ZenN Guidelines
Translation of technical knowledge for nearly zero energy neighbourhoods
Overview

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Common Barriers and Challenges in Current Practice

A study on common barriers and challenges in current residential nZEB renovation practice in Europe was carried out in the ZenN project during 2013, focusing on technical, financial, social, environmental, health, organizational and legal aspects.

The study resulted in a number of general conclusions and experiences for Europe regarding both the barriers for taking the decision for nZEB renovation and challenges in the planning and implementation process of nZEB renovation. The main conclusions and recommendations to consider are:

- There are technical solutions for nZEB renovation, but existing building structure and technical system affect both decisions for nZEB renovations and the nZEB renovation process.
- High investment costs is the main financial barrier and challenge for nZEB renovation, but not impossible to overcome.
- The acceptance and knowledge among residents as well as communication with residents are important factors for successful nZEB renovation.
- Energy behaviour of residents needs to be considered after nZEB renovation – in order to reach set energy targets.
- Environmental and health issues are seen as drivers of nZEB renovations, not as barriers or challenges.

For a full summary of barriers and challenges for nZEB renovation, see final Report on common definition for nZEB renovation.

Building structure and technical system provides limitations

In both decision-making process and retrofitting process there are acknowledgement that technical solutions exist but the existing building structure and technical system sets limits to what extent these solutions can be implemented, which in the end also can affect the possibility for an nZEB renovation. This limitation is especially evident where architectural and cultural values of the buildings needs to be conserved, making the decision-making and retrofitting processes even more challenging. This is different to what can be faced in new builds and it needs to be considered for an nZEB renovation.

High investment costs need to be considered

Furthermore, existing technical solutions for nZEB are considered as expensive; adding to the main financial challenge of having high investment in nZEB renovation projects – which is both a barrier in the decision-making process and a challenge in the retrofit process. Those conducting the renovation cannot be guaranteed to see a return of the investment. The rationale behind attaining little return on investment is often related to social aspects, such as residents not staying long enough in a building to benefit from the payback period (often between 15–30 years) or landlords being unable to, or not wanting to, raise rents among their residents. For return of investment, a long-term ownership and/or new financial or profitability models are often needed.

However, there also exist working financial instruments and schemes that have been implemented in countries around Europe, either on national or local level, to try to overcome the key financial barriers and challenges to nZEB renovations. Although there is no perfect nZEB renovation financial scheme yet, the existing instruments could be consolidated in order to make one. Public authorities, primarily all local and national authorities, have a leading role to play in setting up financing schemes which works in relation to the national or local contexts. It is also important that the level of ambition of financial programs rise in order to have greater impact and unlock further private investment for nZEB renovation.

Acceptance and knowledge of residents as well as communication with residents as important success factors

While a lack of knowledge and awareness amongst residents has been identified as both a barrier in the decision making process and a challenge in the nZEB renovation process, the need for communication with residents is especially emphasized during the retrofit process – after the decision is taken. In general, early communication, dialogue and information both between involved actors and organizations of an nZEB renovation project – as well as with the residents – are seen as key for a successful nZEB renovation in order to increase acceptance and knowledge.

The use of good examples in nZEB renovations is recommended in order to increase the knowledge among both professionals and general public about energy efficient renovations and technical solutions. Evidently, involving residents in the nZEB process adds another complexity into the organization of nZEB renovation projects, which is especially evident depending on the ownership structure of the building. The ownership structure of buildings, e.g. if each apartments are privately owned or a rental apartment building, often plays a part as to what extent that residents are involved in the decision-making process to renovate or not.

While the ownership structure is viewed as a barrier in the decision making process, both as an organizational barrier and financial barrier, ongoing communication with residents as well as communication with and...
between wider project partners was acknowledged as important throughout the retrofit process — no matter the ownership structure.

Energy behavior of residents needs to be considered to meet energy targets

Furthermore, residents’ behavior after a completed renovation is also seen as a challenge in the retrofitting process as it is indicative of the impact of the project. Around Europe, there are examples of different strategies to address residents’ energy behaviors.

While some suggest training as a way to teach people how to behave more energy efficient, or reduce residents’ energy use by installing individual meters and debiting, another proposal is to monitor the building energy use after the residents have been living in the building for a period of time and then change the system in place to be more compatible with user behavior.

Therefore, there is an issue of whether the technical solution should influence the end user or whether the end user should influence the technical solution that needs to be resolved.

Nevertheless, a follow-up after nZEB renovation projects is important to validate nZEB targets set within the project and to ensure that residents are using building as designed or that any alternations of technical system are done to suit living habits.

Environment and health as nZEB renovation drivers

Environmental and health issues are neither seen as a main barrier for taking a decision for nZEB renovation or a challenge during the renovation process. Rather, aspects such as improved indoor air quality and environment are seen as drivers for residential nZEB renovations.

However, issues such as change in moisture content when making the building more airtight and the consideration of dust, noise and removal of health hazardous materials during the renovations should be considered in relation to the retrofitting process.

Summary of the main barriers identified for taking the decision for nZEB renovation

Main barriers identified for taking the decision for nZEB renovation:
- Technical barriers: Existing building structure and technical system limit the choice of technical solutions that can be used and where technical solutions can be found, they are often costly and not financially viable.
- Financial barriers: Investment cost too high
- Social barriers: Lack of knowledge or interest for energy efficiency among residents and building owners, often due to lack of awareness combined with challenges with architectural and cultural values.
- Environmental/health barriers: No common environmental/health barriers were highlighted.
- Organizational/legal barriers: The ownership structure and need for consensus among several homeowners can hinder a nZEB renovations.

Main challenges identified in the planning and implementation process of nZEB renovation:
- Technical challenges: Existing building structure and technical systems limit the choice of technical solutions possible for nZEB renovations.
- Financial challenges: Building owners are unlikely to make a return on investment.
- Social challenges: The need for communication and information early in the renovation process to increase acceptance among residents.
- Environmental/health challenges: The risk of moisture must be taken into consideration when making a building more airtight.
- Organizational/legal challenges: The need for an extensive communication between involved organizations and actors early in the process.

For all references in the chapter, see final Report on common definition for nZEB renovation, which can be downloaded at the website: http://zenn.ivl.se/
Common Definition for nZEB Renovation

One important aspect when considering energy efficient renovation is to define the goal. To help in this aspect we have defined the level for Near Zero Energy energy neighbourhood (2014) and how to evaluate the energy efficiency afterwards. This gives the premises of what is meant by a nearly zero energy

ZenN describes nZEN as “A nearly zero energy neighbourhood is a cluster of residential units where the overall energy demand is low and is partly met by renewable energy, self-produced within the neighbourhood.”

Deliverable D1.2 supplies a detailed description of what parameters that are to be measured in order to be able to analyse the pilot buildings in the nZEN context and compare them with each other. The deliverable is highly influenced by work done in the field of nearly zero energy buildings (nZEB).

D1.2 is divided in two:
1) Part A – Literature review, which presents current knowledge regarding ZEB definitions.
2) Part B – Common definition of nZEB renovation, which presents the definition agreed upon by the ZenN partners.

Five main sources were identified that gives state-of-art knowledge in order to aid in defining an nZEB renovation (nZEB):

• EPBD – CA (Concerted Action) REHVA papers (Kurnitski, Allard et al. 2013)

The structure of both Part A and Part B is based on the structure of IEA SHC Task 40 / EBC Annex 52 “Towards Net Zero Energy Solar Buildings” (IEA 2012), which considers five main criteria: Building system boundary, Weighting system, Net ZEB balance, Temporal energy match characteristics and Measurement and verification. In part B, the last part (Measurement and verification) is excluded and instead described in detail in Deliverable 3.2: “Monitoring platform definition”.

A last chapter called “Net ZEB evaluation” is included instead, describing the pilot cases before and after the renovation, using the common nZEB definition and IEA net ZEB evaluation tool.

The building system boundary
The physical boundary may be on a single building or on a cluster of buildings. For the sites with multiple buildings and site energy centres as is the case in ZenN, the system boundary is extended so that it covers entire site with multiple buildings and decentralized production.

The balance boundary defines how the operational phase is considered in terms of energy use. ZenN partners agreed to adopt the prEN 15603 default choice (table A3 in (prEN15603 2013)) that includes heating, cooling, ventilation and domestic hot water; but also to open up for a second set of calculations where lighting is included as well.

Also a set of boundary conditions has been specified for each pilot case, describing functionality, space effectiveness, climate and comfort.

Weighting system
A weighting system converts the physical units into effectiveness, climate and comfort.

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Temporal energy match characteristics
The correlation between load and generation (load matching) will be illustrated through the indicators “Load cover factor” and “Supply cover factor” (IEA 2014). Both are to be calculated based on hourly values. The grid interaction will be illustrated through indicators introduced in (IEA 2014); “Generation multiple” and “Dimensioning rate”, and related graphs. Both are calculated based on hourly values and input on nominal grid connection capacity.

Net ZEB evaluation
The Net ZEB evaluation is done by seeing generation in relation to load using different units such as delivered energy, primary energy and carbon intensity. The “after-figures” are here based on theoretical values collected through BEST tables included in ZenN Annex I- Description of Work (DoW).
Technical Evaluation and General Recommendations on Retrofitting Measures

The evaluation of technical measures performed in the modelling stage of the ZenN project resulted in several general conclusions and experiences. The most important are described below.

- There is a high potential for energy efficiency in similar neighborhoods.
- All relevant actors should be involved and targets should be set early in the process.
- Neighborhood level solutions should be prioritized over building level solutions.
- Focusing on technical details is sustainable; both environmentally and economically.

A high potential for increased energy efficiency

An overall conclusion is that there is a truly high potential for energy efficiency in parts of the existing building stock in the participating countries. The calculated results implied that all the ZenN demo building retrofitting projects should be able to provide a 45 percent final energy saving or more (for monitored results of the energy performance, see D3.3 Results monitoring), and approximately the same percentages of greenhouse gas emissions, through the retrofitting measures (see figures 1 and 2 below).

This could imply that the potential is high for equal buildings outside of the project.

Setting initial targets and involving all actors at an early stage

To accomplish a nearly-zero energy building renovation, as defined in chapter 3 of ZenN D3.1, it is important that the building owner involve all relevant actors at an early stage and, with help from experts in the design team, set initial requirements and targets in terms of reduction in delivered energy, primary energy and GHG emissions. Figures 1 and 2 can be used as a guideline for which targets that can be set in similar cases as these demonstrations.

Prioritizing neighborhood solutions

The evaluation shows that neighbourhood level solutions generally should be prioritized over individual solutions at building level, as they are more cost-effective and more resource efficient. As an example, D3.1 confirms that the neighborhood approaches applied in the Mogel demonstration makes it possible to integrate new systems and technologies for rehabilitation that would not have been feasible if considering a smaller scale (building level) approach. The neighborhood approach thus makes it easier to include more sustainable energy management strategies in a cost-efficient way.

For the demonstration project in Økern, different scenarios implied that improvements are made by focusing on technical details in the different retrofitting actions; for example reducing thermal bridges, higher heat exchanger efficiency and increased PV area. Looking at the economical evaluation the general impression from Økern is that reducing energy through these detail improvements gives fairly similar life cycle costs. This means that reducing energy is sustainable, not only in environmental terms, but also economically.

More in depth conclusions have also been stated on the individual measures performed within ZenN, and these are presented in the further paragraphs below.

Improvements of the building envelope should always be analyzed – economic viability vary

Thermal improvements of the building envelope should always be analyzed and implemented if they are economically feasible. The analyses have given different conclusions in the demo projects. In Mogel, a large reduction in heating demand is obtained with the implemented thermal insulation on facades and better thermal performance of windows. In Lindängen, on the other hand, no insulation improvements could be justified based on both high investment costs and that it would disturb residents, as well as too good condition of the existing facades. A general consideration when improving the air tightness is making sure that a good indoor air quality is maintained and that moisture related problems are prevented, specifically when mechanical ventilation is not applied.
Heat recovery from separated grey water not fully economically viable yet

Reducing energy for DHW becomes more important when the building envelope is well insulated. However, the calculated solutions for heat recovery from separated grey water—which can decrease the DHW energy need—have not proven to be fully economically viable yet, as presented in D3.1.

Summary of the technical evaluation and general recommendations on retrofitting measures

- There is a high potential for energy efficiency in similar neighborhoods.
- All relevant actors should be involved and targets should be set early in the process.
- Neighborhood level solutions should be prioritized over building level solutions.
- Focusing on technical details is sustainable both environmentally and economically.
- Improvements of the building envelope should always be analyzed (the economic viability vary between the cases).
- Analyze whether a complete or partial window replacement is the best solution.
- Heat recovery from exhaust air is generally a cost-efficient measure that always should be considered.
- Exhaust air heat pumps should be analyzed thoroughly due to the increased electricity use (not only in a final energy perspective, but also primary energy and greenhouse gas emission perspective).
- Mechanical exhaust and supply air ventilation with heat recovery (ESX) include retrofitting challenges such as high investment costs and disturbances for residents.
- Solutions for heat recovery from separated grey water have not proven to be fully economically viable yet, as presented in D3.1 in the final Guidelines report.

For all references in the chapter, see final Report on common definition for nZEB renovation, which can be downloaded at the website: http://zenn.ivl.se/
Monitoring Platform Definition

Measurement and monitoring campaigns after a retrofitting process in a building or a neighborhood makes it possible to verify the reached energy performance and comfort conditions. Therefore, monitoring is a useful tool in order to measure the actual net zero energy balance (NZEB).

In order to evaluate the final performance of the retrofitted buildings within the ZenN project, existing possibilities were analyzed with the aim of defining the most reasonable and suitable monitoring platform for each demo building.

This analysis resulted in a general procedure which could be applicable to other buildings and contains the following main aspects:

- Approaches for energy balance
- System boundaries
- Selection of physical parameters to be monitored, monitoring period and timestep
- Physical components of the monitoring system and communication technology
- Normalization of data to allow comparisons between scenarios (before and after retrofitting)

Determine the energy balance

NZEB can be understood as a condition that is satisfied when weighted supply energy meets or exceeds weighted demand over a period of time, normally a year. Therefore, in order to verify the condition of NZEB, an energy balance has to be performed. Basically, there are two ways to measure and check the energy balance in a district or building:

- Load/generation balance: to compare the energy use and renewable energy generation. This method allows a clear understanding of the real conditions in the building; whether the energy generation is able to match the load.
- Import/export balance: comparing the delivered and the feed-in energy. In general, this balance enables simpler monitoring systems, but values are not directly comparable with calculated values in thermal simulations. It is not possible to distinguish which part of the energy consumption comes from external energy sources or from on-site generated and self-consumed.

A third option is also possible using monthly net values of load and generation i.e. monthly net balance.

As far as possible, it is recommendable that the load/generation scheme is prioritized in the exported/imported energy scheme.

For further details about these approaches see D1.2 and D3.2, section 3.

Define the balance boundaries

System boundary has to be extended so that it covers the entire site with multiple buildings and decentralized or onsite production from either on-site or off-site renewables. Nevertheless, because of difficulties regarding either access to the district level energy carrier metering or the limited resources to monitor all parameters in all buildings, the analysis is focused on a smaller sample of buildings/apartments. Then, following a bottom-up approach that considers the neighborhoods as a sum of buildings/dwellings, conclusions to the overall district are drawn.

In summary, to have an idea of the main energy uses and building loads it is recommendable to identify within the monitoring boundaries all the energy flows and transformations, including (1) energy delivered and exported from the neighborhood by different energy carriers, (2) energy transformation in technical building systems (including renewable outputs) and (3) energy delivered to meet energy needs of the demonstration buildings in an energy flow chart.
Which parameters to measure and when

From the performed analysis in the ZenN project general recommendations can be given regarding the selection of parameters that should be included within the balance of NZEB.

On one hand, it is important to consider that for metering purposes the exclusion of any energy use from the balance boundary increases the complexity of the monitoring system; requiring the installations of additional meters and thus moving from a whole building monitoring approach to sub-metering. Therefore, a compromise between complexity of the metering system and targeted system boundaries values should have to be done.

On the other hand, the energy consumption data should be specified as final energy (energy supplied to the final consumer for all energy uses). In order to verify the NZEB balance, primary energy factors have to be used to transform energy use into common metrics.

The selection of parameters to be measured, and that have been executed within ZenN project, could be applicable to other buildings. These parameters are divided into three categories:

- **a) Energy use by the buildings’ technical systems in order to meet the buildings’ energy needs**
  - Parameters to include: energy consumption due to heating, cooling, ventilation, humidification and dehumidification, domestic hot water, lighting for non-residential buildings, electric equipment of the central systems, etc.

- **b) Renewable energy generation onsite**
  - The energy generated by the building within ZenN projects refer basically to the electricity generated in photovoltaic panel and the thermal energy generated in solar thermal panels, but they can also consider other technologies as ground, air or solar source heat pumps, cogeneration units, etc.

- **c) Additional parameters**
  - Parameters suggested to be measured: weather variables (mainly outside air temperature, humidity, solar radiation and wind) and internal comfort conditions (internal temperature and humidity).
  - Optional parameters: occupancy profiles (uses, population, operating hours etc.) and additional building on site test as thermography analysis or airtightness measures by means of the specific test called blowerdoor test.

In order to have a clear idea about the energy consumption and generation in the building it is recommendable to perform an energy flow diagram.

For weather dependent loads a proper time span for measuring and calculating the balance is assumed, often implicitly, to be a year or several years. A year covers all the operation settings with respect to the meteorological conditions and loads of the building. If data cannot be obtained for a complete year, shorter representative periods are also acceptable.

Regarding the frequency of the data recording a short logging period of 10 minutes or less are recommendable. This in order to capture building dynamism and distinguish consumption patterns by each load in overall energy carriers consumptions. Nevertheless, data should be at least based on one hour frequency in order to make any comparison with values of the energy simulations.

Where to install the sensors

Sensor selection depends on the quality (accuracy, precision, rate of response range and output), quantity, installation restrictions, method of measurement required and the resources to purchase and support it.

During the definition of the monitoring platform in the ZenN project, metering potential devices and recommendable measure points were identified. For further details about the suitable sensors see D3.2, section 3.4. The description of main specifications for each demo site can be found in D3.2, section 6.

The importance to normalizing data

For a building sector space heating, space cooling and onsite renewable production are very sensitive to climate. To avoid any misleading conclusion energy use figures may be normalized to ensure performance comparability from pre /post intervention scenarios and comparability with computer simulation results. Normalization is done by correcting energy use figures by the external factors that could distort the energy use calculations, such as weather conditions, set points, schedules, etc.

For space heating the normalization is usually carried out based on the number of heating degree days (HDD), although other inverse method models are also used for normalization. The adjustment factor is usually defined as the ratio between the normal number of HDD and the actual number of HDD. Being a “normal” winter is based on a long –term number of degree-days. For PV production the indicator that is basically used to make comparisons is a so called performance ratio, which relates the actual PV AC production with the peak power of the panel at standard conditions.

For further details about normalization techniques see D3.2, section 3.4

**Summary of recommended steps for defining monitoring platform**

- **Define system boundaries (building, neighborhood, production plants etc.)**
- **Identification of parameters to be measure should be based on the type of energy balance to perform.**
  - Outline the ideal monitoring scheme
  - Perform an analysis of barriers of ideal scheme and make required assumptions to define real monitoring scheme.
- **Definition of monitoring schedule and required frequency (depending on the aim of monitoring system).**
- **Select sensors, positioning, data login devices and other equipment suitable for evaluating selected parameters.**
- **State normalization procedure.**

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Results Monitoring

The monitoring report presents energy balance figures from the ZenN project demonstrators, after a monitoring process which has covered the course of a year of operation. In this report, the real energy use of the buildings, obtained through on-site monitoring, has been compared with the previously established energy consumption targets which were obtained through simulation models.

The monitoring report has displayed the overall energy performance through annual indicators (e.g.: kWh per m² and year), bearing in mind the expected results and possible causes of deviation. The main indicators (KPIs) investigated for each demonstrator in the course of a year of operation. In this report, the figures from the ZenN project demonstrators, after a monitoring process which has covered the previously established energy consumption targets; raising awareness on how to operate and commissioning of the solutions.

Concerning on-site renewable generation, the relation between the building energy load and the energy generation must be considered in order to achieve the appropriate match. (Figure 2)

Energy retrofitting potential to reduce energy loads of existing buildings

At a general level, the monitored results have shown a reduction of 26–67 percent of building energy loads referred to final energy in the retrofitted buildings. This displays the general great potential to reduce energy loads in similar neighborhoods.

The expected reductions were in the range of 53–69 percent and the major deviations from the expected results are in Arlequin 40 (Grenoble) and Mogel (Eibar). The following graph shows the monitored energy breakdowns of all the 5 demonstrators referring to primary energy, compared to the renewable energy on-site generation (self-consumed part) in each of them. See figure 1.

Concerning on-site renewable generation, the relation between the building energy load and the energy generation must be considered in order to achieve the appropriate match. (Figure 2)

Importance of implementation and commissioning of the solutions

The proper execution/implementation of the designed solutions, e.g. warranting insulation continuity and air tightness of the building envelope whilst removing all thermal bridges, is essential to achieve the expected results in building energy loads.

Concerning active technologies, besides the implementation, commissioning is of high relevance in order to achieve the expected results. This includes the settings and control functions of the operation mode of all active systems: mechanical ventilation system, solar-thermal panels, heat pumps with ventilation exhaust air heat recovery, PV panels and illumination control.

This has been displayed in Arlequin 50, where the water distribution for the heating system is regulated by two-way valves and controlled by a temperature sensor and where after the regulation systems performance was optimum; and in Mogel, where some of the solar panels were not working properly. In this regard, detailed monitoring has been a beneficial tool to identify the cause of problems and optimizing the operation.

Effective maintenance is necessary to meet the expected targets

Not only commissioning is important for the proper operation of buildings, but also periodic maintenance of the systems is necessary to meet the expected energy performance. The chosen solutions are simple and well-proven, the technologies perform efficiently. Design is important, but also the implementation and commissioning of the solutions.

Figure 1. Energy breakdown in all the demonstration sites compared to renewable energy self-consumed generation.

Figure 2. Load and on-site generation of renewables illustrated over a year. Note that the calculation of the load matching indicators should be done with hourly values. The figure shows monthly values for simplicity.

Potential to integrate on-site renewable energies to reach NZEB

The renewable energy share is higher than 90 percent in Grenoble where district heating is fed by biomass. Furthermore, PV panels have been installed in the rooftop of the car-park located in the neighbourhood. In the case of Oslo and Malmö, the PV panels’ electricity production have contributed to 7.5 percent and 4.3 percent of the total energy demand of the buildings, with the panels installed in buildings’ rooftop.

As seen in Figure 1, these PV panels’ contribution in a sole electricity perspective is more significant. In the case of Mogel, the area of flat solar collectors installed on the rooftop is able to cover 30 percent of the DHW load, as initially expected. However, the distribution side needs optimization, why the monitored final renewable share of the DHW demand is lower at this point.

Simple well-proven solutions and effective technologies

The solutions prescribed in the simulation project stage are reliable market solutions. However, either due to new procedures of installation/integration or due to the involvement of different disciplines and skills that must work in close collaboration, systems are sometimes not functioning according to the expectations after the installation. For several of the demonstrations, further improvements of the energy performance are expected when all measurements have been furtherly adjusted.

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Concerning on-site renewable generation, the relation between the building energy load and the energy generation must be considered in order to achieve the appropriate match. (Figure 2)

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Effective maintenance is necessary to meet the expected targets

Not only commissioning is important for the proper operation of buildings, but also periodic maintenance of the systems is necessary to meet the expected energy performance. The chosen solutions are simple and well-proven, the technologies perform efficiently. Design is important, but also the implementation and commissioning of the solutions.
User behaviour is determinant to meet energy targets

Regarding heating systems, for which major energy use is made, Arlequin 40 and Mogel show the major deviations comparing the initial simulations with the final performance. In these two neighbourhoods, building tenants have control of the space heating indoor settings through access to boilers and the usual valves (called “thermostatic valves”) at the inlet of heaters. As a result, high technological solutions and retrofitting efforts could be wasted if user behaviour is more squandering than expected.

Hence, training actions to the tenants and staff on how to operate their buildings can bring further energy reductions in these neighbourhoods, showing the impact of their actions in their energy bills.

Overall, the detailed monitoring platforms installed in the 4 demonstration sites of ZenN have demonstrated that achieving NZEB in existing buildings is possible. The monitoring platforms also function as a valuable tool to identify potential operation problems, to optimize system operation during commissioning and to identify areas of further improvement concerning future projects of nearly zero energy neighbourhoods.

Summary of general conclusions from the analysis of monitoring results

- Energy retrofitting has a great potential to reduce the energy loads of existing buildings (as displayed through the ZenN demonstration sites).
- There is potential to integrate on-site renewable energy generation to match building loads and reach NZEB.
- The chosen solutions are simple and well-proven, and technologies perform efficiently.
- Design is important, but also the implementation and commissioning of the solutions.
- Maintenance of the systems is necessary to meet the expected energy targets.
- User behavior is determinant in reaching these targets; raising awareness on how to operate buildings more efficiently is of high relevance to achieve energy targets.

For all references in the chapter, see final Report on common definition for nZEB renovation, which can be downloaded at the website: http://zenn.ivl.se/
Improvement Proposals for Replication Actions

Before a retrofitting process can start, a detailed energy analysis is needed to find the most energy efficient measures for that specific building. Deliverable D3.1 presents different retrofitting scenarios for each of the pilot buildings and chooses one scenario which presents how the final retrofitting will be done. Deliverable D3.3 presents results from the monitoring, to see how the calculated values correspond to real life.

Making use of available data from monitoring carried out in D3.3, and information regarding possible improvement actions and associated additional energy consumption reduction figures gathered during D3.1, D3.4 theoretically analyses the feasibility of improvement proposals. The results from D3.4 is oriented towards safe inclusion of viable technologies developed during the course of the project.

Improvement proposals for the pilot buildings are summaries in the tables.

### Proposals for replication actions, Lindängen

<table>
<thead>
<tr>
<th>Improvements proposals</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>If applying an exhaust air heat pump solution, the scale of the Lindängen installation and the efficiency makes it a well-balanced solution in terms of final and primary energy decrease as well as reducing climate impact in Swedish conditions.</td>
<td>With a COP of approximately 5 and a purely renewable energy supply, the primary energy consumption as well as the climate impact of the buildings should decrease with this solution.</td>
</tr>
<tr>
<td>The property electricity retrofitting measures have improved the building energy performance more than according to the simulation. The sub-metering system has demonstrated that the lighting electricity use is very low.</td>
<td>Difficult to evaluate if even better installations could have been installed.</td>
</tr>
<tr>
<td>PV solutions like this one seem to be reliable in terms of conformity between the expected and achieved energy generation. The metered PV cell electricity generation was even higher than expected. The normal-year corrected figure indicates that the generation could become lower other years, but it is nevertheless difficult to draw any conclusions on this. Since approximately 20 % of the PV electricity generated during the year was exported to the grid, there is still room for improvements of these solutions (local energy storage and new types of utilization of excessive electricity).</td>
<td>Solutions for local energy storage or utilization of the excessive electricity should be assessed and tried furtherly, e.g. for the insurance of a maintained good electricity quality on the grid (small-scale PV electricity export could cause disturbances).</td>
</tr>
<tr>
<td>The indoor temperature metering gives a very clear view of the heating system adjustment needs.</td>
<td>-</td>
</tr>
<tr>
<td>The sub-metering of property electricity gives a good overview of the performance of the technical installations. The sub-metering system of property electricity has functioned well and given many good insights, but has only been implemented in one of the buildings. For a more assured overview of all of the buildings, the same detailed metering system should have to be installed in all.</td>
<td>Operation disruptions and malfunctioning is not easy to detect and assess in detail in the buildings without the sub-metering system. It is also simplified to assess the performance of a sub-metered building if the same metering systems are installed in several equal buildings.</td>
</tr>
</tbody>
</table>

### Proposals for replication actions, Økern

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>A large share of electricity consumption can be covered by locally produced energy. PV was the chosen energy solution at Økern. The walls can be used (together with the roof) to get a larger area of PV panels installation (this was presented by numbers in Scenario 2 and 3 in D3.1).</td>
<td>The building was renovated up to the Norwegian Passive House level. Although the requirements was high, there could have been larger focus on reduction of thermal bridges and increased air tightness (Sc 2 and 3 in D3.1), resulting in better U-values in walls.</td>
</tr>
<tr>
<td>Renovation of building envelope with a large emphasis on energy efficiency. The building was renovated up to the Norwegian Passive House level.</td>
<td>Renovating buildings up to the Norwegian passive house level results in an increased level of insulation and large emphasis on air tightness. This makes a large difference when the starting point is a building from the 1970’s (Økern was built in 1975). The resulting building envelope ended up as a very efficient building, but some more energy reduction would have been possible if the requirements on energy efficiency were stricter.</td>
</tr>
<tr>
<td>Installation of balanced ventilation system with heat recovery. The installed ventilation equipment had 80% heat recovery. The heat exchanger efficiency can be increased further by technical equipment chosen as basis for calculations in Scenario 2, D3.1.</td>
<td>Balanced ventilation with 80% heat recovery is a common and settled technology and more progressive heat exchanger technology can be found at the market to increase the energy efficiency further.</td>
</tr>
<tr>
<td>The sub-metering of property electricity gives a good overview of the performance of the technical installations. The sub-metering system of property electricity has functioned well and given many good insights, but has only been implemented in one of the buildings. For a more assured overview of all of the buildings, the same detailed metering system should have to be installed in all.</td>
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</tr>
</tbody>
</table>
### Improvement proposals for replication actions, Arlequin 40/50

<table>
<thead>
<tr>
<th>Proposals for replication actions</th>
<th>Improvement proposals based on experiences from D3.1/D3.3</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renovation of building envelope with a large emphasis on energy efficiency and detail correction (Thermal bridges) thanks to a thermal bridge reference book to be considered for any new retrofitting operation.</td>
<td>The buildings were renovated according to the French Low Consumption retrofitting standard. The requirements to reach a higher level of performances lead to focus on reduction of thermal bridges resulting in better U-values in walls and roofs.</td>
<td>The engineering firms do not consider thermal bridges impact when energy performances are estimated.</td>
</tr>
<tr>
<td>Air tightness improvement process</td>
<td>The usual value for air tightness according to the French Low Consumption retrofitting standard has not been considered as sufficiently ambitious. A target at level of Q4 &lt; 1.1 m3/h.m² (French standard) has been chosen but only an average maximal value was specified for the tested apartment.</td>
<td>-</td>
</tr>
<tr>
<td>Indoor thermal regulation</td>
<td>The control of indoor temperature has been improved for the building ARLEQUIN 50 with a 2 ways valve controlled by temperature sensors located in the living room. It has allowed to reduce overheating during winter time and to reduce heating energy consumption.</td>
<td>A monitoring campaign in Lyon of a 55 flats social housing retrofitted building has shown the efficiency of such a technical solution. A reduction of 20% of heating energy consumption has been measured with 2 ways valve controlled by temperature sensors located in the living room compare to usual thermostatic valves mounted on the heater.</td>
</tr>
<tr>
<td>Auxiliary pump optimisation</td>
<td>As heating demands has been dramatically reduced thanks to thermal insulation, specific electric consumption can reach a high part of global energy balance of buildings. Consequently, the circulation pump control strategies should be optimized, if possible with integration of storage capacity to allow pump stopping.</td>
<td>Building monitoring campaigns have proven that auxiliary pumps could reach more than 20 kWh/m² year if they are not controlled in a correct way for heating and DHW. With adaptation of hydraulic architecture and control strategies, such energy consumption can be dramatically reduced.</td>
</tr>
<tr>
<td>Installation of ventilation system with minimal controlled air flow</td>
<td>The installed ventilation equipments ensure minimal air flow in dwellings to warranty indoor air quality (Hygrometric B according to French standard). The CO2 rate can reach up to 2000 ppm in a case of Hygrometric B ventilation system in dwelling, because of too low air flows. Only Hygrometric A ventilation system show a good compromise between air quality and energy efficiency.</td>
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</tr>
</tbody>
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### Improvement proposals for replication actions, Eibar

<table>
<thead>
<tr>
<th>Proposals for replication actions</th>
<th>Improvement proposals based on experiences from D3.1/D3.3</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promote/encourage the substitution of poor windows although it is an individual actuation</td>
<td>Higher space energy use for dwellings with old windows.</td>
<td>Poor thermal transmittance and leaky windows lead to increase the space heating needs because of the low surface temperatures of the glazing’s and higher infiltration rates.</td>
</tr>
<tr>
<td>Integral retrofitting of building envelope</td>
<td>Warranty insulation continuity and air tightness in the whole building envelope, specially in window / façade joints.</td>
<td>The joint of the façade/window is one of the weak points of the façade and lead to unwanted external air infiltrations.</td>
</tr>
<tr>
<td>Air tight shutter/roller boxes</td>
<td>Ensure the well execution of roller boxes, plugs or any wire coming from the façade</td>
<td>These are generally weak points related with airtightness.</td>
</tr>
<tr>
<td>Ensure insulation is warranted between conditioned and non-conditioned spaces</td>
<td>-</td>
<td>In order to reduce any thermal losses between roof/ceiling slabs and ground/ floor slab.</td>
</tr>
<tr>
<td>Ensure insulation continuity in thermal bridges (balconies) and any recessing surfaces</td>
<td>IR thermography has shown that these are areas that need further analyzed</td>
<td>-</td>
</tr>
<tr>
<td>Promote the substitution of existing boilers for condensing boilers</td>
<td>-</td>
<td>In order to improve the performance ratio.</td>
</tr>
<tr>
<td>Recommend the installation of thermostats</td>
<td>In order to warranty a stable indoor comfort temperature and this not surpassed.</td>
<td>Any additional 1°C of space heating increases sharply the space heating energy use.</td>
</tr>
<tr>
<td>Optimize solar thermal panels function mode and commisioning</td>
<td>Panels performance is far from what was expected.</td>
<td>A better performance can be achieved with the primary circuits set points.</td>
</tr>
</tbody>
</table>

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**Summary of the improvement proposals for replication actions**

The tables summaries improvement proposals for each building giving valuable information for replication actions. The experiences is unique for each pilot but some common features can be seen:

- The building envelopes was mainly retrofitted according to well-known standards and higher ambitions could have been set on air tightness and U-values to get larger degree of energy reduction.
- The choice and design of the ventilation system is of great importance for the final energy consumption.

For all references in the chapter, see final Report on common definition for nZEB renovation, which can be downloaded at the website: http://zenn.ivl.se/
Taxonomy of Near-zero Energy Renovation Options and their Influence on Architectural and Cultural Heritage

Taxonomy of near-zero energy renovation options and their influence on architectural and cultural heritage is developed in two ways. Firstly, the taxonomy of near-zero energy renovation is examined taking into account both technical and non-technical drivers – Stakeholder Awareness and Behavior, Economic and Ownership Structures, Legislation, Governance and Policy, Architectural Values and Cultural Heritage.

Through current state-of-the-art work in this area, the taxonomy of near-zero renovation options develops group clusters of non-technical drivers and also builds on the work of ZenN D1.1. "Common barriers and challenges in current practices".

Secondly, cultural heritage and architectural values are examined using the assessment tool Spatial Quality (Acre and Wyckmans 2014) where four general concerns related to cultural heritage value in architecture are considered: maintenance of architectural features of facades’ composition, materials and components of the building structure; changes in the internal organisation of the plan and changes regarding the use of spaces. These concerns are taken into consideration in spatial quality analysis.

The main conclusions and recommendations to consider are:
- By focusing on what influences the drivers, whether it is technical or non-technical, taxonomy of near-zero energy renovation options opens up a new way to consider drivers.
- The taxonomy of near-zero energy renovation options are described separately stakeholder awareness and behavior, economic and ownership structures, legislation, governance and policy, architectural values and cultural heritage. However, they are at the same time co-depend and in certain aspects overlap. For example, there are overlapping challenges concerning how to find technical solutions which are cost effective for historic buildings and that are linking technical, economic and architectural values with cultural heritage.
- The spatial quality assessment for the ZenN demonstrator of Grenoble indicates that spatial quality is affected by the dwelling renovation.

Taxonomy of near-zero energy renovation options
The taxonomy is divided by non-technical drivers of economic and ownership structures: stakeholder awareness and behaviour; legislation policy and governance; and architectural values and cultural heritage. Technical drivers are also considered.

Economic and ownership structures
Business models and incentives used in the demonstration
What are the alternative business models and incentives that can be used to reduce investment costs?
- What public funding for retrofitting is available for nearly Zero Energy Building (nZEB) renovation in the demonstrations?
- What are the existing financial instruments that come from the private and public sector?
- What are the potentials to reduce the investment costs through development of lifecycles, performance-based market services or risk allocation?

Socio-economic benefits for various stakeholders
Has the following been developed during the renovation and planning together with the end-user?
- Criteria for user comfort.
- Criteria for energy performance.
- Added values.
- Ownership structure and need for consensus.
- Are there consensus problems in the ownership structure?
- Is risk allocation considered by all involved stakeholders?

Stakeholder awareness and behavior
Culture of energy awareness
What impact does a gap in knowledge among stakeholders have both during and post renovation?
- How have the different stakeholders shown awareness in the renovation? For example, by residents demanding promotional and educational actions or energy efficient solutions.
- Are there any initiatives or programs developed to change residential behavior that in turn can increase the chances of the renovation being used as designed?
- Has there been any resistance to change behavioral mindset regarding energy efficiency?

Initiation of user centric development
- How have different stakeholders been involved in the design of the renovation?
- If and how has the project management team provided information or involved residents?
- What are the logistic challenges in managing an occupied site over a long period of time?

Legislation, policy and governance
Political goals with local climate and resource
- Which are the local, national and European energy performance targets that promotes the use of ZenN?
- Are eco-labels or accreditation for energy efficiency influential on the renovation process?
- How do the health and safety aspects of ZenN renovation differ from a non-ZenN renovation?
- How are resources used to reduce the carbon footprint of citizens in a ZenN demonstration site?

Leadership and decision-making structures
- How do policy objectives encourage ZenN renovation?
- Which are the local and European policies that influence ZenN renovation?
- How are decisions made and implemented in the renovation?
- What legislation on energy renewable resources impacts residential owners and the grid?
- Are there regulations which restrict ZenN renovation?

Architectural values and cultural heritage
Impact of architecture and cultural values
- How are maintaining aesthetics in cultural heritage of existing buildings considered?
- How is well-being and comfort addressed?
- What challenges are foreseen in integrating new building systems with old building systems, when also considering architectural value and cultural heritage?
- What is the service life of the renovation for architecture and cultural heritage buildings?
- How is the renovation revitalising the local urban neighbourhoods?

Restrictions which limit choice of market solutions
- What are the economic considerations that should be taken into account regarding an architectural and cultural heritage renovation?
- In historic and cultural heritage buildings there are restrictions on what can be changed or built. How do these restrictions impact the business models for ZenN?

Regulations for historic buildings
- Have current regulations facilitated or inhibited the integrity of the renovation?
- What are the challenges in historic buildings regarding accessibility for Universal Design?
- What are the important considerations regarding compatibility when introducing energy efficiency into historical buildings?

Technical
- The building system boundary.
- Weighting system.
- Net ZEB balance.
- Temporal energy match characteristics.
- Measurement and verification.

Architectural value and cultural heritage: Spatial Quality Assessment
Spatial quality is a non-technical driver defined by four determinants which include residential use, building and block scales, and indoor and outdoor environments (Acre and Wyckmans 2014). The four determinants are (1) view, (2) internal spatial arrangements, (3) transition between public and private spaces, and (4) perceived, built, and human densities (Acre and Wyckmans 2014). Visual privacy and quality of the view are the main topics considered in the spatial quality determinant of view (1). Internal spatiality and spatial arrangements (2) considers the articulation between indoor spaces and its boundaries, and articulation among adjacent internal
spaces. The physical barriers between public and private domains are the focus of the determinant of (3) transition between public and private spaces. Perceived, built and human densities (4) consider the proportion and boundaries of the block, as well as both built and human densities.

A spatial quality assessment is developed based on the four determinants. The assessment aims to explore the potential of building renovation as a promoter of occupants’ well-being and quality of life, by connecting spatial quality and energy-efficiency in the dwellings. Non-technical concerns such as views, spatial arrangements, public-private spaces and density are clearer to human perception, and may therefore improve users’ willingness towards energy-efficient renovation.

The result of the spatial quality assessment for the ZenN demonstrator of Grenoble indicates that spatial quality is affected by the dwelling renovation. The assessment also indicates that the impact of the renovation is positive in most of the issues of concern for the four spatial quality determinants.

Views (1) and internal spatial arrangements (2) are the most benefitted determinants with the dwelling renovation. Transition between public and private spaces (3), and perceived, built, and human densities (4) are the least affected, however the effects of the renovation on these determinants are also positive. Positive measures that increase spatial quality in the apartment units are for example new openings in the facade, and changes in the plan of the apartments.

Summary of taxonomy of near-zero energy renovation options and their influence on architectural and cultural heritage

- Taxonomy of near zero energy renovation options opens up a new way to consider drivers by focusing on what influences the driver; whether it is technical or non-technical.
- Overlap is considered as the questions are developed so they cover a cross section of stakeholders and are not specific to just one type of stakeholder.
- Architectural value and cultural heritage was examined in terms of its characteristics associated with spatial quality.

For all references in the chapter, see final Report on common definition for nZEB renovation, which can be downloaded at the website: http://zenn.ivl.se/
Stakeholder Awareness and Behavior

A Stakeholder Awareness and Behavior study was conducted in 2015 in order to better understand the holistic view of implementing energy efficiency measures into the renovation process.

The study resulted in a number of general conclusions and experiences which can be read in more detail in the D4.2 report Stakeholder Awareness and Behaviour. Below are some key conclusions and recommendations to be used as a guide for future renovations of zero energy neighbourhoods.

The main conclusions and recommendations to consider are:

Stakeholder awareness:
- ZEB/ZenN is a new concept and not necessarily understood by all stakeholders. This can lead to scepticism both on implementation and in use. Misconceptions need to be overcome in order to avoid negative prejudices that in turn are hindering the process.
- Ongoing two-way communication between project participants and end-users throughout the renovation is key for informed decision making, mitigating conflict and developing knowledgeable users of energy efficiency neighbourhoods.

Stakeholder behaviour:
- Training is often required to update the skills of contractors in order to install energy efficiency technology in a correct way. Training is also necessary for end-users so they can understand how to obtain optimum energy use of the building.
- An adjustment period is needed in nearly Zero Energy Neighbourhoods to allow users to familiarise themselves with any energy efficient technical impact on their behaviour. It is also needed in order to address any technical functionality problems as the building goes from renovation to full operational use.

ZEB/ZenN is a new concept
Project teams were sometimes sceptical regarding if the energy efficiency targets could be reached. There were misconceptions or prejudices towards some of the technologies being introduced. One example of a misconception was that the hot water, heated by solar panels in a neighbourhood, was expected by the residents to become cold after a number of people in the building showered (which is not the case). Another example was that nearly zero energy building would mean zero energy bills, (which is not the case). The danger of not addressing misconceptions is that negative opinions can be fostered against an energy efficiency renovation or the technology is not being used optimally and thus reducing the potential for a building that is preforming energy efficiently. Participants of the demonstration projects managed misconceptions by showcasing completed and successful phases of the demonstration to residents and through study visits that illustrated the benefits of ZEBN. They also used other diverse two-way communication approaches.

Ongoing two-way communication
A common ground is required and developed through ongoing communication during the renovation process, in order to overcome scepticism and misconceptions. More than one key person was often required to organise the communication efforts. Within the project teams, it was discovered that it was valuable to have a knowledgeable and experienced expert, who knew the technical implementation of energy efficiency or knows where to access information, in order to build the team’s confidence that they could reach the stated target.

However, two-way communication was done by linking the project teams to the end user and vice versa. This was particularly evident through the use of a steering group, made up of representatives from each stakeholder group, to address problems and come up with creative solutions.

Some projects had one individual located in the residential building, or hired individuals to be part of the project, alternatively had telephone communication with the building owner - in order to address local concerns among residents. A common trend with communication in most aspects of the demonstration was that it remained open, receptive and a two-way channel.
The demonstrators have been quite innovative, not necessarily in terms of the chosen technology (best practice) but in terms of the social and communication aspects they integrated into the technical renovation.

The Arlequin demonstrator highlighted a collective spirit in the project team that gave a sense of direction and helped integrate the ambitious energy targets into the ongoing renovation process. Mogel’s communication strategies resulted in overcoming negative attitudes amongst residents in the initial stage of the renovation process.

During the testing and commissioning phase in Økern, the building owner was very responsive to staff concerns. This responsiveness was appreciated by staff who stated the building owner listened and addressed their concerns quickly.

Close collaboration between contractors and consultants in the Lindängen demonstrator resulted in innovation platforms in order to replicate the gained knowledge in other projects. All these measures were important for successful progress in energy efficiency planning, design, implementation, testing, commissioning and operations.

Training
Technologies used in the demonstrations were proven but building contractors required training both to update their skills on installing technology as well as to understand the wider impact that the technology would have on the other elements of the building. The necessity of updating skills brings up the question as to who will pay for training—the building owner or the contractors company. Training was noted as being important in all demonstrations as it builds knowledge and understanding of a ZenN renovation.

There is also an awareness that residents do not necessary know how to use the energy efficient technology or maintain it in an optimal way. Responses to this lack of knowledge was handled by providing training to end-users during initial occupation of the building, and the development of a guidance manual on how to maintain the energy systems and use the energy systems in an optimal way. There is a need for follow-up training with end users as they become familiar with a building and which can be done through repeating training and/or a permanent reference such as a guidance manual. Such training attempts to overcome the end user’s lack of knowledge regarding how the intended design of the building is expected to be used.

Adjustment period
It is not possible to foresee all possible problems of the installed energy efficiency technology and it is likely that the initial months of operation will require an adjustment period. This adjustment period is to allow users to familiarise themselves with how the technology impacts (or not) their day to day living, or any functionality problems that occur with the technology as it goes into full operation. During the adjustment period both the building owners and residents should be prepared and made aware of that there may be initial problems with the different systems installed—not foreseen before occupancy. Such preparation should include a support plan in terms of how problems are addressed and tracked. During this adjustment period it is important to remind residents of the benefits of the system and keep the line of communication open.

Summary of Stakeholder awareness and behavior
- The demonstrators have been quite innovative, not necessarily in terms of the chosen technology (best practice) but in terms of the social and communication aspects they integrated into the technical renovation.
- The Arlequin demonstrator highlighted a collective spirit in the project team that gave a sense of direction and helped integrate the ambitious energy targets into the ongoing renovation process. Mogel’s communication strategies resulted in overcoming negative attitudes amongst residents in the initial stage of the renovation process.
- Close collaboration between contractors and consultants in the Lindängen demonstrator resulted in innovation platforms in order to replicate the gained knowledge in other projects. All these measures were important for successful progress in energy efficiency planning, design, implementation, testing, commissioning and operations.

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Economic and Ownership Structures

During the project, a study on economic and ownership structures of ZenN demonstration buildings has been carried out. As a result, a report has been published providing conclusions and recommendations regarding financial aspects of nZEB renovations. The aim of the report was to analyze different financial schemes that were implemented within the ZenN project, and propose efficient solutions for energy-efficient retrofitting.

In general, the main challenge concerning energy-efficient renovations is associated with a short time horizon, in economic science known as high time preference. The point is that many investors or property owners are not willing to invest in nZEB renovation because of the long payback time of such investment. Another challenge of such investments is the lack of capital needed to implement nZEB refurbishments, as well as reluctance of real estate owners to take high credits. It is also connected with some hesitation or lack of knowledge whether new, ecological solutions are indeed as profitable as it has been said.

Among promising financing models that make it possible to handle the aforementioned challenges are Third Party Financing and the Energy Savings Performance Contracting (with participation of Energy Saving Company – ESCO).

The ZenN project provided the following conclusions, recommendations and respondents’ (owners, managers, residents’ representatives etc.) suggestions:

- Owners were pretty satisfied with the financing scheme applied in the ZenN project, some that are replicable.
- Banks consider loans in a rigorous and unified way.
- Subsidies were important incentives for deciding to take part in retrofitting.
- Financial incentives were essential motivation for tenants.
- There is a big difference in the specificity and motivation in case of commercial and municipal entities.
- There is a need for flexible approach to finance and technologies in grant awarding procedure.

Generating the return on investment in residential rented apartments
It can raise problems when an owner of a building is not its user. Expenses are made by an owner, while incentives and utility upgrades are used by tenants. Thus, owners can be discouraged to invest in energy-efficient renovations. However, some solutions of this problem can be proposed.

As in the case of the renovation performed in France within the ZenN project, the landlord may use the rental costs in order to generate gains without affecting the level of costs bore by the residents. Considering that the cost of utilities drops significantly after the refurbishment, it is possible to use the existing financial gap to deliver additional income for the investors. An owner of a building has the right to increase rental costs of apartments located in a building; taking into consideration renovation and improvements that have been performed.

Connecting energetic renovations with other refurbishment
In case of the renovation performed in Spanish demonstration case (Elbarr, Mogel), many of the dwellers were mostly interested in acquiring lifts in their buildings. It was an important investment for them. Thus, it was the strategy promoted by Debegesa and the Basque Government to try to connect the energy efficient renovations with other previously requested installations and modifications of the buildings. It is advisable to use such a combined investment approach in order to encourage owners to involve energy efficiency measures in other types of projects.

Keeping a low percentage of funds as a cash reserve in case of additional costs
An initial budget of renovations should be slightly expanded in order to give financial security for project implementers. Additional money would allow to omit any challenges related to unexpected expenses that would arise due to new, unforeseen and necessary construction work. Taking into account a complexity of deep energy efficient renovation, a possibility of being faced with some unscheduled renovation may occur.

Importance of sustainability of funding
There is a need for a different approach to financing nZEB renovations in terms of the duration of the subsidies. The ZenN project partners mentioned the importance of continuity of the financing programs or instruments. In the case of projects coordinated by public entities there is a strong need for a financing source that would go on for a longer period of time, without interrupting the continuity of financing options. This would pave the way for more extensive projects, involving a renovation of greater number of building. Considering that a financing source would not change, the formalities required to obtain the funds would also be identical. This would enable investors to use the financing options more effectively and efficiently for future projects.

New opportunities for financing nZEB renovations
There are some innovative instruments for financing energy improvements that have been applied in a couple of countries. The financing models for nZEB renovations can be improved in particular by attaching loans to properties rather than owners or tenants and making loans flexible to the changing users or property rights, including the loan instalments in utility bills or deducting the loaned money from property tax bills. Among these instruments are: The Green Deal (the UK), Property Assessed Clean Energy Program (PACE, the USA), Public Third Party Investor (France).
Pretty high level of the owner’s satisfaction with the financing scheme applied in the project

Majority of the ZenN project partners indicated they would either use the same financial model again in future projects or would be willing to recommend the solution to other building owners.

Although in the case of the Spanish demo site the model also had been a great success, the owners of the Eibar properties had certain doubts concerning the replicability of the investment. They were implied inter alia by the fact that the project was strongly dependent on public support that as mentioned above is not stable enough (both in timeframe and structure).

Moreover, the ownership structure was very fragmented in this case and required individual approach to some of the residents. This challenge, however, was overcome with success. On top of that, residents of other buildings who at first did not agree with the renovation have contacted Degebesa and expressed their great interest in such renovation. The key issue here is to show the residents that in reality they will gain great benefits of such investment.

However, the renovation performed in Eibar ended with a big success and had great impact on the local communities. This success is a key factor for the Replication Plan that is looking for the maximum repetition of this retrofitting model in the region of Debarrenango and the Basque Country. This domino effect is also visible in the case of the Oslo demo site, where additional plans for future renovations have been also made as a result of the ZenN project influence.

Rigorous approach of financial institutions

One of the conclusions of the financial barriers analysis is the fact that banks treat finances in rigorous, traditional and unified way. The fact that the funds are required for energy-efficient retrofitting on a large scale does not change the approach of financial institutions.

Many banks are quite cautious when it comes to financing investments with relatively high risk. This may result in difficulties when some of the co-owners of a retrofitted property are denied financing and cannot participate in the refurbishment project. Naturally, most of banks are not willing to offer much lower interest rates for their clients when it is not in their best financial interest.

Importance of subsidies for engaging in refurbishment

In all the ZenN demonstration cases the subsidies were assessed as very important and necessary sources of funds for the planned refurbishments. In most cases, the grants were a big element of motivation for engaging in such a venture. It is sometimes hard to encourage building owners to invest in energy-efficient technologies. This phenomenon is well documented in the case of the Spanish demo site in Eibar.

Importance of financial incentive for tenants

Without the financial incentive, the environmental benefits alone are not enough to convince an average user of a dwelling to invest in retrofitting, even if it arises with an opportunity for a subsidy. The regional and local governments are aware of that; that is why they are placing their attention on providing financing for these types of projects and providing support tools that will enable the owners to approach energy efficient retrofitting more successfully.

Different specificity and motivation of commercial and municipal entities

There is a large difference in the specificity and motivation for retrofitting between commercial and municipal properties. Apart from trying to generate financial and energy savings, the public entities are also interested in improving energy performance due to ideological causes. Setting good examples and disseminating the idea of nZEB renovation may be more important in case of public buildings than any financial gain that may arise in the process.

Importance of flexible finance and flexibility in supporting a vast variety of technologies in subsidizing

The building owners pointed out it is important to have a surplus of funds when performing ambitious energy-efficient renovation, since additional needs may arise if difficulties appear along the way of the refl. Second, it is important for owners not to be limited by financing entity to using technologies that are not the best to perform a given refl.

Summary of the conclusions financial models for nZEB renovations

- It may be considered a challenge when an owner of a building does not inhabit it, since he can lack motivation to engage in the energy-efficient retrofitting; however, there are possibilities of financial benefits for him coming from such investments.
- It can be beneficial to connect the energy efficient renovations with other previously requested installations and modifications of the buildings.
- The initial budget of the renovations should be slightly expanded and low percentage of funds should be kept as cash reserve in case of arising of unforeseen expenses.
- There is a strong need for a financing source that would go on for a longer period of time, without interrupting the continuity of financing options.
- There are some very promising innovative mechanism that can be applied in the EU for nZEB renovations and can become very popular.
- Buildings owners were pretty satisfied with the financing scheme applied in the ZenN project, and declared that they would use the same models in the future or recommend them for others.

For all references in the chapter, see final Report on common definition for nZEB renovation, which can be downloaded at the website: http://zenn.ivl.se/
Legislation, Governance and Policy – Key Success Factors for Increased Replication

The ZenN report “Legislation, governance and policy – key success factors for increased replication” enlightens the policy related challenges and success factors within the energy retrofitting field. The main objective is to provide an overview of the policy and governance process of EU within residential energy retrofitting as well as the implementation of national legislation and policy measures in the five countries represented in ZenN. Through this, critical success factors within the policy and legislative field for increased residential energy retrofitting have been identified and analysed.

The study was carried out through comprehensive literature reviews and analysis of experiences gathered at workshops and interviews in the project. The literature included investigations from the European Commission, national authorities in the studied countries and academic theses. The interviews and workshops were carried out with the ZenN demonstration building owners, contractors and other stakeholders within the field of energy efficiency retrofitting in each country.

Through the experiences gathered in Sweden, Poland, Norway, France and Spain, common patterns within legislation, governance and policy for residential energy retrofitting were possible to identify. Many of the barriers are common between the countries, and four general areas of success factors for increased replication of residential energy retrofitting have been pinpointed:

- The importance of a high national political ambition and effective national energy efficiency requirements
- The importance of improving financial/economic support systems
- The importance of increased and equalized knowledge among the energy retrofitting stakeholders
- The importance of national policy measures to overcome barriers for renewable energy

The importance of a high national political ambition and effective national energy efficiency requirements has been demonstrated through current policy barriers identified for the represented countries. Generally it can be concluded that a more consistent chain of policy actions is necessary, from the comprehensive level of EU Directives and national targets to detailed regulations and control systems of the buildings’ real energy performance.

For several countries comprised in the study, including Poland and Norway, the national requirements on energy efficiency in strategic policy documents and in building regulations have been questioned. For Poland, a common scepticism among parties interested in increased energy efficiency in the construction trade has been described. The scepticism implies that the strategic documents will not bring any sufficient effects to Polish construction, since they are not supported by relevant regulations. For Norway, the energy efficiency standards and codes have been described as not pushing the building industry sufficiently forward in an energy efficiency perspective.

Climate and Energy Framework

The need to improve national political ambitions has also been expressed in terms of compliance and control systems for energy efficiency. An example is the lacking sanctions in France in cases where national legally defined objectives are not fulfilled, e.g. energy efficiency targets on retrofitted or new constructions. This lacking effect and sanctions demonstrates the need to not only set the correct requirements, but also to improve the compliance and control systems that ensure these are fulfilled.

General conclusions on different types of national targets and requirements are included in an assessment of EU’s Renewable Energy Directive (see ZenN report). This states that national provisions are most efficient if they are mandatory, well-defined and with requirements of national targets rather than specific actions at regional or local level. According to this, the incorporation of national legally binding targets in the EU 2020 Climate and Energy Package and the EU 2030 Climate and Energy Framework should be an efficient strategy.

The importance of improving financial/economic support systems has been expressed in different ways depending on the national or regional circumstances. A general and significant challenge described in this chapter and previous ZenN reports are high investment amounts. It is clearly displayed that improved financial support for energy retrofitting could be necessary even for cases where an anticipated profitability could be seen for retrofitting investments.

In Sweden, the demonstration retrofitting project was possible to finance only through an already available loan facility at the bank. A bank would not have allowed any new loan opportunity for retrofitting if the investment included any recovery uncertainties, according to the building owner. This demonstrates a general financing difficulty and need for improved financing opportunities, especially for housing companies that already have high mortgages.

Also, an overall focus on short-term investments and short payback time is a barrier to consider in the forming of financial supports. For Norway it is described that developers and building owners main focus tends to be on profitable terms of the design/construction phase if they are not going to operate the building themselves. In this scenario, their focus on costs remains on the planning and construction side but not on the long-term energy efficiency use of the building. For Spain it has been described that solutions with payback periods longer than 10 years are not considered interesting for building owners and for Sweden the corresponding period is described as approximately 7 to 8 years. This could imply a need for more long-term (more energy-efficient) perspectives among building owners, but also a political focus on improving the financial incentives for measures with long payback time.

A balanced and motivated solution

A further economic problem for residential energy retrofitting is that a potential retrofitting project could imply the risk of a decreased tenant base if the retrofitting allows and requires a rental increase. This could for example often be the case in deprived areas where tenants have low capacity to pay the increased rents. A financial support of grants for tenants living in retrofitted buildings has been discussed in Sweden to help solve this situation. This measure could be a balanced and motivated solution to enable more retrofitting projects and to recompense the tenants.
Barriers within national strategies have been found in Poland with reference to the Polish Strategy of Energy Security and Environment. The strategy implies that it should be expected that the Polish power industry will be based mainly on coal in the long term. The importance of national coal resources and the mining industry is reflected in the strategy, and this overall orientation towards coal-energy supply has been described among the main policy and governance barriers.

It is important to form sufficient national targets and policy measures, and also to be perceptive to any obstacles found in the current implemented policy measures. Obstacles found in current policy measures include uncertainty in how much financial support that could be expected for renewable energy generation during the full lifetime of the generation plants. In Norway, regulation updates changing the level of obtainable financial support was made during the course of the ZenN demo project. The updates enable local PV system owners to sell electricity to the grid companies regardless of which network they belong to.

Further financial and economic measures discussed to solve the problems have been e.g. possibilities for building owners to apply tax-free deposits of profit into retrofitting funds, credit-guarantee systems, zero interest loans, income tax credits and municipal financing funds for energy efficiency retrofitting. The importance of increased and equalized knowledge among the energy retrofitting stakeholders has been displayed throughout the different national studies in the project.

The need to increase the knowledge consist e.g. of inadequate insight for building owners in their retrofitting needs and potential in retrofitting measures. The time and costs needed for building owners to gather this knowledge sometimes in itself aggravate the possibilities to find out about the benefits and to form retrofitting projects.

The need of equalization of retrofitting knowledge is illustrated by different views displayed from building owners and contractors on the building retrofitting needs and their benefits. Their different knowledge and interests make it difficult to form successful retrofitting concepts agreed upon all.

In France and Norway, research and information centers within low-energy construction, retrofitting and urban renewal have been implemented for enabling solutions to these problems. Corresponding agencies are also under development e.g. in Sweden. Further policy measures aimed to improve the knowledge are increased studies of best practice examples and an increase of web based guidance. The importance of national policy measures to overcome barriers for renewable energy has been widely displayed and analyzed for all participating countries.

Important to form sufficient national targets and policy measures

Barriers for a large-scale expansion in renewable energy generation have been found e.g. within overall national energy strategies and within uncertain financial support systems.

The support was implemented after the PV system at the Norwegian demonstration site, Økern, was installed. This support encourages investments in larger scale PV solutions, and could have altered the investment scale at Økern if having been implemented earlier. Uncertainties over time for financial supports are also present in Sweden. The financial support given by the electricity certificate system is uncertain and variable since it is a marked based system.

All renewable energy producers are allowed to receive a certain amount of electricity certificates in proportion to the scale of their production. The income obtained from the certificates is uncertain, since this depends on how many electricity certificates that the energy suppliers are required to purchase and declare as well as on the competition at the certificates market from other renewable energy producers.

This uncertainty in what level of financial support that the policy systems will provide is important to address for enabling more renewable energy generation investments.

In Norway regulation updates made local PV system owners to sell electricity to the grid companies regardless of which network they belong to.
The design kit aids the transferability of lessons learned and dimensions from demonstration projects to new nZEB renovation projects through guiding questions and the provision of examples from lessons learned in the ZenN demonstration projects. The relevance of and the need to include non-technical drivers is illustrated both by the ZenN demonstration projects and by the wider literature. The following outlines the transferable use of the holistic design kit for projects who are not included in the ZenN project.

The use of the design kit is applicable to other future ZenN projects as it aims to aid stakeholders to consider which non-technical drivers should be included and how to include non-technical drivers as part of the decision-making process. In this way, it is a thinking tool for stakeholders’ use at the different parts of the decision-making process. In this way, it is a thinking tool for stakeholders’ use at the different parts of the decision-making process.

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We recommend implementing the design kit in at least stages of the renovation process.

There are three main elements of the design kit: (1) dimensions developed for non-technical drivers for nZEB renovation; (2) guiding questions which a project can refine to case-specific questions; and (3) a workshop to discuss results indicator questions, to identify gaps in knowledge and to facilitate decision making related to non-technical drivers. The following outlines each of these three elements.

### 1. Dimensions

We have developed dimensions from the lessons learned in each ZenN demonstration project based on four non-technical drivers:

- Architectural values and cultural heritage
- Stakeholder awareness and behavior
- Economic and ownership structures
- Legislation, governance and policy

In the table to the left, the key dimensions associated with each of the aforementioned drivers, which are a starting point to develop indicators for future projects. Each dimension is based on lessons learned by the demonstrators.

<table>
<thead>
<tr>
<th>Driver</th>
<th>Dimension</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Architectural value and cultural heritage</td>
<td>Design details integrate energy targets</td>
<td>Examining different design details to assess what potentials exist for energy performance solutions.</td>
</tr>
<tr>
<td>2. Architectural value and cultural heritage</td>
<td>Balancing energy performance, architectural value and cultural heritage</td>
<td>Creating win-win solutions that provide high architectural value, cultural heritage and energy performance.</td>
</tr>
<tr>
<td>3. Stakeholder awareness and behavior</td>
<td>Energy performance solutions which complement user functionality</td>
<td>Collaboration amongst knowledgeable stakeholders on design and functionality to ensure realization of energy targets and building user requirements.</td>
</tr>
<tr>
<td>4. Stakeholder awareness and behavior</td>
<td>Managing misconceptions</td>
<td>nZEB renovation and associated concepts/approaches are new for many stakeholders involved in residential renovation and they do not always understand them.</td>
</tr>
<tr>
<td>5. Stakeholder awareness and behavior</td>
<td>Strategic thinking and collaborative decision making</td>
<td>Collaboration and participation of diverse stakeholders aids thorough thinking in planning and reflective decisions.</td>
</tr>
<tr>
<td>6. Stakeholder awareness and behavior</td>
<td>Lifecycle perspective</td>
<td>The inclusion of lifecycle thinking includes consideration for functionality and maintainability of energy solutions.</td>
</tr>
<tr>
<td>7. Economic and ownership structures</td>
<td>Managing finance and budget</td>
<td>Examining financial options, e.g. funding schemes or financial institutions who provide loans for nZEB renovation, and preparing a budget to accommodate unexpected costs.</td>
</tr>
<tr>
<td>8. Economic and ownership structures</td>
<td>Solutions to fragmented building ownership and schemes</td>
<td>The party who finances the investment and takes the investment risk is not necessarily the same party who obtains financial benefits from reduced energy use.</td>
</tr>
<tr>
<td>9. Economic and ownership structures</td>
<td>Reducing long and unpredictable payback time</td>
<td>The payback period is the time it takes to recover investment costs and is usually an additional criterion to assess the investment. Investments with a short payback period are often considered safer than a long payback period.</td>
</tr>
<tr>
<td>10. Legislation, governance and policy</td>
<td>Interpreting policy targets and legislation</td>
<td>Different stakeholders interpret policy information differently and these interpretations need consensus.</td>
</tr>
<tr>
<td>11. Legislation, governance and policy</td>
<td>Support from national funding schemes and governing bodies</td>
<td>National funding schemes and governing bodies are important for inspiring projects to be energy efficient. They are often used to reduce the time to obtain a return on investment but can be restrictive which impacts on the type of chosen solutions.</td>
</tr>
<tr>
<td>12. Legislation, governance and policy</td>
<td>Renovation and current building standards</td>
<td>Identifying which energy performance standards and building function standards are achievable in renovation.</td>
</tr>
</tbody>
</table>
2. Guiding and case specific questions

Based on the key dimension table, we developed guiding questions to guide other nZEB renovation projects in their performance assessment of non-technical drivers. The guiding questions are generic, and need to be further refined to the local context of each particular nZEB renovation project. Guiding questions below shows questions for each dimension.

### Guiding questions

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Guiding questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using Design Details to Integrate Energy Targets</td>
<td>What are the possibilities to develop energy performance solutions through examining design details?</td>
</tr>
<tr>
<td>Negotiating Energy Performance with Architectural Value and Heritage Character</td>
<td>How do energy performance solutions complement the building’s cultural heritage/character?</td>
</tr>
<tr>
<td>Energy performance solutions which complement user functionality</td>
<td>What are the changes needed to integrate new energy performance measures in already started projects?</td>
</tr>
<tr>
<td>Managing misconceptions</td>
<td>How are energy performance measures understood by residents/project team?</td>
</tr>
<tr>
<td>Strategic thinking and collaborative decision making</td>
<td>Who are key actors to drive energy efficiency while maintaining wider renovation goals?</td>
</tr>
<tr>
<td>Life cycle perspective</td>
<td>What are the long lasting links between the renovation process and operations? (e.g. maintenance periods)</td>
</tr>
<tr>
<td>Managing finance and budget</td>
<td>What are the options available to increase credit worthiness?</td>
</tr>
<tr>
<td>Solutions to fragmented building ownership and schemes</td>
<td>What approaches/schemes are available to obtain a return on investment in energy retrofitted buildings when the investor is not the occupant?</td>
</tr>
<tr>
<td>Reducing long and difficult to predict payback time</td>
<td>Are there incentives/solutions available for the investor to compensate for or reduce a long payback period?</td>
</tr>
<tr>
<td>Interpreting policy targets and legislation</td>
<td>What policy targets are specific to energy efficiency? How do different stakeholders interpret policies?</td>
</tr>
<tr>
<td>Support from national funding schemes and governing bodies</td>
<td>What are the available national funding schemes?</td>
</tr>
<tr>
<td>Renovation and current building standards</td>
<td>Are the project’s energy performance targets higher than national required standards?</td>
</tr>
</tbody>
</table>

### Case specific questions

Case-based questions can be developed for a specific nZEB renovation project, to determine the project-related value for the dimensions. The table below shows an example of case specific questions developed for a specific nZEB renovation project based on the guiding questions. The table is a list of statements based on the experiences of some of the ZenN demonstrations (but not specifically associated with one), developed to obtain different stakeholder’s personal views of the project development. These personal views may differ depending on the stakeholder.

<table>
<thead>
<tr>
<th>Energy performance solutions which complement user functionality</th>
<th>Classifications</th>
<th>Life cycle stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy performance solutions do not risk negatively impacting renovation goals.</td>
<td>Degree to which solutions meet energy performance targets.</td>
<td>Degree to which budget constraints reduce choice of optimum solutions.</td>
</tr>
<tr>
<td>Energy efficiency measures do not risk negatively impacting renovation goals.</td>
<td>Degree to which you perceive energy performance solutions will affect functional requirements of buildings.</td>
<td></td>
</tr>
<tr>
<td>Degree which residents are involved in decisions of renovation.</td>
<td>Degree which residents are involved in decisions of renovation.</td>
<td></td>
</tr>
</tbody>
</table>

### 3. Workshop and meetings

The third element of the nZEB design kit consists of workshops/meetings to discuss responses to case specific questions in order to develop a common understanding of the results. The results should show the weight/relative value each stakeholder gives to each of the dimensions for non-technical drivers of ZEB renovation. It is likely that stakeholders will have different perspectives on how to meet energy performance for a specific project stakeholders consider differently. This allows discussion of the different perspectives of the project and helps to build consensus for decisions. Workshops and meetings are good platforms to solve potential future problems before they occur and feed into the decision making process. This type of workshop/meeting allows representatives of the project stakeholders to set out non-technical indicators for the project and agree on which indicators to prioritize at which stage of the project to optimize the decision-making processes. In the workshop/meeting, a plan could be developed on how to implement decisions that arise as a result of the outputs from the design kit.

There may also be a need to collect further information where decisions could not be made due to the scarce knowledge available. Having a workshop or meeting to discuss the results provides the opportunity to discuss similar and different perspectives of the renovation and come to a common ground for decision-making.