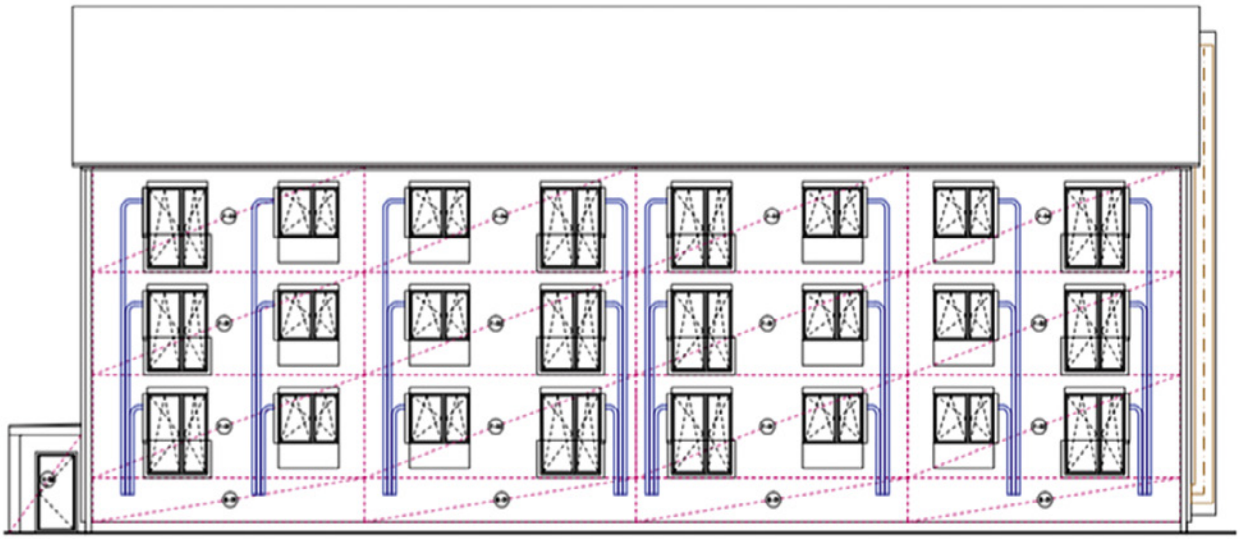

Figure 6.19. Set of 12 standard panels and 4 plinth panels on the eastern facade. New prefabricated entrance (on the left), new “chimney” accommodating new HVAC ducts (on the right).

afterwards. There are special elements that provide closing the gap between the wall and roof panels.

Special modules are also developed to be attached at one sidewall; they create a new “chimney” which includes air inlets and outlets to and from the central HVAC unit with heat recovery.

4. Prefab panels

Each standard panel consists of a structural core made from timber frames, which are filled with thermal insulation and decked by fire resistant boards from both sides, and windows are fixed to the structural elements. On the outer side of the core, plaster finishing is applied on wood fiberboards (see Fig. 6.20).

On the back side of the core there is a layer of soft thermal insulation 120–140 mm thick. This soft layer integrates air ducts for mechanical ventilation of each flat, new wiring for sensors and internet distribution and piping for the cases a new heat distribution system is needed (see Fig. 6.21). In the same layer outlets of the ventilation air are also integrated, which are attached to the frame adjacent to windows.

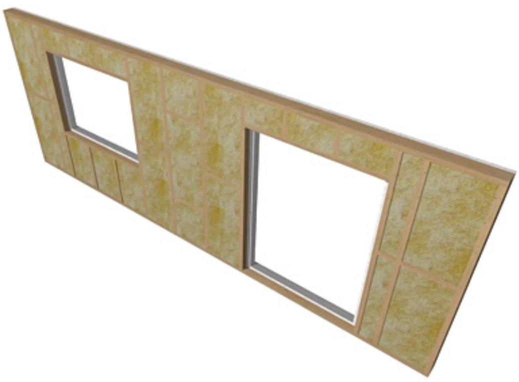

Figure 6.20. Structural core of a wall panel made of timber elements, fire-resistant boards from both sides filled with mineral wool.

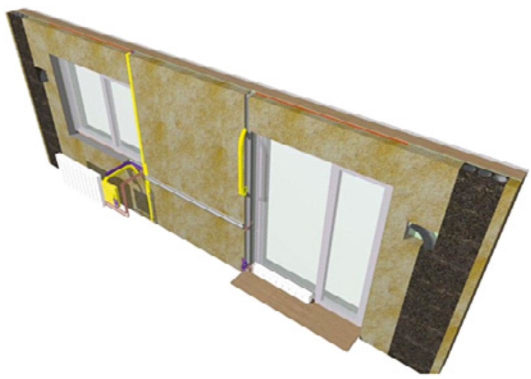

Figure 6.21. Soft layer on the back of the core, which will be in contact with the wall of the existing building.

Figure 6.22. Final setting of the external wall module on the existing wall structure.

The prefab wall panels are attached to the existing masonry wall, usually 450 mm wide. Additional extension of the openings (after dismantling the old windows) for larger windows is possible, as well as the finishing. The window sills and jambs are finished by cladding made from furniture boards. The wiring and piping are accessible through small doors in the window jambs; the design of all technological boxes is airtight. The final setting is presented in Fig. 6.22.

MORE CONNECT

7

CASE BACKGROUND

7

CASE BACKGROUND

Lead author: OVE MØRCK

The implementation of the MORE-CONNECT pilot projects were subject to an overall set of framework conditions. These include the official EU-indicators for nearly zero energy buildings, zero energy buildings and the country specific implementation of these. Besides, explicit conditions include the climate conditions in each country, the predominant building typologies and the assessment methodology adapted within the MORE-CONNECT project to evaluate the completed projects against the pre-set targets.

The following four paragraphs elaborate on each of these elements of the framework conditions. Section 7.1 Indicators describes the definition of nearly zero energy buildings (nZEB) including an analysis of the EU directive on zero energy buildings – the EPBD recast 2010 – and its implementation in the Member Countries. Section 7.2 Climate zones presents the climatic parameters that influence building energy performance, climate classification, heating and cooling degree days, European heating and cooling indexes and a Photovoltaic solar electricity potential in Europe. Section 7.3 Assessment of building typologies introduces the concept of building typologies and a housing assessment format, which provides an overview of different typologies of housing and a series of characteristics that give an indication of the possibilities for renovating using different technologies. As mentioned above, the fourth part presents the assessment methodology agreed upon within the MORE-CONNECT project starting with the scope of the assessment and the boundary conditions. The main part is dedicated to description of how the MORE-CONNECT solutions impact costs, primary energy use and greenhouse gas emissions. The paragraph concludes with an outline of the procedure to follow for undertaking the assessment.

7.1 INDICATORS

Project Results: Deliverable 3.2 and 3.4
Lead author: JOHN VAN OORSCHOT
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There are many tools and methodologies that can measure sustainability. Mostly these are made up of many indicators, grouped and weighed, which gives one aggregated outcome as an indication of sustainability. However, many properties and performances get lost in the cumulated mix of indicators, which makes it difficult to steer developments in the desired directions. Therefore, it is better to work with separate indicators for specific desired performances.

Which is what the EU did, when it launched the EPBD recast, setting energy performance requirements for buildings. The section presents a short analysis of these requirements, since they mostly determine how EU countries will approach the building and renovation sector.

7.1.1 THE DEFINITION OF NEARLY ZERO ENERGY BUILDINGS, A SHORT ANALYSIS OF THE EU DIRECTIVE ON ZERO ENERGY BUILDINGS (EPBD RECAST 2010)

For some years, zero energy buildings and energy neutral buildings are in the focus of public attention and are widely discussed. There are many variations in terms and definitions. Some years ago, I analyzed the description “zero energy building”, and concluded that it consists of three elements: the target (zero), the source (energy) and the applied system (building). Many combinations of these three elements are possible, like, for instance, “zero emissions building(s)" or "100 % renewable energy community", and other. The EU chose the (nearly) zero energy buildings.

In fact, zero energy is not possible, of course. *Zero* usually points to the fact that zero fossil fuels are used, not energy itself. Or even better – zero impact from energy use, which implies use of energy only from streaming resources: resources that are naturally renewed so that there is no depletion, or side effects of their use (not including the energy for production of conversion devices). It is good to notice that solar radiation and all related secondary flows are the only sources that have a net contribution to the global energy stock (when stored), all other sources deplete the earthbound available stock. It is obvious that in general we attempt to increase our use of solar radiation related energy flows. Without going into too much detail, we can give a short practical definition of a zero energy building: The building acquires all its energy from renewable sources on the building or within the plot belonging to the building. The electricity grid may be used to balance shortages and surpluses, such as temporal stockage (mainly to store surplus in summer and take it back in winter).

Energy-neutral in that case is that the building uses only renewable energy, but not from within the building plot per se, it may be imported from elsewhere, for instance, from distant wind turbines, or even "green" electricity in general.

It is important to keep that consideration in mind, when we start looking into the legal requirements. Meanwhile, regulations have been developed based on the European directive known as EPBD recast 2010, which are implemented by 2018 and beyond. The directive requires that all public buildings from 2018 on and all other buildings form 2020 on should be nearly zero energy. This is a ground for extensive discussion, especially the addition of the attribute "nearly".

What is the formal description? Article 2 in the EPBD recast directive states:

'*nearly zero-energy building' means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;*

Nearly zero, in fact, implies close to zero, and does not say anything about the level of balance between demand and supply: It simply implies that all demand is supplied form renewables. Which does not mean that the demand should be low, if only it is in the (near-) balance with (renewable) supply (and the amount of solar energy is in fact not of interest, it is a free, non-depleting and polluting source) (see also Chapter 8). Nevertheless, the article speaks indeed of a "very low amount of energy", to continue stating that a significant part should come from renewables (the near balance, thus). But then the article creates confusion, "from sources on site or nearby". In that case, the zero building is superfluous, if energy can come from outside the building plot. Besides, the double use of *nearby* and *nearly* in one definition is confusing.

The official translations of the directive to apply in each EU country legislation are even more interesting. The Dutch version goes:

2. "bijna-energieneutraal gebouw": gebouw met een zeer hoge energieprestatie, zoals vastgesteld volgens bijlage I. De dichtbij nul liggende of zeer lage hoeveelheid energie die is vereist, dient in zeer aanzienlijke mate te worden geleverd uit hernieuwbare bronnen, en dient energie die ter plaatse of dichtbij uit hernieuwbare bronnen wordt geproduceerd te bevatten;

("nearly energy neutral building") In fact, *zero* has disappeared overall here; the definition speaks only of "*nearly energy neutral",* which in fact is a legally incorrect translation (if English is the primary source). The Dutch version also speaks of "aanzienlijke mate", which can be back translated as "substantial share" (of RE) which is not as definite as "significant". "Dient te bevatten" is back-translated as "should contain" (...energy produced on site or nearby), which is also very weak, and the system border becomes quite irrelevant this way.

The German language version contains a definition *"niedrig-energiegebaude",* which in the official translation is a *"low energy building"*, and in fact only refers to demand, which should be low, but nothing is said about supply (in the term itself, that is).

France speaks of a *"bâtiment dont la consommation d'énergie est quasi nulle',* as does Spain, *"edificio de consumo de energía casi nulo*", which can be back-translated as "nearly zero energy consumption". Both have *nearly zero* attribute copied, at the same time, both language versions introduce the notion of *consumption* (instead of building), suggesting only 'demand'. While Sweden, for instance, sticks to the original definition: *"nära-nollenergibyggnad" – "near zero energy building."*

Other articles in the EPBD explain some of the concepts used, like "energy performance":

Art 4. 'energy performance of a building' means the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting;

In other words, it includes building related energy, plus (hot) water (inhabitant related), excluding "comfort and luxury energy" for appliances like laundry machines and television. The use of the phrase "measured amount of energy" is interesting; it implies end user demand. That is correct, of course, since primary energy would not make sense leaving out fossil fuels in the zero approach.

Article 6 states with regard to "renewable sources",

Article 6*: 'energy from renewable sources' means energy from renewable non-fossil sources, namely wind, solar, aero thermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.*

Basically, it covers all energy not from fossils, and therefore includes energy from bio-fuels. It can be further discussed whether landfill and sewage gas is a renewable source. However, it does cover nuclear energy.

It is written in Article 14 that all countries should aim at the "*most cost-optimal level"* of energy performance,

Article 14: *'cost-optimal level' means the energy performance level which leads to the lowest cost during the estimated economic lifecycle, where [...].*

With this statement, it is not clear how "near" is near, in fact, it is not an energy supply question but a cost optimization question, undermining all previous targets.

Moreover, part of the directive also requires the Member States to take measures to formulate ambitions for renovating buildings towards nearly zero energy buildings. This means all countries should send their plans to the EU, which is also supported by the measures laid down in the last year's Energy Efficiency Directive.

In the annex to the EPBD recast, a more detailed description of how to *calculate* the nearly zero energy targets is provided:

1. *The energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs.*
2. *The energy performance of a building shall be expressed in a transparent manner and shall include an energy performance indicator and a numeric indicator of primary energy use, based on primary energy factors per energy carrier, which may be based on national or regional annual weighted averages or a specific value for on-site production.*

Here things are mixed up, and the two articles are contradictory. The first mentions the energy that is consumed, while the second refers to primary energy. Referring to the energy consumed, it meant to say end-use, the demand in the building, which is not the same as primary energy. It is confusing and strange since primary energy of fossil fuels is a completely obsolete concept on the way to a renewable energy based society: primary energy is an artifact from the fossil-based era, in which solar energy was seen as primitive. But the route from solar radiation to electricity is far more effective if it is direct rather than if it goes the long way from the solar radiation to biomass and sedimentation that creates fossil fuels.

Besides, the lighting energy has disappeared in the annex articles.

A few remarks should be added at the end of this exploratory essay. If a building is a zero energy building, as meant by the definition in the introduction, energy in fact is no more an issue. The energy is free (solar radiation, wind, earth heat, etc.) and harmless. The criterion is then re-defined to specify how many materials have to be invested in either reducing demand or making production available in the right form.

The energy question has become a materials question (another reason why primary energy has become senseless as a parameter). Materials require, in addition to the mass resources, substantial energy amounts to be produced, which is currently not taken into account, although you could read that in "energy demand over the lifecycle" includes materials energy impacts (see Chapter 8 how this works as researched and applied within this MORE-CONNECT project).

The remaining question is how the EU Member States will in fact deal with these EPBD recast requirements, especially the countries (the Netherlands and Germany, for instance), which are already introducing not nearly but net zero energy buildings.

Based on these findings, the best practical approach would be to address the EPBD recast based requirements in the following way:

All new buildings (or retrofitted buildings) are required to be *designed* as zero energy buildings, thus including all options to acquire all necessary energy within their building plot. In addition, *nearly* is then redirected towards an investment question related to the cost-optimal part: The building may spread investments being constructed as a *nearly* zero energy building. For instance, only a half of the solar panels is installed, the second batch is added in ten years or so. The remaining part, the difference between zero and nearly zero, has to be supplied from “nearby” renewable resources, for instance, as certified ‘green energy”.

Thus, in any case, a building is energy neutral and zero energy ready (the no-regret approach). However, the building will be defined ‘nearly zero’, otherwise, 100 % green energy could still close the deal.

Designing for zero energy allows for easy comparison of materials energy invested to find the lowest rebound impact effect, as described in Chapter 10.

http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32010L0031:EN:NOT

www.sustainablebuilding.eu (see project MAXergy for the referred research).

Annex: Article 2 EPBD recast, in different languages:

German:

2. “Niedrigstenergiegebäude” ein Gebäude, das eine sehr hohe, nach Anhang I bestimmte Gesamtenergieeffizienz aufweist. Der fast bei Null liegende oder sehr geringe Energiebedarf sollte zu einem ganz wesentlichen Teil durch Energie aus erneuerbaren Quellen —einschließlich Energie aus erneuerbaren Quellen, die am Standort oder in der Nähe erzeugt wird — gedeckt werden;

French:

2) “bâtiment dont la consommation d’énergie est quasi nulle”, un bâtiment qui a des performances énergétiques très élevées déterminées conformément à l’annexe I. La quantité quasi nulle ou très basse d’énergie requise devrait être couverte dans une très large mesure par de l’énergie produite à partir de sources renouvelables, notamment l’énergie produite à partir de sources renouvelables sur place ou à proximité;

Spanish:

2) “edificio de consumo de energía casi nulo”: edificio con un nivel de eficiencia energética muy alto, que se determinará de conformidad con el anexo I. La cantidad casi nula o muy baja de energía requerida debería estar cubierta, en muy amplia medida, por energía procedente de fuentes renovables, incluida energía procedente de fuentes renovables producida in situ o en el entorno;

Swedish:

2. nära-nollenergibyggnad: en byggnad som har mycket hög energiprestanda, som bestäms i enlighet med bilaga I. Nära nollmängden eller den mycket låga mängden energi som krävs bör i mycket hög grad tillföras i form av energi från förnybara energikällor, inklusive energi från förnybara energikällor som produceras på plats, eller i närheten,

Danish:

“næsten energineutral bygning”: en bygning, der har en meget høj energimæssig ydeevne, fastlagt i overensstem melse med bilag I. Den ubetydelige eller meget lille energimængde, der kræves, bør i meget væsentlig grad dækkes af energi fra vedvarende energikilder, herunder vedvarende energi produceret på stedet eller i nærheden

Latvian:

“gandrīz nulles enerģijas ēka” ir ēka ar ļoti augstu energoefektivitāti, kā noteikts saskaņā ar I pielikumu. Gandrīz nulles vai ļoti maza daudzuma vajadzīgo enerģiju būtu ļoti lielā mērā jāsedz no atjaunojamajiem enerģijas avotiem, tostarp uz vietas vai netālu ražotu enerģiju no atjaunojamajiem avotiem;

Portugese:

“Edifício com necessidades quase nulas de energia”, um edifício com um desempenho energético muito elevado, determinado nos termos do anexo I. As necessidades de energia quase nulas ou muito pequenas deverão ser cobertas em grande medida por energia proveniente de fontes renováveis, incluindo energia proveniente de fontes renováveis produzida no local ou nas proximidades;

Czech:

“budovou s téměř nulovou spotřebou energie” budova, jejíž energetická náročnost určená podle přílohy I je velmi nízká. Téměř nulová či nízká spotřeba požadované energie by měla být ve značném rozsahu pokryta z obnovitelných zdrojů, včetně energie z obnovitelných zdrojů vyráběné v místě či v jeho okolí;

Estonian:

“liginullenergiahoone” – hoone, mille I lisa kohaselt määratud energiatõhusus on väga suur. Nullilähedane või väga väike nõutava energia kogus peaks olulisel määral pärinema taastuvatest energiaallikatest, sealhulgas kohapeal või lähiümbruses taastuvatest energiaallikatest toodetud energiast;

7.1.2 LESSONS LEARNED FROM THE INDICATORS USED IN THE BUILDING PRACTICE

The Netherlands is one of the first countries in the world that has set a mandatory material performance requirement (‘MPG’) for new buildings since 2018, which is unique, after 25 years of pushing and trying. There is a set ambition, although very low to start with [1], as almost any building complies, but it could be used to enforce performance to a higher level in future. Unfortunately, performance calculation should be done based on 11 categories, which are sometimes cause-related and sometimes effect-related, and are weighted using economic values. The two most important causes of future problems – materials depletion (scarcity) and CO_2 emissions (climate change) – are therefore hidden in the total evaluation. The first is valued at 16 cts/kg (to compensate impact) and the other – at 5 cts/kg, which is quite subjective: any value can be changed tomorrow, depending on the government and banks' mood.

There is an even more important issue: The economic considerations are just an indicator, nobody will really pay for depletion or CO_2, it is just a calculation. But even if someone paid, that would still not be a solution, since the problems will not be solved if we can continue polluting just by paying for it. The target implied by the Paris Agreement is to go for an absolute zero, which means no more CO_2 emissions and complete termination of material depletion (that is, living within restoring capacity of the system).

The mandatory calculation is a start, of course. Most countries do not even have the system of materials evaluation in place, at best, it is part of a broader, generic and voluntary tool developed by practice. Also in the Netherlands, the MPG is part of a broader practice-oriented voluntary tool, like GPR or BREEAM. In such a tool, these two most important items, CO_2 and depletion, are consequently part of the 11 money weighed categories in the resource section (MPG), which, in their turn, are part of four to eight main categories (think of Water, or Management, or even 'future value'), each with its own weighing factor that is more or less subjectively chosen, often in a multi-criteria – multi-stakeholder process. The real issue of today – limiting CO_2 emissions – is hidden and not relevant in the total score. And CO_2 is not only about operational energy, it also is about energy embodied by materials. Impact of aluminium, for instance, a material with the highest CO_2 emissions per unit of function, is completely hidden, so that alternatives with much lower impact will not turn up in the calculations. In this way, it can happen that an office retrofit with aluminium facade cladding can be awarded a national BREEAM excellence award. Many facade alternatives have a much lower CO_2 impact, especially bio-based, which also score better in many other categories (like materials depletion, since they are re-generated). But these don't automatically pop up, in these tools for building practice. Besides, most data used for these calculations are not even publicly accessible.

In general, these assessment tools all over the world value mainly investments, measures and products/technologies to create sustainability. None of these tools value doing less, or doing nothing: creating less floor area or reducing comfort (and as a consequence – CO_2). They all start from a certain comfort level, which is pretty high in industrialized countries, and most of the time value comfort improvements beyond that level. It can be understood, but one should be aware that if the ambition is to lower environmental impact, these tools will not help. In other words, if we want to reduce environmental impact, the current tools are not helpful: Most of the non-environmental issues are or should already be covered in the national housing/building legislation, it is not relevant to put these again in an environmental tool. It should be about doing the same with less, not doing more with the same (impact).

Internationally, it is the same: All prevailing assessment tools for practice are based on a weighed scoring system of many categories. In some cases, there are scientific figures at the fundamental level, but then they again are regrouped and weighed in many categories.

LEED is one of the worst in its kind, it is constructed from inimitable values and points. This approach has led to a complete cult of consultancy, education, auditing, etc. The discussion most of the times is about the increase in the real estate (money) value of buildings with a LEED label, instead of about the lower environmental impacts, which is even often doubted [3]. In fact, it is a real estate selling instrument. It will not lead us towards reduction of materials impact or CO_2 reduction, even the operational energy reductions are doubtful [4].

Aggressive lobbying of LEED related organizations persuaded many countries to adopt a similar approach. It will take years to change that again, when reduction of environmental impact only or CO_2 reduction is becoming a dawning issue to focus on.

On top of that, all these instruments apply a method of stacking measures, while an integral approach is required, which, as we know since the nineties, can only be achieved with some basic performance indicators for key issues and values, without adding up, weighing, or packing with secondary needs and wants.

If you want to reduce material depletion, you should measure material depletion. And to reduce CO_2, CO_2 should be measured and evaluated, not comfort, or health, or management or economy.

The same applies for creating (nearly) zero energy houses and retrofitted houses. We have to stick to measure that are aimed for – divestment from fossil fuels and reduction of CO_2 emissions. That is the indicators to be used including, as it was argued, the impacts of fossil fuels and/or CO_2 from materials as well to avoid creating a huge rebound effect.

The rest should be left to normal building legislation and regulation – doing the same with less. Otherwise, the building sector will create "better buildings", maybe, but surely will contribute nothing to CO_2 reduction. We should be aware that not only one house should be evaluated, but also the effect of the total stock retrofitted to stay within a country's CO_2 budget under the Paris Agreement. This has been studied in [5].

When it comes to retrofitting houses in the EU, a straight indicator evaluation approach is used to find the optimal combination of measures for housing retrofit, as described in Chapter 10.

[1] http://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels-gebouwen/milieuprestatie-gebouwen

[2] Casbee: http://www.ibec.or.jp/CASBEE/english/index.htm

[3] See discussions:
https://www.linkedin.com/pulse/usgbc-itself-sustainable-jerry-yudelson?trk=hp-feed-article-title-ppl-follow
https://www.linkedin.com/groups/59930/59930-6198000480694657028
http://www.leedexposed.com/
https://www.duurzaamgebouwd.nl/onderzoek/20080814-zin-en-onzin-over-leed (Dutch)

[4] http://www.prnewswire.com/news-releases/leed-certification-fails-to-increase-energy-efficiency-says-environmental-policy-alliance-247899251.html

[5] http://www.buildingscarbonbudget.org

7.2 CLIMATE ZONES

Project Results: Deliverable 2.1
Lead author: TARGO KALAMEES
Co-author(s): OVE MØRCK

Due to the diversity of the European building sector and climate, each state has to define national (n)ZEB approaches reflecting national, regional or local conditions.

"Nearly Zero Energy Hotels" (neZEH, http://www.nezeh.eu/) and "Collaboration for Housing nearly zero-energy renovation" (COHERENO, http://www.cohereno.eu) projects have collected national (n)ZEB definitions. The European Commission has also submitted a report to the European Parliament and the Council about the progress achieved by the Member States pursuing Nearly Zero-Energy Building targets (COM(2013) 483 final/2, 2013). Buso et al. (2014) have grouped (n)ZEB definitions according to ECOFYS classification (ECOFYS, 2013) into five European climate zones as shown in Figure 7.1.

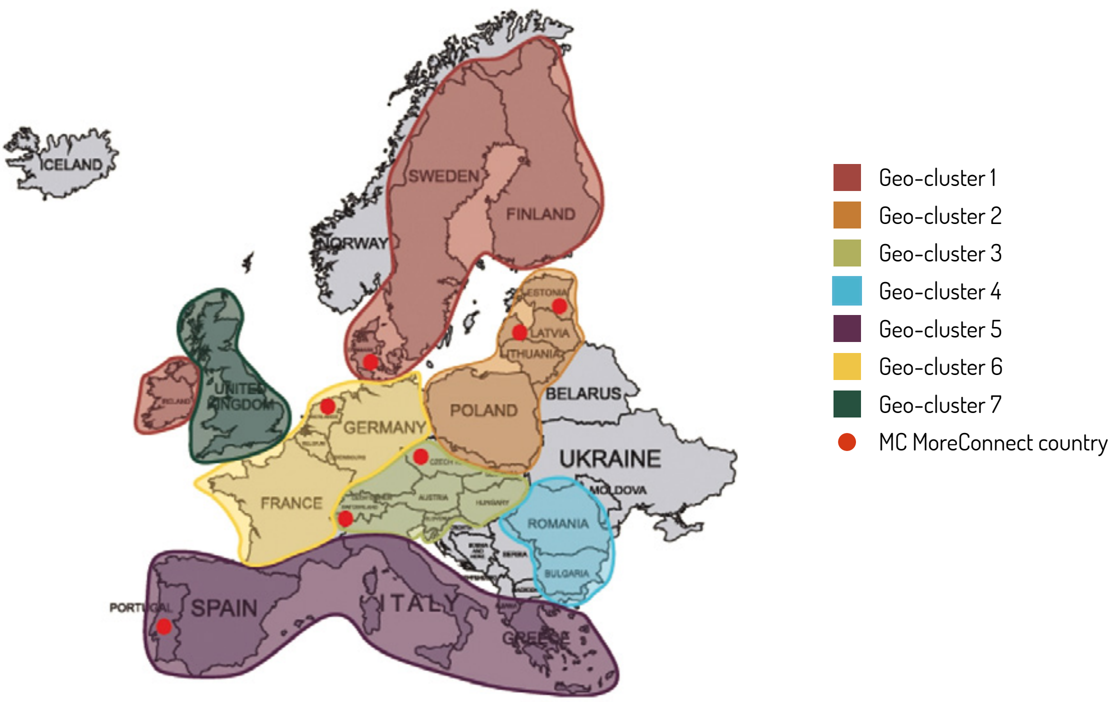


Figure 7.1. Climate zones suitable for ranking of technology options and comparison of building performance.

7.2.1 CLIMATE OF EUROPE

Climate is a key factor in choosing specific technological solutions (D'Agostino and Parker 2018). When energy performance of buildings is analyzed, different climate condition should be taken into account.

Western Europe is influenced by the ocean and Southern Europe is influenced by the Mediterranean See. The Gulf Stream strongly influences the climate in Northwestern regions, it keeps air mild over the high-latitude North-Western region over the winter months. Eastern Europe has a drier continental climate.

7.2.2 CLIMATE PARAMETERS INFLUENCING ENERGY PERFORMANCE OF BUILDINGS

Energy demand of buildings is influenced by many climatic parameters. Primary climatic parameters that influence indoor climate and energy performance of buildings are:

- Outdoor air temperature;
- Solar radiation (direct and diffuse);
- Wind (speed and direction);
- Air humidity;
- Infrared radiation.

Temperature and solar radiation affect both heating and cooling demand (Kalamees et al. 2012). Wind has a strong impact on air infiltration and, therefore, heating and cooling energy demand. Humidity does not affect heat demand, but it influences cooling coil capacity greatly. Additionally, the influence of these climate parameters also depends on the type of building and the purpose for which the climatic data are used. For example, the cooling and heat demand of an office building with a glass façade, which is completely exposed, is influenced by solar radiation differently than that of a detached house with a relatively small glazed area and solar protection from the neighborhood.

In different climatic zones, the importance of climatic parameters is different. Taking into account the distribution of the buildings in the climatic zones a weighted average influence of temperature and solar radiation on the heating and cooling energy demand was calculated in Finland (Figure 7.2).

7.2.3 KÖPPEN-GEIGER CLASSIFICATION

The Köppen climate classification (Köppen 1884) is one of the most widely-used climate classification systems. The Köppen climate classification divides climates into five main climate groups, with each group being divided based on seasonal precipitation and temperature patterns.

7.2.4 HEATING AND COOLING DEGREE DAYS

Heating and cooling degree days are the measure of how cold or warm a location is. A degree day compares the mean outdoor temperatures recorded for a location to the base temperature. Depending on the methods, internal heat gains are taken or not into account in determining the base temperature.

Heating degree days indicator (HDD) provides a rough estimate of seasonal heating requirements. It can be calculated as the total heat loss coefficient *H*, W/K (thermal transmittance multiplied by the area of the thermal envelope, linear thermal

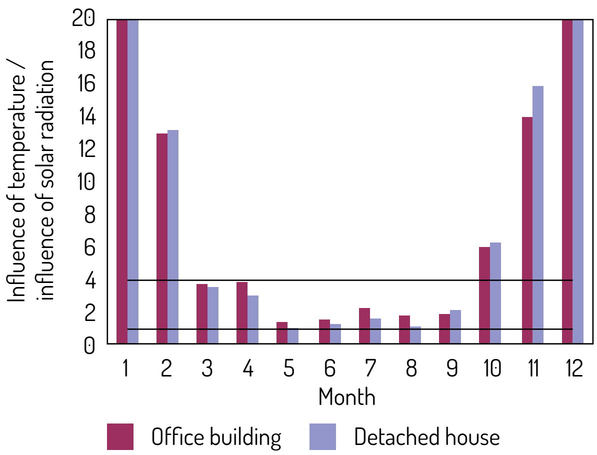
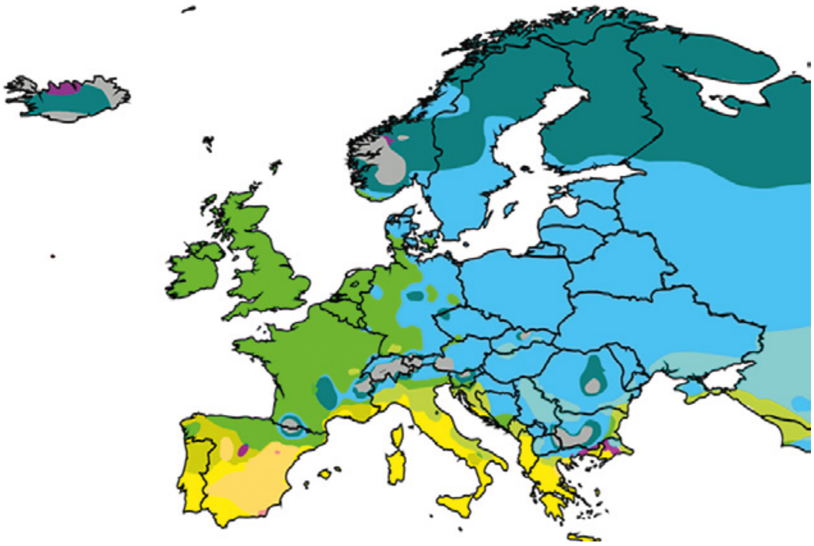


Figure 7.2. Weighted average influence of temperature and solar radiation on the heating and cooling energy demand in Finland. The columns show the ratios between the influences of the these two climate variables (Kalamees et al. 2012).



Csa — Hot-summer Mediterranean climate; coldest month averaging above 0 °C, at least one month's average temperature above 22 °C (71.6 °F), and at least four months averaging above 10 °C. At least three times as much precipitation in the wettest month of winter as in the driest month of summer, and driest month of summer receives less than 30 mm.

Cfb — Temperate oceanic climate; coldest month averaging above 0 °C, all months with average temperatures below 22 °C, and at least four months averaging above 10 °C. No significant precipitation difference between seasons.

Dfb — Warm-summer humid continental climate; coldest month averaging below −3 °C, all months with average temperatures below 22 °C, and at least four months averaging above 10 °C. No significant precipitation difference between seasons.

Dfc — Subarctic climate; coldest month averaging below −3 °C (27 °F) and 1–3 months averaging above 10 °C (50 °F). No significant precipitation difference between seasons.

Figure 7.3. According to Köppen – Geiger climate classification, there are four prevailing climatic zones in Europe.

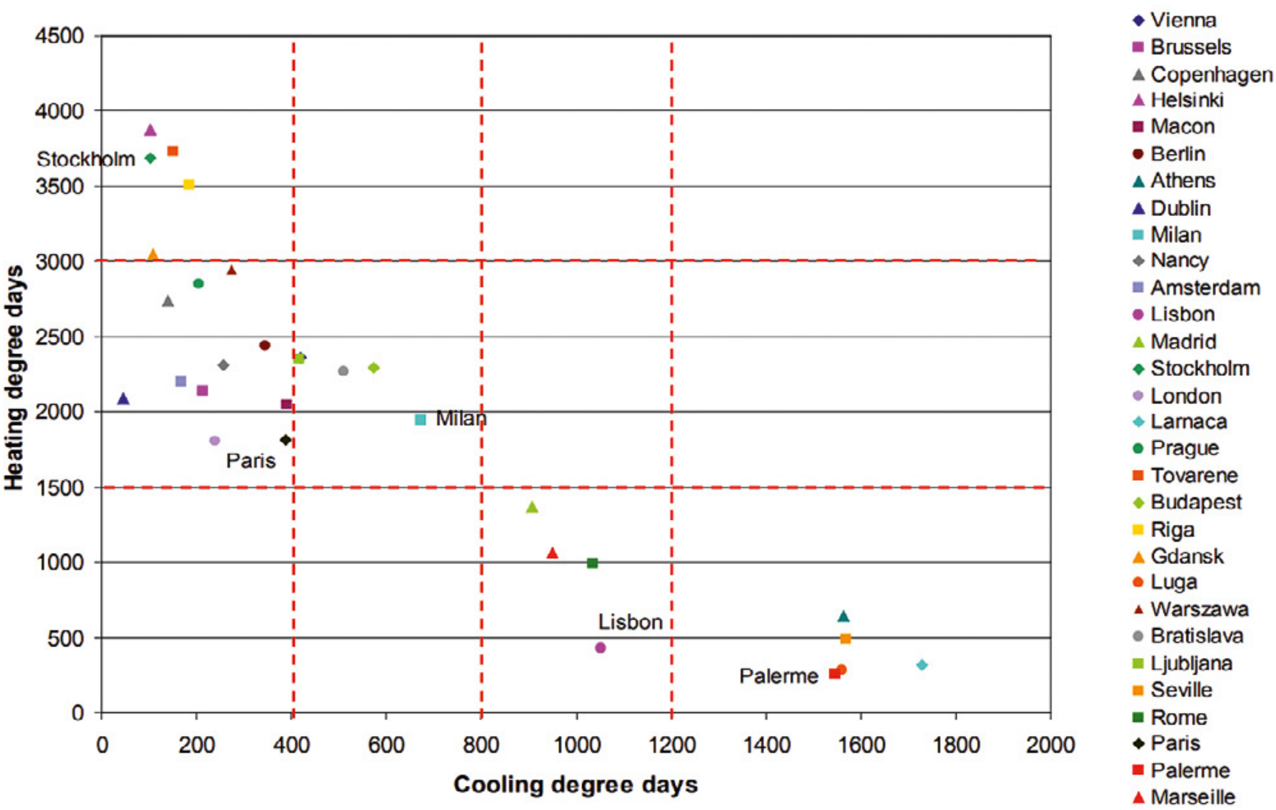


Figure 7.4. Heating degree days and cooling degree days for 30 European cities (Hermelink Andreas et al. 2013).

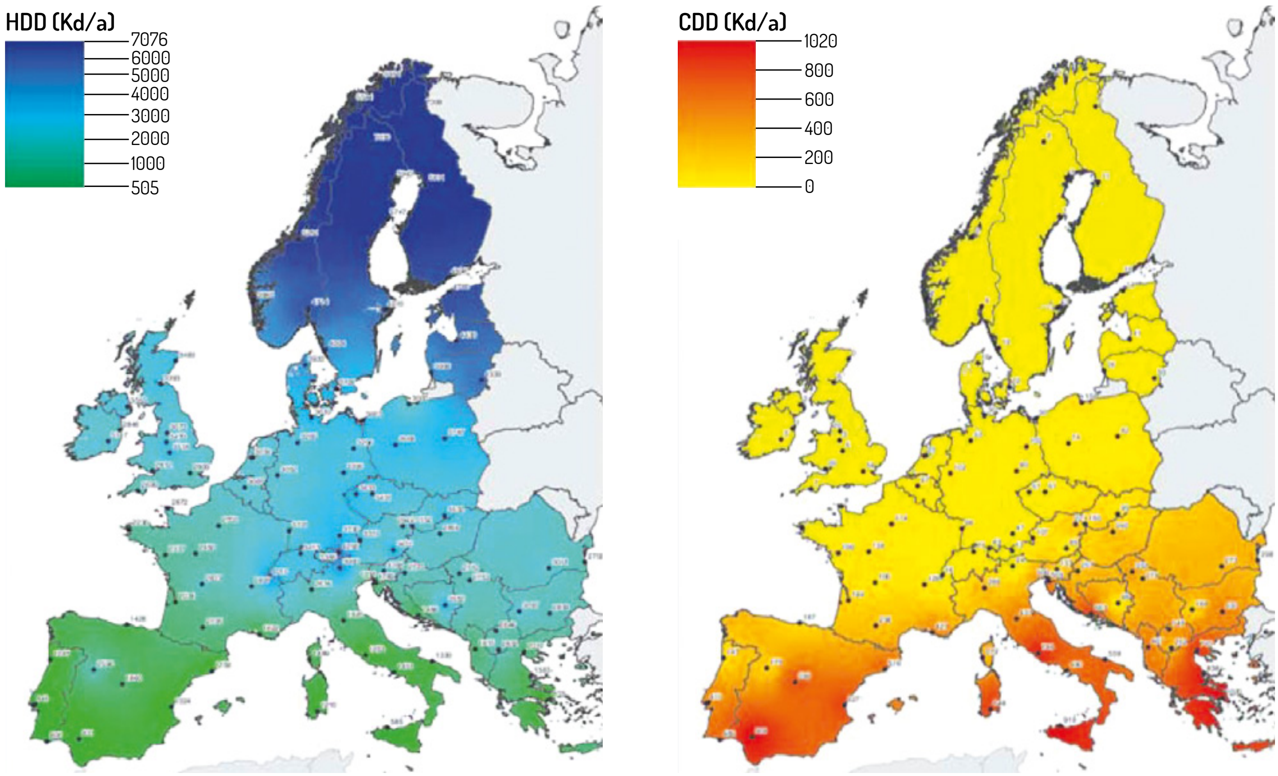


Figure 7.5. European heating degree days (left) and cooling degree days (right) (PVSites 2016).

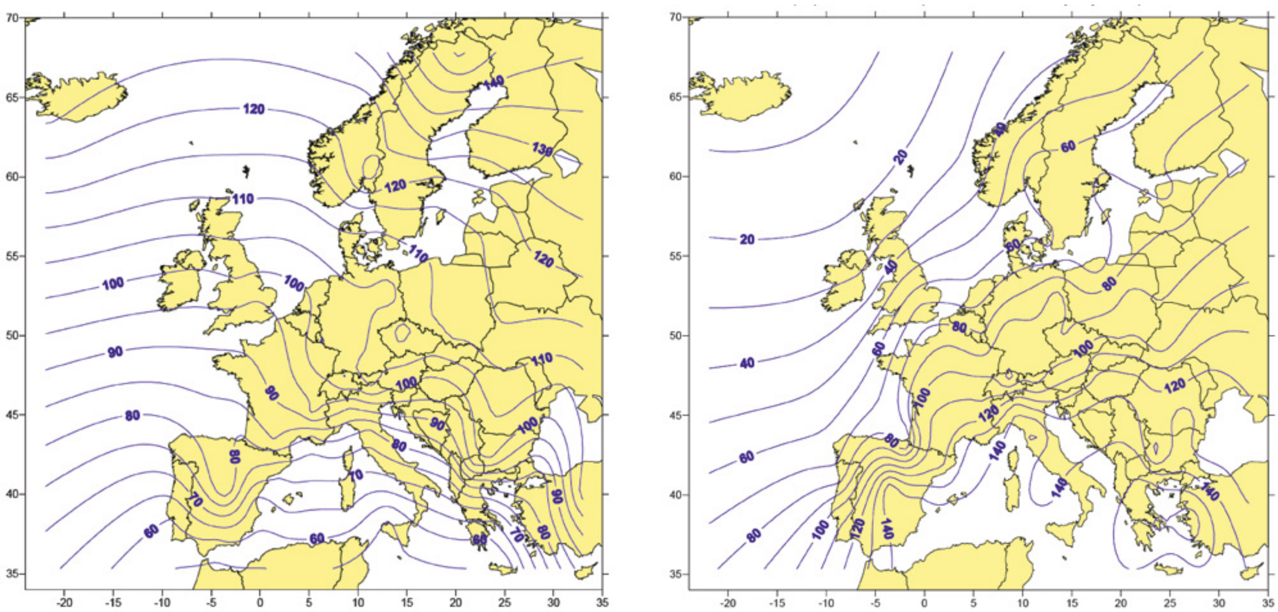


Figure 7.6. European Heating Index (left) and European Cooling Index (right) (Werner 2005).

transmittance multiplied by the length of the thermal bridges, point thermal transmittance multiplied by the number of the thermal bridges, heat loss by air leakages)

$$Q = \frac{H \cdot 24 \cdot HDD}{1000}, \text{kWh},$$

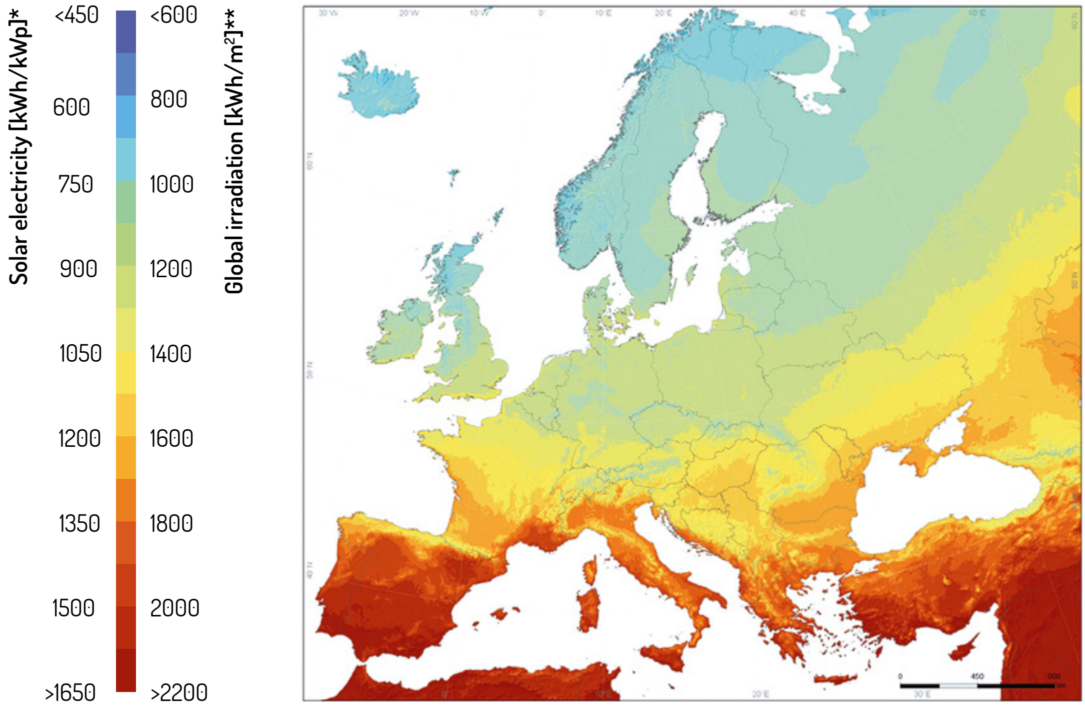
1000 (to convert W to kW), 24 (to convert hours in a day).

7.2.5. EUROPEAN HEATING INDEX AND EUROPEAN COOLING INDEX

The Ecoheatcool project used 80 cities in Europe to develop the European Heating Index (EHI) and European Cooling Index (ECI). The index is normalized, where 100 is equal to an average European condition. Using a reference degree-day number of 2600, corresponding to an annual average outdoor temperature just above 10 °C, fulfills this normalization. Strasbourg in France is the typical space-heating city in Europe, with a heating index of 100.

7.2.6. PHOTOVOLTAIC SOLAR ELECTRICITY POTENTIAL

Figure 7.7 shows the annual sum of global irradiation on horizontal and optimally inclined surface. Over most of the regions, the data represent the average of the period 1998–2011, however, north of 58° N, the data represent the 10-years average of the period 1981–1990 (PVSites 2016). All data values are given as kWh/m^2. The same color legend represents also potential solar electricity [kWh/kWp] generated by a 1 kWp system per year with photovoltaic modules mounted at an optimum inclination and assuming system performance ratio 0.75.



* Yearly sum of solar electricity generated by 1 kWp system with optimally-inclined modules and performance ratio 0.75

** Yearly sum of global irradiation incident on optimally-inclined south-oriented photovoltaic modules

Figure 7.7. European solar irradiation map.

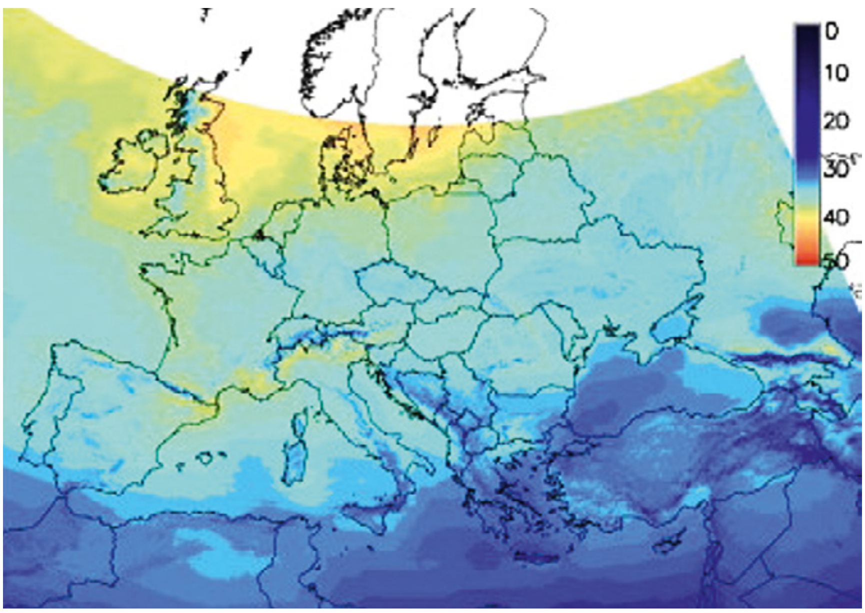


Figure 7.8. Optimum angle for fixed-mounted south-facing PV modules as calculated using the PVGIS-CMSAF database (Huld, Müller, and Gambardella 2012).

7.3 ASSESSMENT OF BUILDING TYPOLOGIES

Project Results: Deliverable 3.3 and 3.8
Lead author: RONALD ROVERS
Co-author(s): JOHN VAN OORSCHOT

7.3.1 SHORT INTRODUCTION

Background – The main goal of the MORE-CONNECT project is to develop a solution with respect to innovative, prefabricated building envelope elements for MOdular REtrofitting and smart CONNECTions. These building envelope elements contribute to the transformation of the European housing towards nearly Energy Zero Buildings (nZEB). Point of departure is the assessment of the European housing in order to determine which typologies are most suitable to be upgraded towards nZEB with prefabricated building envelope elements; i.e. a baseline assessment, which determines which market segment MORE-CONNECT will focus on.

Problem definition – Within the European housing sector a diversity of housing typologies can be found, which are characteristic for a specific region (for example, detached housing in the Netherlands) or relatively common throughout Europe (for example, apartment buildings). Preliminary national and international studies already provided meaningful insights into housing typologies. The most important publication is this respect is the TABULA report (2012) which includes an assessment of the energy performance of the European housing stock. The assessment presented in this report will build upon the Tabula report with respect to the generic building typology, the TABULA Typology Concept (Building Type Matrix). However, the TABULA report provides limited detailed information about the technological conditions of the building structure and the building envelope. This information is considered critical to the assessment of the European housing in order to determine which housing typology is most suitable to upgrade to nearly energy zero applying prefabricated building envelope elements.

Purpose – This chapter includes the assessment of housing typology based on national housing statistics. Next, based on the pilot residential buildings included in the MORE-CONNECT project, a detailed technical assessment will be presented. This assessment is considered to be necessary to determine whether and how prefabricated (n)ZEB retrofit elements can be applied concerning a specific building typology. These insights include in particular detailed information about building geometry, the structure of the building and the configuration of the building envelope including building service technology. Based on these insights a decision-making tool (decision-making tree) has been developed, which supports the assessment of housing in order to determine the applicability of the MORE-CONNECT retrofit concept.

Boundary conditions – This chapter has been developed taking into account several boundary conditions. First, this report will build upon the TABULA Typology Concept but will not replicate the energy performance calculations, which can be found in the 'TABULA WebTool' (http://webtool.building-typology.eu/webtool/). Second, financial aspects concerning the most cost-effective investment and the project and/or the MORE-CONNECT retrofit requirements are not considered within this chapter either. These issues are addressed elsewhere.

Methodology – Within the participating countries, national statistics and the TABULA report were used to develop a generic Building Type Matrix. Next, national (research) reports and expert opinions were used to assess building geometry, the structure of the building and the configuration of the building envelope in more detail. Third, the results were collected and processed within a format underlying this chapter (included in appendix A). As follow up, this assessment will inform decision makers which building typology or typologies can be renovated according the MORE-CONNECT concept for which the (n)ZEB retrofit elements will be developed.

7.3.2 METHODOLOGY: ASSESSMENT OF BUILDING TYPOLOGIES IN THE CONTEXT OF MODULAR NZEB RETROFIT CONCEPTS

Research approach

The aim of this study was to investigate the housing typology within the EU in order to determine the suitability of modular (n)ZEB retrofit concepts (MORE-CONNECT).

Data collection and analysis

The data collection and analysis was conducted based on a standard form which can be found in appendix A. Part 1 builds upon the TABULA's building type matrix (see the box further) and national housing statistics. Part 1 provides an overview of the national housing stock and provides the data about potentially interesting housing typologies, which MORE-CONNECT could (should) address. Moreover, MORE-CONNECT aims at developing one common platform for production lines (process platform), from which different solutions for each geo-cluster can be produced.

Based on the statistics from Part 1, the potential of the MORE-CONNECT concept and its distinct production lines can be determined.

TABULA's Building Type Matrix

[TABULA, 2012, p. 7]: The energy performance of buildings correlates with a number of parameters including the year of construction, the building size and the neighbour situation, the type and age of the supply system and the question of already implemented energy saving measures. If these features are known for a given building it will be possible to quickly give an estimation of its energy performance. This principle can also reduce the effort for the energy assessment of a total building portfolio (municipalities, housing companies) or a national building stock, as far as typological criteria are known.

The term "building typology" refers to a systematic description of the criteria for the definition of typical buildings as well as to a set of exemplary buildings representing the building types.
In the past few decades, different experience with building typologies has been gained in the European countries. The idea of the IEE project TABULA was to examine them and to come to a concerted approach to the field of residential buildings. A focus was placed on the energy consumption for space heating and hot water. The overall objective was to promote understanding of the structure and of the modernization processes of the building sector in different countries and – in the long run – to learn from each other about successful energy saving strategies.

The residential building typologies elaborated during TABULA form a data pool of the countries' residential building stocks. They offer different application opportunities: Single exemplary buildings can be used as showcase examples to give the first estimation of energy saving potentials of real buildings. The set of exemplary buildings, complemented with statistical data about the national building stocks, can be applied for modelling the energy demand of the countries' residential building sectors and form a basis for further scenario analyses. From a European point of view, the harmonized approach of the TABULA project provides a framework for cross-country comparisons of residential building stocks against the background of energy efficiency.

[TABULA, 2012, p 8]: An overview of the national building typology is given by the "Building Type Matrix". The columns of the matrix represent four building size classes (single-family houses, terraced houses, multi-family houses, apartment blocks), the rows – a certain number of construction year classes. The start year and end year of the construction year classes are individually defined for each country. The single cells of the matrix form the generic "Building Types" of a country.

An exemplary building is assigned to each generic building type of a country (cell of the classification grid), it is represented by a photo and the data of the thermal envelope. This building is supposed to be a typical representative of the building type, meaning that it has the features that can commonly be found in houses of the respective age and size class. The envelope area and the heat transfer coefficients of the exemplary building are not necessarily representative in a statistical sense.
In addition, heat supply systems for space heating and domestic hot water are defined, which can commonly be found in the housing stock differentiated by energy carrier, heat generator type and energy efficiency level.

Part 1 follows the general classification of the housing stock at the national and European level (Episcope project for example). It can be learned from these attempts that these assessments are too generic in nature to inform the development of a modular retrofit concept. What is missing is an in-depth analysis of the structural and financial characteristics of these typologies. However, it has to be emphasized that such extensive assessments are time consuming and costly and it will be challenging to meaningfully classify housing based on detailed information (including geo-cluster (local) specific characteristics). In order to determine if a specific building is suitable for retrofit with MORE-CONNECT a more detailed assessment is suggested. Parts 2-6 collect case or building specific data

Figure 7.9. Conceptual idea of the housing assessment format: property will be assessed in the way a MORE-CONNECT contractor / provider would do in case of a tender.

including the overall pilot building information; (architectural and geometric) design specifications; structural design specifications; building technical system specifications, and building performance indicators. According to the format developed in this report, it can be determined in more detail how many buildings can be retrofitted with a specific product-market combination following the guidelines of the MORE-CONNECT platform (advanced prefabricated, multifunctional building envelope elements for modular retrofitting). Thus, the assessment of housing typologies across Europe can be useful in order to determine which type of housing will be considered when developing the MORE-CONNECT solutions.

Figure 7.9 presents the conceptual idea behind the detailed assessment: property will be assessed in the way a MORE-CONNECT contractor / provider would do in case of a tender. When deciding upon an (n)ZEB retrofit approach for a specific residential building, it has first to be decided which alternative solutions to select from. Moreover, it is necessary to decide whether the modular MORE-CONNECT concept could provide a (cost-effective) solution from a product-market combination point of view. Table 7.1 includes the parameters, which need to be assessed. The assessment form is included in Appendix A.

In the subsequent section, an example building is assessed according to the developed methodology.

ASSESSMENT OF HISTORICAL (MONUMENT) AND AESTHETIC RESIDENTIAL BUILDING CHARACTERISTICS

Assessment of historical (monument) characteristics

Residential buildings, which are considered for renovation, need to be assessed in terms of their monument (protected) status, ascribed by local municipalities, provinces/regions or by the national government. Monument protection includes the entire property and all the parts (components) of the real estate, such as the foundation, facade and facade parts (e.g. also steps, stairs and/or landing), the supporting structure, roof, floors, floor finish and interior (e.g. ceiling, wall finishing, stairs, doors and fireplaces) as parts of the protected monument.

Strict codes have been developed regarding modifications that are allowed. In case of residential buildings with the monument status, renovation using the MORE-CONNECT principle (placing a prefabricated facade and/or roof) is not possible because the building (facade) will be (drastically) modified.

Assessment of aesthetic characteristics

Besides the historic characteristics, it is also necessary to make an inventory of the aesthetic characteristics with respect to the insurmountable objections against replacing the facade (and/or roof). To replace a facade a building permit is in many cases mandatory. A permit application is important for the applicant and can also affect local residents or other interested parties.

<table>
<tr><th colspan="2">Parameter</th><th>Assessment</th></tr>
<tr><td>Housing statistics (Part 1)</td><td>National housing statistics</td><td>Assessment of MORE-CONNECT market potential; the following link could be helpful: http://episcope.eu/building-typology/</td></tr>
<tr><td rowspan="7">Overall building information* (Part 2)</td><td>Monument status</td><td>The building cannot be renovated with prefabricated facade elements when the building is considered a monument (major adjustments to the building (design) are prohibited</td></tr>
<tr><td>Building aesthetics</td><td>Aesthetic building design could impede renovation when the facade is replaced with prefabricated elements</td></tr>
<tr><td>Business case</td><td>(Additional) financial slack (mortgage, income, savings from energy and maintenance cost reduction) to cover the investment, i.e. the business case for the project</td></tr>
<tr><td>Site plan</td><td>Accessibility of the building site when considering renovation with prefabricated elements (logistics)</td></tr>
<tr><td>Legal requirements</td><td>Alterations to the building design and floor plan (increase of floor space) have consequences for the building permit</td></tr>
<tr><td>Energy grid</td><td>Interconnectedness with energy grid: possibilities to deliver surplus of energy to the grid</td></tr>
<tr><td>Housing typology</td><td>Assessment of housing typology including (semi-)detached, mid-row / end-row terraced, multifamily housing with/without galleries, maisonette, other types of MFH (high-rise)</td></tr>
<tr><td rowspan="5">Architectural design (Part 3)</td><td rowspan="5">Architectural design characteristics</td><td>Assessment of the floor plan of the building: typology and dimensions (x, y)</td></tr>
<tr><td>Assessment of the cross-section of the building: dimensions (z)</td></tr>
<tr><td>Assessment of roof design (shape, overhang): typology, U-value [W/(m^2 K]</td></tr>
<tr><td>Assessment of facade design: fixed-free; open-closed; U-value [W/(m^2 K]</td></tr>
<tr><td>Building extensions and complementary facade elements: bay window, French balconies, etc.</td></tr>
<tr><td rowspan="4">Structural design# (Part 4)</td><td rowspan="4">Structural design characteristics</td><td>Loadbearing scheme: inclusion of (front-back) facade in the load bearing structure</td></tr>
<tr><td>Assessment of structural capabilities of foundations</td></tr>
<tr><td>Assessment of vertical structures (including openings)</td></tr>
<tr><td>Assessment of roofing structure</td></tr>
<tr><td rowspan="5">Building technical systems (Part 5)</td><td rowspan="5">Building technical system</td><td>Assessment of indoor climate systems with respect to heating/ cooling and available energy sources (district/central heating system and renewables)</td></tr>
<tr><td>Assessment of ventilation system: inclusion in facade/roof structure</td></tr>
<tr><td>Assessment of electrical wiring: inclusion in facade/roof structure</td></tr>
<tr><td>Assessment of water piping: inclusion in facade/roof structure</td></tr>
<tr><td>Assessment of drainage system: inclusion in facade/roof structure</td></tr>
<tr><td rowspan="6">Building performance$ (Part 6)</td><td rowspan="6">Building performance</td><td>Assessment energy performance: costs, energy consumption</td></tr>
<tr><td>Assessment environmental impact: CO_2 emission</td></tr>
<tr><td>Assessment of building acoustics including noise from service systems and the acoustic performance of the building envelope and separation walls (between apartments)</td></tr>
<tr><td>Assessment of the daylight level in the dwellings (when affected by the renovation)</td></tr>
<tr><td>Assessment of the air tightness</td></tr>
<tr><td>Assessment of moisture safety / hygrothermal design</td></tr>
</table>

Table 7.1. The housing assessment format – see appendix A for the assessment form.

ASSESSMENT OF A BUSINESS CASE: FINANCIAL ISSUES RELATED TO ENERGY COSTS

Ultimately, a solid business case has a decisive effect on the decision to adopt MORE-CONNECT and retrofit a residential building accordingly. Therefore, financial performance indicators of the residential building need to be assessed and the energy costs in particular. Savings on the energy costs could provide or at least contribute to the financial resources to invest in the renovation. This assessment is the first indication about the applicability of the MORE-CONNECT retrofit concept from a business case point of view. Thus, high energy cost increases the potential of the MORE-CONNECT concept while from the energy cost saving point of view, the retrofit investment can be justified. Moreover, in some countries (n)ZEB retrofit investments are subsidized, which further improves the affordability. Details about the business case are discussed elsewhere in this book.

ASSESSMENT OF STRUCTURAL RESIDENTIAL BUILDING CHARACTERISTICS

The assessment includes a detailed analysis of the structural characteristics of a property. The assessment includes several data sheets, which are presented below. In its essence, during this assessment it will be determined if the modular, prefabricated MORE-CONNECT elements technologically ‘match’ the residential building. First, Table XXX presents some statistics about the building stock.

These statistics can be used in order to determine the market potential of the product-market combination (not further assessed here, beyond the scope of this report). Second, Table XXX provides a general description of the residential building in order to determine the potential of the building regarding the nZEB retrofit investment. Finally, Table 7.1 presents the detailed technological assessment (structural characteristics) of the building.

7.4 SPECIFICATIONS AND ASSESSMENT OF MORE-CONNECT SOLUTIONS

Project Results: Deliverable 5.2 and 6.1
Lead author: WALTER OTT
Co-author(s): OVE MØRCK

MORE-CONNECT solutions are elaborated for six different geo-clusters with widely varying climatic, building stock, economic and institutional preconditions. Deep renovation of the existing buildings by MORE-CONNECT solutions is striving for ambitious energy and CO_2-related targets (ZEB or (n)ZEB). Therefore, an appropriate methodology to assess correctly the impacts of the favorable MORE-CONNECT concepts chosen and to search for cost effective (least costly) solutions to meet the pre-set targets was developed, taking into account the somewhat more complex situation of building renovation compared to new building construction.

7.4.1 SCOPE OF ASSESSMENT AND SYSTEM BOUNDARIES

System boundaries, on-site electricity or heat production

The system boundary considered is “net delivered energy”, comprising energy carriers delivered to the building minus on-site generated energy exported from the building to the grid or to a heating/cooling energy distribution system. The primary energy conversion factor of energy exported to the grid or to a heating/cooling energy distribution system corresponds to the conversion factor for the energy replaced in the grid or in the energy distribution system.

Assessed energy use and emissions

Primary energy use and the related greenhouse gas emissions of a building comprise:

- Operational energy use for space heating, space cooling, ventilation, domestic hot water, auxiliary electricity demand (for building integrated technical systems such as fans, pumps, electric valves, control devices, etc.), appliances, lighting;

- Embodied energy use associated with the production of materials, building elements and technical installations added within building renovation, comprising embodied energy for insulation and building materials, technical equipment and renewable energy heating or generation systems like PV or thermal collectors.

Primary energy use and greenhouse gas emissions are calculated by taking into account conversion efficiencies of the heating systems and emission factors as well as primary energy factors of the energy carriers including up-stream emissions and energy use (from LCA). It is recommended to use national primary energy and GHG emissions conversion factors.

Embodied energy use of MC-elements is transformed to a yearly energy use and to yearly emissions, respectively, dividing the embodied energy (emissions) by the number of years of expected service lifetime of the renovated building elements.

Cost assessment

Basically, the integration of the cost perspective is based on a life cycle cost approach, albeit initial investment costs, which are often most decisive for the decision makers, are disclosed too. A private cost/benefit perspective is assumed, comprising:

- Initial investment costs (and replacement costs of elements which are replaced within the assessment period);
- Energy costs, including existing energy taxes and CO_2 taxes;
- Maintenance and operational costs.

Life-cycle-cost and cost-effectiveness calculations are carried out dynamically, either with the annuity method or with the global cost method (discounted cash flow method).

Apart from the costs incurred implementing the selected favorable MORE-CONNECT renovation options in the pilot projects, it was requested to estimate potential cost reductions by economies of scale after successful introduction of the concepts in the market.

Subsidies for energy related measures are excluded from the assessment of costs and benefits to have an assessment, which is undistorted by currently prevailing subsidy programs that might change over time.

Co-benefits of MORE-CONNECT solutions

MORE-CONNECT solutions have still rather higher initial investment costs than corresponding traditional renovation solutions, since potential economies of scale have not yet been realized. Besides energy consumption, energy cost and CO_2 reduction benefits of MC-solutions, there is a variety of further benefits, which do not show up in the cost, energy and emission balances but which might be important for the decision of owners for MORE-CONNECT solutions for (deep) renovation of the existing buildings:

- Compared to traditional renovation solutions, within the MORE-CONNECT solutions energy related (deep) renovation of facades, roofs, heating/domestic hot water/ventilation systems can be carried out fast, which allows the users to stay in the building. This is favorable for the users and prevents or reduces rent losses for the owners;
- Ventilation as an element of the MORE-CONNECT solution: Safeguards air comfort and prevents moisture;
- Allows aesthetic improvement of the buildings, which might result in a higher building value;
- MORE-CONNECT solutions may provide for the enlargement of living space (e.g. integration of a balcony into the heated living area).

7.4.2 IMPACT OF MORE-CONNECT SOLUTIONS ON ENERGY USE, CO_2 AND COST COMPARISON WITH A REFERENCE CASE

To correctly determine the impacts of the renovation packages within MORE-CONNECT solutions on costs, primary energy use and greenhouse gas emissions, it is necessary to define a common reference renovation case as it would be carried out if no energy related renovation with MORE-CONNECT solutions was implemented. This “anyway renovation” comprises the restoration of the functionality of the renovated building elements, yet without improvement of the energy performance. Typical ‘anyway renovation’ measures carried out are repairing and painting of the facade, replacement of worn-out elements by the elements of the same kind, replacement of a fossil heating system by a new fossil heating system of the same kind, etc.

The renovation packages taken into consideration are then compared to this “anyway renovation” approach to determine the net energy related impact of the MORE-CONNECT-solution in comparison with this “anyway renovation” option (energy, CO_2, cost).

This approach is illustrated in the following figure:

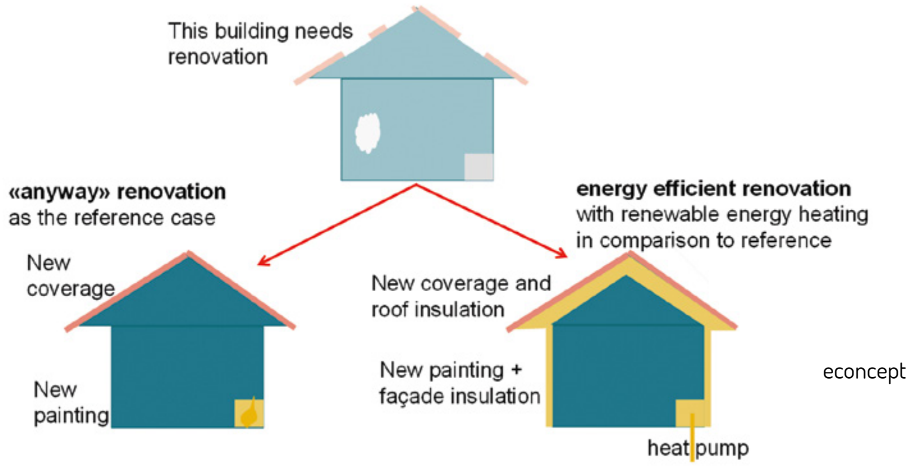


Figure 7.10. "Anyway renovation" vs. "energy efficient renovation with MORE-CONNECT solutions": Different renovation packages improving the energy performance of the building are compared with a renovation, which would be necessary "anyway" to restore the building functionalities.

7.4.3 OVERVIEW OF THE ASSESSMENT PROCEDURE

The following figure summarizes the procedure for assessing the (net-) impacts of MORE-CONNECT solutions on cost, primary energy use and CO_2 emissions:

1. Definition of the reference building
Collect the necessary building data for the assessment: Dimensions and energy properties of all building elements having an influence on the energy performance and GHG emissions.

2. Definition of framework parameters
Define economic parameters such as energy prices, interest rates and exchange rates, emission factors, primary energy factors and climate data, etc.

3. Definition and assessment of the reference case
Define "anyway renovation" measures for the reference case, determine related service lives, associated costs, maintenance costs, energy needs. Calculate impacts on primary energy use, greenhouse gas emissions and costs for the reference case.

4. Definition and assessment of different renovation packages
Define which MORE-CONNECT measures are investigated. Aggregate measures to renovation packages, starting with the most economical first. Determine related service lives, associated costs, maintenance costs, energy needs. Calculate impacts on primary energy use, greenhouse gas emissions and costs for the renovation case with MORE-CONNECT measures.

5. Comparison
Compare the impacts of the reference case with different renovation packages of MORE-CONNECT measures and with different heating systems on greenhouse gas emissions, primary energy use and costs in the graphs as shown in Figure 7.10.

6. Sensitivities
Carry out sensitivity calculations, at least with respect to energy prices and initial energy performance of the reference building.

7. Evaluation and selection
Evaluate and take informed decision on which renovation concept to choose for pilots.

Figure 7.11. Overview of the assessment procedure for the selection of favorable concepts for the pilot projects.

MORE—
CONNECT

8

DESIGN GUIDELINES

8

DESIGN GUIDELINES

Project Results: Deliverables 3.2 and 3.4
Lead author: JOHN VAN OORSCHOT
Co-author(s): RONALD ROVERS

8.1 SHORT INTRODUCTION

8.1.1 BACKGROUND

To improve the current building stock towards nearly zero energy buildings, retrofitting surpassed the level of the improvement of isolated building components, such as roofs, facades or heating systems. This approach often results in inefficient solutions. Optimal results cannot be achieved by single renovation measures, and even worse, new problems could arise, including local condensation or overheating.

MORE-CONNECT aims to develop and demonstrate an innovative modular building renovation concept for housing across different EU geo-clusters. The concept is based on largely standardized facade and roof systems that are suitable for prefabrication. The highly insulated new building envelope includes the integration of HVAC systems among other technologies (like PV).

This report links to Work package 3: System integration of the H_2020 project MORE-CONNECT. One of the key issues related to this work package is the development of design rules or guidelines, which support the design process of prefabricated modular facade elements. As it has been emphasised in multiple innovation projects in this field, like ANNEX 50, Progetone and MORE-CONNECT, the lack of knowledge on innovative deep retrofit design methodologies, including the adoption of prefabricated systems, is hindering the wider market adoption of such highly promising technological solution.

Problem definition:

The lack of knowledge on innovative deep retrofit design methodologies, including the adoption of prefabricated systems, is hindering the wider market adoption of such highly promising technological solutions.

Therefore, this chapter aims to outline the design guidelines for modular prefabricated facade. These design guidelines in particular should take into account the needs of the client(s) and/or occupants. In contrast, industry is looking for opportunities to create a market out of single demonstration projects and therefore is aiming at replicability and industrialization. Thus, the design guidelines should balance industrialization and customization in terms of mass-customization.

Aim of the project:

The aim of this project encompasses the development of guidelines for the design of prefabricated facade modules taking into account user/owner (aesthetic) options within the basic elements configuration and within performance criteria linked to (n)ZEB retrofitting of existing housing.

The following seven steps are characteristic for deep retrofitting toward zero energy housing (ANNEX 50; Van Oorschot et al., 2016):

1. **Market potential evaluation and preliminary building analysis**
   Preliminary assessment of the potential of the existing property takes into account multiple options ranging from value retention, part(ial) renovation, comprehensive renovation or a new building replacement. Investors can select from the following options:
   1) suspend investment in favour of the status quo;
   2) invest to preserve the property, i.e. “anyway renovations” (for a period up to 10 years);
   3) invest to renovate the property (for a period up to 25 years);
   4) invest to transform the property according to the principles of a nearly zero energy build environment (for a period up to 50 years);

5) invest to replace the property, or;
6) to sell the property.

2. **Needs analysis**
   Identifying the needs and parameters of the most important stakeholders and multipliers of advanced retrofit: owners, planners, constructors and public authorities
3. **Building analysis**
   Detailed analysis of the built structure and its relevant system components in order to identify retrofit options
4. **Target agreement**
   Combining retrofit options to provide a building strategy with high added value over the entire life cycle.
5. **Planning and design**
   Planning and design of the project, including the design of prefabricated facade modules
6. **Execution**
   During this step, the project will be realized on site including mounting the prefabricated facade modules.
7. **Target effectiveness evaluation**
   Evaluation of objectives reached during at least one year of operation after work completion.

Following steps I to IV, it first has to be decided whether or not to invest in deep retrofitting from a strategic real estate policy perspective (Annex 50, Van Oorschot et al., 2016). Subsequently, it is not only necessary to evaluate what the needs of the involved stakeholders are, in particular, occupants, it is also necessary to determine whether the building meets the requirements to be renovated according to the principles of modular facade elements (MORE-CONNECT WP 3.1; Annex 50). Finally, after the concept and design requirements are determined, the planning and realization phases will implement the deep retrofitting concept into practice. Thus, during these preliminary steps it is necessary to decide which approach will be adopted and implemented in the project (steps V and VI). Accordingly, during the realization phase the retrofitting solution will be designed and engineered. This report addresses the design guidelines for the prefabricated renovation modules, during step 6. The other steps fall beyond the scope of this report. This publication specifically builds upon the insights from the previous research and development projects related to deep renovation, including:

- ANNEX 50
- Bouwhulpgroep
- 2D Gevel.

See also:
www.empa-ren.ch/A50.htm
www.ecbcs.org/annexes/annex50.htm
https://www.progetone.eu/project/
http://www.more-connect.eu/

8.1.2 METHODOLOGY

Two methodologies have been applied to develop this chapter. First, desk research has been conducted to review previous experience with respect to the design of prefabricated facade modules. Second, building upon innovative design methods, design guidelines are developed based on the insights developed in the MORE-CONNECT case project. Therefore, this report builds upon a design approach developed by Van den Kroonenberg (Siers, 2004; www.bouwnext.nl).

8.2 THEORETICAL BACKGROUND – MODULARITY IN THE HOUSING SECTOR

Modern methods of construction (MMC) are innovative building practices that aim to improve the quality of construction assets. In many cases, they displace work from the construction site to the factory. It speeds up construction time on site and improves product's performance; it reduces defects in the construction, waste of materials, number of workers on site, risks and construction costs (Pan, Gibb, & Dainty, 2007). MMC comprises modular building, preassembly, prefabrication, offsite production (OSP), offsite manufacturing, industrialized building, and other innovative construction practices on and off site (Rahman, 2013).

Modularity is a technique, which builds larger systems by combining smaller sub-systems. A modular innovation is a significant improvement (or even a new concept) within a specific area, which does not require changes in other components or systems (Henderson & Clark, 1990). Modular systems are designed independently but still function as an integrated whole. By breaking up products into sub-systems or modules, designers, producers and users have developed enormous flexibility to intervene in the process of product development. Modularity in design encourages competition, different agents can develop a product or sub-system that can be coupled to the main system. In addition, same products can be developed in parallel and a bigger rate of innovation can be expected from it (Baldwin & Clark, 2003). When modularity is just starting to be adopted and implemented in a company, it requires more coordination between product developers to set the interfaces between modules. Designers must work in collaboration and have general knowledge of the overall product to set stable design rules that function as a solid base for the development of the modular product.

8.2.1 CHARACTERISTICS AND DESIGN RULES OF PRODUCT MODULARITY

Modular architecture is characterized by having a one-to-one mapping from functional elements in the function structure to the physical components of the product, and implies no tied interfaces between components. Modular innovation allows straightforward implementation, with no changes in other systems. Responsibilities and liabilities are easy to be allocated since they are coupled to the product developer.

In an ideal and completely modular architecture, a modular component of the architecture system should be able to be replaced without affecting other modules of the system or its overall performance. Modularity is based on the principle of interdependence of modules with independence across them. Design rules clarify the interactions across a product's sub-systems, reduce component specificity, and provide a form of embedded control that reduces the need for overt hierarchical control or ongoing communication during concurrent improvements of individual subsystems. Product architecture, interfaces, integration protocols and testing standards are the design rule categories upon which decisions are made to conceive new modular products (Baldwin & Clark, 2000)

Box 1: Key challenge of modularity: primitive learning processes about the design rules

Thorough knowledge of the construction of the existing housing is the key to the development of modular deep-retrofitting solutions, especially since retrofitting appears to be cyclical. Every ten to fifteen years retrofitting needs to be 'reinvented' for the housing being erected or adjusted. However, the residential sector has a poor history concerning systematic data collection about the existing housing stock. Knowledge about possibilities, constraints and bottlenecks of the existing building is poorly documented, especially when it comes to additions.

Nevertheless, the first generation two-dimensional solutions of facade renovation have been developed decades ago. Although theoretically one knows how to do it, the performance is eventually disturbed by deviations that have not been taken into account beforehand: size tolerances, impact of demolition and corners (3D). The negative effects of deviations come to light when they need to be corrected during the execution and normally result in additional work and cost, and loss of quality. When choosing a 'seal form' (airtightness), the existing building structure in relation to the assembly principle needs to be considered with respect to the method of insulating and 'sealing' and the manner of execution. There must be a proper alignment of the requirements.

At present, working with the existing building is an ongoing exploration journey through the history of construction. Due to the lack of documentation, partly due to the lack of continuity in practice, every individual and every construction must build up their expertise. Knowledge development is thus a very primitive learning process and a key bottleneck of the advancement of deep retrofitting.

Box 2: Example of (successful) modular consumer durables

O-BAG [1]

[1] http://www.obagshop.nl/

8.2.2 MODULARITY IN THE HOUSING SECTOR

Modularity is an MMC that aims to improve the quality and efficiency in the construction sector. In this sector, there is a recurring dilemma involving the need of having standard products to increase quality and the need of flexible customized products to satisfy the needs of the clients. Customers value distinctiveness and customization of their property, while construction companies look for solutions that reduce costs and delivery time and increase product quality. Baldwin and Clark (2000) present modularization as a way to mitigating client demands for variation and supplier requirements for repetitiveness.

Box 3: Example of the modular housing components

PREFAB BOX-IN-BOX BATHROOM POD - FAAY PREFAB PRODUCTS [1]

CLIMATE BOX – NATHAN [2]

PLUSDAK – STAFIER SOLAR SYSTEMS [3]

1 https://www.faayprefabproducts.nl/prefab-badkamers/

2 http://www.nathanprojects.nl/projecten/woningbouw/nul-op-de-meter-woningen-met-nathan-energiemodule/

3 http://www.plusdak.nl/

8.2.3 MODULARITY AND DEEP RETROFITTING

Currently, there are about 7 million dwelling in the Netherlands and about 250 million in Europe. Deep retrofitting of the European housing stock could benefit from a modularity approach for a variety of reasons.

1) Environmental impact

In 2015, the household sector was the second largest producer of greenhouse gas emissions in Europe (Eurostat, 2016). The European Commission is therefore looking at costs-efficient ways to make European economy more climate-friendly and less energy consuming. Emissions from houses can almost completely be cut by making use of passive technologies, refurbishing old buildings and substituting fossil fuels with renewable fuels (Directive2002/91/EC, 2002). In 2010 the Energy Performance of Buildings Directive (EPBD) set a directive (Directive2002/91/EC, 2002) to improve the energy efficiency of EU buildings. Energy performance improvement can be reached by implementing innovative (n)ZEB retrofit solutions by which an outdated house stock can be upgraded and energy consumption can be reduced (van Oorschot, Hofman, & Halman, 2016).

2) Viable business case (mass-customization)

There are already several deep retrofitting concepts available in the market, most of which are based on the so-called 'one-time-good' approach: the house is brought with one intervention from the current level toward the level of a new build or even zero energy housing. From a (n)ZEB policy perspective, this is an excellent starting point, however, the question is whether this is the most cost effective way. Is enough attention paid to the comfort of living, or should the resident change his or her behavior? In addition, in practice, the most important question is whether these deep-retrofitting concepts are affordable. As a result, the return on investment takes up to 50 years. This limits large-scale application of such concepts.

3) Shortage of craftsmen

The available working force capacity for total residential construction sector will be a major problem in the long term. The increase in maintenance and renovation leads to two major problems in the current mode of production:

- An unfavorable cost-benefit ratio (too expensive in relation to new construction);
- Traditional approaches are labor intensive and within the market characterized by shortage of craftsmen they could become problematic in terms of production.

4) Changing market demand

Client demand has changed over time, in particular with respect to the level of customization in housing design and comfort. First, professional clients, building owners and housing associations transfer risks and tasks to the industry and demand a smoothly organized and speedy process. They allow variation in design (occupants are granted a certain level of customization), but within a consistent image quality, because of the value of their possession over time. Next, end users (occupants) demand more comfort at a better value for money, more freedom of choice, appearance that is more individual and less inconvenience during the retrofitting process. Finally, society demands more sustainability, safety and health.

Taken together, the advantages of a modular deep retrofitting approach encompass (see also Annex 50, Plug&play; Bouwhulpgroep):

1. Product-oriented instead of the traditional project-based approach;
2. An improved cost-quality ratio. Due to the limited productivity development in retrofitting and the impact of (poor) labor productivity, retrofitting is becoming increasingly expensive;
3. Improved energy efficiency resulting in a low(er) environmental impact. The quality additions to the existing building must be at least energy zero;
4. High level of customization. Individuality is inextricably linked to (appropriate) customization;
5. Limitation of risks. Intervention in existing homes is always linked to short and long-term risks. Developing the solution, this aspect will require extra attention, establishing a clear relationship between the existing and added quality.

By decomposing housing into different modules, the existing housing stock could be structured in a different way. In contrast to structuring the building stock into typologies based on layout and year of construction, housing could also be structured based on the modules it is composed of. For example, a roof can be the same module for different types of dwellings in different geographic locations. The challenge will be not to view a dwelling as an 'off' product, but rather as a composition of various components, which change over time (http://www.bestaandewoningbouw.nl/de-familie-doorzon/).

If dwellings and the deep-retrofitting solution are considered from a modularity perspective, i.e. as an aggregation of 'loosely coupled' products and materials, the sector and the market alike could benefit from mass-customized deep-retrofitting solutions of high quality. In this respect, modularity combines standardization and customization. First, modules can be replicated in subsequent projects and stimulate learning practices. Next, occupants could choose between multiple suppliers and customize the modules to their needs and wishes (based on preselection of alternatives). This provides an opportunity to achieve better quality at a lower price (scale benefits) during construction as well as adjustment over time.

The carriers of such standardization are the modules, which comprise a single dwelling or apartment block. A module is defined as a composition of related building components and materials that provide a utility function of a building or single dwelling (such as roof, facade, home interior, etc.). Housing typically consists of the following basic modules, which need to be considered to modularize deep retrofitting (Liebregts and Van Bergen, 2010; Verbouwkompas, 2015; Energiesprong, 2016):

1. Foundation;
2. Facade (Figure 8.3);
3. Roof structure (Figure 8.4);
4. Layout (floorplan);
5. Extensions;
6. Built-in structures (kitchen, bathroom, toilet, staircase, meter cabinet);
7. Energy installation (heat pump, photovoltaics).

Box 4: Housing modules – definition

A module is defined as a composition of related building components and materials that provide a utility function of a building or single dwelling. This development began with the kitchen and today has been copied by other module suppliers (Box 3).

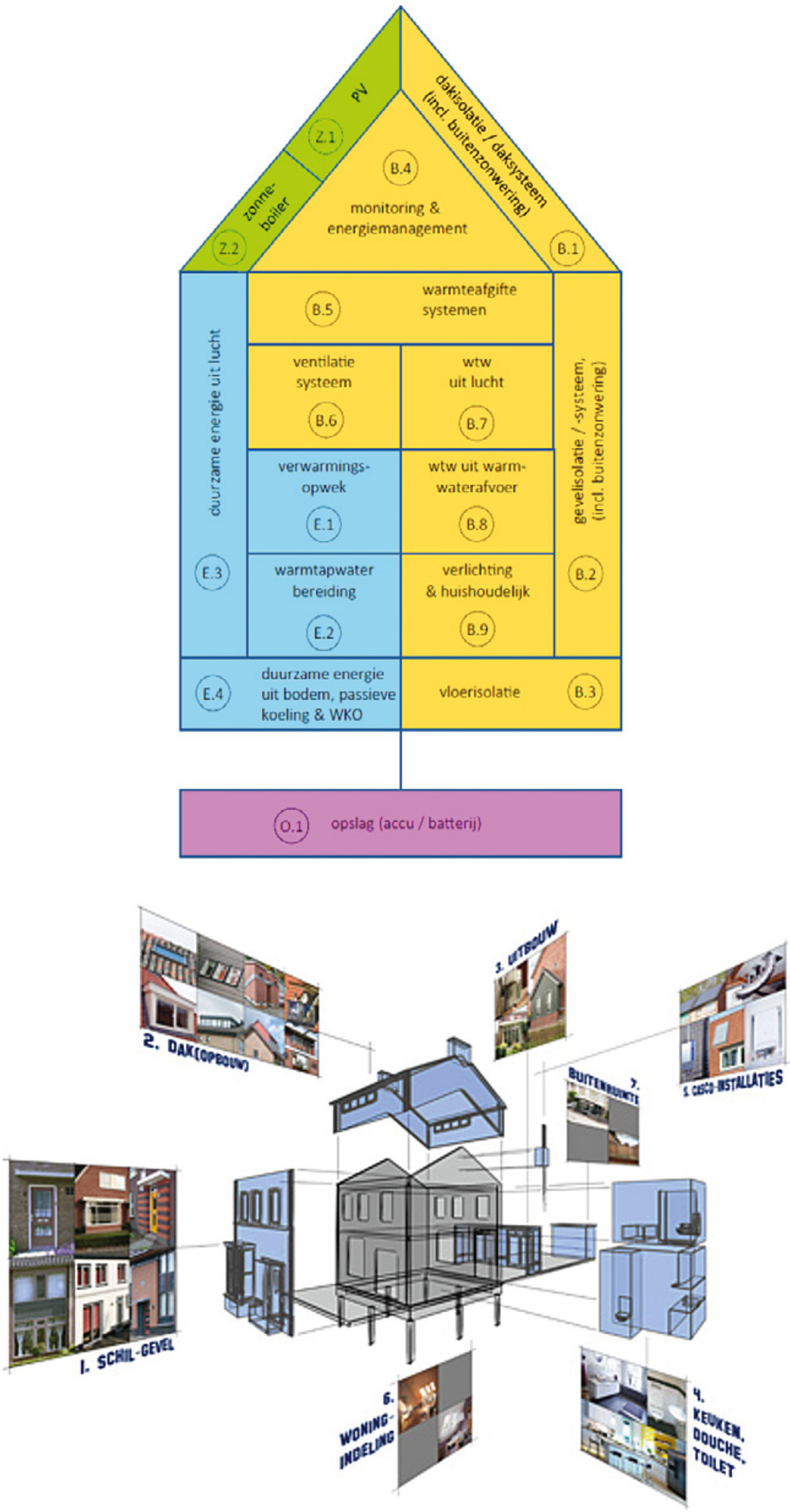
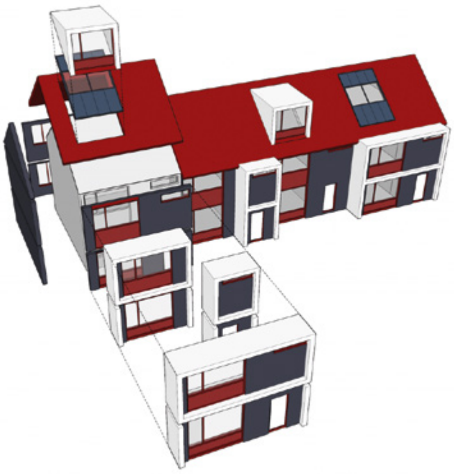
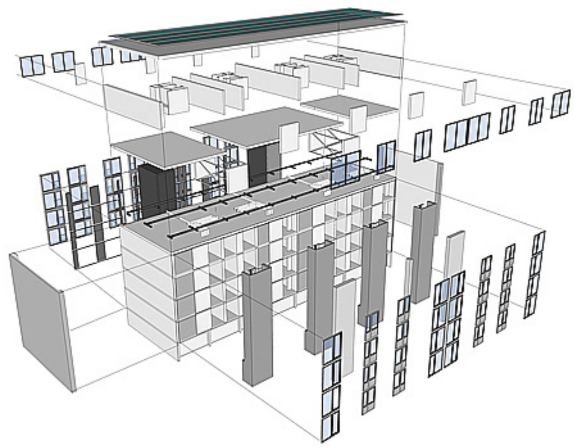


Figure 8.1. Modularity, key components when considering deep retrofitting (adopted from Energiesprong, 2016).



Single-family housing [1]



Apartment building [2]

Figure 8.2. Project based design alternatives from a modular deep-retrofitting perspective.

[1] http://www.hollands-ontwerp.nl/vandaag-experiment-morgen-bewezen-techniek/#more-1127

[2] http://www.duurzaaminstaal.nl/p/587/endis-portiekflat-renovatie.html

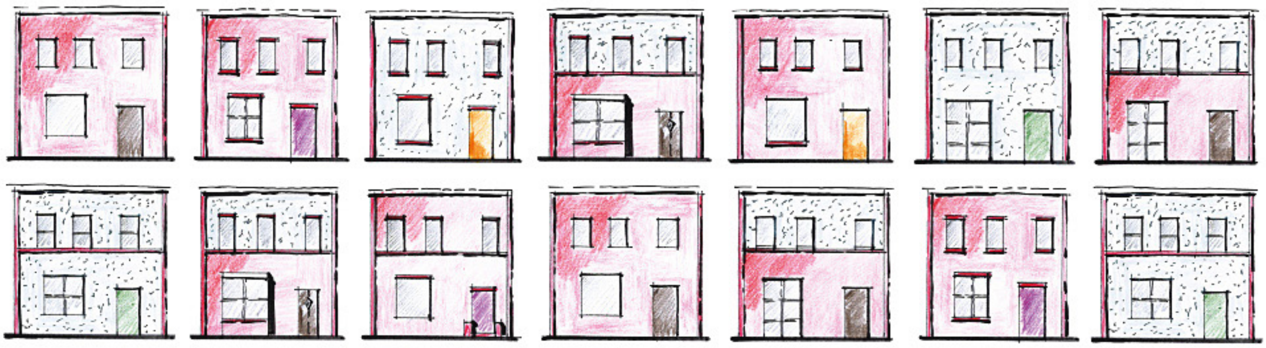


Figure 8.3. Design alternatives of the roof subsystems. These typologies shape the market of facade modules (adopted from: http://www.bouwhulparchief.nl/onderzoek/eindhoven_alliantiegevelbeam.php).

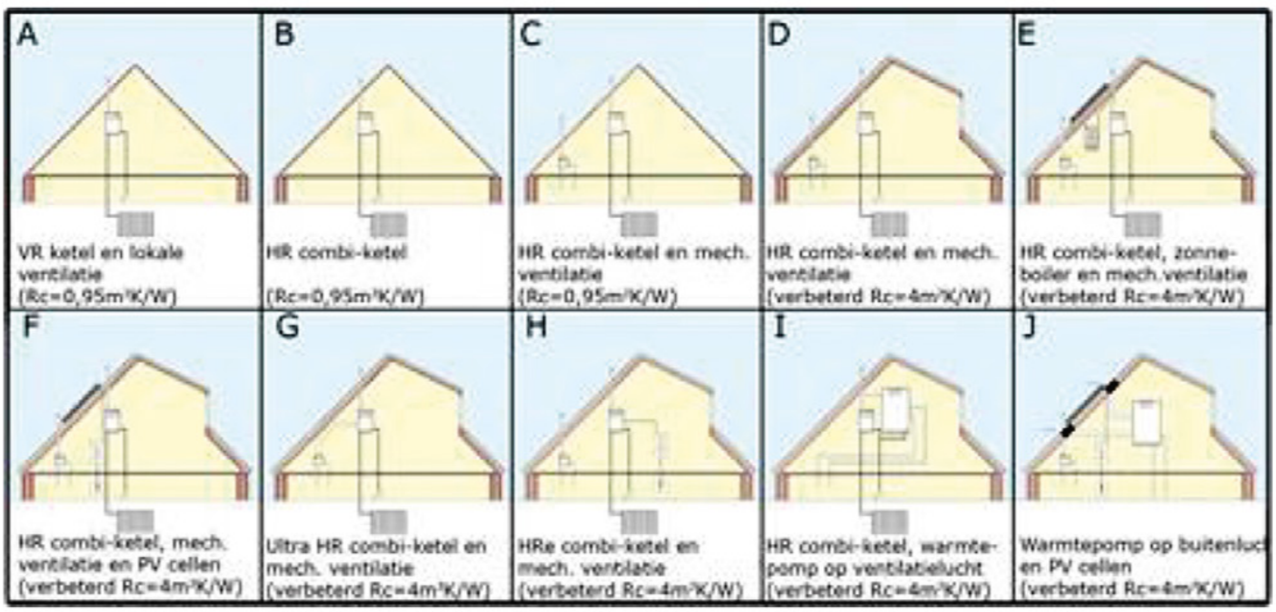


Figure 8.4. Design alternatives of the roof subsystems. These typologies shape the market of roof modules (adopted from: http://www.bouwhulparchief.nl/onderzoek/eindhoven_alliantiegevelbeam.php).

Box 5: Deep retrofitting costs

Modular deep-retrofitting practices lend themselves to optimizing production (costs). Extensive prefabrication and 'dry' assembly at the building site contributes to cost optimization. An indication of the building costs:

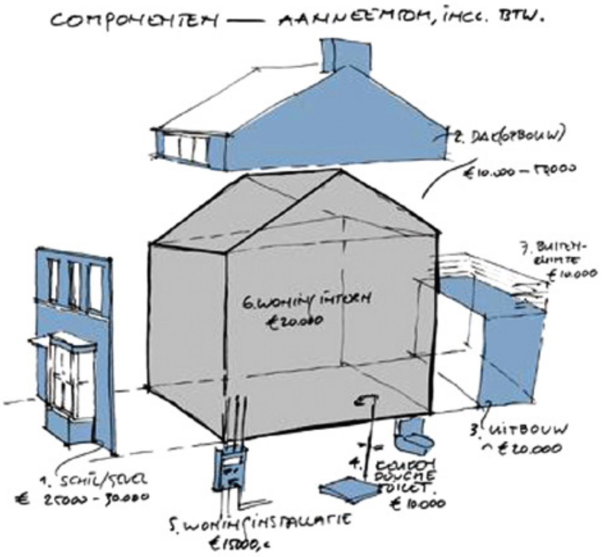


Table 8.1. Housing transformation investments versus new-build investments (demolition costs and land cost not included).

Concept characteristics	First generation deep-retrofitting projects in the Netherlands (2007)	Optimization (2016)	New build
Energy label (improvement)	G/F --> A++	G/F --> ZEB	A++
€/dwelling * (case study)	€90,000-120,000-	€65,000-85,000-	€115,000-
€/dwelling * (reference)	€65,000-85,000-	€45,000-65,000-	€81,000 (average for rent market in the Netherlands)

* labor and materials; about 40 % of new build costs are made up by labor costs. In contrast, in case of renovation labor costs constitute about 60 %. Optimization results from diminishing labor on-site (by 10-20 %) as a result of standardization (http://www.bestaandewoningbouw.nl/met-component-renovatie-30-goedkoper/)

Kosten opbouw renovatie versus nieuwbouw

	Arbeid		Materiaal		Totaal	
Nieuwbouw	€ 46.000	100	€ 69.000	100	115000	100
Hoog niveau renovatie	€ 78.000	170	€ 52.000	75	130000	113
Component renovatie traditioneel	€ 78.000	170	€ 52.000	75	130000	113
Component renovatie geoptimaliseerd	€ 52.000	113	€ 48.000	70	100000	87

Kosten ex BTW

8.2.4 DESIGN REQUIREMENTS AND BASIC STRUCTURE OF THE MODULE

8.2.4.1 Design requirements

The design of the building envelope, the facade in particular, needs to meet several performance criteria. Moreover, it should be architecturally appealing. These criteria relate to the physical, structural performance of the building envelope (TU Delft, 1994).

Architectural (adapted from TU Delft, 1994)

Open (glass)	Closed (solids)
Plane, level facade, with little intersecting parts	Dynamic, with many inward and protruding parts
Simple design, composition consisting of a few parts	Complex, composition of many parts
Predominantly vertically oriented elements	Predominantly horizontally oriented elements
Large elements, (half) storey high elements	Small elements, brickwork, framework

Building physics (adapted from TU Delft, 1994)

Collecting and discharging rain, snow or external condensation	Prevention of vapor diffusion from inside to outside; preventing condensation in the structure
Noice absorption, both insite and outsite	Noice reflection
Airtightness	Ventilation
Heat absorption and minimizing temperature fluctuations	Limiting heat loss in winter, preventing cold radiation and condensation
Sun light reflection, reflection of radiation to avoid high surface temperatures	Sun light transmition

Structural (adapted from TU Delft, 1994)

Load bearing; floor load bearing, part of the main support structure		Non-load bearing
Contributes to the stability of the main bearing structure		Contributes NOT to the stability of the main bearing structure
Monolith, made up of one layer		Multilayered
Made up of bricks or blocks of various materials	prefabricated (storey high) elements (various materials), suspended on the floor or on individual auxiliary styles	Made up of framework, for example, curtain wall, timber frame
In front of vertical support structure (column, walls)	Between support structure (column, walls)	Behind support structure (column, walls)
In front of horizontal support structure (floor or roof)		Behind horizontal support structure (floor or roof)

The flexibility of the MORE-CONNECT facade modules allows their application on a wide array of housing typologies distinguishing between archetypes, thermal properties, geo-localization, and energy systems. Taking into account project(-site) based boundary conditions, the design of the modules needs to take into account the following basic technical requirements:

- Energy sources;
  - ✓ Various combinations of electricity, district heating, natural gas, biomass boiler;
  - ✓ Presence of active production from RES including PV on roofs, additional facade installation and domestic hot water (DMW) from solar panels;
- Heating system
  - ✓ High-efficiency heat pumps, inclusion of heat recovery systems;
  - ✓ Possible source of heat or electricity for circulating DHW;
- Ventilation system
  - ✓ Mechanical ventilation with heat recovery;
  - ✓ Requirements on air ducts in modules;
  - ✓ Need for HVAC modules (possible locations: cellar / loft / outside);
  - ✓ Need for indoor air ducts for exhaust air – indoor modules needed;
- Smart connectors
  - ✓ Mechanical smart connectors (for structural support and joints);
  - ✓ Air ducts;
  - ✓ Heating pipes;
  - ✓ Low voltage for controls of electricity loads;
  - ✓ PV wiring;
- Smart building management, monitoring, and control
  - ✓ Temperature;
  - ✓ Humidity;
  - ✓ CO_2;
  - ✓ Heat flows;
  - ✓ Individual room control.

Besides these technical requirements, additional project requirements are suggested related to a range of items, which are linked to different 'functionalities'. These criteria include or relate to (Adopted from Geavanceerde plug&play gevel 2D voor renovatie, report BouwhulpGroep and Cauberg-Huygen):

1. Social security within the building and immediate environment;
2. Burglary safety;
3. Accessibility of the building and immediate environment;
4. Accessibility of the housing unit including the accessibility of single spaces within;
5. Accessibility to home appliances and service installations (concerning maintenance of specific components);
6. Maintenance of the building and immediate environment;
7. Building identity;
8. Identity of home appliances and finishing;
9. Luxury appearance of the building;
10. Luxury appearance of home appliances and finishes;
11. Size and spaciousness of housing units;
12. Flexibility;
13. Ease of use of home appliances and service installations;
14. Healthy indoor climate;
15. Comfortable indoor climate (thermal / acoustic).

Box 6: Generalized list of requirements

The development of the prefabricated facade modules is based on the premise that the proposed solution must meet some common design targets, including (Progetone, MORE-CONNECT wp2):

- Be adjustable to fulfill the needs of target typologies in different climatic and seismic conditions;
- Be variable in their thermal properties, providing various levels of refurbished building energy
- Performance;
- Enable variability in design of external surfaces;
- Enable mounting/anchoring of outdoor extensions such as balconies and shading devices according
- to the architectural requirements;
- Ensure compatibility for reinforcing the existing structure for seismic stability;
- Integrate air ducts for HVAC systems, piping for heat distribution, wiring (electricity, internet,
- sensors, TV, etc.)
- Integrate renewable energy systems;
- Be compatible with alternative thermal insulation systems;
- Fit for all situations where the renovation project requires complete, partial or no removal of existing structures;
- Enable fast installation without need of scaffolding;
- Be based on modules that are transportable with standard means of transport.

Prefabricated facade modules bring about innovation in deep retrofit solutions, compared to traditional refurbishing techniques, technologies, and practices. As each building has intrinsic boundary conditions and differences in technological requirements, the demands of the building users also vary, i.e. in terms of the need for building extensions, variability in comfort requirements on a way to meeting legislation regulations. Several key innovation aspects (Progetone) include:

- Rapid improvement of building energy performance and user living comfort: a combination of high-performing technologies embodied in the multifunctional modules, including thick layers of thermal (super) insulation materials, new low-U-value windows, use of renewable energy sources, HVAC and energy systems, as well as advanced control systems, etc.
- Minimal intervention (low-intrusiveness) to user life during the renovation: The renovation process is faster compared to traditional solutions since much technology is embedded in the modules and mounting on site. Key elements are installed over the exterior walls (when existing envelope is kept), so low-intrusiveness is ensured also due to the main external character of the intervention.
- Extension of the building area: When there is a sufficient space around the building, prefabricated modular systems can enlarge the usable area of the housing unit. It can be made either by small additional structures such as balconies (see the P2Endure project) or by larger glazed winter gardens. Another way is the extension to the loft or upon the roof of the existing building, or providing an opportunity to customize the flat the user's way (see the MORE-CONNECT project).
- Passive strategies: The renovation process can include the adoption of extension of building area with modular systems to significantly reduce the need for mechanical systems. Modular glass facade additions around the perimeter of the building can enhance the overall performance (energy demand and comfort) of an existing building effectively, by creation of buffer spaces. Buffer spaces allow the modulation of the indoor temperature, taking advantage of the radiative temperature difference between the building environment and the sky temperature during the summer and winter season.
- Alternative passive strategies for deep retrofit, including the enhancement of both energy performance and comfort for the users, entail the prevention of solar radiation from reaching the building and its interior, to avoid indoor overheating and glare conditions. This can be achieved by including obstacles such as shading devices within the modular elements for deep retrofit or directly manipulating the solar-optical properties of glazed surfaces (high reflectivity, thermochromic, electrochromic, holographic glasses) used for the prefabricated components.
- Flexible architectural design: The renovation process becomes flexible enough to cope with all sets of challenges from boundary conditions and needs of the building stakeholders, allowing variable configuration of the diverse technologies, including:
  - ✓ Joints: Thinking of apartment houses, panels cannot be manufactured in size of the whole facade, therefore they have to be connected to seal the facade and to ensure the mechanical cooperation of the whole structure. The flexible design can also enable joining in an inner or outer corner of the building.
  - ✓ A variety of external surfaces: The designed panel can allow the execution of any common type of facade finishing (thin plaster, wooden cladding, cement boards, etc.).
  - ✓ The combination of external surfaces: The designed panel can allow combination with other types of facade renovation systems, such External Thermal Insulation Composite System (ETICS), for instance, in the basement or on one facade.

Various lessons have been learned from the previous projects concerning the overall success of deep retrofitting with prefabricated modules. This has resulted in several implications for the design of the modules (http://www.hollands-ontwerp.nl/prijsvraag-hollands-ontwerp-award-2012/; Liebregts & Van Bergen, 2011):

Smart and fast

During the construction work, restraint of nuisance and the good cost-quality ratio are of utmost importance. Construction work should be based on the principle 'done while you wait'. Furthermore, construction work should be completed in time according to plan.

Additional comfort: insulation and safety

Proper comfort and safety are quality aspects that change over time and are partly influenced by technical developments and capabilities. Combining deep retrofitting with additional comfort measures enhances the future value of the property.

Architectural appearance

The architectural appearance has a positive effect on the acceptance of the deep retrofitting; i.e. technical limitations should not affect the architectural performance of the design.

Performance guarantees

While deep retrofitting is costly on the one hand and often involves technologies which building owners and occupants are not acquainted to on the other hand, performance guarantees are essential to get deep retrofitting adopted. Next, services with respect to maintenance could contribute to acceptability of deep-retrofitting solution.

Customer service 24 hours

In addition to maintenance service, customer service can also be offered as a 24-hour service (today this is already offered to the market for specific component including the glass service and the gas-boiler service).

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">Concept / vision</th></tr>
<tr><th>Smart & Fast: The extent to which the existing techniques for improving the cost-quality ratio are used</th><th>Integral: The extent to which the intervention addresses a variety of market needs</th><th>Affordability: Mass-customization, balancing mass production principles and customization</th></tr>
<tr><td rowspan="16">Aspects of deep retrofitting</td><td rowspan="6">Product: quality improvement of the building.</td><td>Customization:</td><td>Comfort, space and (aesthetic) appearance:</td><td>Reduction:</td></tr>
<tr><td rowspan="3">To what extend individual occupant needs are accounted for? Which alternatives / options to select from?</td><td rowspan="3">Which performance criteria are taken into account?</td><td>To what extend is the environmental impact (energy reduction) of the building reduced?</td></tr>
<tr><td>Standard modules:</td></tr>
<tr><td>To what extend are standardized modules/ components applied (cost reduction)?</td></tr>
<tr><td>Level of prefabrication:</td><td>Synergy (1+1=3):</td><td>Reduction exploitation costs:</td></tr>
<tr><td>To what extend is on-site labor reduced?</td><td>To what extend does the project benefit from a holistic approach with respect to the overall project performance?</td><td>To what extend are the exploitation costs reduced?</td></tr>
<tr><td rowspan="6">Process: quality insurance.</td><td>Reduction construction time:</td><td>Environmental impact</td><td>Standardization:</td></tr>
<tr><td>To what extend is the construction time reduced in contrast to a more traditional project approach?</td><td>What is the environmental impact (in contrast to a more traditional project approach)?</td><td rowspan="3">What is the level of standardization within the project?</td></tr>
<tr><td>Reduction hindrance:</td><td>TCO Total Cost of Ownership:</td></tr>
<tr><td>To what extend does the project disturb the involved occupants (in contrast to a more traditional project approach)?</td><td>What is the effect on the 'total cost of ownership'?</td></tr>
<tr><td>Overhead costs:</td><td>Client orientation:</td><td>Project stages:</td></tr>
<tr><td>To what extend are the project specific costs reduced (relocation, allowances)?</td><td>To what extend does the project build upon the principles of a 'customer-centric' approach?</td><td>At what stages of the project are considerable cost reductions achieved?</td></tr>
<tr><td rowspan="4">Collaboration project partners</td><td>Reduction of project preparation time:</td><td>Quality guarantees</td><td>Finance and affordability</td></tr>
<tr><td>To what extend is the project preparation time reduced by improved collaboration between project partners?</td><td>Do the project partners guarantee long-term quality performance?</td><td>How does the business case look like? Which financial incentives are applied to ensure affordability?</td></tr>
<tr><td>Reduction of overhead costs:</td><td>Knowledge</td><td>Innovation cost/benefit ratio</td></tr>
<tr><td>To what extend are the project overhead costs reduced as a result from improved collaboration?</td><td>Which tools are used to ensure knowledge transition from project to project?</td><td>Which innovations are introduced to improve cost/benefit ratio of the deep-retrofitting approach?</td></tr>
</table>

Table 8.2. Nine performance fields of deep retrofitting (http://www.hollands-ontwerp.nl/prijsvraag-hollands-ontwerp-award-2012/; Liebregts & Van Bergen, 2011).

8.2.4.2 Basic structure of the module

Depending on the building typology and characteristics, diverse retrofit strategies for the design of the basic modules can be applied (MORE-CONNECT WP2.2):

- Complete removal of the facade and/or roof and full replacement;
- Partial removal;
- No removal of the facade and/or roof and addition of prefab elements.

Given the variability in external structures of the building types taken into account and the requirement of integration of air ducts, wiring and piping into the external modules, design strategies must consider different possible ways of mounting the prefabricated modules. Also, the geometry of the wall modules and their relative position depend on the following key questions:

1. Can the original external wall be removed?
2. Is there any structural vertical element to enable connection of the piping, wiring and air ducts close to the floor structure?
3. Can the window openings be extended (depending on the material and structure of the walls)?

The design choices for the basic modular panels and elements are the result of a decision-making process that takes systematic account of the boundary conditions of the building and of the architectural, normative, and comfort requirements of the building stakeholders.

There are two different approaches to retrofit module design (Annex 50). The first approach includes totally prefabricated modules. In contrast, the other concentrates on prefabrication at the window area as the area with the highest density of details. Moreover, prefabricated modules for roofs and balconies are developed in the same way, i.e. customization to the project site depends on the interfaces between the modules, see Figure 8.5.

Fundamentally, and in line with the design guidelines developed in Annex 50 and confirmed by the MORE-CONNECT project, the module consists of the following layers:

1. An equalizing layer mounted on the existing outer wall;
2. A load bearing construction with insulation layer and integrated ducts;
3. The second layer of insulation material. The thickness of the insulation can be chosen depending on the desired U-value;
4. A cladding layer that can be prefabricated and delivered with the module or mounted on site.

For example (case study De Kroeven, NL):
Wall construction U-value: 0.107 W/(m^2 K)

- Existing brickwork 100 mm
- OSB 15 mm
- Cellulose fiber insulation 350 mm
- Damp open MDF 15 mm
- cavity 30 mm
- Natural slates 10 mm

>Total 520 mm

Facade and roof modules can be designed 'freely' for the following architecturally relevant points (Annex 50; Plug & Play 2D):

- Shape of the module (consider mounting possibilities);
- Recessions and projections (e.g. bays, dormers);
- Measurements of the modules (maximal measurements: 3.5 m · 3.5 m · 12 m);
- Measurement and number of openings;
- Design of reveals and railings;
- Construction material (wood, wood-metal, metal);
- Cladding material (all standard facade materials are possible);
- Shadowing elements (all standard sun protection systems can be integrated);
- Integration of solar energy (photovoltaic and photo thermal);
- Technical equipment (integrated risers for central ventilation and electrics, decentralized ventilation systems, automatic shadowing systems, integration of solar energy).

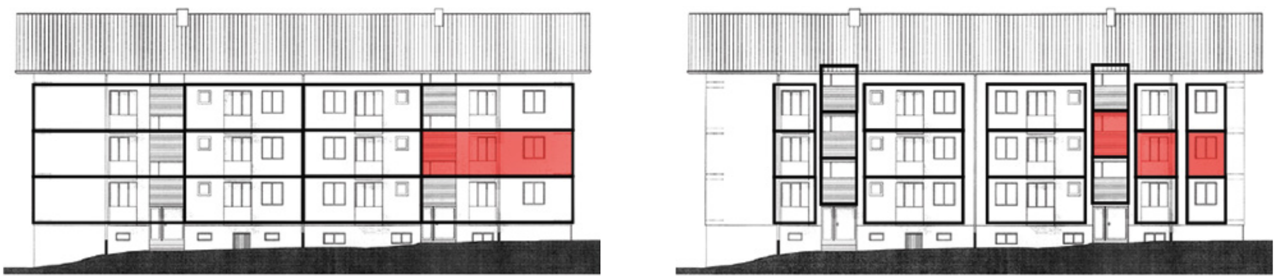


Figure 8.5. Two design and construction approaches to modular retrofit systems, i.e. the totally modular prefabricated design and the semi-prefabricated design (adopted from Annex 50).

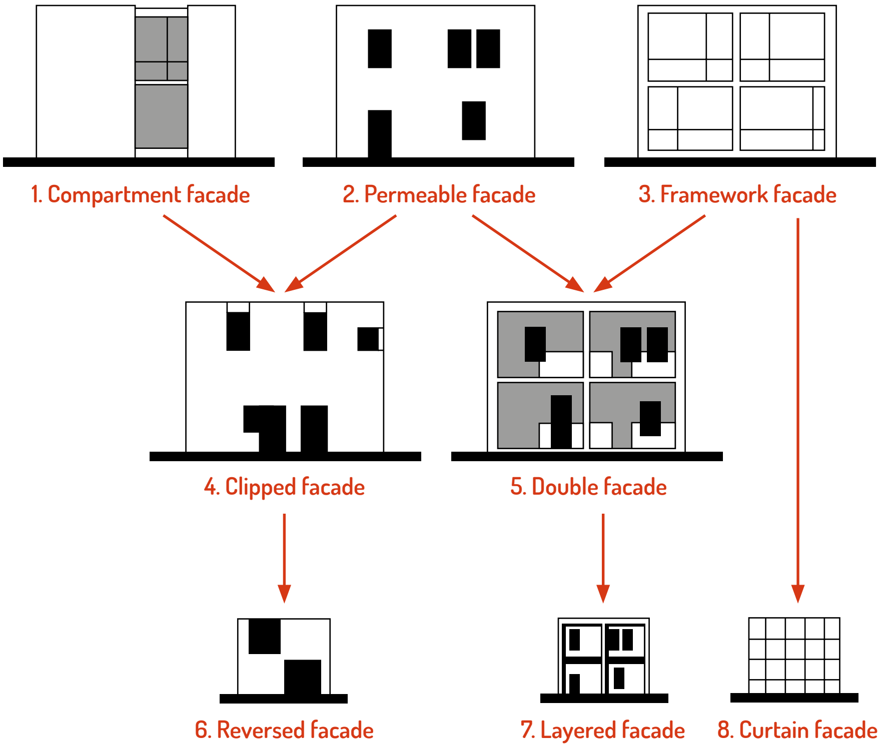


Figure 8.6. Main facade typologies affecting the orientation of the facade modules (adopted from TUDelft, 1994).

Specification of module sizes

The specification of maximal possible and minimum sufficient sizes of the basic module is determined by criteria of transport and sizes of available materials:

- What standardized sizes of necessary boards, sheets or plate material are available?
- How to minimize clippings?
- What is the maximum size of a module for transportation?
- What is the maximum size for delivering on-site and lifting to the facade due to the ranges for set-up area and possible lifting auxiliaries?

Specification of facade typology and module orientation

The orientation – vertically or horizontally – depends on the facade typology, the load bearing capacity and structural design building/facade. Different facade typologies have different effects on the orientation and subsequent design of the prefabricated modules. Framework facades, for example, affect a pattern – load bearing points are fixed and determine the module size. The facade typology and, subsequently, the orientation affect:

- Architectural appearance (dominated by horizontally or vertically lines);
- Assembling procedure;
- Integration of components (glazing, ducts, BIPV, et cetera).

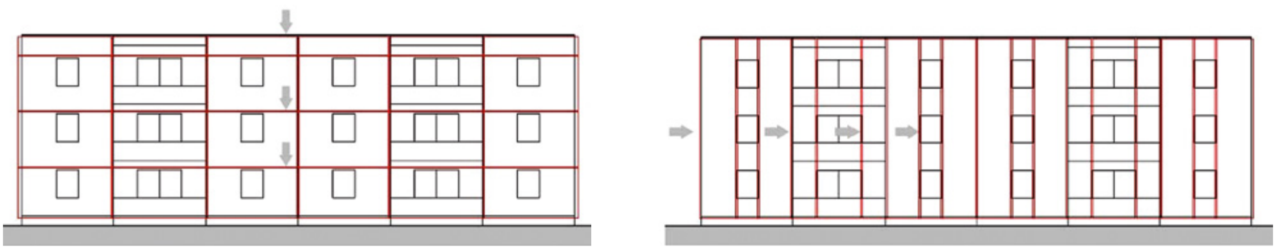


Figure 8.7. Grid applied to design of the modular facade panels: horizontal or vertical orientation (adopted from Annex 50).

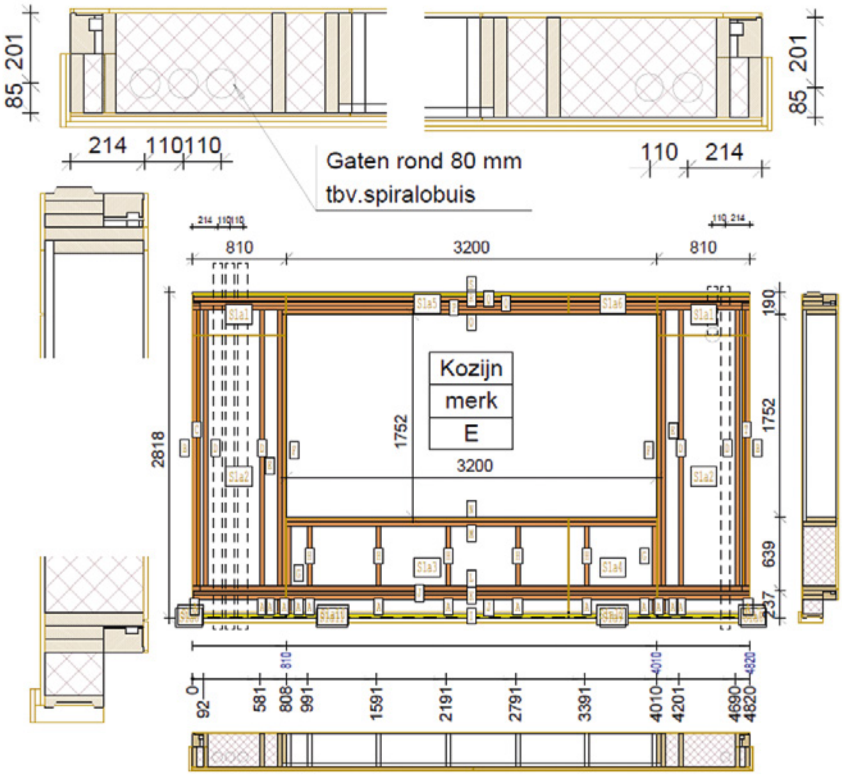


Figure 8.8. Basic module design developed by WEBO, producer of modular timber frame elements in the Netherlands.

8.2.5 (ARCHITECTURAL) DESIGN ASPECTS – A MORPHOLOGICAL OVERVIEW

8.2.5.1 Applying a morphological design approach

There are several innovative design methods. An example of this is the methodical design process based on a morphological design approach developed by Van den Kroonenberg (Siers, 2004; www.bouwnext.nl). The aim of the morphological overview is to systematically assess all possible solutions to a complex problem.

The methodical design process structures the design process into three phases:

1) Problem definition – In the first phase, the problem or improvement is defined. The result of this phase is a program of requirements.

2) Method determination – In order to achieve the stated goal, a certain function or (sub-) functions must be performed. A function can often be performed in several ways, i.e. alternatives. The alternatives can be expressed in schematic sketches and structured in a table or a morphological overview. The functions are displayed vertically in the morphological overview. In the horizontal direction, different

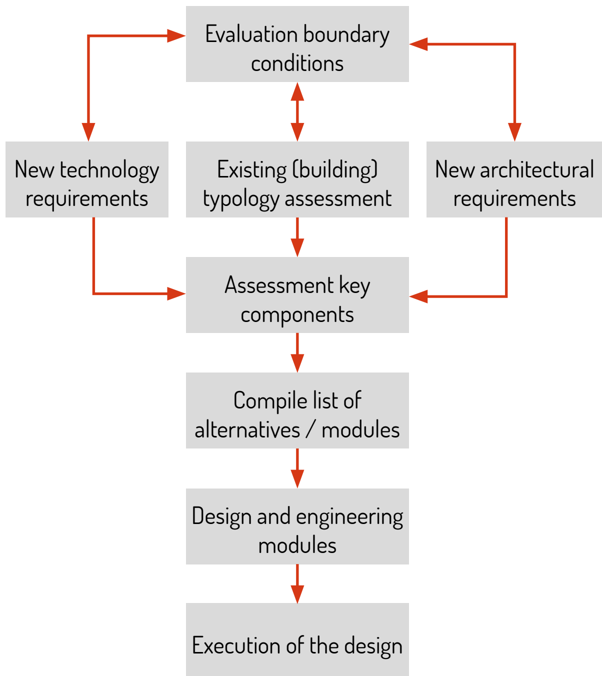
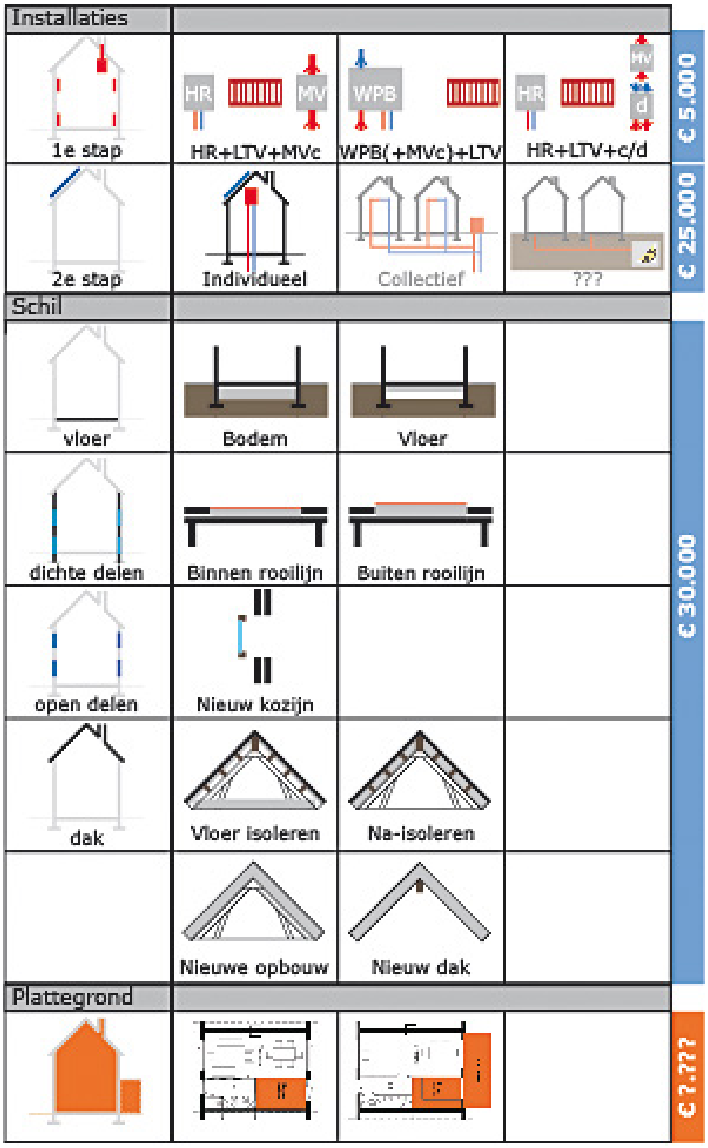


Figure 8.9. Design process.



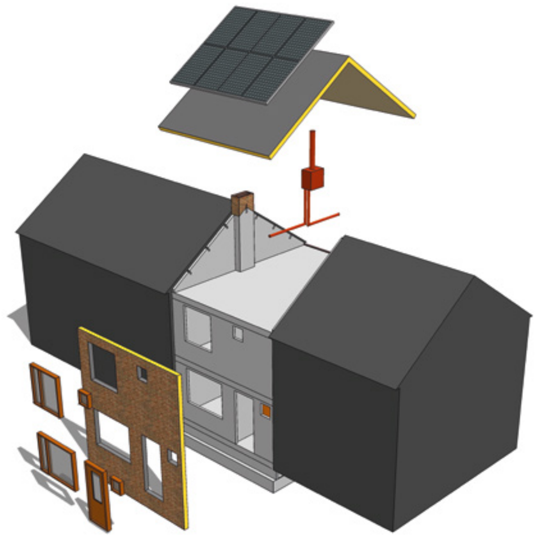


Figure 8.10. Design strategies could include a morphological design approach (adopted from Jonkers and Dijkmans, 2012 and http://www.hollands-ontwerp.nl/nominatie-hollands-ontwerp-award-2012-van-e-naar-beter/).

alternatives for the functions are displayed. A number of alternatives can be combined into a logical design. This is called a structure. In the morphological overview, the structure is indicated by a structural line between different alternatives. A final solution should be selected from the prototypes developed. Typically, an objective selection technique is used, the so-called multi-criteria analysis (Kesselring method). The multi-criteria analysis is performed based on the program of requirements developed in Phase 1.

3) Formatting – In the third phase, the most suitable prototype is turned into a design, in this project, the design of a facade module.

The morphological design strategy provides an approach to organizing the design process of modules applied in the housing sector. Modularity offers flexibility and considerable freedom of design (Baldwin and Clark, 2000). The components, which constitute the module, can be organized within morphological overview. These components can be mixed and matched according pre-developed design rules. Flexibility not only relates to the architectural components. Technical components such as blinds, ducts, etc. can be incorporated easily and cheaply into the prefabricated module at the factory. In addition, elements for active solar energy use can be integrated in all modules (Annex 50).

Derived from the morphological design strategy, the design process of prefabricated facade modules includes the following five phases (MORE-CONNECT WP2):

1. Assessing the boundary conditions of the building;
2. Definition of technological and architectural requirements (including specific individual occupant needs) in relation to building extension and variability in comfort;
3. Compilation of a list of basic modules

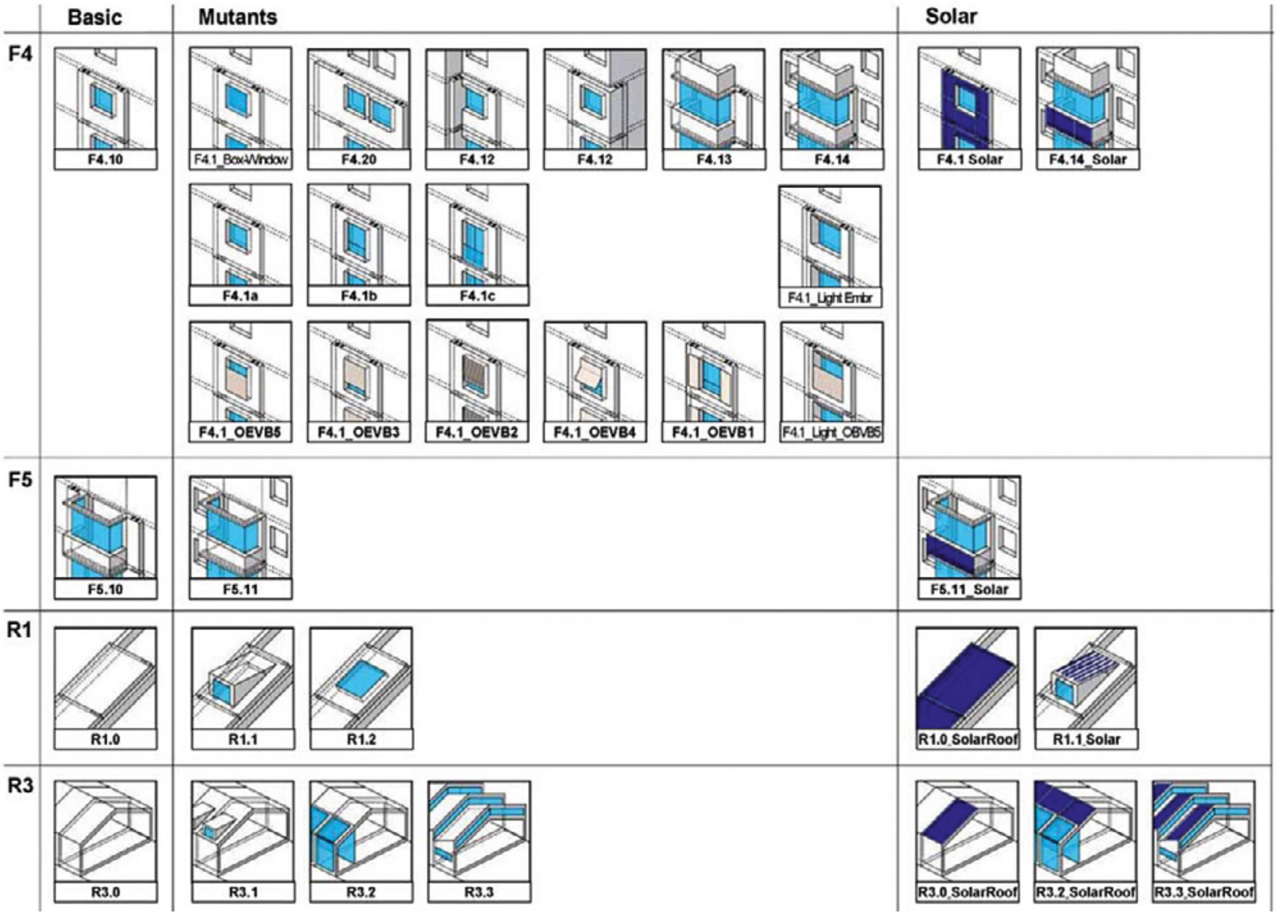


Figure 8.11. Design alternatives for specific modules, which are part of the building envelope (Annex 50).

addressing design targets building upon the morphological overview;
4. Design and engineering of the module(s);
5. Execution of the project;

8.2.5.2 Background of the morphological design of a facade module

In this section, some key design 'functions' are explained. These design functions are the cornerstones of the morphological overview with respect to designing facade modules. This section specifically builds upon the Annex 50 project.

Structural design

There are two different scenarios:

- The existing structure is able to bear the loads of the new facade system;
- The existing structure is not able to bear the load of the new facade system.

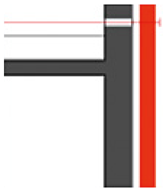
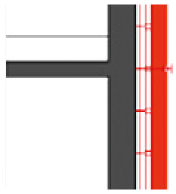
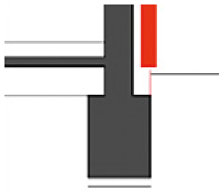
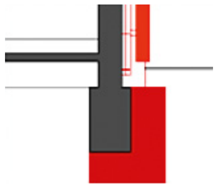
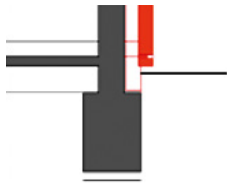
If the load bearing capacity is too little either a load distributing substructure is possible or the new facade has to be implemented as a self-standing construction. Very often, the foundation – invisible from outside – is forgotten. To avoid future settings an examination of the bearing capacity of the existing foundation should show, which further loads can be carried. If capacities are too little, either reinforcement of the existing foundation may solve the problem or a new foundation is necessary.

Depending on whether a standing or suspended construction system is chosen, it is either possible to fix the modules directly upon the old facade or to mount a substructure. Depending on the module size, it is possible to implement a single-span beam construction or a continuous beam construction.

Furthermore, the fastening subsurface influences the bearing system – it is either a massive structure, a skeleton or plate type construction.

Massive constructions, such as subsurface, offer a possibility of either direct fixing or mounting a substructure. A substructure evens out uneven facades in preliminary stages. A faster proceeding of further module assembly is possible. Nevertheless, mounting the substructure needs preparation on-site and therefore either scaffolding or mobile cranes are necessary.

Fixing at floor level has the advantage of potential better load bearing properties, because intermediate floors are mostly made as reinforced concrete slabs or there is an existing grid beam. Even if walls have low load bearing capacities (like porous concrete or gas concrete, etc.) skeleton-

	Suspended construction		**Standing construction**	
Substructure	Load application "suspension" within eaves, attic or roof 	Load distributing substructure upon existing subsurface 	Area-covering structure element (module acts as plate), additional fixing on the top necessary 	Area-covering structure element (module acts as plate), several fixing points all over the facade 
Foundation	Load transmission via existing construction → existing foundation is sufficient 	Load transmission via existing construction → existing foundation has to be reinforced 	New foundation 	Load application upon the plinth via existing foundation 
Dimensioning	Slimmer module sizes	Slimmer module sizes	Thicker module sizes necessary (Buckling stability)	Lower thickness of modules (shorter buckling length)

or plate-type construction systems offer limited possibilities of direct fixing – the raster has to be adapted to the possible subsurface fixing points. The direct fixing extends the assembly procedure but no preliminary work is necessary.

Module sizes spanning more than one level are difficult to implement (transport and lifting). A possible size could be a sanding module spanning the entire height of the facade, but with limited width (about 3 meters). Every system that uses more fixing points with smaller distances in-between reduces bearing loads and improves capacity to resist wind loads. Additionally, the buckling length is reduced – the entire construction can be designed slimmer.

The challenge within old buildings is the uncertainness of load bearing properties and load capacities as well as uneven subsurface or damages in the existing structure.

There is a broad product range of manufacturers offering fixing and mounting systems. They can differentiate in dot-shaped and line supported fixings systems. Every dot-shaped fixing carries loads selectively and in a concentrated way into subsurface, may be disadvantageous when there are weak points within the old walls. Line supported fixing system are more flexible due to inhomogeneous existing structures.

Individual support brackets are suitable support areas for standing construction systems at the bottom.

However, they can also be used for support of suspended or standing constructions at the top. Furthermore, every fixing system has to be able to absorb movements and stresses caused by temperature-related expansions. The acceptance of these movements can be guaranteed by the arrangement of elongated holes between the substructure and the module.

Wooden substructures: if timber framework or wood-based boards have been applied, it subsequently makes sense to use the same material for the substructures. The advantage is easy workability –customization on-site is easy, they are lightweight compared to steel and different profiles are available. The disadvantage is that compared to steel or aluminium substructures wooden substructures have the lower load bearing capacity, are characterized by poorer form-retentive property and combustibility. Due to fire prevention requirements, it should be proved in each case whether a planned timber substructure is sufficient. In order to find adequate anchors or dowels or further fixing possibilities for different applications, a lot of product catalogues or guidelines are available. The following can be mentioned as examples (but there are more of them offering good advice):

www.fischer.de/desktopdefault.aspx/tabid-244/150_read-120/

www.hilti.at/data/editorials/-11888/ratgeber_duebel_online-2005.pdf. Download 09.11.2009

	Single-span beam construction Module system is mounted directly on subsurface or upon substructure	**Continuous beam construction** Continuous beam acts as substructure
Suspended construction	Fixed support on top 	Fixed support on top 
Standing construction	Fixed support at the bottom 	Fixed support at the bottom 
Evaluation	Modules have to be self-supporting. Additional substructure not mandatory. Without substructure every module has to be adjusted during assembling. Interchangeability of each module is possible.	Modules may be designed slimmer. Equalization of uneven subsurfaces by substructure. Assembling modules on substructures enables faster proceeding. Single modules are exchangeable.
Tolerances	Tolerances to allow movements emerging from temperature of each module.	Tolerances to allow movements emerging from temperature of each module.

Fixed support

Slide bearing

Fixed support at the bottom, slide bearing on top

Fixed support on the bottom, slide bearing at the bottom

www.wuerth.de/de/medien/zul/duebel/uebersicht-duebel.pdf
www.werkzeugforum.de/fileadmin/pdfs/know_how_duebel.pdf

After a period of 20-25 years, the existing building services (HVAC27 systems) can be considered outdated.

The renewal of DHW or heating dissipation leads to measures within the existing installation shafts or new ones have to be installed. But in any case it is necessary to carry out measures within the apartments.

Due to binding legal regulations concerning the protection of tenants or condominiums it is often very difficult to implement comprehensive renewal of piping if only one occupant does not agree to the planned measures. However, the chance to complete renovation of building structure and buildings services should not be forgotten. A comprehensive renovation (thermal envelope and building services) provides the possibility to optimize all systems and to complete renovation all at once.

The upgrading of piping or installation as a single measure at a later date is more expensive than carrying them out together with other works. In addition, it will lead to further disturbance and discomfort for users.

Interface design between modules

The design of the module chain first influences assembly, fixing and joining techniques, but has further implications for maintenance and repair. Interactions are shown in Table 8.11.

The design of joint formation is decisive for further work planning. On one hand, the surface of the facade has to be waterproof against driving rain and the entire new envelope should constitute an air tight layer. On the other hand, if there are damages or the necessity to access the intermediate space, the inter-mountability should be possible. Additionally, tolerances between the single modules should allow easy assembly and expansion, and movements caused by temperature.

Cladding materials

As proven in several deep retrofitting projects with modular facade panels, a diversity of (conventional) facade materials can be applied. From a structural perspective, the overall weight of the module needs to be considered, specifically while the finishing has a considerable impact of the overall weight. As a result, the total weight of the facade could become a problem for the existing structure and the foundations and the strength of the structural interfaces have to be dimensioned accordingly. Next, architectural preferences and cultural heritage have to be contrasted with technical and economic consequences of the finishing selected. Overall, cladding alternatives can be subdivided according to the following principles:

- Material selection;
- Colour selection;
- Pattern selection;
- Installed during prefabrication versus on-site finishing.

See Figure 8.12 for a short overview of facade designs applied in the Netherlands.

Integrated components

Prefabricated modules bear the potential of easy integration of additional components. The basic assembly is done in the production facility under guaranteed conditions. The interfaces between the components within the elements are key to the integration of a variety of components. This reflects the design rules of the module. These interfaces need to be engineered and completed carefully. Moreover, any expansion or extension (balconies, new arcades, winter gardens, etc.) can be prefabricated in a system-integrated way as components of the module or as a module itself. Key components, apart from the loadbearing structure, insulation and cladding, include windows and glazing, shading and ducts and piping of the HVAC system.

Windows and glazing

Windows are substantial components within any facade, they are visually and technically demanding, due to their complexity. The interface between the basic module and the window frame should be developed carefully with respect to airtightness and thermal bridges. The key performance indicators of windows and glazing include:

- Optimized supply with natural daylight;
- Outlook for occupants;
- Insight from outside;
- Optimisation of solar gain (hazard of overheating during summer).

Visual appearance is partly shaped by the position of the window within the module (exterior flush-mounted, centred in the reveal or interior flush-mounted).

Installation concept

The following measures can be necessary:

- Renewal or adoption of energy generation for DHW and space heating;
- Renewal or adoption of the distribution and/or dissipation system for DHW and space heating;
- Renewal or adoption of heat storage for DHW and space heating
- Renewal or adoption of further piping or wiring (water, sewage, electric wiring, television, etc.)

First, it should be decided, which installation has to be renewed. Existing installation should be checked:

- On functionality – it is not always necessary to demount fully functional installation;
- On their potential for optimisation – after renovation the entire system should be optimized from generation to distribution

Figure 8.12. Different cladding materials and designs applied in Dutch deep-retrofitting projects.

and dissipation.

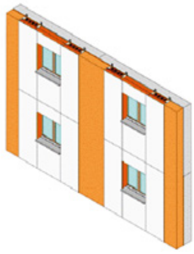
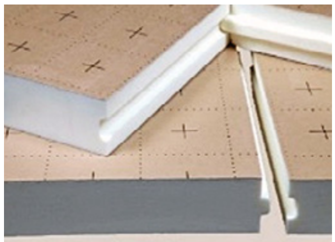
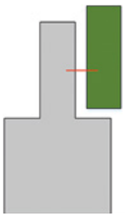
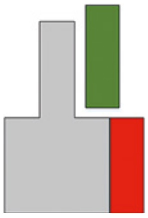
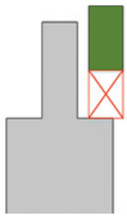
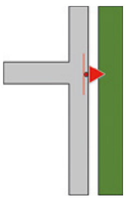
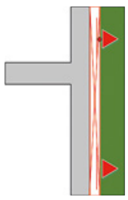
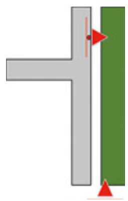
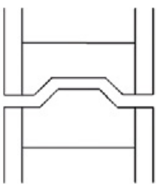
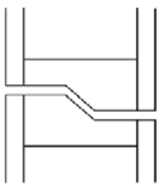
Shaping a new thermal envelope provides the opportunity to integrate prefabricated installation modules on the outside of the existing wall but inside the new thermal envelope. Prefabricated installation inside the buildings is currently state-of-the-art. Not only shafts, even entire installation blocks or comprehensive sanitary blocks are prefabricated, transported on-site and fixed on the planned positions, only some connecting work is necessary. This technology can be adopted for external use.

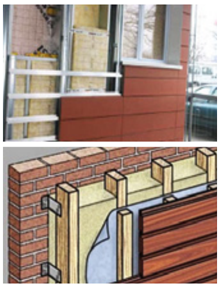
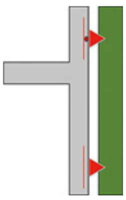
But so far it has not been implemented during renovation; maybe the problem of arranging water conducting pipes at low temperatures outside has not been solved yet. The advantage of installation on the outside within renovation project is that installation working inside the apartments are reduced, occupants are less disturbed and it is possible to renew piping during occupancy. If one tenant refuses works within his/her flat it is possible to connect all other apartments to the new installation system because it is not necessary to lead pipes through this specific unit.

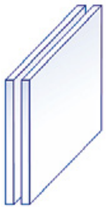
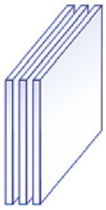
Active energy generation within building envelope: Building Integrated Photovoltaics (BIPV)

Until now, the main function of the facade was the protection against weather or outdoor

Design guide: morphological overview of MORE-CONNECT facade modules

	A	B	C
		Concept	
Basic module and interface (module-building) **Prefabricated panels: Structural Insulated Panels (SIPs – standard, I-beam, bamboo)**	Prefabricated, horizontal orientation modules 	Prefabricated, vertical orientation modules 	Semi-prefabricated, combination of prefab modules and on-site finishing 
Insulation (material)	Mineral / glass wool 	Cellulose (recycled paper) 	PUR/XPS/PE insulation 
(n)ZEB installation concept	Decentralized heating system: gas boiler + low temp + MV(c) (+ PV)	Decentralized heating system: heat pump (air) + gas boiler + low temp (+ PV)	Decentralized heating system: heat pump (water) + low temperature + MV(c-d) (+ PV)
		Interfaces and components	
Interface foundation	Load transmission through existing structure (existing foundation is sufficient) 	Existing foundation need to be reinforced / replaced 	'Structural adaptor' between the module and foundation 
Interface building	Suspended construction: horizontal (floor and roof) structures 	Suspended construction: substructure upon existing surface (facade) 	Standing construction: mounted on foundation, add. fixing on top 
Interface module	Fixed interface 	Flexible (re-mountable) 	

E	F	G
Concept		
Traditional – small components assembled on site 		
Wood-fiber insulation 	Bio-based (cotton; flax; hemp) 	Aerogel insulation 
Central heating system: district heating; industrial residual heating		
Interfaces and components		
Standing construction: fixed upon existing surface (facade) 		

	A	B	C
Ducts and piping HVAC	Ventilation ducts integrated in the module (mechanical ventilation)	Ventilation ducts included in separated spaces (mechanical ventilation)	Ventilation box (including heat recovery)
Openings	No frame	Thermally decoupled wooden frame (Accoya)	Aluminium frame with wooden finishing
Glazing	Double glazing 	Triple glazing 	
Other integrated components	Shading / blinds	Energy modules	
Active energy generation: BIPV	Smart windows	BIPV mounted on/integrated into the modules	
Cladding	Masonry (brickwork, slips) 	Plaster 	Tiles 

conditions and the maintenance of indoor climate conditions, as well as shaping the visual appearance of a building. Active energy generation offers exciting opportunities from both a design and technological perspective. New opportunities emerge from the developments within the field of Building Integrated Photovoltaics (BIPV). BIPV, as stated by subtask C of Task 15 (http://www.iea-pvps.org/) and based on EN 50583 and on the European Construction Product Regulation (CPR) 305/2011, is defined as follows (Technical Secretariat of European Commission, 2015 and Payet et al., 2014): Photovoltaic modules are considered to be building-integrated if the PV modules form construction product which is produced and placed on the market for incorporation in permanent manner in construction works or parts thereof, and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works. Different systems (photovoltaic, photo thermal, flat collectors, tube collectors, etc.) can be installed in/on the facade modules at the factory. So far, BIPV has not been applied at a large scale within facade modules yet. In contrast, several projects have been completed with BIPV applied on roofs.

Due to system complexity, architects and energy engineers must co-operate at a very early planning stage.

Many relevant preliminary decisions of the architect during the design phase have significant influence on the further operation of the active systems. Orientation, incline, position and size are determined by the shape of the thermal envelope.

E	F	G
Natural (demand-driven) ventilation via facade openings	Summer night ventilation	
Wooden frame with air chambers	Plastic frame	
Cladding 	Panels 	

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TECHNICAL ISSUES

Lead author: ANTONÍN LUPÍŠEK
Co-author(s): ALEŠ ZIKMUND, JIŘÍ NOVÁK, MARTIN VOLF

Development of modular systems for retrofitting of existing buildings poses several technical challenges. First of all, compared to new construction, there are a number of requirements and limitations in structural and architectural design of construction components imposed by the existing structures and their conditions. The second challenge is represented by the requirements towards the connections among the new additions and the existing structures and among the newly added parts. There are various structural requirements to the structural connections among modules and among modules and existing facades, as well as connections of HVAC systems and sensors. Besides, there are also physical requirements with regard to thermal properties, durability and water- and air-tightness of the new building envelopes. Special requirements arise from the fact that the modules have to be easy to transport and fast to assemble onsite – all the pieces of the puzzle in the end have to fit together with minimum distance tolerances.

8.3 COMPONENTS

Project Results: Deliverables 2.2 and 2.5
Lead author: ANTONÍN LUPÍŠEK
Co-author(s): ALEŠ ZIKMUND, MARTIN VOLF

The general modules consist of a large number of components and layers with different functions: structural elements of the modules, thermal insulating layers, windows and doors, airtight layers and connections, integrated HVAC systems, renewable energy systems, shading elements, structural connectors and anchorage elements, exterior surface layers, and interior surface layers including flexible connectors between new and old parts of the building interior.

The components or layers can have one, more, or even all functions joined in one. Also, depending on the building geometry, retrofitting scope, economical or energy performance, not all layers have to appear in the final design.

8.3.1 MODULE BEARING STRUCTURE

8.3.1.1 Wood-based frame

The wood-based frame presents a basic solution of module bearing structure, which can be favorable due to sufficient stiffness of the wood, good workability, good availability almost all over the Europe, satisfying thermal properties, and outstanding environmental parameters.

Utilization of the wood-based frame comes from the traditional wood construction industry and presents no difficulties for prefabrication in the current wooden building factories. Also, the computer-aided machinery is broadly available and the preciseness of the production can be very high.

For the energy efficient design, the wooden bearing structure must be protected by the compact layer of insulation.

8.3.1.2 Metal frame

In some applications, a metal frame can be preferred. Steel (or even aluminium) has fewer environmentally favorable parameters, but it is 100 % recyclable. For the countries, where the cost of wood is too high or higher stiffness is needed, the metallic frame represents a good choice.

8.3.1.3 Composite frame

The custom-made composite frame can be selected as an advanced material for the similar application as a wooden framework. The composite material has usually more homogenous structure compared to wood, guaranteed qualities and may be easily adjusted to any shape envisioned by the design.

8.3.1.4 No specific bearing structure

In the case of 3D printed facade, no special bearing structure is needed. The bearing framework is not present in the facade at all.

8.3.2 THERMAL INSULATING MATERIALS

The addition of a significant layer of thermal insulation is necessary to provide the house sufficient energy performance after the refurbishment. On the other hand, very thick layer of insulation dims the passive solar gains through by shading the openings. High performance insulation is favorable from the energy or geometrical point of view, but very costly at the same time. As the thicknesses of the original walls is significant and cannot be removed in every case, the optimal variant for each building needs to be found.

8.3.2.1 Mineral wool

Typical problems of the common buildings from the survey pointed at the technical favorability of the mineral wool-based insulating materials. Stone wool or glass wool have low lambda values (below 0.04 W m^{-1} K^{-1}), they are fire-resistant and available at reasonable cost. These materials allow the water vapor to diffuse naturally in or out from the structure without condensing and raising the moisture content in the original building after refurbishment. This quality is crucial for perfect retrofit and solving the problems of original building.

8.3.2.2 Polystyrene, polyurethane foam

Polystyrene boards (lambda values below 0.04 W m^{-1} K^{-1}), polyurethane (PUR, lambda values 0.033-0.045 W m^{-1} K^{-1}), polyisocyanurate foams (PIR, lambda values 0.023-0.021 W m^{-1} K^{-1}), or phenolic foams (lambda values 0.024–0.021 W m^{-1} K^{-1}) are reasonable materials for dry climates or buildings with airtight original walls in good condition. The cost can be one of the lowest (expanded polystyrene, EPS), however, the moisture content of the original structure and the flammability must be considered.

8.3.2.3 Natural insulating materials

Natural insulating materials, such as wood wool, flax fiber or hemp fiber insulation, can be used. These materials have about 20 % higher lambda values (0.045–0.05 W m^{-1} K^{-1}) than average EPS of mineral wool (0.038–0.04 W m^{-1} K^{-1}). Higher conductivity therefore needs to be compensated by higher thickness, which can be problematic. In addition, the cost is considerably higher (about 30 %) than in case of the more frequent ETICS materials. Anyway, very favorable environmental parameters of these materials are the reason to take these materials in account.

8.3.2.4 Vacuum insulating panels, aerogel

Vacuum insulating panels (VIPs) or aerogel insulating materials are one of the high-end materials available in the market. The very high price is balanced by the reduced thickness of the layer (with λ = 0.007 W m^{-1} K^{-1} for VIP, λ = 0.02 W m^{-1} K^{-1} for aerogel). These materials should be used for detailing, where the lack of space has to be substituted by excellent thermal properties of material. VIPs must be ordered in exact dimensions and shape and cannot be shaped onsite.

8.3.2.5 3D printed facade

Ytong Multipor mineral insulation boards might be used as thermal insulation for 3D printed facades. According to [1], it consists of 100 % homogeneous material with heat conductivity of 0.045 W m^{-1} K^{-1}. Primarily the mass of structures in contact with the indoor space as well as the percentage of window area in the exterior structures are decisive for the thermal insulation in summer. If the insulating material in the external thermal insulation composite system is calculated by itself, the heat storage capacity of Ytong Multipor is relatively high due to its density (115 kg/m^3) at the same insulation thickness.

8.3.3 WINDOWS AND DOORS

8.3.3.1 Double and triple glazed windows and doors

The glazing provided with the modules should be adjustable to the customers' and the buildings' need. Therefore, the universal connection must be provided in the standard, usual form to accommodate the available glazing units and reach competitive prices. The thermal parameters vary according to the geo-clusters, the specific parameters have to be selected according to local climatic conditions.

8.3.3.2 PV-cell glazing

The area of photovoltaic installation can be extended by using the PV-cell glazing. It might be favorable for the building with high glazing ratio. The gains about 115 Wp m^{-2} can be reached.

8.3.4 AIRTIGHT LAYER

The airtight layer position varies according to the geometrical setting of the modules and the building typology. In cases where the original structure is airtight enough and without faults, it is not necessary to create a completely new airtight layer. When the original structure is demounted, the new airtight layer must be provided by the system. The planar airtightness has to be ensured by application of airtight layer in combination reliable airtight inter-modular joints.

8.3.5 EXTERIOR SURFACE LAYER

8.3.5.1 Fully or partially prefabricated plaster

For buildings surrounded by very similar buildings with plaster facades in a very compact and unified urban settlement, it should be possible to use plaster as a final exterior layer. On the other hand, plastering is a wet process that slows down the deep refurbishment process and application of the whole plaster facade goes against the MORE-CONNECT goals. Therefore, a mixed solution is designed – a final layer of plaster is made in the factory (a precast plaster) except for 10–15 cm strip along the panel boundary. Rendering mesh is conversely left bigger overlapping the panel. Joint of the panels is later finished on site and overlapping rendering meshes ensure the integrity of the plaster. Finishing process is distinctly less time-consuming and it can be done, for example, from the scissor lift or small mobile crane. Another solution is the use of robotic 3D printed plaster – see below.

8.3.5.2 3D printed final facade

Another possibility to make plaster facade is to use robotic 3D print. The preprogramed robot hanging on the wire can "climb" the wall without the need of scaffolding, ladder or crane so the application of the plaster is faster and there is no space requirement on the plot around the insulated building. The scanned 3D surface of the facade is installed in the robot memory and adjusted by sensors, so the robot knows locations of openings, corners or other obstacles.

8.3.5.3 Clinker bricks

Brick look can be achieved with bricks or clinker bricks in front of ventilation gap respectively. The advantages are that the panel can be finished in the factory, the surface is divided with mortar, so the panel cleft does not disturb the integrity. Disadvantage of clinker bricks is that they are heavy, which could result in need for more anchors.

8.3.5.4 Brick tiles

The solution used on similarly retrofitted houses in the Netherlands uses classic or plastic brick tiles, which are glued to the panel surface. They are very easy to install, and can be prefabricated in the factory. Using fine pattern, the cleft between panels can be visible. The physical properties of the tiles, such as diffusion resistance factor or flame spread index, have to be considered. The latter may be a reason for disqualifying such solution in some countries (for instance, in Czechia, the thermal insulation adjacent to the ventilation gap has to be incombustible, as combustible material in conjunction with ventilation gap chimney effect might allow severe fire spread).

8.3.5.5 Facade boards

Cavity wall (a wall with ventilation gap) can be also provided with some facade boards of various material base. The most frequent options include cement board, metallic sheets or some kind of composite boards. Production program produces the boards that are mostly smaller than the dimensions of the whole MORE-CONNECT panel and facade pattern must be designed. Therefore, the clefts between panels are on the facade almost unnoticeable or unresolvable respectively.

8.3.5.6 BIPV

Building Integrated Photovoltaics (BIPV) is a special type of facade board. In case the facade face is made with the PV panels, position of other accessories such as switchboxes and cables must be taken into account. Switchboxes must be big enough not just to accommodate the switches but also to prevent switches from overheating.

Use of incombustible insulation beneath the facade face is also required.

8.3.5.7 Wooden cladding

The last type of the cavity wall is the one with wooden cladding. The principle is the same as mentioned in the previous chapters, however, there are some specifics to be noted. Wooden facade, if untreated, may change its colour and shade, and it may change the face of the whole building. The design must account for this feature or frequent renewing wet processes must be planned in the future. Various treatments of wood are available to limit the wear of the surface (paints, chemical treatment, heat treatment). Wooden or any other combustible cladding may also limit the use of such facade due to lower fire resistance than other alternatives.

8.3.6 INTERIOR SURFACE LAYER

In the interior, plaster on the wall and on the window linings is assumed. Removing the window and installing the MORE-CONNECT wall panel module, some unevenness or defects of the existing plaster may occur. There are two main options of interior surface treatment: firstly, a new plaster layer can even out the flaws, additional cladding from boards can be mounted over the existing walls.

8.3.6.1 Plaster wall

Application of a new plaster on the wall is the simplest choice, when there is time and space for such activity in the inhabitant's flat. For the best light permeation and to ensure the possibility of combination, white colour on the lining is designed but also other colours can be used.

However, it is a wet process that slows down the whole workflow. Moreover, cables or piping going in the facade panel must enter the interior and it must be somehow covered. Therefore, grooves or sockets must be done in the plaster and covered again.

8.3.6.2 Cladding

Cladding is chosen, when no time shall be wasted. Using thin high-density fibreboards (HDF), a new lining is done very quickly and infrastructure can be led beneath the surface. Again, a white board is universal but other textures and shades are produced. On the other side, the openings in the board and the shaft inside, as well as the connections of the board on the corner of the lining should be made very accurately.

8.3.7 INTEGRATED SYSTEMS

8.3.7.1 Electrical wiring

All the ducts and wires can be led in the first layer of the module from the interior side. Refurbishment modules can provide to the users:

- Internet / Ethernet connection;
- TV / Satellite signal;
- Wireless network (Wi-Fi router);
- Home control system interface;
- Window blinds control interface.

All those wiring systems and appliances can be offered to the user. The connection may be made in the window siding.

8.3.7.2 Hydraulic heating loop

The hydraulic heating pipes present one of the challenges for the prefabrication process of the entire modular system. For most of the cases, air heating is sufficient. For extreme climatic conditions or buildings with higher heating demand, the new hydraulic heating system can be provided. The connections of the pipes can be done during module installation. The pipes should be reachable from behind the window siding cover.

8.3.7.3 Ventilation

The system is provided with the ventilation system in every refurbishment alternative. Every apartment's window is provided with the ventilation inlet. In case the typology allows favorable placement of both intake and exhaust air ducts, both can be integrated in the facade modules. In case an apartment does not have a favorable disposition, the exhaust ducts have to be installed in the interior of the building. The challenge is to prefabricate the system so that building up the interior ventilation would not affect the duration of the refurbishment significantly.

8.3.7.4 Window blinds

The refurbishment system should provide sufficient shading devices, where applicable. Sufficient shading might be done by creating such facade elements as canopies, sunblinds, etc. The movable electric window blinds may be a general option.

8.3.7.5 Renewable energy sources

For the general design, integration of the PV panels in the facade and roof modules is assumed.

8.3.8 HANGING STRUCTURES AND SHADING ELEMENTS

8.3.8.1 Balconies

In some cases, an extension of the original building is favorable. The smaller apartments are, the more important the newly built additional balcony or reading room can be. It can be observed considering the behavior of non-refurbished building users. The modular system should provide the possibility of extending the facade by safe systematic solution.

8.3.8.2 Shading devices

Proper shading devices should be part of responsible low energy design, the proper shading can save energy during both summer and winter seasons. The particular solution has to be adjusted according to the geo-cluster.

8.4 PANEL-FACADE CONNECTORS

Project Results: Deliverable 2.4
Lead author: ANTONÍN LUPÍŠEK
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8.4.1 GEOMETRIC ARRANGEMENT

Given the variability in external structures of the building types under consideration and the requirement with regard to integration of air ducts, wiring and piping into the external modules, there was a need to consider the possible ways of mounting the wall insulation modules in more detail.

The accessibility of module joints from the interior is essential for enabling mounting of the modules without the need for scaffolding. The geometry of the wall modules and their relative position depend on the following factors:

- Can the original external wall be removed?
- Are there any French windows (that enables easier connection of the piping, wiring and air ducts close to the floor structure)?
- Can the window openings be extended (depending on the material and structure of the walls)?

The design consequences of the boundary conditions are apparent from the following scheme.

Because both refurbishment speed and the montage simplicity are desirable, connection of the integrated systems shall be done in the openings. The system connections can be carefully connected from the interior by the workers during montage and enable further quality check.

The integrated systems and their connections are the reason why the following analysis of the geometrical variants should be conducted. They are described for the very basic wall module containing all systems with two openings. In different buildings with a different number of openings, which can be refurbished installing one module, more space can be available for connections and not all openings should be used for that purpose (Fig. 8.13).

8.4.2 CONNECTING ELEMENTS

The main purpose of these connectors is fixing the panel to the substructure. Substructure is considered the main supporting structure of the object. Connectors ensure a tight connection that can withstand the expected load. It must also ensure rectification of uneven surfaces and speed of assembly.

Mechanical resistance and stability of the connectors must be designed in accordance with valid standards and regulations. In continental conditions, these are primarily represented by the European standards EN 1990 (basis of structural design), EN 1991 (common types of loads – self weight, fire conditions, snow loads, wind loads, thermal loads and others), EN 1992 (design of concrete structures), EN 1993 (design of steel structures, EN 1995 (design of timber structures), and EN1996 (design of masonry structures).

There are various ways of designing the functional principles of the anchors. As there are requirements towards very fast installation of the prefabricated modules on site, it is recommended to pre-install anchors on the existing facades, beams or columns that provide rectification in all directions. The type of anchors depends on the base material of the existing wall or other load bearing structure.

Broad variety of anchoring systems is available in the market. Pin connectors (mechanical anchors, chemical anchors and screws) allow for one-dimensional rectification, metal or composite angled elements allow for 2D rectification and special anchors allow for full 3D rectification.

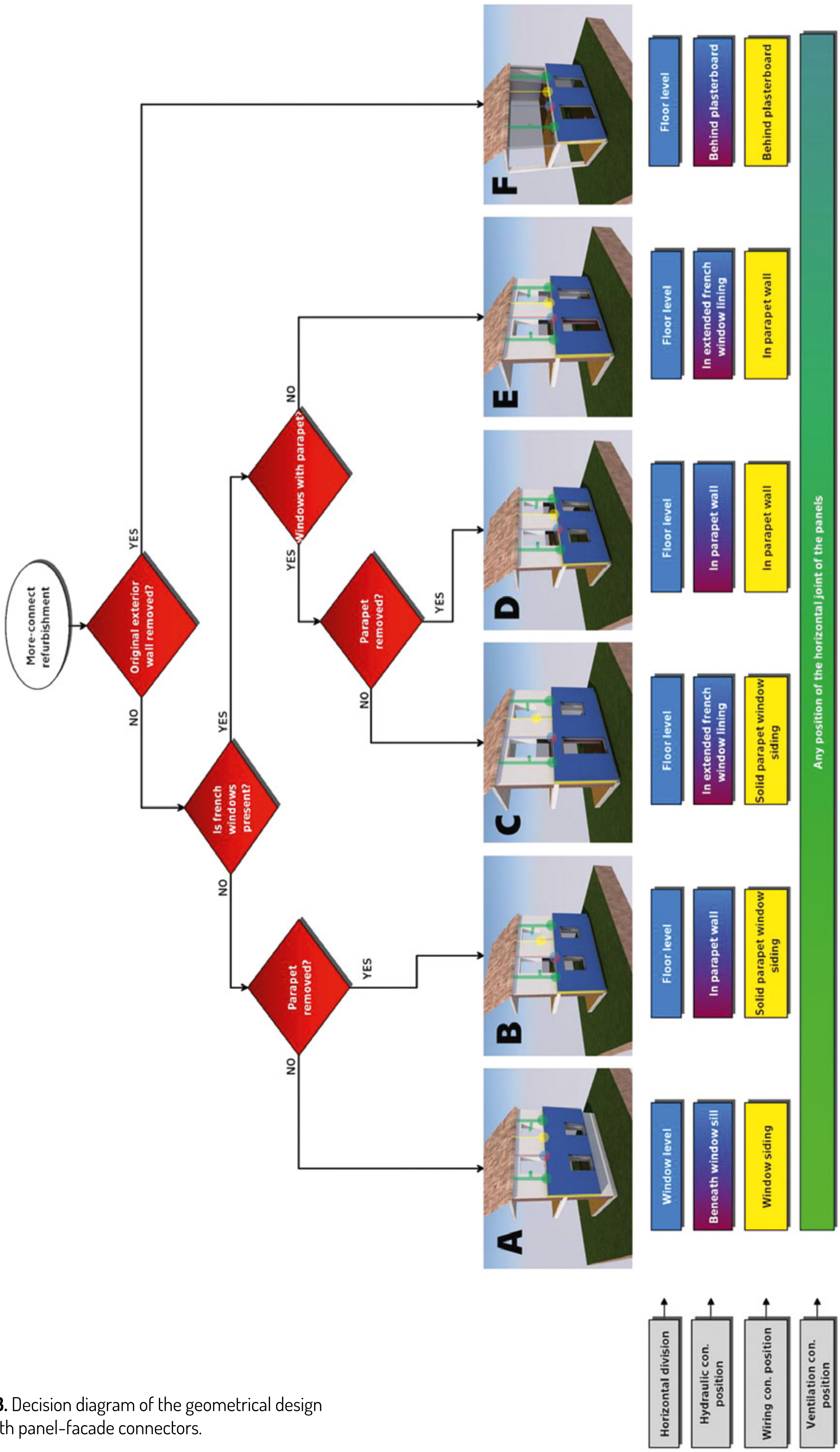


Figure 8.13. Decision diagram of the geometrical design variants with panel-facade connectors.

8.5 INDOOR-OUTDOOR CONNECTIONS

Project Results: Deliverable 2.4
Lead author: ANTONÍN LUPÍŠEK,
Co-author(s): JIŘÍ NOVÁK, MARTIN VOLF

8.5.1 NEED FOR AIRTIGHT CONNECTIONS

A modular system consisting of prefabricated modules that are added to a facade of an existing building needs to have airtight solutions for joints and other key details. There are multiple reasons to request airtightness of building envelopes: moisture safety, energy savings, indoor comfort, fire safety and acoustics.

As regards moisture safety in winter season, there is a need to prevent the indoor wet air to get into the structure – convection of the wet indoor air through the structure may result in an interstitial condensation during the cold season causing the risk of moisture damage. Conversely, in the summer season it is necessary to prevent the outdoor wet air from getting to the colder structure.

For the sake of energy saving, it is highly desirable to prevent the leakage of indoor conditioned air from the building to avoid an excessive heat loss during the heating season. It is also necessary to prevent the outdoor non-conditioned air getting into the building in order to reduce the risk of summer overheating or to avoid an extra energy demand for cooling, if the building is equipped with a cooling system.

Airtightness of the building envelope contributes to provision of comfortable thermal conditions. In winter season, it is ensured by preventing flows of cold outdoor air that are unpleasant to the building occupants and that could lower the temperature of the internal surfaces. It also prevents propagation of odours or other air pollutants through the leaks in the structure.

With regard to fire safety, the air tightness of the building envelope is important to prevent propagation of fire or smoke through the leaks in the structure.

Airtightness of the building envelope also prevents propagation of airborne noise through the leaks in the structure.

8.5.2 REQUIREMENTS

There are three levels of requirements for the airtightness:

- Airtightness of the whole building (tested by blower door test onsite, the requirements are often defined at the national level in technical standards, building code or energy efficiency programs);
- Airtightness of modular facade as a whole (measured air leakage through specific area of a facade);
- Airtightness of panel joints (measured air leakage through specific length of joint).

8.5.3 CRITICAL ELEMENTS AND DETAILS

These critical elements and details usually need to be properly designed for airtightness:

- Airtightness of module bodies – Airtightness of the main air barrier layer, airtightness of joints inside modules, air tightness of integrated windows and doors and penetrations through modules: airtightness of wiring, piping or structural elements led through the structure;
- Airtightness of module joints;
- Airtightness of the interface between the modules and existing structure – joints of the module with existing walls and joints of the modules with existing window or door frame.

8.5.4 TYPICAL SOLUTIONS FOR AIRTIGHTNESS

OSB boards, solid wood (CLT panels), plastic membranes (typically foils made of polyethylene), wax paper, metal sheets, metallic foils (typically aluminium) and plasters are usually used as the main air barrier layers in light envelope structures. The main challenges consist in limiting the problems with poor airtightness of OSB boards and ensuring protection against damage during transport and in-situ works and robustness and durability of the chosen solutions.

Expansion tapes, airstop tapes, gluing, various fillers, rubber and EPDM gaskets, mastics (sealants) and expansion foams are used to ensure airtightness of the joints inside the modules. Quality of workmanship is critical and the main challenges include minimization of the number of necessary joints and provision of product durability (tapes, glues).

Typical solutions for sealing the joints between the module structure and integrated window or door frames include airtight tapes, airtight PU foams and expansion tapes. It is critical to provide simple solutions for window fastening in the factory and to assure workmanship quality.

Various sleeves, grommets, gaskets, plastic sealants (butyl tapes), mastics (sealants) or expansion foams are typically used in module penetrations that ensure airtightness of wiring, piping or structural elements led through the structure. The main challenges related to penetrations include limiting the number of necessary penetrations and avoiding air tightening in-situ. Factory air tightening of penetrations and use of system solutions are preferred.

The typical measures to ensure airtightness of module joints comprise tapes, mastics, rubber/ EPDM profiles or glues. The main challenges are water tightness and avoidance of the air- and water tightening works in-situ.

Tapes, foils, plaster–tape, expansion tapes, airtight PU foams are typically used for sealing the joints of modules with the existing walls.

8.6 THE ENGINE

Project Results: Deliverable 2.3 and 3.7
Lead author: TARGO KALAMEES , JURGIS ZEMITIS
Co-author(s): ANTONÍN LUPÍŠEK

Modular prefab integrated HVAC units

Nowadays, all multi apartment buildings as well as single family houses have such vitally important HVAC components as heating system, hot water system, ventilation and cooling system in case higher indoor comfort level is required during the summer. Use of renewable and sustainable energy is one of the EU top priorities in order to ensure significant reduction of greenhouse gas emission caused by the building sector.

Usually heating systems, ventilation systems and cooling equipment are installed separately in different technical rooms and in some cases even on the floors or ceilings. Additional installation of renewable energy sources in the later stages may require significant reconstruction of the existing HVAC system. Typical components of modular HVAC unit are:

- Heat exchanger for heating loop;
- Hot water heat exchanger;
- Local energy source (gas boiler, heat pump, connection to external energy sources);
- Expansion tank;
- Air handling unit including ventilation heat recovery.

In order to minimize installation costs and time, as well as to ensure installation quality and simple modernization during lifetime, the multifunctional modular HVAC unit “house engine” should be introduced. “House engine” is a compact energy unit, which can be easily connected to such building systems as heating, ventilation, hot water supply and cooling. Due to its compact form, the initial design of “house engine” should include possible options for future upgrade. Identification of the optional components of the “house engine” is shown in Figure 8.14.

In addition, possible modifications could include installation of district cooling/heating sub-station.

Some already implemented solutions have shown good potential for future implementation. The modular solutions are shown in Figure 8.15.

Modular HVAC units already have been tested in apartment buildings across Europe (Fig. 8.15a). The main benefits include short installation time, indoor space optimizations, noise reduction, easy maintenance, etc. In addition to HVAC prefabricated solutions, modular pipe units can be used to reduce on-site installation time (Fig. 8.16).

Embedded water pipes have several disadvantages, such as high risk of leaks. By placing the ventilation ducts inside the insulation of external envelope the U-value is reduced, this means that the ducts should not be too large, or the insulation layer must be sufficient. At the same time, locating the ventilation ducts outside the building envelope allows using higher air velocity in them as compared to the situation when the ducts are placed inside the rooms.

Two different basic approaches to supply air duct design are used in practice. The first approach (Fig. 8.17a) is used when each apartment has a

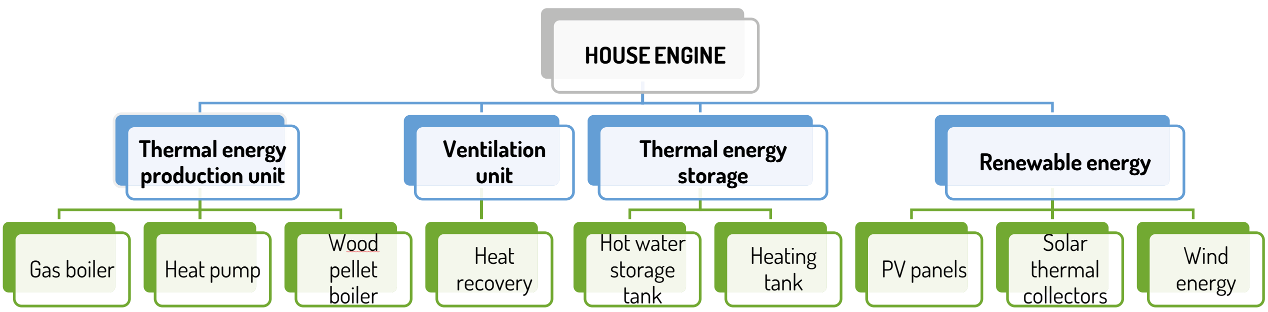
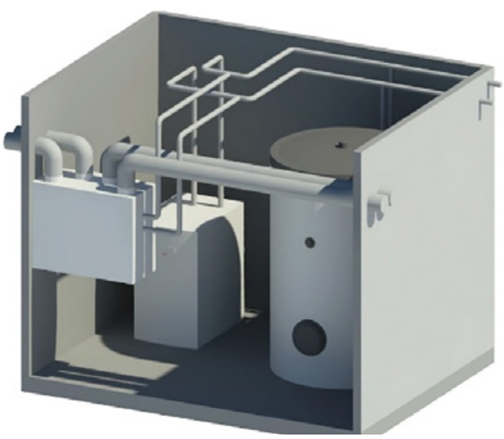
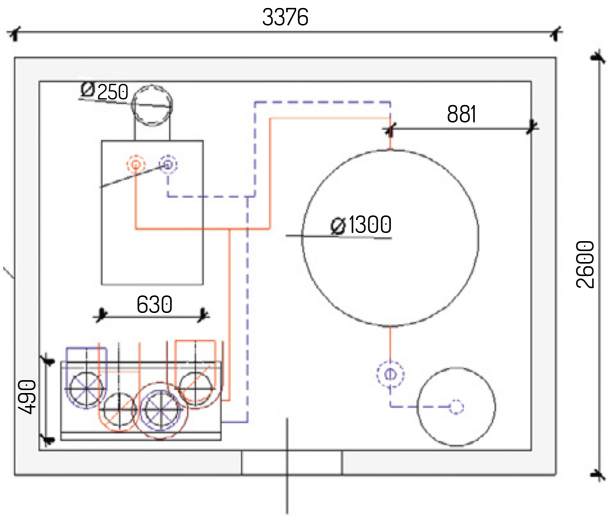


Figure 8.14. Optional components of “house engine” HVAC systems.



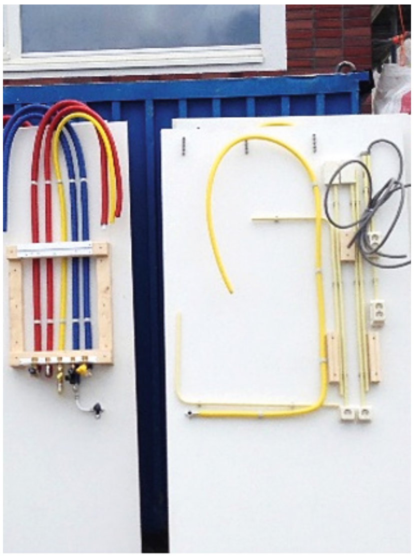
a) 24 kW natural gas HVAC units.

b) Already existing solutions, the Netherlands.

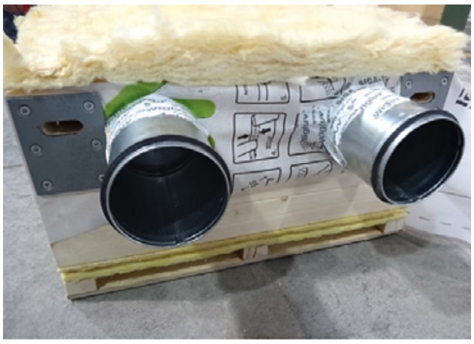


c) Possible dimensions of 24 kW natural gas HVAC units.

Figure 8.15. Modular HVAC units.



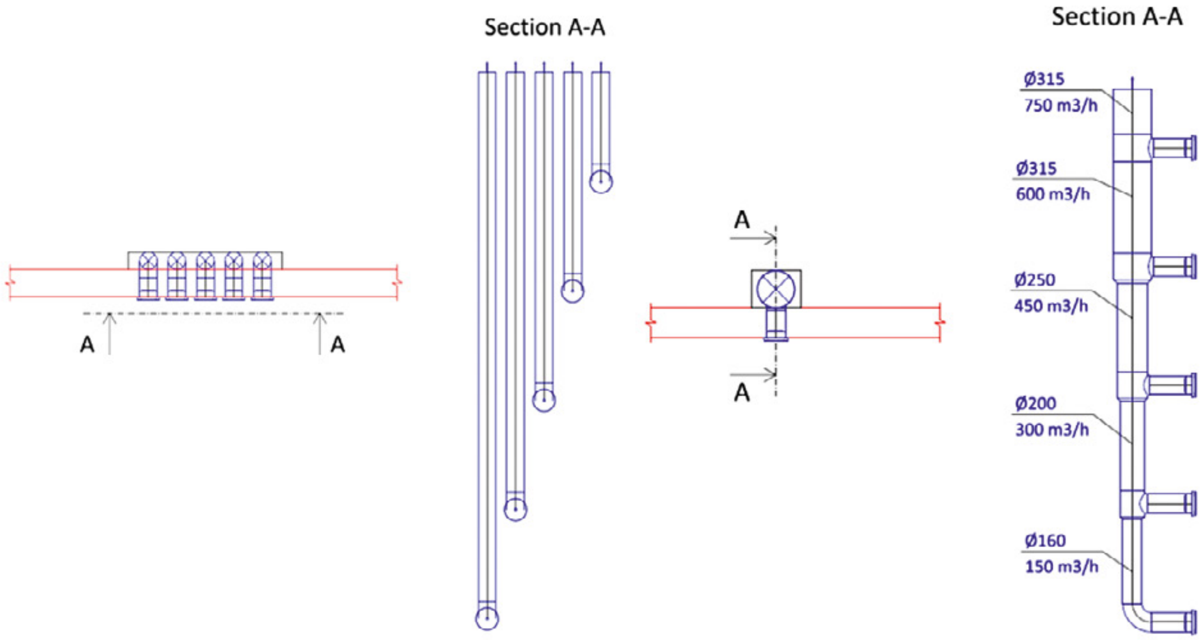
a) Water and gas pipe prefabricated solution.



b) Ventilation duct installation.

b) Ventilation duct connectors.

Figure 8.16. Modular pipe installation.



a) Separate ventilation duct risers.

b) One main ventilation duct riser.

Figure 8.17. Ventilation duct risers.

separate duct, which comes from the main branch near the air-handling unit. The second approach is used when there is one main raiser that gradually decreases in size starting from top to bottom floor (Fig. 8.17b). To reduce noise movement between apartments through ventilation ducts installation of noise dampeners is needed. Technical solution requires higher diameters, thus causing reduction of thermal insulation layer thickness.

The evaluation of duct diameters for MORE-CONENCT geo-clusters is shown in Table 8.3 and Table 8.4.

Velocity in ducts	Round duct size, mm					
	Latvia (140 m³/h)	Estonia (119 m³/h)	Denmark (50 m³/h)	Czechia (126 m³/h)	Portugal (135 m³/h)	Netherlands (200 m³/h)
< 3 m/s	160	125	100	125	160	80
< 4 m/s	125	125	100	100	125	80
< 6 m/s	100	100	100	100	100	80

In the Netherlands all rooms are separately supplied and deducted

Table 8.3. Necessary diameters of ducts in case of separate ducts (raiser) to each apartment.

Velocity in ducts	Round duct size, mm					
	Latvia (700 m³/h)	Estonia (595 m³/h)	Denmark (250 m³/h)	Czechia (630 m³/h)	Portugal (675 m³/h)	Netherlands (200 m³/h)
< 3 m/s	315	315	200	315	315	n/a
< 4 m/s	250	250	160	250	250	n/a
< 6 m/s	250	200	125	200	200	n/a

Not applicable for Netherlands pilots (row houses)

Table 8.4. The necessary diameter of the largest air duct in case of one main riser.

CONCLUSIONS AND FUTURE READING

Potential integration of renewable energy sources into renovation process is a major issue to reach the (n)ZEB status. The possible principles and main functionalities of "house engine" are described. It is believed that they can be the future of engineering systems and serve as the heart of the house, especially in case of renovations when all systems should be made compact while connected to the existing networks. They must include all basic equipment such as heat exchanger for heating systems connection, hot water heat exchanger, local energy source, expansion tanks and all necessary valves, air handling unit with heat recovery section and in some cases even cooling source. Some already implemented HVAC engine solutions that envision installation of service systems into prefabricated modular insulation elements have shown good potential for future implementation.

8.7 PRODUCTION PROCESS – PREFABRICATION

Project Results: Deliverable 4.3, 4.4 and 4.5
Lead author: ANATOLIJS BORODINECS
Co-author(s): JAN KAMPHUIS, MODRIS DOBELIS

Building Information Modelling (BIM) is a complex process of managing not only design documentation in 3D format, but also management of all consecutive stages of design analysis followed by construction management including facility management after site completion. Successful collaboration uniting the efforts of architects, constructors and HVAC engineers would make the work of all stakeholders more productive; it can be further promoted by the existing information technologies, with have provided collaboration options for a long time.

Contemporary hardware and software provide many opportunities for modern designers. It may appear surprising that these opportunities are not employed in the everyday practice and are not used at full capacity. Expenses and training are two main limiting factors. The BIM learning curve could be one of the top barriers to its implementation in construction. There is an opinion that wide application of BIM concept is limited mainly due to other two factors that may appear even more important – human factor and change factor (Shilovitsky, 2012). BIM implementation is not really about software, it is about organizational change. Customer experience has demonstrated that people and processes are far more important than technology.

Prefabrication of elements in the factory in contrast to the on-site fabrication reduces field labor costs and time and increases accuracy in high quality construction. There are more tools and options readily available in a controlled environment of the jobsite to perform work more precisely, and it is less costly in a shorter time. Prefabrication requires design and field accuracy. BIM can provide this level of accuracy by including specifications, sequence, finishes, and the 3D visualization for each component. However, the construction team must make sure that BIM is interoperable with the software used by fabricators. This way the contractors can use BIM and design details for the product in their fabrication software. Once the details are approved, the products can be fabricated using Computer Numerical Control (CNC) machines. Furthermore, construction managers must administer the procurement schedule of the products. Overall, prefabricated products must be delivered to the installation site on time.

Summary of the approaches used by MORE-CONNECT partners is presented in Figure 8.18.

All project partners used a manual and semi-automatic data transformation from cloud to BIM. Manual BIM modelling proved to be most efficient and ensured the fastest workflow as compared to conventional on-site measurements. This method also minimizes efforts and time spent as well as cost of post-work when finding and fixing errors after automatic BIM model generation process (Cho Y.K. et al. 2015; Xiong X. 2013). Automatic process of BIM modelling was less successful in case of old buildings due to some practical reasons. One is related to foundation settlement, which causes serious problems in design of prefabricated insulation panels. Foundation settlement of the building analyzed in the present study was almost 13 cm on the 10 m long base. Window openings are neither rectangular nor orthogonal in vertical and horizontal directions. Another factor preventing automatic recognition is that in practice the external walls very often are neither planar nor strictly vertical. In addition, manual correction for existing electrical wires required extra time to insure precise panel dimensions. Pros and cons of using point cloud proceeding to the building model are described in Table 8.5.

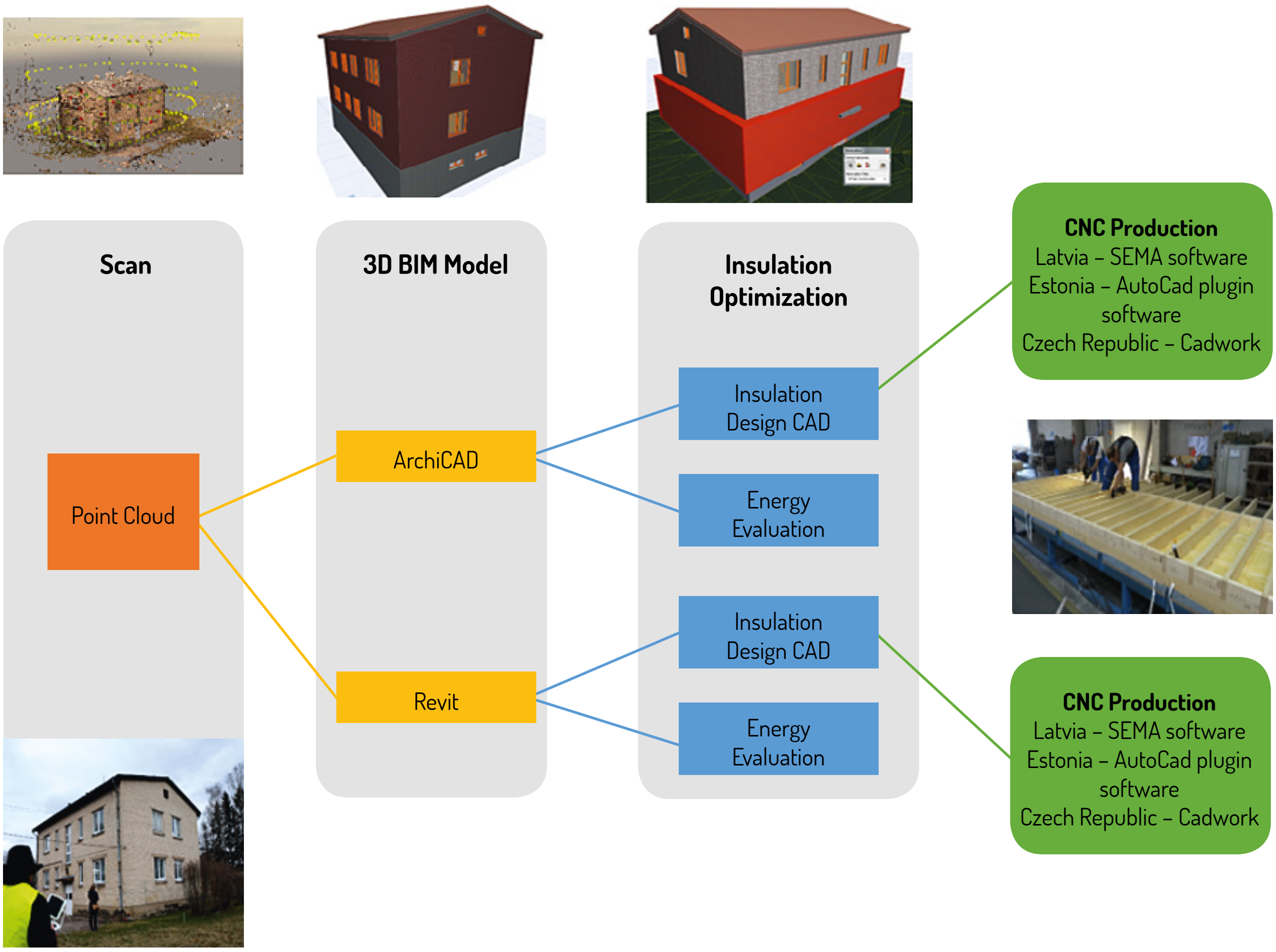


Figure 8.18. BIM approach used within the MORE-CONNECT project.

MANUAL	SEMI-AUTOMATIC	AUTOMATIC	FROM PHOTOS (automatically)
•From seperate points •Create object (walls, windows, doors) •Average time consumption, easy but does not reflect real situation	•From cross sections •Create mesh, smartsurface or solid elements •Convert to object (walls, windows, doors) •Fast, easy, shows real situation, conversion problems	•Create mesh •Correct the mesh •Convert to object •Fast, but needs a lot of work for correcting the mesh and to divide into seperate object types •Shows real situation	•Create mesh •Divide mesh to seperate •Correct the mesh •Convert to object •Very complicated, a lot of photos and correction work are needed

Table 8.5. Point cloud to building model.

Literature

Shilovitsky O. 2012. Why PLM and BIM Fail in the Same Way? Beyond PLM. Available online: http://beyondplm.com/2012/05/04/why-plm-and-bim-fail-in-the-same-way. (Nov 30, 2015).

Wang C. & Cho Y.K. 2015. Performance Evaluation of Automatically Generated BIM from Laser Scanner Data for Sustainability Analyses. Procedia Engineering, 118, pp. 918-925

Xiong X., Adan A., Akinci B., Huber D. 2013. Automatic creation of semantically rich 3D building models from laser scanner data. Automation in Construction, 31, pp. 325-337.

8.8 PRODUCTION PROCESS – ON-SITE ASSEMBLY

Project Results: Deliverable 3.3
Lead author: JOHN VAN OORSCHOT

Modular architecture is characterized by one-to-one mapping of the functional elements in the function structure to the physical components of the product, and presumes no tied interfaces between components. Modular innovation allows straightforward implementation, with no changes in other systems. Responsibilities and liabilities are easy to allocate since they are bound to the product developer.

In an ideal and completely modular architecture, a modular component of the architecture system can be easily replaced without affecting other modules of the system or its overall performance. Modularity is based on the principle of interdependence of the modules with independence across them. Design rules clarify the interactions across a product's sub-systems, reduce component specificity, and provide a form of embedded control that reduces the need for overt hierarchical control or ongoing communication during concurrent improvements of individual subsystems. Product architecture, interfaces, integration protocols and testing standards are the categories of design rules upon which decisions are made to conceive new modular products (Baldwin & Clark, 2000).

Currently, there are about 7 million dwelling in the Netherlands, and about 250 million in Europe. Deep retrofitting of the European housing stock could benefit from a modularity approach for a variety of reasons.

8.9 DIGITAL BUILDING MODELLING

Project Results: Deliverable 4.1
Lead author: EVA MATOUŠKOVÁ
Co-author(s): MARTINA FALTÝNOVÁ

According to the Oxford Dictionary, geomatics is defined as the mathematics of the Earth, the science of collecting (with some instruments), processing

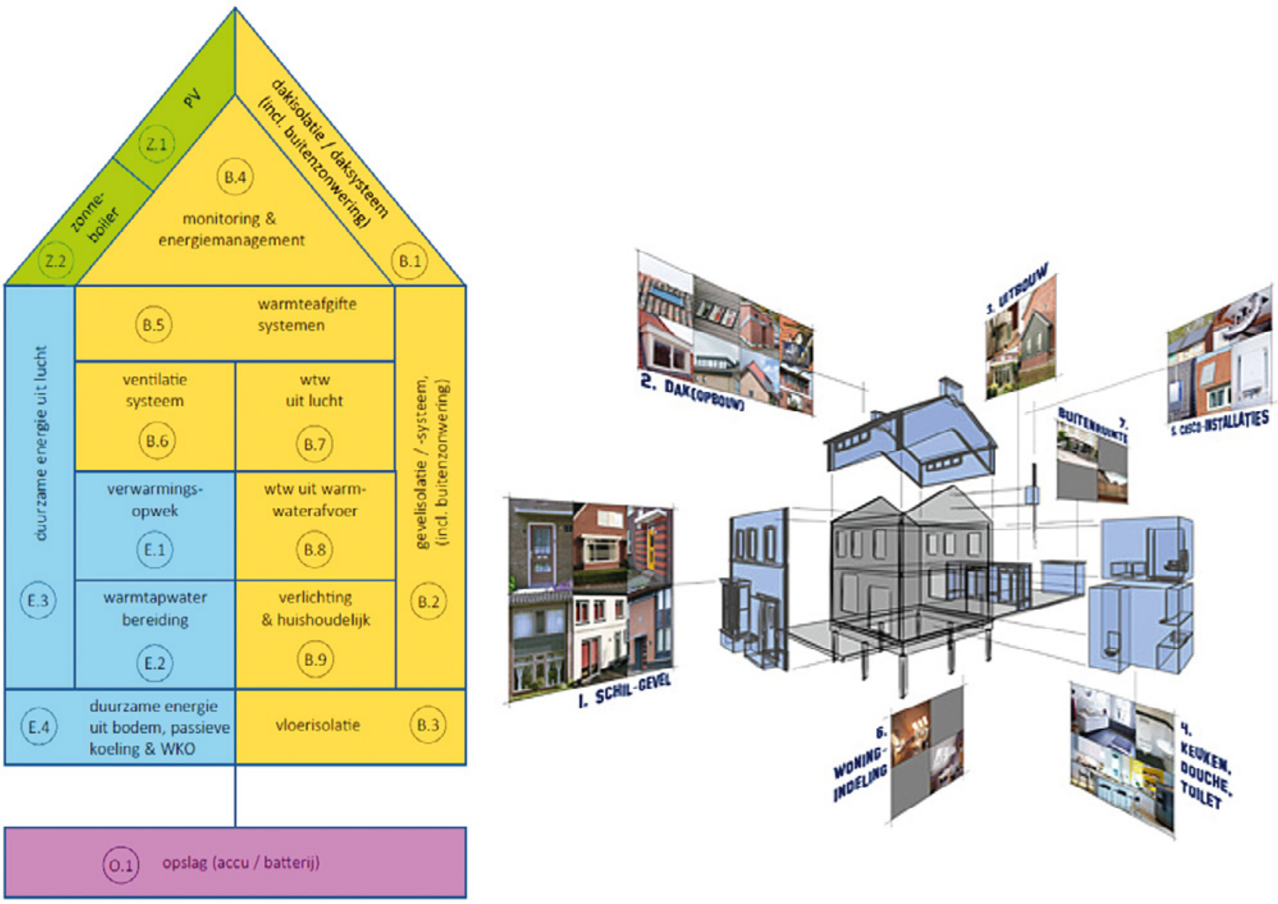


Figure 8.19. Modularity; key components when considering deep retrofitting (adopted from Energiesprong, 2016).

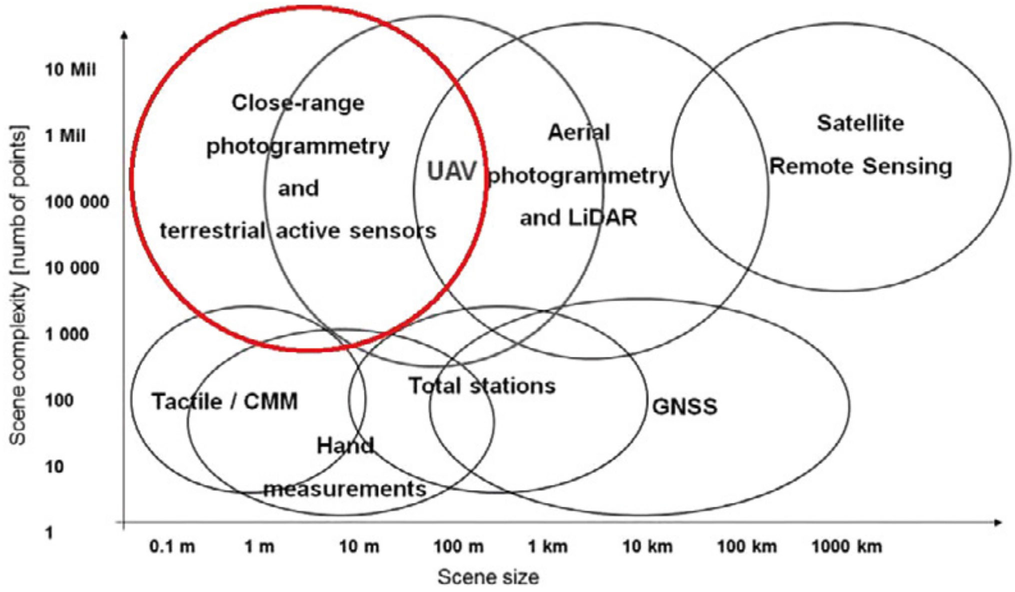


Figure 8.20. Geomatics techniques for the 3D data acquisition shown according to the object/scene dimensions and complexity of the reconstructed digital model (Remondino; Campana, 2014).

(with some techniques), analyzing and interpreting data related to the Earth's surface.

Better understanding of geomatics techniques and methodology will lead to more exact specifications of project requirements for surveyors and to cost optimization of the geomatics work (surveying, processing of the data and information transfer into the desired software in the appropriate format).

The quality of building documentation is crucial when prefabricated modular elements are used in facade reconstruction.

Surveying techniques performed within the MORE-CONNECT project consist mainly of laser scanning and photogrammetry. These methods have replaced traditional surveying techniques in many applications. Traditional recording methods based on hand recording, e.g. by means of tape measurement, are too subjective, time consuming and applicable only to small areas. In contrast to the terrestrial surveying and analytical photogrammetry, which require manual interpretation in order to derive a representation of the sensed objects, these new automatic recording methods allow an automated dense sampling of the object surface within a short time (Pfeifer; Briese, 2007). It is enabled due to the speed of acquiring high-density data and highly automated processing. These methods are used to obtain a 3D model of the building of interest. Basic principles and characteristics of the methods are described below.

Photogrammetric and laser scanning methods have been used and tested for the building documentation in the MORE-CONNECT project. Testing shows that both methods are convenient.

The choice of a particular method is based on project specifications and requirements as well as on the preferences of the commissioning party. Use of Ground Control Points (GCP) is recommended when higher accuracy is required (<5 mm) and when larger objects (residential houses) are of interest. Geodetic total station provides fine and quick GCP measurements.

References

PFEIFER, N.; BRIESE, Ch., 2007. Laser scanning – principles and applications. http://publik.tuwien.ac.at/files/pub-geo_1951.pdf

REMONDINO, F.; CAMPANA, S., 2014. 3D Recording and Modelling in Archaeology and Cultural Heritage: Theory and Best Practices. Archaeopress, p.171, ISBN 978-1-4073-1230-9.

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9

ENERGY AND MATERIALS

9

ENERGY AND MATERIALS

Project Results: Deliverable 3.2, 3.4 and 3.5
Lead author: RONALD ROVERS
Co-author(s): JOHN VAN OORSCHOT, ROMAN BOLLIGER

Designing and constructing a house is an optimization task: many properties have to be combined in one design. Energy is a special issue to be considered: materials are invested to reduce energy demand, and nowadays materials to generate renewable energy on site are invested as well aimed at creation of (n)ZEB or ZEB buildings on location.

With retrofit or refurbishment with CO_2 reduction in mind, this optimization becomes the major task: A decision on the amount of added insulation has to be made, which in many cases is directly related to the number of PV elements that have to be installed to generate energy to meet the remaining operational energy demand. In the end, it is a trade-off between investing materials in either more insulation or more panels [1].

This is even more obvious when we arrive at a zero energy building target, or even energy plus buildings. Actually, in that case, there is no impact from the operational energy, only from the materials invested: The PV panels are a materials investment that comes inclusive with energy (generation).

This balance between materials invested in reduction and materials invested in production (Fig. 9.1) can be established at different levels: More insulation leads to fewer panels required, less insulation requires more energy generating panels. In all cases, a zero energy building is designed in the end. However, the question is which alternatives will have the least materials impact, since now the real fossil fuel and CO_2 related impact are considered.

It is of course obvious that when end-use demand is reduced (due to change of inhabitant behavior and house use, e.g. heating fewer rooms), combined material investments for reduction and production will be lower leading to lower CO_2 emissions required to reach zero operational energy.

Therefore, it is of utmost importance to evaluate different combinations to find out what is the optimal balance with the lowest CO_2 emissions at a given end use demand. There are many tools to calculate environmental impact, but if only one house configuration is calculated, for instance,

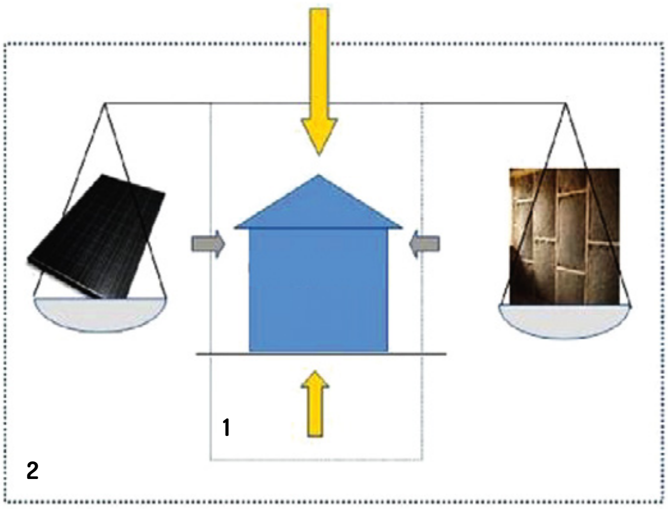

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Figure 9.1. Balance.

the renovation of an old house, the new situation will always score better than the old situation. However, this might not be the optimal solution. Comprehensive informed conclusions cannot be made considering only one checkpoint.

This is also important implementing (n)ZEB or 80 % CO_2 reduction concepts. Since these do not aim at zero energy situation as their first target, development of the concepts usually starts with the focus on extreme energy demand reduction. However, eventually these houses will make the next step towards zero energy or energy-plus buildings by adding PV panels and other technologies. Therefore, any intermediate result may not appear to be the best from fossil fuels /CO_2 point of view, since it was not optimized with that in mind, only extreme energy reduction was considered as a criterion.

That is one of the reasons why some explorations have been conducted within the MORE-CONNECT project considering the zero energy or ZEB situation as a reference case for a certain part of the project. It has several advantages: It makes concepts comparable over several climate zones, since zero remains zero everywhere, and sub-optimization of partial reduction is avoided. Besides, when the optimal concept is found, it is always possible to scale it down to the optimal solution – to 80 pct situation, for instance, by installing fewer PV panels, and thus reduce investments. In case PV panels are installed in future, it is clear that the end result will be optimal from both energy and materials impact point of view.

This report describes the indicators used in such approach, as well as explores the process of optimization of the embodied energy/CO_2 emissions in a zero balance design or retrofit case. The basic decision tool/approach is developed, and within the joint MORE-CONNECT workshops, the relations among technical aspects, investment consequences, comfort and behavioral adaptation are explored. To analyze the material related CO_2 impacts of retrofitting the EU housing stock in more detail, the author took part in a joint international initiative to explore the real impact of the climate change agreement. The initiative addresses such question as how much CO_2 can be released before the 2-degree threshold is passed and what are the consequences of CO_2 investment in the European housing stock retrofit. These issues will be briefly discussed in the end, since they are vital in establishing the balance level compatible with the 2-degree scenario.

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PILOT EXPERIENCE

10

PILOT EXPERIENCE

Project Results: Deliverable 5.3-5.7
Lead author: OVE MØRCK

10.1 INTRODUCTION

This chapter summarises the experience of the energy renovation demonstration projects carried out in the context of the EU Horizon2020 MORE-CONNECT project. These projects demonstrate implementation of new prefab technologies to lower the renovation costs and reduce the working time at the building site in six countries: Czechia, Denmark, Estonia, Latvia, the Netherlands, and Portugal. As these projects have demonstrated the technologies for the first time, they are referred to as pilot projects. The project comprises five pilot projects and two so-called real life learning lab environments.

The experience covers the complete work chain from production of the prototypes of the first prefabricated elements to their realization at the building sites; it also includes evaluation of the whole process. The experience gained has been documented in four deliverables of the project, which in addition to the pilots themselves represent the results of the MORE-CONNECT project. These deliverables also form the basis of this paper. The full versions of deliverables can be downloaded from the MORE-CONNECT website: www.more.connect.eu.

10.2 PRODUCTION OF PROTOTYPES OF PREFABRICATED ELEMENTS

This deliverable documents the work related to the development and manufacturing of the prototypes of prefabricated building renovation elements by producers participating in MORE-CONNECT: BJW, WEBO, Matek, ZTC, Invela, Ennogie and Darkglobe. The documents present the following data on each producer:

- Photos of the elements with comments about the details/components and production process;
- Details of production process, e.g. amount, production time, etc.
- Results of quality control checks.

The prefabricated renovation modules have been developed for the markets in the Netherlands, Latvia, Estonia, Czechia, Denmark and Portugal.

The figures below illustrate the development and testing of some prefab elements.

Figure 10.1. Preparation for the assembly test in Czechia – fixing connection elements for air ducts and piping.

Figure 10.2. Design and construction of the first prototype elements in Estonia.

10.3 REALISATION OF FIVE PILOT SITES

This deliverable documents the actual renovation of the pilot buildings using the prefab construction elements and other energy renovation measures. In some cases, renovation may include partial or total removal of the existing structures (facades, roofs, installations), depending on the renovation methodology (total replacement, partial replacement or addition of elements). For each country, the pilot project documentation covers:

- The entire process, including recordings of the essential steps using photos and videos;
- Recording and evaluation of performance of the smart plug & play connectors in practice.

The photos in Figure 10.3 show different stages of prefabricated element installation in Estonia.

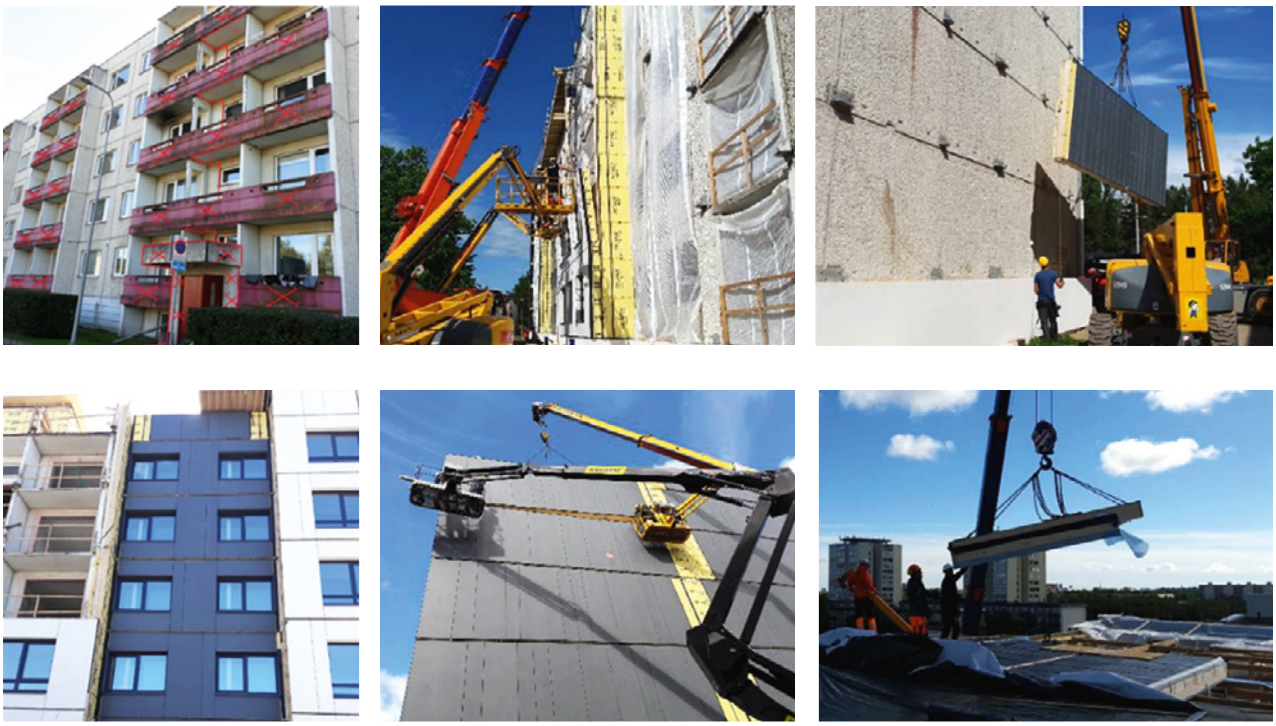

Figure 10.3. Installation of modular elements on the Estonian pilot building - summer 2017.

10.4 REALISATION OF TWO REAL LIFE LEARNING LAB ENVIRONMENTS

Within the MORE-CONNECT, a Real Life Learning Lab (RLLL) situation was used in two locations. These RLLL situations are more suitable for deep testing of specific solutions like smart plug & play connections, advanced controls, building physics, moisture behavior, zero energy solutions and testing of special and specific materials like super insulation, bio-based composites and 3D printed materials on a small scale semi-lab setting. The two RLLL settings have been organized in Czechia and the Netherlands.

The focus at the Czech RLLL was made on:

- Testing of connections among modules and of advanced control systems;
- Provision of a showcase for dissemination.

The focus at the Dutch RLLL was on:

- Testing of prefab multifunctional facades, roofs and 'engines' (installation platforms);
- Monitoring of energy use and detailed monitoring of thermal comfort and health.

10.5 EVALUATION OF THE QUALITY OF CONSTRUCTION WORKS - FEEDBACK FROM THE PILOT PROJECTS

The total renovation process was evaluated and analyzed in two steps. The first evaluation was carried out at the end of the third year. The second will be made upon completion of the project. The evaluation was carried out for each pilot covering the following phases: design, production of elements and installation.

The experience of the Danish PV-roof manufacturer Ennogie is presented here as an example of lessons learned. Within the MORE-CONNECT, Ennogie has developed several prototypes of its Solar Energy Roof making a particular focus on the methods of mounting and flashing details to create a customer and installer driven plug-and-play solution. Before actual installation on the pilot building, Ennogie completed two prototype installations. Learning from this experience regarding installation methods and workmanship, Ennogie changed the way the cables are assembled and packed, which led to a 10 % efficiency increase of onsite installation.

10.6 CONCLUSION

Within MORE-CONNECT, extensive development of prefabricated building elements and demonstration of their implementation in the pilot projects have been carried out in the participating countries.

MORE—
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COSTS AND SELECTION

11

COSTS AND SELECTION

Project Results: Deliverable 5.9, 6.2, 6.3 and 6.4
Lead author: ROMAN BOLLIGER
Co-author(s): JAN KAMPHUIS

11.1 LESSONS LEARNED

Assessments for identifying favorable building renovation concepts with prefabricated elements were carried out in six European countries within the MORE-CONNECT project. The identified renovation concepts allow to significantly reduce primary energy use and greenhouse gas emissions, yet are not in all cases cost-effective with respect to the reference case. Results suggest that there is a need for further research to bring costs down by exploiting the upscaling potential of building renovation through prefabricated elements.

11.2 METHODOLOGY

The following section presents an overview of the assessments carried out to select favorable building renovation concepts with prefabricated elements in the MORE-CONNECT project, which were tested in the pilot projects. The idea is that these assessments provide information to building owners or building professionals intending to apply the MORE-CONNECT approach.

The life-cycle approach was applied in assessments to determine costs, primary energy use and greenhouse gas emissions of various building renovation concepts.

To correctly determine the impacts of the renovation packages with MORE-CONNECT solutions on costs, primary energy use and greenhouse gas emissions, it is necessary to define a common reference renovation case as it would be carried out if no energy performance related renovation with MORE-CONNECT solutions was implemented. This reference renovation is called “anyway renovation”. It implies restoration of the functionality of the renovated building elements, yet without improvement of their energy performance. The renovation packages taken into consideration are then compared to this “anyway renovation” case.

The main results of the assessment carried out in each country involved are presented below.

11.3 RESULTS

11.3.1 CZECHIA

The assessment of the investigated reference building carried out in Czechia has resulted in the following findings:

To identify a favorable building renovation concept in Czechia, apart from other elements, different types of wall insulation were investigated. Compared to the reference case, they all decreased greenhouse gas emissions burden by about 40 %. The MORE-CONNECT solution with 10 cm of the main insulation layer had similar environmental impact as the 30cm ETICS, but the price of the former is higher by about 12 %. The MORE-CONNECT solution with 20 cm of the main insulation showed slightly lower environmental impact than the 10cm MORE-CONNECT solution at almost the same price in case plastic frame windows were used. Aluminium frames were connected with higher costs (by 4 %), wooden frames were the most expensive option (cost higher by 14 % compared to plastic frames). The MORE-CONNECT solution containing vacuum insulation layer throughout the panel to reach better insulation parameters without significant increase in thickness came at a noticeably higher cost with only negligible decrease in primary energy use or greenhouse gas emissions.

The results indicate that the MORE-CONNECT solution for walls may be comparable to ETICS with EPS. The costs appeared to be only slightly higher in case of MORE-CONNECT panels, while the use of ETICS resulted in higher greenhouse gas emissions. Therefore, MORE-CONNECT panels with 20 cm of main thermal insulation and plastic-frame windows were considered to be the optimal solution for walls. This solution means 42 % reduction of primary energy, 43 % reduction of GHG emissions and 25 % saving of yearly costs compared to the reference case (“anyway renovation”).

Furthermore, the following measures were included in the renovation package selected as the favorable concept for implementation in the pilot project: The attic floor is provided with 40 cm of blown wood fiber insulation; 14 cm of additional mineral wool insulation are used in the basement; new triple-glazed windows with plastic frames and U-value of 0.7 W/(m^2 K) are installed; a ventilation system is connected with warm-air heating.

11.3.2 DENMARK

The assessment of the investigated reference building carried out in Denmark has resulted in the following findings:

Calculations to analyze the development of energy renovation concept performed for four heating systems show that (n)ZEB targets can be reached for all of these heating systems. Only in case an oil burner is used as a heating supply system this can be done cost-effectively at once, that is, at the same or reduced total costs compared to the reference case. However, considering the financial value of co-benefits from energy renovation, all cases appear cost-effective.

The favorable concept, which was selected within the MORE-CONNECT project, comprises the following elements:

- The roof is insulated with 30 cm layer of mineral wool;
- The wall is insulated with 20 cm layer of mineral wool;
- The windows are replaced with 3-layer low energy windows;
- A balanced mechanical ventilation system with high efficiency heat recovery is installed combined with new sealing to obtain increased airtightness of the building;
- 2 m^2 thermal solar collectors per apartment are installed;
- 5 m^2 PV system per apartment is installed.

11.3.3 ESTONIA

The assessment of the investigated reference building carried out in Estonia has resulted in the following findings:

Renovation solutions were selected to achieve the (n)ZEB energy efficiency level (EPC class A). (n) ZEB level also requires on-site renewable energy production in addition to the reduction of energy consumption. District heating is the heat source for the investigated building is, and it has not changed because it is obligatory to use district heating as a heat source in the district heating area.

The favorable concept, which was selected within the MORE-CONNECT project, comprises the following elements:

- The wall is insulated with a MORE-CONNECT prefab element including 30–35 cm of insulation;
- The roof is insulated with MORE-CONNECT prefab element including 30 cm of insulation;
- New triple glazing windows were installed into the element in the factory conditions;
- Installation of HVAC engine: supply-exhaust ventilation system with heat recovery was installed;
- 100 m^2 solar collectors for domestic hot water and 90 m^2 PV panels (10 kW) were installed on the roof.

11.3.4 LATVIA

The assessment of the investigated reference building carried out in Latvia has resulted in the following findings:

An assessment of various possible renovation packages was carried out to identify favorable concepts. In total, nine different packages were evaluated. Regarding the heating system, it was found out that a heat pump and wood systems are the most cost-effective solutions. There are two main reasons why the heat pump and wood systems were not chosen: the effective legislation requires that buildings connected to the existing district heating retain their connection to the district heating grid; installation of an underground loop of the heat pump requires extra permission from local authorities and landowners.

The favorable concept, which was selected within the MORE-CONNECT project, comprises the following elements:

- The existing district heating system is chosen as the heating system. It has the second lowest primary energy use and reasonably low CO_2 emission values.
- Wall insulation with prefabricated panel including 20 cm layer of mineral wool was chosen as the solution, which allows for significant energy savings with optimal life cycle costs.

In the investigated building, the attic slab is already insulated with 20 mm layer of mineral wool. Only minor repair works are necessary to restore the existing thermal insulation of the attic. Cellar ceiling insulation was not taken into consideration, since the height of the cellar in the investigated building is small and an extra layer of insulation would significantly reduce space height.

11.3.5 NETHERLANDS

The assessment of the investigated reference building carried out in the Netherlands has resulted in the following findings:

An 80 % reduction of primary energy use can be achieved with a package of measures for deep renovation of the building, including a MORE-CONNECT prefabricated element. This is possible for all three heating systems investigated: natural gas, heat pump, and wood pellets. All of these far-reaching renovation packages were found to be cost-effective with respect to the reference case. In terms of emissions, the renovation package with wood pellets is the most favorable option. However, there are some practical considerations in the Netherlands concerning wood pellets.

The favorable concept, which was selected within the MORE-CONNECT project, comprises the following elements:

- The wall is insulated with a MORE-CONNECT prefab element including 28 cm layer of mineral wool;
- The roof is insulated with MORE-CONNECT prefab element including 28 cm layer of mineral wool;
- The ground floor is additionally insulated with PUR insulation (U = 0.22 W/(m^2 K));
- New windows with U-value of 0.8 W/(m^2 K) (triple glazing) are installed;
- Installation of HVAC engine: supply-exhaust ventilation system with heat recovery;
- 40 m^2 PV panels (6.4 kWp) are installed on the roof.

11.3.6 PORTUGAL

The assessment of the investigated reference building carried out in Portugal has resulted in the following findings: the most significant measures improving the energy performance of the building include replacement of the domestic hot water (DWH) and HVAC systems and the addition of insulation to the exterior walls. Currently, the prefabricated panel developed within the scope of the MORE-CONNECT project requires considerable investment because it does not yet have an optimized assembly line suitable for mass production, which affects the cost-effectiveness of the solution. However, with the foreseen optimization of the prefabrication system, the cost of the panels can be reduced by about 70 % compared with the actual values, making the solution much more attractive to the market.

Based on the assessment carried out, the selection of the favorable concept does not change with respect to the envelope of the building when considering the embodied energy and embodied carbon emissions of the materials used. The favorable concept, which was selected within the MORE-CONNECT project, comprises the following elements:

- Installation of the optimized prefabricated module together with a 10 cm layer of mineral wool to be applied between the existing exterior walls and the prefab module;
- 6 cm added insulation to the roof and cellar;
- Biomass boiler for heating and DWH.

11.4 CONCLUSIONS

Favorable concepts that significantly reduce greenhouse gas emissions and primary energy use with prefabricated elements in all geo-clusters covered by the MORE-CONNECT project have been identified. Although the selected favorable concepts often appear to be cost-effective in comparison with the related reference cases, it has also been observed that currently in many cases the costs of the prefabricated elements are higher than those of conventional renovation solutions. However, due to the possibilities for upscaling of the industrialized processes for producing the prefabricated panels, there is a potential that costs can be further brought down to make building renovation concepts with prefabricated elements more cost-effective in the future.

MORE—
CONNECT

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MORE-CONNECT ONE-STOP SHOP CONCEPT

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MORE-CONNECT ONE-STOP SHOP CONCEPT

Project Results: Deliverable 6.4
Lead author: GUUS DE HAAS

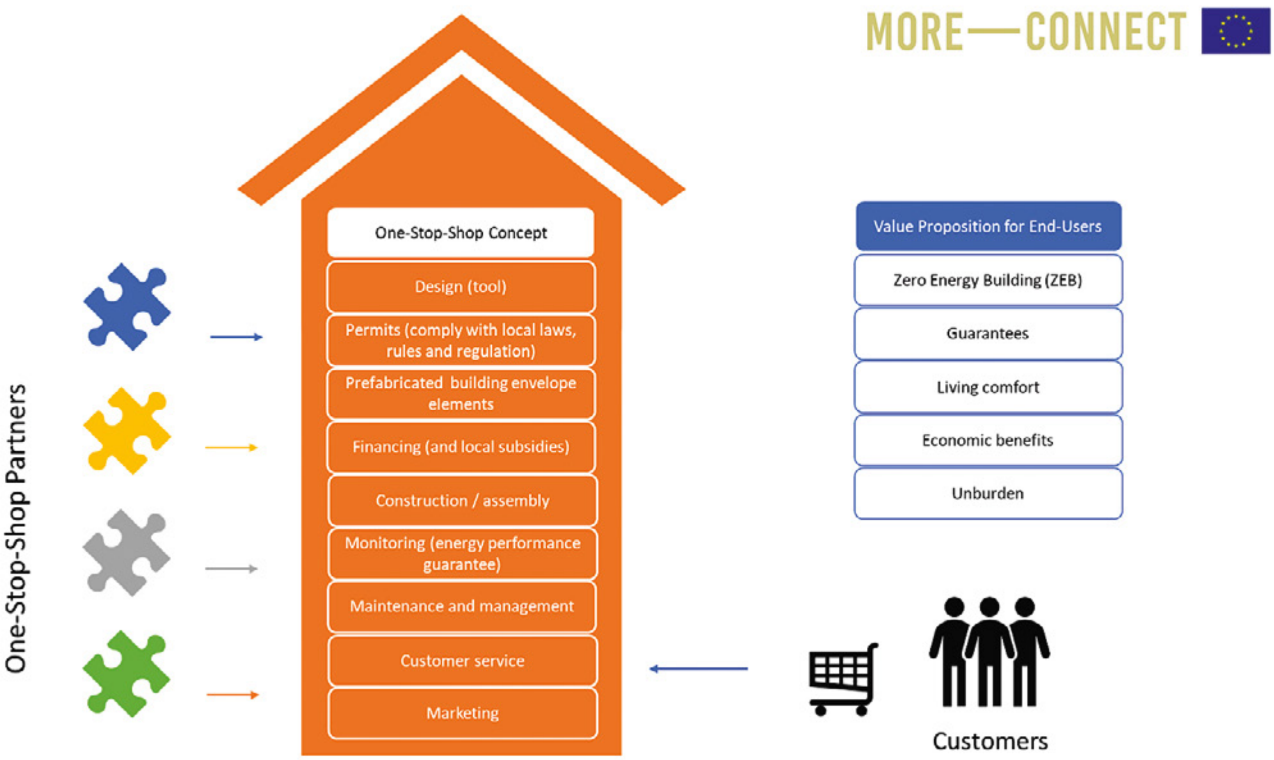
12.1 WHAT IS A 'ONE-STOP SHOP'

A one-stop shop is a company / consortium that offers a variety of products or services to its customers. One-stop shop can refer to a specific location, meaning that all requirements of a client can be met in that location. For example, a bank may be able to offer you not only personal banking services and loans, but also investment advice, investment instruments and insurance policies. Compared to visiting a separate institution to address each need separately, the one-stop shop saves the consumer a lot of time and effort.

12.2 MODELS FOR A ONE-STOP SHOP CONCEPT (EU)

Offering concepts is not new and certainly not exclusive to (n)ZEB projects. All MORE-CONNECT SME partners have been engaged in offering new-build housing construction concepts for several years.

This also applies to other themes. For example, guaranteeing performance is important not only for ZEB but also for maintenance and installation companies. A lot of knowledge about such



issues topical for the industry has already been accumulated.

Yet there is a difference. Within ZEB renovation projects, there are some issues that should be or at least are 'strongly recommended' to be included in the concept, like guaranteeing performance, long-term maintenance contracts, renovating in occupied state, marketing, etc. Thus, accounting for this necessity and interrelation between different issues, construction companies currently make offerings of products or concepts that are radically different from the traditional methods.

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CONCLUSIONS AND RECOMMENDATIONS

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CONCLUSIONS AND RECOMMENDATIONS

FROM EXPERIENCE SO FAR

Europe is facing a major challenge in bringing CO_2 emissions from 250 million+ houses down to zero or nearly zero. One of the major options is to retrofit this stock and add prefab panels to roofs and facades, and to add solar panels to cover the remaining (reduced) need for operational energy. This is a challenge in itself, since the housing stock greatly differs, as well as available roof surfaces and energy production potential in different climate zones.

The research so far has shown that retrofitting with prefab panels is a viable option all over Europe. The geo-clusters can learn a lot from each other and can co-innovate: many technical solutions are applicable in all regions, as well as the production process. In the MORE-CONNECT project, these options will be developed and documented in the final deliverables. However, the devil is in the details: for each project, it is necessary to look for an individual optimal configuration of panels and installations as well as potential for solar power generation. The optimal configuration mainly depends on the starting situation: What is the need for heating (cooling), what are the options to reduce demand before the retrofit, in the use and behavior in and of the house. The MORE-CONNECT project assumes there is no adaptation beforehand. The project concentrates on the reduction of the negative effects of the existing building and production of the positive effects. A few concepts should be analyzed to ensure the optimal detailing of the prefab panels in order to limit the rebound effect of the embodied energy of the materials.

Financing of the retrofit is another major difference. It greatly depends on how energy bills are settled, whether there is a feed in tariffs, and, last bit not least, how payback periods for investment loans are calculated.

Upscaling the whole process is another important issue, for which production facilities blue prints should be developed to be further multiplied throughout Europe. Development of basic configurations will be part of the second phase of the MORE-CONNECT.

Overall, it seems that development of the project is the most important phase of retrofitting within the MORE-CONNECT approach: Many difficulties can be avoided by a detailed and cyclic design process. For the building sector used to solving many small issues at the building site that is a challenge in itself, especially when the entire retrofit process should take place in a few days to avoid disturbing the inhabitants and to reduce costs at the building site ("measure twice cut once").

The general experience from partners can be summarized by the phrase "keep it as simple as possible!", which is mainly applicable to prefab retrofit approaches rather than to general construction.

ANNEX I

The "Gas phase out" concept

In some countries, gas is a major source to heat houses directly. In the Netherlands, nearly all houses have a gas connection for heating and cooking. The main trend now is to go for an all-electric option and disconnect from the natural gas. There are two reasons for that move – it is done to eliminate the use of fossil fuels and to reduce gas extractions in Groningen and thus prevent further soil setting resulting in regular small earthquakes.

There are two ways to reduce gas consumption: to disconnect every retrofitted house from gas supply (the current trend), or to provide every house with a small heat pump operating in the hybrid mode driven by PV.

The first option will take decades before all houses are retrofitted, the second option can be realized in a few years, since this requires no substantial work, and is a matter of adding a small heat pump. The advantage is that all houses can reduce gas consumption (and CO_2 emissions) significantly in the short term, gas will be needed only in the coldest period when the heat pump is not sufficient. With the climate getting warmer, the length of really cold periods will decrease, and less and less gas will be required. This has a few advantages: 1) fast reduction overall; 2) smaller rebound effect in material investments; 3) no disruption for inhabitants (easy installation); 4) no capital destruction creating a large amount of waste from dumped gas equipment (and relatively cheap compared to a total makeover); 5) no sub-optimization: a major renovation might take place later, when the investments in gas infrastructure are written off, and new innovative appliances enter the market.

It is even easily adaptable for further reductions, for instance, if this approach is combined with reducing the heated area, or installation of (electric) infrared heating devices for less used rooms (which function only when people are present) a further improvement can be made. Of course, such easy basic measures as double glazing and cavity wall insulation can be applied as well.

This option has not been calculated in detail, it has emerged from the analysis of other options as a possible and interesting route. It is mentioned here to make the overview comprehensive. This option should be studied in the future.