D3.7_ Recommendations as Key Results of the Pilot Case Studies

INTELLIGENT ENERGY – EUROPE II

Energy efficiency and renewable energy in buildings

IEE/12/070

EuroPHit

[Improving the energy performance of step-by-step refurbishment and integration of renewable energies]

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Abstract

A list of key recommendations arising from the EuroPHit project relating to future step-by-step EnerPHit projects is presented in Table 1 below. Each of the recommendations is further elaborated in the text below, some of which are illustrated with photographs and diagrams. Additional recommendations concerning building integrated photovoltaic panels are provided in the Appendix.

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Table 1: Key EuroPHit Recommendations Concerning Step-by-Step EnerPHit

1 Policy Considerations

Develop a Long Term Vision for Existing Building Stock

Building owners should be facilitated to develop a long term sustainable vision for their property(ies). Development of a long term vision will drive all subsequent decisions regarding refurbishment and retrofitting. This vision should be underpinned by the objective of achieving the highest level of energy efficiency gains for the occupants along with providing high comfort, good indoor air quality and mould-free conditions. Developing such a vision can be very challenging for building owners especially if they have not been exposed to the possibilities that exist. Furthermore, municipalities often undertake retrofit measures as part of required maintenance works but these can be on a 'reactive' basis rather than a 'proactive' approach. It is imperative that the building science community connect with owners of extensive building stock and help them to develop meaningful long-term sustainable visions for their property portfolios.

Incentivise Deep Retrofits – Dis-Incentivise Shallow Retrofits

It is quite commonplace for government programmes to incentivize retrofitting through the provision of supports and grants. Typically, such incentives are pitched at encouraging homeowners to target shallow retrofits and are mostly aimed at insulation and window replacement with little focus on air sealing, heat recovery ventilation or tackling thermal bridges. Dr. Urge-Vorsatz (Co-Author of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report) urged attendees of the 2014 International Passive House Conference to “avoid shallow retrofits” stressing it is “better to wait out for deep retrofit” and calling in governments “to revisit support schemes around shallow retrofits”.

2 Awareness Raising

Develop Exemplar Case Studies

Given that many of the details required for EnerPHit projects are unfamiliar to the design and contracting community, the development of local and accessible exemplar case studies is judged to be critical. The EuroPHit project has successfully contributed towards the development of such case studies, but additional examples would be highly beneficial in all countries. The International Passive House Open Days is an excellent method for providing access to such projects and their designers and contractors. Access to the construction details for such projects is also critical – Architects and designers can benefit hugely from such support, thereby obviating the need to ‘reinvent the wheel’.

Success stories of local authorities should be highly recognized and actively promoted and certificates, awards and publicity should be widely used to motivate elected municipal officers. In summary, success stories should be celebrated as a mean to encouraging others to pursue EnerPHit.

Promote Awareness of EnerPHit and Step by Step Retrofitting

Probably the most critical factor concerning the implementation of step-by-step deep retrofitting is the lack of awareness of this concept on the part of local administrators, building designers, building owners and construction workers. Deep retrofitting is rarely undertaken outside of the Passive House community and implementing this on a step-by-step basis is a totally new concept – even for many involved in Passive House. A core recommendation of this project, therefore, is to use every effort to promote the concept of step-by-step retrofitting to the EnerPHit standard. There needs to be sustained promotion of successful examples and case studies.

Increase Profile and Status of Certified Passive House Designers

The role of Passive House Consultant is not yet well recognized in some regions and ultimate responsibility for the project typically lies with the project Architect or Engineer. The Bulgarian partner in EuroPHit shared their experience that when project investors introduce Passive House Consultants to the project, the Architect sometimes refuse to participate in the process. The Consultant in such instances might not have any authority to make critical decisions regarding the project and may have no input regarding quality control on-site. The status of Passive House Consultant needs to be promoted in such instances and they need to be given responsibility and authority as an important member of the retrofit design team.

3 Pre-Construction Phase

Allow Additional Up-Front Design Time

The success or otherwise of an EnerPHit projects is greatly dependent on the quality of detailing completed in advance of going on-site. But the level of detailing required, including thermal bridge calculations, energy modelling in Passive House Planning Package and possible hygrothermal analysis, is more extensive than that typically executed for refurbishment projects. Additional time needs to be set aside for such detailing and analysis as well as the iterative design process commonly found in Passive House projects where the designers strive to improve and optimize the details.

Review Potential for Building Integrated Photovoltaic Modules

Building Integrated Photovoltaics (BIPV) refers to photovoltaic cells and modules which can be integrated into the building envelope as part of the building structure, and therefore can replace conventional building materials, rather than being installed afterwards. Thus, BIPV solar modules have the role of a building element in addition to the function of producing electricity. When BIPV modules are planned to be integrated in the building envelope, they should be considered during the design phase in order to obtain the most appropriate products.

Require Pre-Qualification Appraisal and Training of Bidders

The building owner should implement a ‘pre-qualification’ requirement to the bidding process to try and attract only firms experienced in deep retrofits to tender for the work. It must also be appreciated, however, that in many countries building contractors will simply not have had the experience of delivering such projects. In that instance, it is recommended that the building owner requires interested bidders to complete a pre-bidding training programme. The training programme should be sufficient to expose the contractors to the details, materials and techniques envisaged for the project (likely to require two days minimum).

Avoid Lowest Bid Price Approach in Tendering

The core thrust of the EuroPHit project is to bring about a shift in approach to retrofitting from the all-prevailing ‘shallow’ method, where inefficiencies are locked-in for decades, to a ‘deep’ solution where the cost-optimal works are implemented. Local Authorities putting out retrofit projects for bidding need to establish clear criteria on how tenders are evaluated. If such competitions are judged solely on a ‘lowest-bid’ price, it is highly likely that the full intent of a deep retrofit will not be realised.

A relatively new tool in PHPP is the cost-optimality calculator which estimates the cost per saved kWh for each individual retrofit measure. This economic indicator should be used in the evaluation of future bid competitions in order to ensure that the most advantageous tenders are identified. Incorporation of this indicator would probably require training the quantity surveyors involved.

Include ‘Contractor Design Portion’ in the Procurement Process

For complex projects involving challenging façade refurbishment, it is wise to include CDP (contractor design portion) in the procurement process. The objective of this is to draw from the practical experience of the contractor in terms of increasing the ‘buildability’ of the project as well as developing a logical and efficient sequence to the works involved. Sequencing of works is critically important in retrofit projects, especially concerning the airtightness challenge which is greatly dependent on so many disparate members of the building site team. One must be open to changing the design approach mid-stream depending on what plays out on site during the construction. This was required in one of the Irish projects whereby the original intention of placing the airtight layer on the inside had to be changed to the exterior, as illustrated below.

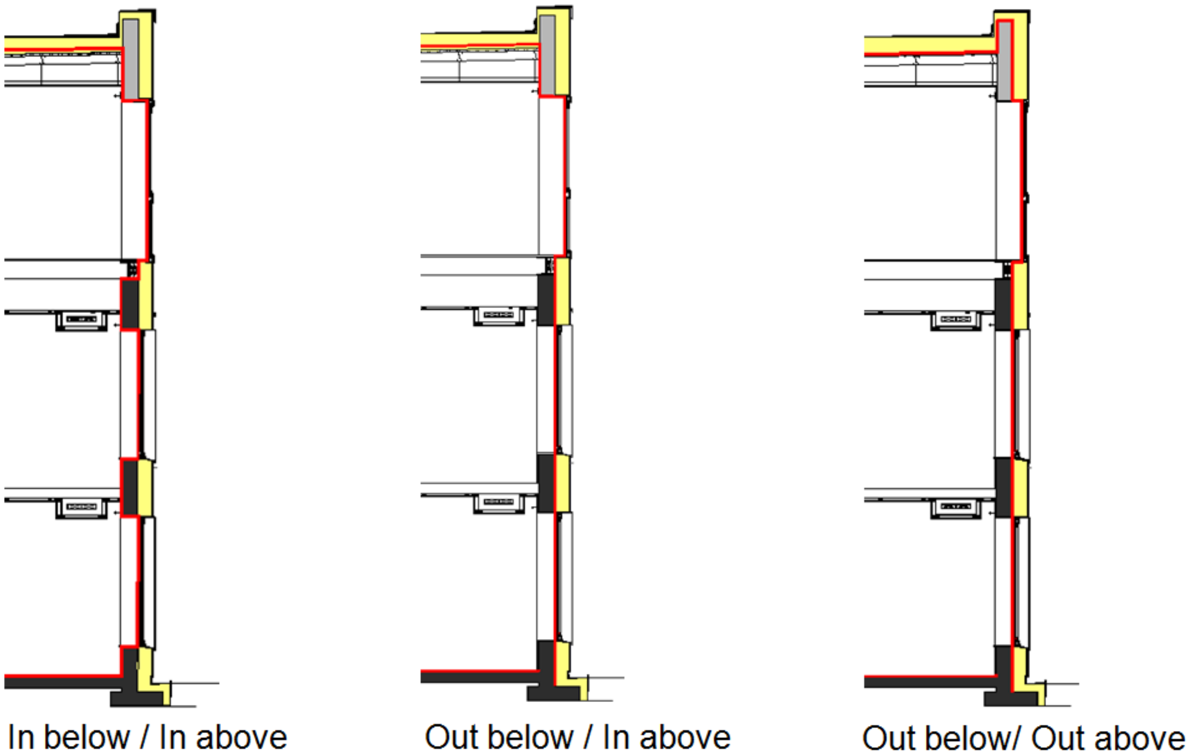

Figure 1: CS01 airtight line journey

Responsiveness to site constraints is an inherent part of deep retrofitting works as was discovered in the above Irish project where the ‘red-line’ for airtightness shifted from inside to outside soon after project commencement.

Calculate the Cost Efficiency of Each Retrofit Measure

Crude financial analysis of retrofit measures are all too often applied by building owners when considering energy efficiency measures. Static measures such as ‘payback’ are used to steer long term objectives for a building, with owners often seeking 7 years or less ‘pay-back’ on individual measures. But why should a product such as roof insulation, which can have a useful life of 50+ years, be expected to ‘pay-back’ in a fraction of its lifetime.

The most appropriate economic indicator to determine what measures should be undertaken is the ‘cost to save a kWh of energy’ used in PHPP 9. This comprehensive analysis incorporates the expected service life of the measure being considered, the energy saving arising, the cost of borrowing, residual value of the product once it has been paid for, annual maintenance costs[1] and energy costs. This calculation determines the cost to save 1 kWh from the retrofit measure being evaluated. If the cost to save 1 kWh is less then cost to purchase 1 kWh, then the measure is profitable. Some measures will be highly 'profitable' whereas other will be less so or may even be unprofitable when considered in isolation. They key objective of the analysis is to ensure that the average (or 'global') cost to save 1 kWh across all measures is less than or equal to the cost to purchase 1 kWh.

4 Quality Assurance

Assign a Deep Retrofit Project Manager

Deep retrofits typically require the use of an interdisciplinary team working on a multitude of steps over an extended period for a Client or building owner that might not be intimately familiar with the intricacies of the work involved. For that reason, it is recommended that the building owner appoints a key person (an experienced retrofit project manager) to oversee the delivery of the project and ensure that all of the objectives are reached. The project manager must have a good technical knowledge of the steps involved in the retrofit and an excellent understanding of the sequence of operations required to meet the overall project objectives.

Municipalities typically will not have in-house staff with sufficient expertise in deep-retrofitting to the EnerPHit standard. It is especially important such municipalities on-board (either directly or indirectly) the right expertise to the team so that deep retrofitting is achieved.

Develop and Promote Pool of Certified Passive House Designers and Tradespersons

In most countries in Europe there now exist a pool of Certified Passive House Designers and Certified Passive House tradespersons. Furthermore, each of the EuroPHit partners has trained designers and tradesperson as part of the project including content developed specifically in the field of retrofitting. Promotion of this available talent needs to be rolled out in each country to ensure there is awareness of the available skills pool. Whilst all of the certified designers and tradesperson are listed on the Passive House Institute databases, local authorities and building owners may not be aware of that international database.

It is recommended that the status of 'Certified Passive House Designer' and 'Certified Passive House Tradesperson' be recognized in each country. In addition, national training programmes for Certified Passive House Tradespersons should be rolled out in each country.

Appoint Experienced On-Site Inspectors

It is imperative that the details developed by the designers and specifiers are accurately realized on-site and without compromise. Many of the details, materials and techniques will be unfamiliar to the contractors (both team leaders as well as general operatives). Accordingly, it is crucial that the building owner has an experienced representative who regularly visits the building site to carry out inspections and quality assurance checks. The

[1] The EuroPHit project in Portsmouth UK placed a high emphasis on reduced maintenance in their analysis on proceeding with a deep retrofit to the EnerPHit standard.

person appointed must have excellent communication skills and hands-on practical experience of the construction methods required. Impromptu informal ‘training’ of construction workers will be required from time to time and the inspector should have an open mind to consider suggestions from the crew on alternative means of achieving the goals of the project (whilst not undermining the standards required).

On-site quality assurance is a crucial element. The use of on-site tests such as leakage detection, airtightness tests or thermographic analysis also provide a great support for the identification of implementation errors. It is also important to schedule these tests in a stage of the retrofit process where it is still possible to correct possible errors.

Figure 2: On site airtight taping demonstration

An unannounced visit to a multi-family Passive House project identified a serious short-coming in the airtightness taping of window cills which was immediately addressed through hands-on demonstration and ‘training’ by the project supervisor (also the Architect). This mistake arose despite the extensive detailing package for the project, visible under the arm of one of the design team.

Develop Mock-Ups to Ensure that Continuity is Delivered

The strongest chain is only as good as the weakest link. And so too the same applies to deep retrofit projects such as EnerPHit. The contractor team must be completely on board regarding delivery of an envelope that is insulated and air-sealed without compromise – ‘continuity is king’. The all-too-prevalent attitude of ‘sure it’s good enough’ has to be transformed into one of ‘ “good enough” is not good enough’. A practical example of where this might apply is in the attachment of external envelope systems whereby the contractor has to ensure that a continuous uninterrupted insulation layer is achieved.

Developing mock-ups for the contractors to practice on prior to getting on site will prove extremely useful for both contractors and the design team and will identify any potential unforeseen snags before they emerge.

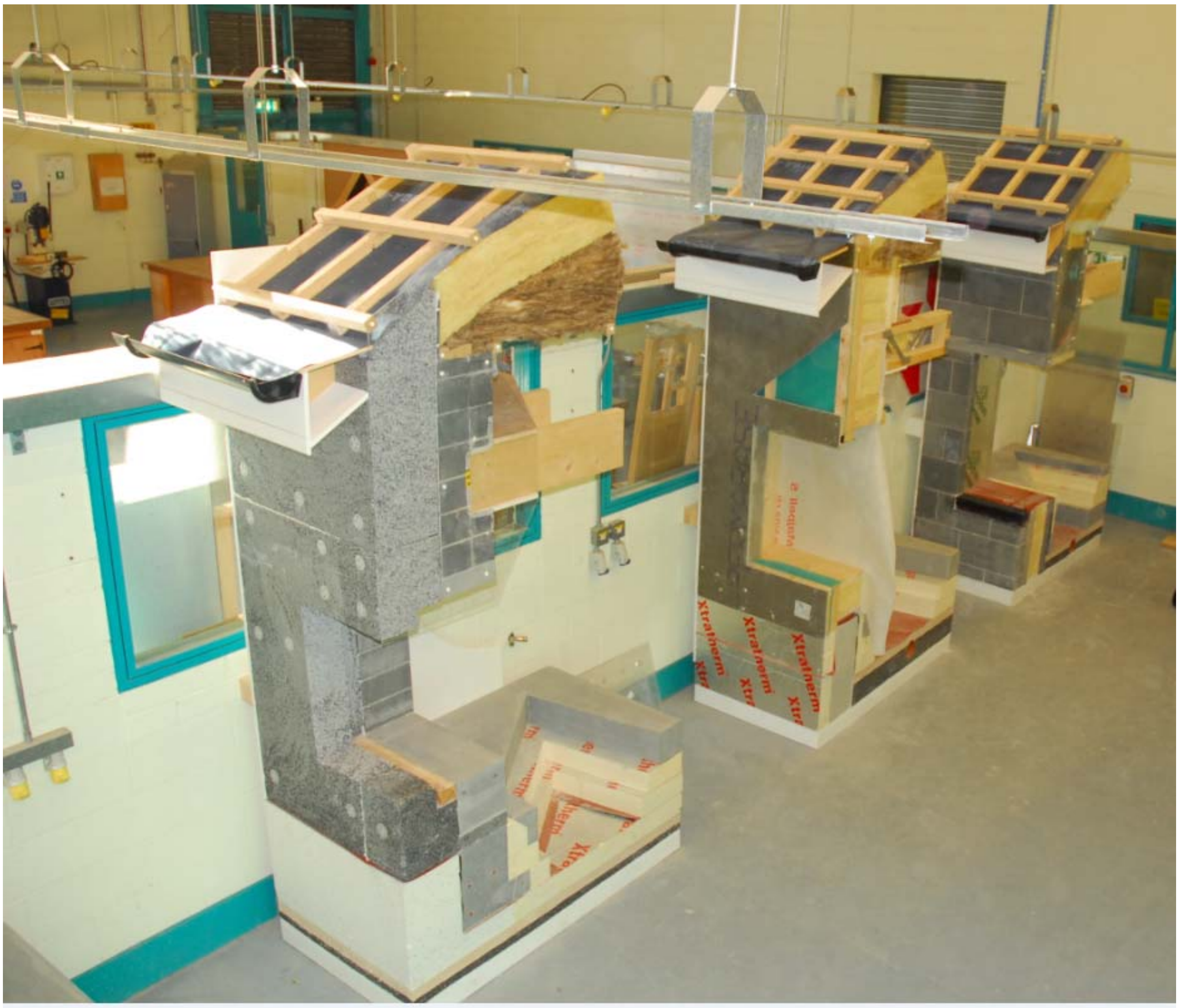

Figure 3: Full-scale mockups

Full-scale mockups such as these can help both design team and contractors to work out the most efficient means of achieving the deep retrofit goals of the project

5 Occupier Considerations

Minimise Disturbance to Tenants

It is important to consult with the building occupiers to ascertain their views about the refurbishment plan and identify whether it will be necessary to decant them during the works. Decanting tenants is hugely disruptive and costly and should be avoided where possible (as was the case with the EuroPHit Portsmouth project in the UK). Given that Passive House retrofits generally favour externally placed insulation, leaving tenants in situ is often feasible.

Related to the issue of decanting or otherwise of tenants is the speed at which the retrofit works can take place. There can be a temptation to complete construction works swiftly with a view to minimizing disruption, steering retrofit plans in the direction of what can be done quickly rather than what represents the best long term investment. Building owners, designers and planners must be encouraged to execute the deepest retrofit possible rather than a quick fix approach.

Liaison through Demonstration Pilot Refurbishments

In the case of retrofitting multi-family units such as apartment blocks, it is recommended that pilot refurbishments are completed to demonstrate to the residents what is envisaged by the building owner. This approach can be useful to assuage any concerns the residents might have concerning the proposed works and thus reach community support for the project. Moreover, there should be a genuine effort in such pilots to seek suggestions from homeowners on what they would like to see realized as part of the retrofit programme. Design charrettes involving the building owner's technical team and members of the community will typically give rise to proposals that derive increased benefits for residents. Residents who have been living in an apartment block for years will have a much greater ability to spot unintended adverse design decisions that a team of consultants with no intimate knowledge of the building. One-to-one consultation with the residents will enable the design team to hone in on what really matters to them and thereby ultimately improve the quality of the overall project for everyone.

Keep in Touch Through Consultation

Consultation with residents who are adversely affected by retrofit works is important not just at project commencement, but in fact right through the project. Appointment of liaison officers representing both the building owner as well as the contractor to ensure that residents are kept informed of progress will help to gain trust between all parties. This level of engagement is especially important on larger, more complex projects.

6 Technical Considerations

Develop a Refurbishment Plan

Building retrofits are predominantly undertaken in a single phase. This is understandable in many respects, not least due to the tendency for people to want to get it all done in one go and not have to spread it out over multiple phases. It is this very tendency to do retrofit works in a single phase, however, that typically results in the energy efficiency measures being 'shallow'. We must encourage building owners, especially owners of larger buildings or owners of multiple buildings such as Local Authorities, to develop and implement a 'Refurbishment Plan' for their projects. This will facilitate the application of a longer term strategy whereby deeper cuts in energy consumption will be achieved.

Refurbishment plans could logically follow normal maintenance programmes such as window replacement, roof repairs, re-plastering or painting facades and so forth. A refurbishment plan, however, should place energy efficiency, comfort and health up front and center. As building components fail or come to the end of their service life, such as ventilation fans, boilers, or windows, they are usually replaced with like-for-like in terms of performance (or, in the case of windows, are not replaced with the best available technology). In these instances, the building owners or managers could refer to the refurbishment plan which sets out the longer term objectives for the building and ensure that maintenance works deliver long term and deep energy savings for the owner.

Refurbishment plans should be based on acceptable intermediate stages which should each be evaluated with regards to cost optimality. They will typically have short, medium and long term goals for the building. If maintenance issues are not the driving force in choosing what steps to do first, then the most profitable measures should take priority. These can be determined in PHPP using the present value calculator in the 'Comparison' worksheet of PHPP 9.

Consider if Step-by-Step Retrofitting is Appropriate

Quite often a building owner will want to execute the entire retrofit in one phase, avoiding a step-by-step approach. However, there will be instances where a step-by-step approach is appropriate, such as those listed below:

- When the initial investment is too high and the building owner has a limited budget. In this case it makes sense to split up the initial investment and divide it in smaller parts.
- When there are strict time constraints for the implementation of the refurbishment measures. This might be the case, for instance, for commercial activities that are opened only during a part of the year, for instance during the summer. In this case the owner might want to implement the retrofit measures during the winter season and the time frame for the implementation is therefore limited. In this case a step-by-step approach works perfectly and gives the possibility to split up the refurbishment process in smaller steps that can be implemented quickly.
- When one component has been recently replaced, for example where windows have been replaced or an EIFS is applied but without the suitable Passive House quality. Whilst these measures typically do not coincide with the optimal solution both from the comfort and economic point of view, it normally does not make sense to replace those components which has been recently installed. In this case it makes more sense to use a step-by-step approach, whereby the owner implements the other retrofit measures and only when the aforementioned component has reached the end of its lifecycle do they replace it and install a new one with Passive House quality.
- The condition of the existing components also has to be considered. It is clearly more urgent to replace components that are at the end of the lifecycle rather than components which are relatively new.

Synchronise Retrofit Steps which are Inter-Dependent

High indoor air quality is a core requirement for all Passive House projects, both new-build and retrofit. Retrofit steps which might adversely affect indoor air quality must be paired with parallel steps which ensure hygienic conditions inside the building. As a practical example of this, wherever the airtightness of the building is being improved a balanced heat recovery mechanical ventilation system should be introduced at the same time. These two steps will (a) reduce uncontrolled air infiltration and exfiltration losses and (b) recovery heat from the exhaust air stream. Similarly, if leaky windows are being replaced with highly sealed units, it is important to ensure high indoor air quality through a mechanical ventilation system.

Sometimes it is easier to implement some refurbishment measures together or before some other measures. In this case it makes sense to do so if there are no other constraints. Replacing the window and installing the external insulation system at the same time typically simplifies the implementation and provides better performances. Another example is the replacement of the heat generation system. Replacing it as the first retrofit measures is not a good approach since it would lead to an oversized heating system once all the energy efficiency measures have been implemented. Therefore, it makes more sense to replace it as the last step and have a correctly sized heat generator.

Facilitate Easy Delivery of Future Measures

How often have you undertaken refurbishment works and come across an annoying short-cut that the previous builder took, leaving it very difficult for you to achieve your objectives? Thus, you end up un-doing something unforeseen before you can really get going on what you initially set out to do.

Make a conscious decision not to create the above scenario for persons charged with delivering subsequent phases of the refurbishment plan. A practical example of this pertains to the window install situation. If the initial phase involves replacing the window, make sure it is placed in the most optimum location for when the wall will be insulated in the future. If, on the other hand, the initial phase involves insulating the wall, make sure it is convenient for the contractor to integrate the window into the wall insulation when the time comes to replace the windows.

Designers are typically not trained to develop sequential construction details that might be implemented over several years (or decades). In response to this, the EuroPHit project developed several step-by-step construction details which illustrate how such phased works might be implemented, such as that included below.

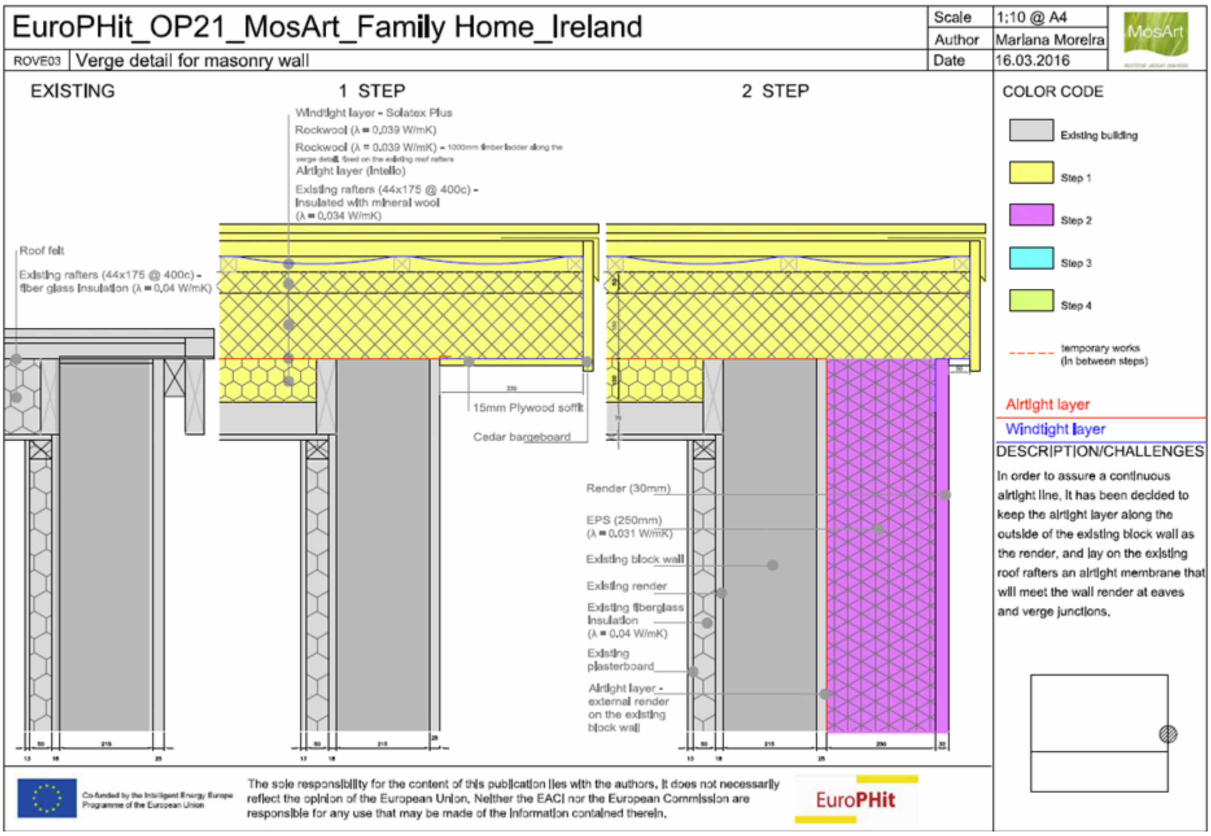

Figure 4: Step-by-step OP21 verge construction detail

Example of a step-by-step construction detail illustrating multiple phases over which the overall objective of significantly improving the envelope would be achieved.

Provide Warranties for Non-Standard Detailing

Contractors involved in step-by-step EnerPHit projects may have concerns regarding the warranties associated with off-standard construction detailing. EnerPHit projects invariably involve thicker levels of insulation than conventionally used, for example. It is possible that producers of components used in EnerPHit projects might not have warranties for the thicknesses required, thereby placing additional risk on the contractors. Accordingly, designers and specifiers need to liaise with component manufacturers to ensure that warranties are available, thereby reducing perceived risk for the contractors involved.

Evaluate Potential for BIPV to Perform Dual Functions

Building integrated photovoltaic solutions (BIPV) are capable of fully replacing conventional construction materials for the building envelope such as skylights, façades, windows, curtain walls, roofs, balcony railings and floors. These multifunctional bioclimatic solutions combine both active and passive properties, providing greater acoustic and thermal insulation and at the same time producing clean energy on site. The design team should seek to identify means by which BIPV can be used not just to produce renewable energy, but also replace 'traditional' façade elements, thereby increasing cost efficiency.

Figure 5: Photovoltaic ventilated facade (source ONYX)

Photovoltaic ventilated façade (a-Si technology). House in Gotarrendura, Ávila (Spain). HERB project (Holistic Energy-Efficient Retrofitting of Residential Buildings) within the funding of the European Commission through its 7th Frame Programme. http://www.euroretrofit.com/. Source ONYX

7 Post Construction Phase

Monitor Performance of EnerPHit Projects

Where public monies are used to support retrofit projects, energy performance monitoring should be required in order to quantify the energy efficiency levels achieved. Many government supported retrofit schemes simply require a theoretical modelling of before and after energy performance without monitoring. It is highly likely that a performance gaps exists between that modelled and that achieved in practice. There are low cost methods currently available for live-monitoring of not just energy consumption but also indoor comfort and indoor air quality which should be implemented to demonstrate the real return achieved on investment in EnerPHit projects.

Appendix

Additional Recommendations Concerning Building Integrated Photovoltaic (BIPV) Modules

The additional recommendations provided below are provided by EuroPHit Partner Onyx.

Take into account the different properties of the different technologies regarding energy production

Crystalline technology glass usually has power values of around 100 – 170 Wp per square meter, depending on the technology, the separation between cells and the efficiency of the cells.

In constructive solutions where electricity generation takes precedence over aesthetic appearance, such as pergolas, brise soleils or canopies, it is usual to choose crystalline silicon technology.

The advantages of crystalline silicon technology over amorphous:

- Greater nominal power per square meter (Wp/m2).
- Less installation surface area to equal power.
- Greater efficiency (between 15% – 17%). Photovoltaic efficiency is defined as the percentage of power converted into electricity from the total sunlight absorbed by a module.

The advantages of the amorphous silicon technology over the crystalline:

- Greater energy production (kWh) at the same installed power (kWp).
- Low temperature coefficient. The yield of amorphous silicon photovoltaic glass under high temperature conditions is better than in crystalline modules.
- Greater capability of producing more energy with diffused light (indirect radiation, cloudiness, shadows, early morning and late at night, less favourable orientation, etc.).
- Better behaviour in the presence of shadows.
- Less dependent on the angle of the installed glass.

Although crystalline silicon is the most efficient among all BIPV technologies, the fact that the architectural PV integration has to keep a certain orientation due to the building characteristics, undermines the efficiency of this technology. Crystalline silicon performance mainly depends on the angle of the light incidence. Efficiency loss due to lighting outside an axis, diffuse radiation or shadows is greater than in the "thin film" technology.

Regarding retrofitting projects, direct exposure of glass to solar radiation rarely would be achieved in an optimal way, being mandatory the harvesting of diffuse radiation. Then, a-Si technology is the one that offers the best result in terms of kWh/kWp installed under these irradiation conditions.

Figure A2: Photovoltaic ventilated façade (a-Si technology). The Black Box, Ávila (Spain). Source ONYX

Take into account the different properties of the different technologies regarding aesthetic considerations

Aesthetic requirements are directly in relation to the compatibility in terms of the retrofitting appearance considering existing surrounding area.
Regarding aesthetic considerations, crystalline technology has certain drawbacks:
The inclusion of silicon wafers into modules produces a visual impact on these, especially in glass / glass configurations.
Another aesthetic limitation consists in the interconnection of the cells with the modules. The crystalline silicon photovoltaic modules have a silver thin wire that collects current from the front surface and another thicker wire that connects the electrodes. These silver stripes present a marked contrast with the uniform appearance of the silicon cells and the materials used in most of the buildings. In addition, the stripes can go in different directions so that may provide a strange aesthetic of the product.

Nevertheless, the visual impact of the cells in crystalline technology can be used to inspire and show a visible commitment to the environmental and energy efficiency.

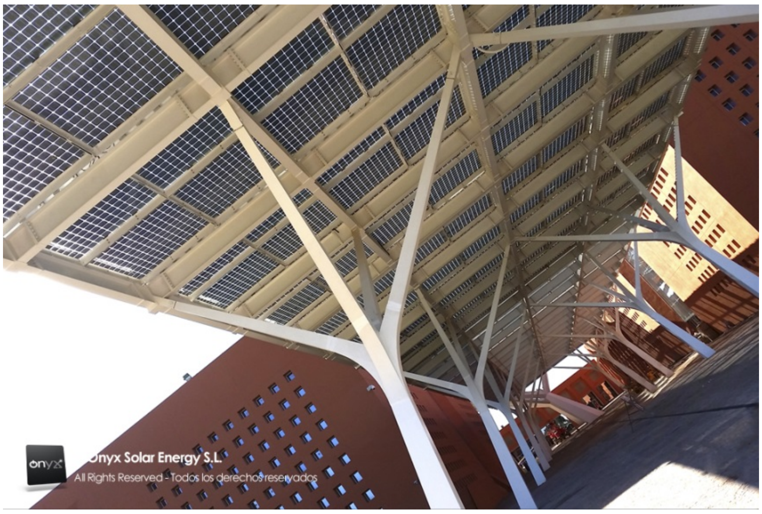

Figure A2: Photovoltaic canopies (a-Si technology). Mohammed VI University, Marrakesh (Morocco). Source ONYX

Similar to the amorphous silicon, the crystalline silicon technology allows the encapsulation to be a way of defining the choice of colors, in combination with transparency. For instance, one could play with different mixtures of opaque color background with Tedlar or ceramic frits in conjunction with with colored cells. Depending on the color of the cells, consequent loss of efficiency may occur.

Within constructive solutions on curtain walls and skylights, where the aesthetic, transparency, and homogeneity (if desired by client) take precedence, amorphous silicon technology is commonly chosen.

Figure 3: Photovoltaic skylight (a-Si technology). Valladolid University, (Spain). Source ONYX

Take into account the different transparency degrees of the PV products

One of the most important characteristics of Onyx Solar's photovoltaic glass is its range of transparencies. We manufacture photovoltaic glass that enables the passage of natural light into the interior of buildings. The fact is that photovoltaic does not reduce indoor habitability. On the contrary, it adapts to the needs of each building.
Onyx Solar recommends different transparency degrees according to the climate and geographical location of the project, as well as the angular positioning of the photovoltaic glass on the building.

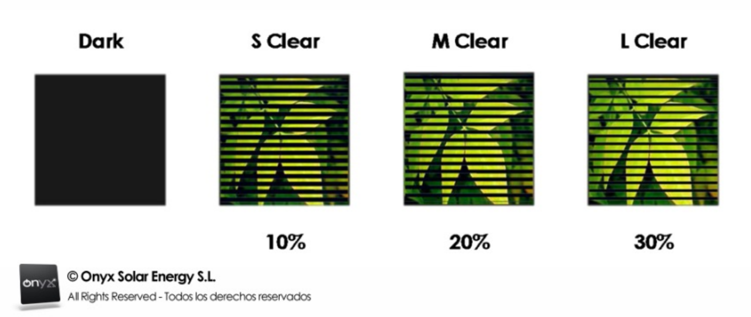

Figure A4: Different transparency degrees (a-Si technology). Source ONYX

In glass with amorphous silicon technology, transparency is achieved through the removal of amorphous silicon layers using a laser etching process. In other words, an amount of the silicon layer is removed by laser depending on the degree of semi-transparency desired per project. Consequently, when the transparent gaps are made on the photovoltaic silicon layer of the glass, the efficiency is reduced in proportion to the degree of semi-transparency achieved. Therefore, a balance must be found between the desired passive properties and expected active properties.
The range of transparencies is what controls the passage of light to the interior of the buildings: between 0 and 30%. This is the visible light transmittance and is a determining factor in most building skylights and glass façades. Depending on the silicon film area removed with the laser, VIS light transmission can vary from 10 to 30%, which is normally the optimal range for interior space with minimum dazzling. It is important to take into account that illumination of interior spaces depends on direct light incidence and indirect lighting due to reflection of the walls, floors or other interior surfaces.
The more usual range is 20%, which means that 80% of the surface area of the glass is active cell, with 20% visible light transmittance. Transparencies can go from opaque (0%) to 30%. The 10, 20 and 30% values refer to the transparency degree of amorphous silicon photovoltaic glass. Each transparency has a suitable nominal power. Peak power depend on transparency degree, and varies from 62 Wp/m2 (dark) to 32 Wp/m2 (transparency of 30%).
As an added value, we can manufacture personalized transparency patterns adapted to the objective of achieving different effects and corporate logos. In most cases, these patterns are non-active. Furthermore, the amorphous silicon technology allows the encapsulation to be a way of defining the choice of colors, in combination with transparency.

As a general reference for skylights with high exposure to solar radiation, a 10% transparency is recommended, whereas for curtain walls and skylights in climate zones with fewer hours of light, the transparency can be 20-30%.

Glazing areas provide natural illumination, saving energy by reducing the need of using artificial lighting. Nevertheless, it is important to consider thermal gains from solar radiation, thereby increasing the need of HVAC systems. For this purpose, semi-transparent thin film photovoltaic glass can be used on glazing systems refurbishment. Not only does it produce free clean energy on site, but also natural illumination is provided. Furthermore, the filtering effect enhances thermal comfort and keeps the interior from deteriorating over time.

Infrared radiation coming from natural sunlight can cause a heat build-up inside building, resulting in thermal imbalance under hot climate conditions. Measurements carried out with a-Si photovoltaic glazing show a significant decrease in radiation transmission of 780nm-2500nm range (near infrared, N-IR), up to 90%.

Due to the greenhouse effect, the temperature of the interior rises when the g-value increases. The g-value and SHGC (Solar Heat Gain Coefficient) indicates the amount of energy that goes through a glazing. The a-Si technology of Onyx Solar provides great protection from such this factor, limiting the g-value to the range of 10-40%.

Another key factor to consider when choosing the right glazing is the negative impact of ultraviolet (UV) radiation into the interiors, on furnishings and people. The architectonic photovoltaic glazing filters up to 99% of the ultraviolet radiation. Regarding the light reflection produced by the photovoltaic glass, values go from 7 to 9%. These values are similar to conventional glazing which normally ranges from 6 to 10%.

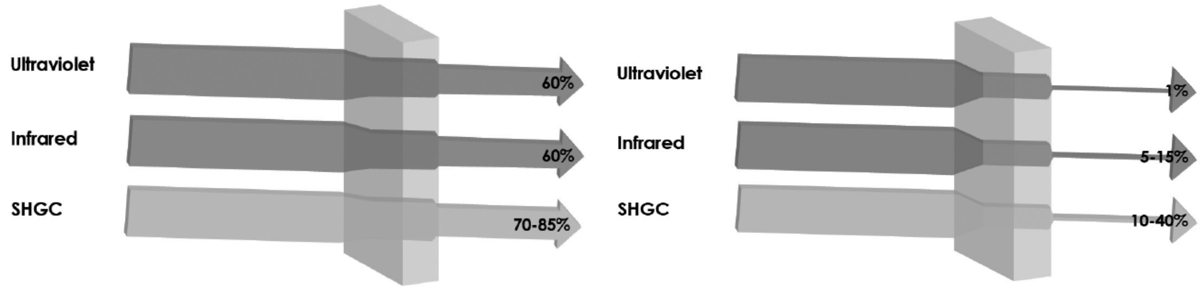

Figure A5: Solar transmittance of conventional glass versus Onyx Solar a-Si photovoltaic glass

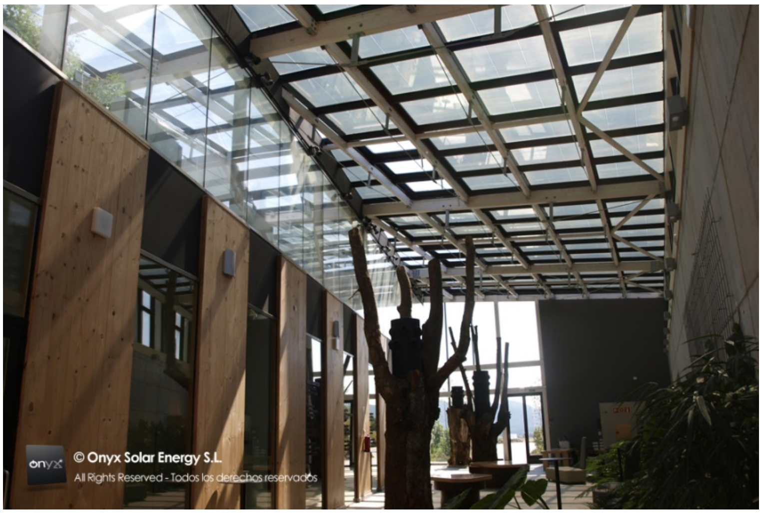

Figure A6: Photovoltaic skylight (a-Si technology). Azurmendi Restaurant, Vizcaya (Spain). Source ONYX

Take into account the safety and insulation requirements of the PV glass

The photovoltaic glass configuration for amorphous silicon technology can vary according to the safety requirements of the glass, from 3+3 laminated glass to 6+3+6 laminated glass. For the correct architectural integration, it is also necessary to consider the thermal and acoustic insulation requirements for the constructive solution. Therefore, it will sometimes be necessary to have double glazed glass with an air space (also available with Argon, Kyrpton, or Zenon). Double or triple glazing photovoltaic insulating units can also be incorporated into the project providing improved thermal insulation properties, reaching U-values of 0.7W/m2K.

Select the adequate fixation system of the glass

Nowadays, the most common mounting and fixing system for BIPV solutions are based on aluminium and steel materials. The main parts are brackets and vertical/horizontal shapes in combination with support or fixing system consisting of vertical/horizontal shapes, staples or clips.

It is recommended to pay special attention to the fact that, sometimes, the installation of BIV system could affect the thermal envelope continuity. Therefore, it is important to take into account whether the retrofit project is based on internal or external insulation system. Internal insulation solutions for facades and roofs are compatible with conventional fixing systems as there is no interference with the thermal barrier. Nevertheless, when the retrofit project considers an external insulation system, a thermal-bridge-free anchorage system, it is important to guarantee the correct thermal behaviour of the building envelope.

Estimate how much energy the system would produce

You can use this application in order to know how much energy it is possible to produce in your building.

http://www.onyxsolar.com/photovoltaic-estimation-tool.html

Enter the value for the photovoltaic installation area you have in mind, select the photovoltaic technology, and it will display the energy that would be generated and its equivalencies in avoided CO2 emissions, hours of light and electric car mileage.

Take into account electrical requirements

The elements of a photovoltaic installation are selected on the basis of a high number of parameters that guarantee the fulfillment of the requirements of the integration, the technical limits of the equipment and the interconnection possibility of the photovoltaic glass.
Functional requirements are mainly focused on shadow limitation, optimal orientation, and compatibility with existing construction systems or the state of electricity grid. The design of a photovoltaic installation has to meet a minimum of technical requirements in order to provide guarantees that the installation operates correctly according to its particular integration conditions. These correct operation requirements can be met under three general rules:
A minimum installed power must be reached for the correct operation of the inverter or regulator, involving a minimum surface area that will vary depending on the technology used and the integration conditions with regard to slant and orientation.
The photovoltaic glass that is connected to said inverter or regulator must be of the same technology with the same sizes and electrical characteristics in order to be connected to each other by meeting some equality requirements. There could be a possibility of compatibility despite not being equal when they are proportional to each other or if the inverter were prepared for this.
The photovoltaic elements that are connected to the same inverter or regulator must have the same orientation and slant in order to guarantee that they work under equal conditions and to avoid penalties due to differences in the electricity generation capacity. Again, there is the possibility of carrying out the interconnection of different orientations and slants, provided the equipment is prepared for this.

Not complying with these general rules will necessitate a more deep and concrete analysis for the design of the installation, bearing in mind that there are particular cases where, excluding the general methodology, a solution provides guarantees.

Select the best energy management system for your building

The electricity generated in photovoltaic installations of architectural integrations can be managed in different ways if we attend to the use to which it is going to be allocated. There are three types of basic installations, namely: installations aimed at direct self-consumption without accumulation; installations aimed at supplying the national grid; and installations designed for self-consumption with accumulation.
The system can be grid-connected, injecting the PV generated energy to the grid during the day, selling it directly to the electrical company under a negotiated fixed price contract.
Another possibility is being grid-connected through a reverse spin counter where a straight discount over the electrical bill is achieved depending on the amount of the generated PV kWh.
At the same time, it is necessary to add that a D.E.R (Distributed Energy Sources) system/concept could be developed integrating in the same manner other sources as CHP

systems, geothermal, solar thermal, biogas from recoveries, etc. counting on multiple storage system.
As an alternative final option, an off-grid system can be developed accumulating the generated energy in batteries and using this energy as a back-up of some electrical building facilities or other needs.